FINAL

HABITAT PLAN FOR THE SOUTH ATLANTIC REGION: ESSENTIAL FISH HABITAT REQUIREMENTS FOR FISHERY MANAGEMENT PLANS OF THE SOUTH ATLANTIC FISHERY MANAGEMENT COUNCIL

THE SHRIMP FISHERY MANAGEMENT PLAN,
THE RED DRUM FISHERY MANAGEMENT PLAN,
THE SNAPPER GROUPER FISHERY MANAGEMENT PLAN,
THE COASTAL MIGRATORY PELAGICS FISHERY MANAGEMENT PLAN,
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THE SPINY LOBSTER FISHERY MANAGEMENT PLAN,
THE CORAL, CORAL REEFS, AND LIVE/HARD BOTTOM HABITAT FISHERY MANAGEMENT PLAN,
THE SARGASSUM HABITAT FISHERY MANAGEMENT PLAN,
AND
THE CALICO SCALLOP FISHERY MANAGEMENT PLAN

OCTOBER 1998

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Prepared by the:
South Atlantic Fishery Management Council

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

1.0 PURPOSE AND NEED

1.1 Historical Overview of SAFMC Activities to Conserve Essential Fish Habitat

Through the years, the Council has taken a leading role in the protection of habitat essential to managed species. This is accomplished through two avenues as directed by the Magnuson-Stevens Act, the first being through direct regulation of fisheries to protect habitat from the direct or indirect impacts of fishing. With the implementation of the Coral Fishery Management Plan and subsequent amendments to that plan, the Council has protected coral, coral reefs, and live/hard bottom habitat in the south Atlantic region by establishing an optimum yield of zero and prohibiting all harvest or possession of these resources which serve as essential fish habitat to many managed species. Another measure adopted by the Council and implemented through the coral plan was the designation of the Oculina Bank Habitat Area of Particular Concern, a unique and fragile deepwater coral habitat off southeast Florida that is protected from all bottom tending fishing gear damage. The Council has also prohibited the use of the following gears in the snapper grouper fishery management plan to protect habitat: bottom longlines in the EEZ inside of 50 fathoms or anywhere south of St. Lucie Inlet Florida, fish traps, bottom tending (roller-rig) trawls on live bottom habitat, and entanglement gear. Also established under the snapper grouper plan is an Experimental Closed Area (experimental marine reserve) where the harvest or possession of all species in the snapper grouper complex is prohibited. Other actions taken by the Council that directly or indirectly protect habitat or ecosystem integrity include: the prohibition of rock shrimp trawling in a designated area around the Oculina Bank, mandatory use of bycatch reduction devices in the penaeid shrimp fishery, a prohibition of the use of drift gill nets in the coastal migratory pelagic fishery; and a mechanism that provides for the concurrent closure of the EEZ to penaeid shrimping if environmental conditions in state waters are such that the overwintering spawning stock is severely depleted.

In addition to implementing regulations to protect habitat from fishing related degradation, the Council actively comments on non-fishing projects or policies that may impact fish habitat. In response to an earlier amendment to the Magnuson Act, the Council adopted a habitat policy and procedure document that established a four state Habitat Advisory Panel and adopted a comment and policy development process. Members of the Habitat Advisory Panel serve as the Councils' habitat contacts and professionals in the field. The Advisory Panel is structured and functions differently than other panels. The Panel is made up of four state sub-panels each having representatives from the state marine fisheries agency, the U S Fish and Wildlife Service, state coastal zone management agency, conservationist, commercial fishermen, and recreational fishermen. In addition to the state representatives, at large members on the overall panel include representatives from EPA Region IV, NMFS Southeast Fisheries Center, NMFS SERO, Atlantic States Marine Fisheries Commission, and NMFS Habitat Conservation Division Headquarters. This body functions as a whole or as sub-panel depending on the scope of the issue. The Panel serves to provide the Council with both expert recommendations on activities being considered for permitting as well as guidance in development of Habitat policy statements. With guidance from the Panel, the Council, has developed and approved policies on; oil and gas exploration, development and transportation; dredging and dredge material disposal; submerged aquatic vegetation, and ocean dumping. These are included in Section 5 of this document under recommendations to protect EFH.

1.2 Habitat Responsibilities as Defined in the Magnuson-Stevens Fishery Conservation and Management Act of 1996

The Magnuson-Stevens Fishery Conservation and Management Act, 16 USC 1801 et seq. Public Law 104-208 reflects the Secretary of Commerce and Fishery Management Council authority and responsibilities for the protection of essential fishery habitat. Section 305 (b) Fish Habitat, indicates the Secretary (through NMFS) shall, within 6 months of the date of enactment of the Sustainable Fisheries Act, establish by regulation guidelines to assist the Councils in the description and identification of essential fish habitat in fishery management plans (including adverse impacts on such habitat) and in the consideration of actions to ensure the conservation and enhancement of such habitat. In addition, the Secretary (through NMFS) shall: set forth a schedule for the amendment of fishery management plans to include the identification of essential fish habitat and for the review and updating of such identifications based on new scientific evidence or other relevant information; in consultation with participants in the fishery, shall provide each Council with recommendations and information regarding each fishery under that Council's authority to assist it in the identification of essential fish habitat, the adverse impacts on that habitat, and the actions that should be considered to ensure the conservation and enhancement of that habitat; review programs administered by the Department of Commerce and ensure that any relevant programs further the conservation and enhancement of essential fish habitat; and the Secretary shall coordinate with and provide information to other Federal agencies to further the conservation and enhancement of essential fish habitat.

The Act specifies that each Federal agency shall consult with the Secretary with respect to any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by such agency that may adversely affect any essential fish habitat identified under this Act. Additional provisions specify that each Council: may comment on and make recommendations to the Secretary and any Federal or State agency concerning any activity authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by any Federal or State agency that, in the view of the Council, may affect the habitat, including essential fish habitat, of a fishery resource under its authority; and shall comment on and make recommendations to the Secretary and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority.

Additional terms in the Act specify provisions for commenting on activities impacting essential fish habitat. If the Secretary receives information from a Council or Federal or State agency or determines from other sources that an action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by any State or Federal agency would adversely affect any essential fish habitat identified under this Act, the Secretary shall recommend to such agency measures that can be taken by such agency to conserve such habitat. Within 30 days after receiving a recommendation, a Federal agency shall provide a detailed response in writing to any Council commenting and the Secretary regarding the matter. The response shall include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on such habitat. In the case of a response that is inconsistent with the recommendations of the Secretary, the Federal agency shall explain its reasons for not following the recommendations.

On December 19, 1997, an interim final rule was published in the Federal Register to implement the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). This rule establishes guidelines to assist the Regional Fishery Management Councils (Councils) and the Secretary of Commerce (Secretary) in the description and identification of EFH in fishery management plans (FMPs), including identification of adverse impacts from both fishing and non-fishing activities on EFH, and identification of actions required to conserve and enhance EFH. The regulations also detail procedures the Secretary (acting through NMFS), other Federal agencies, state agencies, and the Councils will use to coordinate, consult, or provide recommendations on Federal and state activities that may adversely affect EFH. The intended effect of the rule is to promote the protection, conservation, and enhancement of EFH.

Essential fish habitat is defined in the Act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The definition for EFH may include habitat for an individual species or an assemblage of species, whichever is appropriate within each FMP.

For the purpose of interpreting the definition of essential fish habitat: "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are utilized by fish. When appropriate this may include areas used historically. Water quality, including but not limited to nutrient levels, oxygen concentration and turbidity levels is also considered to be a component of this definition. Examples of "waters" that may be considered EFH, include open waters, wetlands, estuarine habitats, riverine habitats, and wetlands hydologically connected to productive water bodies.

"Necessary" , relative to the definition of essential fish habitat, means the habitat required to support a sustainable fishery and a healthy ecosystem. While "spawning, breeding, feeding, or growth to maturity" covers a species full life cycle.

In the context of this definition the term "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities. These communities could encompass mangroves, tidal marshes, mussel beds, cobble with attached fauna, mud and clay burrows, coral reefs and submerged aquatic vegetation. Migratory routes such as rivers and passes serving as passageways to and from anadromous fish spawning grounds should also be considered EFH. Included in the interpretation of "substrate" are artificial reefs and shipwrecks (if providing EFH), and partially or entirely submerged structures such as jetties.

This plan presents the habitat requirements (by life stage where information exists) for species managed by the Council. Available information on environmental and habitat variables that control or limit distribution, abundance, reproduction, growth, survival, and productivity of the managed species is included.

The Council, in working with our Habitat and Coral Advisory Panels and through a series of workshops identified available environmental and fisheries data sources relevant to the managed species that would be useful in describing and identifying EFH. In addition, the EFH workshop process tapped in on habitat experts, at the State, Federal, and regional level, to participate in the description, and identification of EFH in the South Atlantic region. This process allowed the experts in the field to identify major species-specific habitat data gaps, deficits in data availability (i.e., accessibility and application of the data) and in data quality (including considerations of scale and resolution; relevance; and potential biases in collection and interpretation).

Information was compiled where it existed on: current and historic stock size, the geographic range of the managed species, the habitat requirements by life history stage, and the distribution and characteristics of those habitats; the temporal and spatial distribution of each major life history stage: the distribution, density, growth, mortality, and production; collected from all sources of quality information.

According to NMFS guidelines the councils should analyze information within the constraints of the of the available data when describing and identifying essential fish habitat. There are four levels of information. Level one is based on presence / absence distribution data, which is available for some or all portions of the geographic range of a species. At this level this is the only data available to describe the distribution of a species in relation to it's potential habitats. At level 2 data is available for habitat-related densities of species. Level 3 data provides growth, reproduction or survival rates within habitats, and level 4 information provides data on production rates by habitat.

The goal is to obtain the highest level of information. This information would relate the production rates or life history stages of a species to habitat requirements (including, type, quality, quantity and location). It would also track essential habitats necessary to maintain fish production which would be consistent with a sustainable fishery and in addition would demonstrate the managed species' contribution to a healthy ecosystem.

In assessing the relative value of habitats the Council is taking a risk-averse approach. This approach will ensure that adequate areas are protected as EFH of managed species. In the South Atlantic region mostly level 1 and some level 2 data is available. This information was used to identify the geographic range of a species and the presence/absence data was evaluated to identify those habitat areas that are most commonly used and essential for the species. This includes habitats that will better ensure the health of the fish population and the ecosystem. The Council used the best scientific information available to describe and identify EFH in the south Atlantic. Habitat loss and degradation may be contributing to species being identified as overfished, therefore all habitats used by these species are considered essential.

Based on the ecological relationships of species and relationships between species and their habitat the council is taking an ecosystem approach in determining EFH of managed species and species assemblages. This approach is consistent with NMFS guidelines. Through the existing habitat policy, the Council directs the protection of essential fish habitat types and the enhancement and restoration of their quality and quantity.

The general distribution and geographic limits of EFH is described and where information exists presented by life history stage in maps that are part of a developing Council ArcView geographic information system (GIS). Maps developed to date by Council staff, Florida Marine Research Institute, NMFS Southeast Fisheries Science Center, NOAA SEA Division, North Carolina DNR encompass appropriate temporal and spatial variability in presenting the distribution of EFH. Where information exists, seasonal changes are represented in the maps. EFH is identified on maps along with areas used by different life history stages of the species. The maps present the various habitat types described as EFH.

The document also presents information on adverse effects from fishing and describes management measures the Council has implemented to minimize adverse effects on EFH from fishing. The conservation and enhancement measures implemented by the Council to date may include ones that eliminate or minimize physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. The Council has implemented restrictions on fisheries to the extent that no significant activities were identified in the review of gear impact conducted for the NMFS by Auster and Langton (1998) that presented available information on adverse effects of all fishing equipment types used in waters described as EFH. The Council has already prevented, mitigated, or minimized most adverse effects from most fisheries prosecuted in the south Atlantic EEZ.

The Council is considering evidence that a some fishing practices are having an identifiable adverse effect on habitat, and are addressing these in the comprehensive habitat amendment. The Council, as indicated in the previous section, has already used many of the options recommended in the guidelines for managing adverse effects from fishing including: fishing equipment restrictions seasonal and aerial restrictions on the use of specified equipment; equipment modifications to allow the escape of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting equipment in sensitive areas; and prohibitions on fishing activities that cause significant physical damage in EFH; time/area closures including closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern; and harvest limits.

This document identifies non-fishing related activities that have the potential to adversely affect EFH quantity or quality. Examples of theses activities are dredging, fill, excavation, mining, impoundment, discharge, water diversions, thermal additions, actions that contribute to non-point source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Included in this document is an analysis of how fishing and non-fishing activities influence habitat function on an ecosystem or watershed scale. This analysis presents available information describing the ecosystem or watershed and the dependence of managed species on the ecosystem or watershed. An assessment of the cumulative and synergistic effects of multiple threats, including the effects of natural stresses (such as storm damage or climate-based environmental shifts), and an assessment of the ecological risks resulting from the impact of those threats on the managed species' habitat is included.

General conservation and enhancement recommendations are included in Section 5 of this document. These include but are not limited to recommending the enhancement of rivers, streams, and coastal areas, protection of water quality and quantity, recommendations to local and state organizations to minimize destruction/degradation of wetlands, restore and maintain the ecological health of watersheds, and replace lost or degraded EFH.

This document, pursuant to the guidelines, also presents areas which meet the criteria for designation of essential fish habitat-habitat areas of particular concern (EFH-HAPCs) by individual habitat type or managed species or species complex. The following criteria are considered when determining whether a type, or area of EFH is an essential fish habitat-habitat area of particular concern: (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are, or will be, stressing the habitat type; and the rarity of the habitat.. The identification of EFH-HAPCs will continue through the public hearing process and the Council will consider additional areas if identified through this process. A coral HAPC process under the coral plan already exists and differs somewhat from the process recommended in the EFH guidelines.

The Council will periodically review and update EFH information and revise this Habitat Plan document as new information becomes available. NMFS should provide some of this information as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report. A complete review of EFH information will also be conducted as recommended in the guidelines in no longer than 5 years.

1.3 SAFMC Habitat Plan and Comprehensive Habitat Amendment Development Process

A proposed rule was published by NMFS on April 23, 1997 specifying regional fishery management council guidelines for the description and identification of essential fishery habitat (EFH) in fishery management plans, adverse impacts on EFH, and actions to conserve and enhance EFH. In order to address the new essential fish habitat mandates in the Magnuson-Stevens Act, the South Atlantic Council began development of: (1) a habitat plan which will serve as a source document describing EFH (SAFMC 1998a); (2) a comprehensive amendment which will amend each of the existing fishery management plans, identifying and describing EFH and addressing impacts of fishing gear and/or fishing practices on EFH (SAFMC 1998b); and (3) a monitoring program for each fishery management plan to determine new impacts from fishing gear and/or fishing practices in an effort to minimize, to the extent practicable, the adverse impacts on EFH.

The Council, recognizing the scope of the significant task necessary to meet the essential fish habitat mandates of the Magnuson-Stevens Act, called upon the Panel members to serve as or identify appropriate experts to function on a quasi-plan development team. Subsequently, the Council initiated a workshop process to identify habitat experts and information availability to facilitate identifying essential fish habitat in the south Atlantic region. Workshops were conducted on habitat types including, wetlands, oyster/shell habitat, seagrass, pelagic habitat (including Sargassum and water column), coral and live/hard bottom, and artificial reefs. In addition, workshops on the use of GIS to map habitat and species distributions and research and monitoring were also held. The workshop process not only provided the Council with an indication of the availability of information that could be used to identify essential fish habitat but also brought together habitat experts that have participated directly in the drafting of this Habitat Plan.

The Council and NMFS have coordinated their efforts to address their respective EFH mandates in the Magnuson-Stevens Act. Representatives of the NMFS southeast regional habitat team from NMFS Southeast Fisheries Science Center Beaufort Laboratory, NMFS Southeast Regional Office, and NMFS Headquarters are directly involved in the development of this Habitat Plan. On December 19, 1997, an interim final rule was published in the Federal Register to implement the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

2.0 SUMMARY

2.1 Geographic Coverage

The Council, in developing this Habitat Plan, has consolidated the best available information on habitat essential to species managed in the south Atlantic region. The description and distribution of essential fish habitat in this document includes estuarine inshore habitats, mainly focusing on North Carolina, South Carolina, Georgia, and the Florida east coast as well as adjacent offshore marine habitats (e.g. coral, coral reefs, and live/hard bottom habitat, artificial reefs, *Sargassum* habitat and the water column). The structural component of these habitats constitute the basis for the habitat distribution information presented in this document. A primary goal of this document is to relay information on the distribution of managed species and essential fish habitats and provide information to address fishing and non-fishing threats to the watershed or estuarine drainage area.

This document was prepared through a cooperative effort of State, Federal and regional habitat partners on the Councils' Habitat and Coral Advisory Panels, additional technical experts identified during Council EFH workshops, and Council staff. This approach was deemed appropriate and has resulted in a scientifically defensible product that describes the structural characteristics and function by habitat type and presents available information on distribution and use by managed species and their significant prey. The intent of this document is to serve as a source document for all species managed by the Council. It also represents an ecological characterization of the south Atlantic region describing essential fish habitat. The Council is therefore taking a risk-averse approach in describing and protecting essential fish habitat in its area of jurisdiction and making recommendations to protect essential habitat in state waters. The emphasis of the determination is on the interrelationships between habitat and State and Federally managed species and their prey and endangered and threatened species. The vast array of species using these habitats implies that the structural habitats serve such a wide variety of species at different times in different locations that these structural habitats (estuarine, palustrine, coral and live/hard bottom, artificial reefs, and *Sargassum*) are all inclusive as essential to the functioning of a healthy ecosystem in the south Atlantic region. In addition, the water column plays an important role in defining the nature of essential habitat by being the common link.

This document is a living document that will be revised as new information becomes available. New techniques such as Habitat Suitability Index (HSI) modeling being developed may be useful in better identifying these habitats and their use by managed species. In addition, more refined and accurate mapping techniques through geographical information systems (GIS), such as the ones being used in the Coastal Change Analysis Program (C-CAP), under development for south Atlantic states and continued refinement of the SEAMAP bottom mapping effort. These and other activities will provide even more refined information for future Habitat Plan versions.

2.1.1 Estuarine/Inshore Essential Fish Habitat

Estuarine inshore habitats include estuarine emergent vegetation (salt marsh and brackish marsh), estuarine shrub/scrub (mangroves), seagrass, oyster reefs and shell banks, intertidal flats, palustrine emergent and forested (freshwater wetlands), and the estuarine water column. Section 3.1 presents individual detailed descriptions including species use of these habitats.

Estuarine Emergent

Estuarine marshes constitute a complex ecosystem that serves as essential fish habitat but also is vital to wildlife including endangered and threatened species, furbearers and other mammals, waterfowl, wading birds, shore and other birds, reptiles and amphibians, shellfish, and invertebrates. In contrast to freshwater marshes, salt marshes have low species diversity of the higher vertebrates, but high species diversity of invertebrates, including shellfish, and fishes. Optimal estuarine habitat conditions for managed species' spawning, survival, and growth is dependent on protecting the structural integrity as well as the environmental quality of these habitats. In North Carolina, South Carolina, Georgia and Florida, the marsh systems are of principal importance as nursery areas.

More detailed estimates of wetland by county are presented in Appendix A . This compilation of existing wetland habitat may, as refined to hydrological units, begin to serve as a baseline upon which to implement the policy directive and the long-term objective of a net gain of wetland habitats in the South Atlantic region. The Coastal Change Assessment Program (C-CAP) is presently being developed in response to the National Wetlands Policy Forum recommendation to improve inventory, mapping, and monitoring programs by USFWS and NOAA. The program was implemented to develop a nationally standardized geographic information system using ground-based and remote sensing data. It assesses changes in land cover and habitat in US coastal regions to improve understanding of coastal uplands, wetlands, and seagrass beds and their links to distribution, abundance, and health of living marine resources. At this time only South Carolina coastal counties are complete and will represent essential wetland habitat as mapped in that state. The state of Georgia information is under review and as North Carolina and Florida are completed the mapping coverage will be incorporated into the Habitat Plan as the most accurate presentation of inshore essential fish habitat in the South Atlantic region. The ecological value, function and distribution of this essential fish habitat is described in Section 3.1.1.1.

Estuarine Shrub/Scrub Mangroves (from NOAA 1995)

The red mangrove (*Rhizophora mangle*), black mangrove (*Avincennia germinans*), and white mangroves (*Laguncularia erectus*) are the three "true" species found in South Florida (Tomlinson, 1986). Red mangroves have prop roots and viviparous cigar-shaped seedlings, while black mangroves have a pneumataphore root system and gray-green leaves, the undersides of which are encrusted with excreted salt. White mangroves have rounded leaves, with a pair of salt glands on each petiole. Buttonwood (*Conocarpus erectus*), an associated species occurring with mangroves, is found in transitional wetland areas between mangrove and upland areas.

A mangrove classification system has been developed that identifies six major forest types based on geological and hydrological process: riverine, overwash, fringe, basin, dwarf, and hammock (Lugo and Snedaker). Riverine forests do not occur in southeast Florida due to the lack of freshwater rivers and the associated floodplains (Davis, 1943: Minerals Management Service 1990). Fringe forests occur along shorelines inundated by high tides, dominated by red mangroves, and exposed to open water. Tidal flow follows the same directional path along the fringe forest, resulting in sediment and litter accumulation.

Mangrove-related fish communities can be organized along various environmental gradients including salinity, mangrove detritus dependence, and substrate (Odum et al., 1982). The ecological value, function and distribution of this essential fish habitat is described in Section 3.1.1.2

Seagrass Habitat

Seagrass beds in North Carolina and Florida are preferred habitat areas of many managed species including white, brown, and pink shrimp, red drum, and estuarine dependent snapper and grouper species in the larval, juvenile and adult phases of their life cycle. Seagrass meadows provide substrates and environmental conditions which are essential to the feeding, spawning and growth of several managed species. Seagrass meadows are complex ecosystems that are essential habitat because they provide primary productivity, structural complexity, modification of energy regimes, sediment and shoreline stabilization, and nutrient cycling. Section 3.1.1.3 describes the ecological value and function and distribution of this essential fish habitat. The states of North Carolina through CGIA and Florida through FMRI provided geographical information system (GIS) coverage of seagrass habitat. Subsequent reconfiguration of the data was conducted by NMFS SEFSC to create a uniform ArcView format for inclusion into the Councils' essential fish habitat distribution data base and GIS system.

Oyster Reefs and Shell Banks

Oyster and shell essential fish habitat in the South Atlantic can be defined as the natural structures found between (intertidal) and beneath (subtidal) tide lines, that are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats, and from wave-formed shell windrows (Bahr and Lanier 1981). Both intertidal and subtidal populations are found in the tidal creeks and estuaries of the South Atlantic. On the Atlantic coast, the range of the American oyster, *Crassostrea virginica*, extends over a wide latitude (20° N to 54° N). The ecological conditions encountered are diverse and the oyster community is not uniform throughout this range. Where the tidal range is large the oyster builds massive, discrete reefs in the intertidal zone. North of Cape Lookout, in North Carolina, the oyster habitat is dominated by Pamlico Sound and its tributaries. In these wind-driven lagoonal systems, oyster assemblages consist mainly of subtidal beds. Throughout the South Atlantic, oysters are found at varying distances up major drainage basins depending upon typography, salinity, substrate, and other variables.

Several terms used to describe the oyster/shell essential fish habitat are oyster reef, bar, bed, rock, ground and planting. The habitat ranges in size from small scattered clumps to large mounds of living oysters and dead shells. Predation and siltation limit oyster densities at the lower portion and outer regions of the reefs. The vertical elevation of intertidal oyster reefs above mean low water is maximal within the central Georgia coastal zone, where mean tidal amplitude exceeds 2 m (Bahr and Lanier 1981).

Large shell banks or deposits of oyster valves generated by boat wakes are found throughout the South Atlantic, usually along the Atlantic Intracoastal Waterway and heavily traveled rivers. These shell accumulations are usually elongated and conform to the underlying bottom topography from mean low water into the supra littoral zone. Further build-up may result in ridge structures and washovers. In South Carolina, 998 "washed shell" deposits have been located predominantly in the central and southern portion of the State. Washed shell is less resilient, partially abraded oyster shell with a lower specific gravity than recently shucked shells (Anderson 1979).

Intertidal Flats

Variability in the tidal regime along the South Atlantic coast results in considerable regional variability in the distribution and character of the estimated 1 million acres of tidal flat habitat. The coasts of North Carolina and Florida are largely microtidal (0-2m tidal range) with extensive barrier islands and relatively few inlets to extensive sound systems. In these areas wind energy has a strong affect on intertidal flats. In contrast the coasts of South Carolina and Georgia are mesotidal (2-4m) with short barrier islands and numerous tidal inlets so that tidal currents are the primary force effecting the intertidal zone.

Tidal flats are critical structural components of coastal systems that serve as feeding grounds and refuges for a variety of animals. This constantly changing system provides essential fish habitat as; 1) nursery grounds for early stages of development of many benthically oriented estuarine dependent species. 2) refuges and feeding grounds for a variety of forage species of fishes 3) feeding grounds for a variety of specialized predators.

Palustrine Emergent and Forested

Palustrine emergent systems include tidal and non-tidal marshes. A large amount of the energy present in the palustrine emergent vegetation may be exported out of the system. Tidal currents, river currents, and wind energy all act to transport organic carbon downstream to the estuary, which is the nursery area for many of the Council-managed species. Migrating consumers, such as larval and juvenile fish and crustaceans, may feed within the habitat and then move on to the estuary or ocean. These links with managed species demonstrate the essential nature of this habitat type. Section 3.1.2.2 describes the ecological value, function and distribution of this essential fish habitat.

Aquatic Beds

Submersed rooted vascular vegetation in tidal fresh- or freshwater portions of estuaries and their tributaries performs the same functions as those described for seagrasses. Specifically, aquatic bed meadows possess the same four attributes: 1) primary productivity; 2) structural complexity; 3) modification of energy regimes and sediment stabilization; and 4) nutrient cycling. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.2.3.

Estaurine Water Column

This habitat traditionally comprises four salinity categories: oligohaline (< 8 ppt), mesohaline (8-18 ppt), and polyhaline waters (18-30 ppt) with some euhaline water (>30 ppt) around inlets. Alternatively, a three-tier salinity classification is presented by Schreiber and Gill (1995) in their prototype document developing approaches for identifying and assessing important fish habitats: tidal fresh (0-0.5 ppt), mixing (0.5-25 ppt), and sewater (>25 ppt). Saline environments have moving boundaries, but are generally maintained by sea water transported through inlets by tide and wind mixing with fresh water supplied by land runoff. Particulate materials settle from these mixing waters and accumulate as bottom sediments. Coarser-grained sediments, saline waters, and migrating organisms are introduced from the ocean, while finer-grained sediments, nutrients, organic matter, and fresh water are input from rivers and tidal creeks. The sea water component stabilizes the system, with its abundant supply of inorganic chemicals and its relatively conservative temperatures. Closer to the sea, rapid changes in variables such as temperature are moderate compared to shallow upstream waters. Without periodic additions of sea water, seasonal thermal extremes would reduce the biological capacity of the water column as well as reduce the recruitment of fauna from the ocean. While nearby wetlands contain some assimilative capacity abating nutrient enrichment, fresh water inflow and tidal flushing are primarily important for circulation and removal of nutrients and wastes from the estuary.

The water column is composed of horizontal and vertical components. Horizontaly, salinity gradients (decreasing landward) strongly influence the distribution of biota, both directly (physiologically) and indirectly (e.g., emergent vegetation distribution). Horizontal gradients of nutrients, decreasing seaward, affect primarily the distribution of phytoplankton and, secondarily, organisms utilizing this primary productivity. Vertically, the water column may be stratified by salinity (fresh water runoff overlaying heavier salt water), oxygen content (lower values at the bottom associated with high biological oxygen demand due to inadequate vertical mixing), and nutrients, pesticides, industrial wastes, and pathogens (build up to abnormal levels near the bottom from lack of vertical mixing).

2.1.2 Marine/Offshore Essential Fish Habitat

Marine offshore habitats include live/hard bottom, coral and coral reefs, artificial/manmade reefs, pelagic *Sargassum* and water column habitat. Section 3.2 presents individual detailed descriptions including species use of these habitats.

Live/Hard Bottom Habitat

Major fisheries habitats on the Continental Shelf along the southeastern United States from Cape Hatteras to Cape Canaveral (South Atlantic Bight) can be stratified into five general categories: coastal, open shelf, live/hard bottom, shelf edge, and lower shelf based on type of bottom and water temperature. Each of these habitats harbors a distinct association of demersal fishes (Struhsaker 1969) and invertebrates. The description of this essential fish habitat presented in Section 3.2.1.2, segregates the region into two sections: a) Cape Hatteras to Cape Canaveral; and b) Cape Canaveral to the Dry Tortugas. These regions represent temperate, wide-shelf systems and tropical, narrow-shelf systems, respectively. The zoogeographic break between these regions typically occurs between Cape Canaveral and Jupiter Inlet.

Covered by a vast plain of sand and mud underlain at depths of less than a meter by carbonate sandstone is relatively unattractive to fish. Live/hard bottom, usually found near outcropping shelves of sedimentary rock in the zone from 15 to 35 fathoms and at the shelf break, a zone from about 35 to 100 fathoms where the Continental Shelf adjoins the deep ocean basin and is often characterized by steep cliffs and ledges. The live bottom areas constitute essential habitat for warm-temperate and tropical species of snappers, groupers, and associated fishes including 113 species of reef fish representing 43 families of predominately tropical and subtropical fishes off the coasts of North Carolina and South Carolina.

The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2. These geographic coverage's are a compilation of the four state bottom mapping effort in the South East Monitoring and Assessment Program (SEAMAP). The Florida Marine Research Institute developed uniform ArcView coverage's of hard bottom habitat (including coral, coral reefs, live/hard bottom, and artificial reefs) as a 1998 SEAMAP program and provided it to the Council for inclusion into the south Atlantic essential fish habitat distribution data base and GIS system.

Coral and Coral Reefs

Coral reef communities or solitary specimens exist throughout the south Atlantic region from nearshore environments to continental slopes and canyons, including the intermediate shelf zones. Habitats supporting corals and coral-associated species are discussed below in groupings based on their physical and ecological characteristics. Dependent upon many variables, corals may dominate a habitat, be a significant component, or be individuals within a community characterized by other fauna. Geologically and ecologically, the range of coral assemblages and habitat types is equally diverse. The coral reefs of shallow warm waters are typically, though not always, built upon coralline rock and support a wide array of hermatypic and ahermatypic corals, finfish, invertebrates, plants, and microorganisms. Hard bottoms and hard banks, found on a wider bathymetric and geographic scale, often possess high species diversity but may lack hermatypic corals, the supporting coralline structure, or some of the associated biota. In deeper waters, large elongate mounds called deepwater banks, hundreds of meters in length, often support a rich fauna compared to adjacent areas. Lastly are communities including solitary corals. This category often lacks a topographic relief as its substrate, but instead may use a sandy bottom, for example. Coral habitats (i.e., habitats to which coral is a significant contributor) are divided into five categories - solitary corals, hard bottoms, deepwater banks, patch reefs, and outer bank reefs. The order of presentation approximates the ranking of habitat complexity based upon species diversity (e.g., zonation, topographic relief, and other factors). Although attempts have been made to generalize the discussion into definable types, it must be noted that the continuum of habitats includes many more than these five distinct varieties.

The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.1.2. The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2.

Artificial/Manmade Reefs

Manmade reefs are defined for this document as any area within marine waters in which suitable structures or materials have intentionally been placed by man for the purpose of creating, restoring or improving long-term habitat for the eventual exploitation, conservation or preservation of the resulting marine ecosystems naturally established on these sites. Manmade hard bottom habitats are formed when a primary hard substrate is available for the attachment and development of epibenthic assemblages. This substrate is colonized when marine algae and larvae of epibenthic animals successfully settle and thrive. Concurrent with the development of the epibenthic assemblage, demersal reef-dwelling finfish recruit to the new hard bottom habitat. Juvenile life stages will use this habitat for protection from predators, orientation in the water column or on the reef itself and as a feeding area. Adult life stages of demersal reef-dwelling finfish including species managed in the snapper grouper plan, will use the habitat for protection from predation, feeding opportunities, orientation in the water column and on the reef and as spawning sites. Pelagic planktivores occur on hard bottom habitats in high densities and use these habitats for orientation in the water column and feeding opportunities. These species provide important food resources to snapper grouper species and coastal migratory pelagics including king and Spanish mackerel and cobia. The pelagic piscivores use the hard bottom habitats for feeding opportunistically. Most of these species do not take up residence on individual hard bottom outcrops, but will transit through hard bottom areas and feed for varying periods of time.

Manmade hard substrates are considered essential fish habitat in the south Atlantic region because of the use of these habitats by species in the snapper grouper complex, coastal migratory pelagics and prey important to those species. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.2

The State of Florida Marine Research Institute, as part of the 1998 deliverable, provided the Council with uniform Arc View coverage's for inclusion into the south Atlantic essential fish habitat distribution data base and GIS system.

Sargassum

Pelagic brown algae *Sargassum natans* and *S. fluitans* form a dynamic structural habitat within warm waters of the western North Atlantic. Most pelagic *Sargassum* circulates between 20°N and 40°N latitudes and 30°W longitude and the western edge of the Florida Current/Gulf Stream. The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea. Large quantities of *Sargassum* frequently occur on the continental shelf off the southeastern United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore. During calm conditions *Sargassum* may form large irregular mats or simply be scattered in small clumps. Langmuir circulation, internal waves, and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows collectively termed "windrows".

Pelagic *Sargassum* supports a diverse assemblage of marine organisms including fungi, micro-and macro-epiphytes, at least 145 species of invertebrates, over 100 species of fishes, four species of sea turtles, and numerous marine birds. The fishes associated with pelagic *Sargassum* in the western North Atlantic include juveniles as well as adults of a wide variety of species. The carangids and balistids are the most conspicuous, being represented by 21 and 15 species respectively. Therefore, this habitat is considered essential fish habitat because it provides protection, feeding opportunity and use as a spawning substrate to species managed by the Council. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.3.

Additional information is contained in the fishery management plan for pelagic *Sargassum* (SAFMC 1998d).

Water Column

Specific habitats in the water column can best be defined in terms of gradients and discontinuities in temperature, salinity, density, nutrients, light, etc. These "structural" components of the water column environment are not static, but change both in time and space. Therefore, there are numerous potentially distinct water column habitats for a broad array of managed species and life-stages within species.

The discussion of the ecological function of water column habitat and importance to managed species is presented in Section 3.2.3.2.

2.2 List of Fishery Management Plans and Species

South Atlantic Snapper-Grouper

Balistidae--Triggerfishes
- Gray triggerfish, *Balistes capriscus*
- Queen triggerfish, *Balistes vetula*
- Ocean triggerfish, *Canthidermis sufflamen*

Carangidae--Jacks
- Yellow jack, *Caranx bartholomaei*
- Blue runner, *Caranx crysos*
- Crevalle jack, *Caranx hippos*
- Bar jack, *Caranx ruber*
- Greater amberjack, *Seriola dumerili*
- Lesser amberjack, *Seriola fasciata*
- Almaco jack, *Seriola rivoliana*
- Banded rudderfish, *Seriola zonata*

Ephippidae--Spadefishes
- Spadefish, *Chaetodipterus faber*

Haemulidae--Grunts
- Black margate, *Anisotremus surinamensis*
- Porkfish, *Anisotremus virginicus*
- Margate, *Haemulon album*
- Tomtate, *Haemulon aurolineatum*
- Smallmouth grunt, *Haemulon chrysargyreum*
- French grunt, *Haemulon flavolineatum*
- Spanish grunt, *Haemulon macrostomum*
- Cottonwick, *Haemulon melanurum*
- Sailors choice, *Haemulon parrai*
- White grunt, *Haemulon plumieri*
- Blue stripe grunt, *Haemulon sciurus*

Labridae--Wrasses
- Hogfish, *Lachnolaimus maximus*
- Puddingwife, *Halichoeres radiatus*

Lutjanidae--Snappers
- Black snapper, *Apsilus dentatus*
- Queen snapper, *Etelis oculatus*
- Mutton snapper, *Lutjanus analis*
- Schoolmaster, *Lutjanus apodus*
- Blackfin snapper, *Lutjanus buccanella*
- Red snapper, *Lutjanus campechanus*
- Cubera snapper, *Lutjanus cyanopterus*
- Gray snapper, *Lutjanus griseus*
- Mahogany snapper, *Lutjanus mahogoni*
- Dog snapper, *Lutjanus jocu*
- Lane snapper, *Lutjanus synagris*
- Silk snapper, *Lutjanus vivanus*
- Yellowtail snapper, *Ocyurus chrysurus*
- Vermilion snapper, *Rhomboplites aurorubens*

Malacanthidae--Tilefishes
- Blueline tilefish, *Caulolatilus microps*
- Golden tilefish, *Lopholatilus chamaeleonticeps*
- Sand tilefish, *Malacanthus plumieri*

Percichthyidae--Temperate basses
- Wreckfish, *Polyprion americanus*

Serranidae--Sea Basses and Groupers
- Bank sea bass, *Centropristis ocyurus*
- Rock sea bass, *Centropristis philadelphica*
- Black sea bass, *Centropristis striata*
- Rock hind, *Epinephelus adscensionis*
- Graysby, *Epinephelus cruentatus*
- Speckled hind, *Epinephelus drummondhayi*
- Yellowedge grouper, Epinephelus flavolimbatus
- Coney, *Epinephelus fulvus*
- Red hind, *Epinephelus guttatus*
- Jewfish, *Epinephelus itajara*
- Red grouper, *Epinephelus morio*
- Misty grouper, *Epinephelus mystacinus*
- Warsaw grouper, *Epinephelus nigritus*
- Snowy grouper, *Epinephelus niveatus*
- Nassau grouper, *Epinephelus striatus*
- Black grouper, *Mycteroperca bonaci*
- Yellowmouth grouper, *Mycteroperca interstitialis*
- Gag, *Mycteroperca microlepis*
- Scamp, *Mycteroperca phenax*
- Tiger grouper, *Mycteroperca tigris*
- Yellowfin grouper, *Mycteroperca venenosa*

Sparidae--Porgies
- Sheepshead, *Archosargus probatocephalus*
- Grass porgy, *Calamus arctifrons*
- Jolthead porgy, *Calamus bajonado*
- Saucereye porgy, *Calamus*
- Whitebone porgy, *Calamus leucosteus*
- Knobbed porgy, *Calamus nodosus*
- Red porgy, *Pagrus pagrus*
- Longspine porgy, *Stenotomus caprinus*
- Scup, *Stenotomus chrysops*

Coastal Migratory Pelagics

Cero, *Scomberomorus regalis*
Cobia, *Rachycentron canadum*
Dolphin, Coryphaena hippurus
King mackerel, *Scomberomorus cavalla*
Little tunny, *Euthynnus alletteratus*
Spanish mackerel, *Scomberomorus maculatus*

Shrimp Fishery of the South Atlantic Region

Brown shrimp, *Penaeus aztecus*
Pink shrimp, *Penaeus duorarum*
Rock shrimp, *Sicyonia brevirostris*
Royal red shrimp, *Pleoticus robustus*
Seabob shrimp, *Xiphopenaeus kroyeri*
White shrimp, *Penaeus setiferus*

Spiny Lobster

Spiny Lobster, *Panulirus argus*

Golden Crab
Golden Crab, *Chaeceon fenneri*

Coral, Coral Reefs, and Live/Hard Bottom Habitat
Coral belonging to the Class Hydrozoa (fire corals and hydrocorals).
Coral belonging to the Class Anthozoa, Subclass Hexacorallia, Orders Scleractinia (stony corals) and Antipatharia (black corals).
A seafan, *Gorgonia flabellum* or *G. ventalina*
Coral in a coral reef, except for allowable octocoral
Coral in an HAPC, including allowable octocoral
(HAPC means habitat area of particular concern)
Live rock means living marine organisms, or an assemblage thereof, attached to a hard substrate, including dead coral or rock (excluding individual mollusk shells).

Red Drum
Red drum, *Sciaenops ocellatus*

Calico Scallops
Calico Scallops, *Agopecten gibbus*

Sargassum
Sargassum, *Sargassum natans* and *Sargassum fluitans*

3.0 DESCRIPTION, DISTRIBUTION, AND USE OF ESSENTIAL FISH HABITAT
3.1 Estuarine and Inshore Habitats
3.1.1 Estuarine
3.1.1.1 Estuarine Emergent (Saltmarsh and Brackish Marsh)
3.1.1.1.1 Description and Ecological Role and Function

The saltmarsh is a type of wetland. Wetlands are classified on the basis of their hydrology, vegetation and substrate. One classification system proposed by Cowardin et al., (1979) and used by the USFWS classifies wetlands into five ecological systems. Estuarine emergents fall into two of these systems, the Estuarine and Marine. The Estuarine wetland is described as tidal wetlands in low-wave-energy environments, where the salinity is greater than 0.5 parts per thousand (ppt) and is variable owing to evaporation and the mixing of seawater and freshwater. Marine wetlands are described as tidal wetlands that are exposed to waves and currents of the open ocean and have a salinity of greater than 30 ppt. A saltmarsh, as defined by Beeflink (1977), is a "natural or semi-natural salt tolerant grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water level fluctuates either tidal or nontidally". The flora comprise of erect, rooted, herbaceous hydrophytes dominated by salt-tolerant perennial plants (Cowardin et al. 1979). Structure and function of a saltmarsh are influenced by tide, salinity, nutrients and temperature. The saltmarsh can be a stressful environment to plants and animals, with rapid changes occurring in these abiotic variables (Gosselink 1980; Gosselink et al. 1974). Although species diversity may be lower than in other systems, the saltmarsh is one of the most biologically productive ecosystems in the world (Teal 1962; Teal and Teal, 1969). The high primary productivity that occurs in the marsh, and the transfer of detritus into the estuary from the marsh, provides the base of the food chain supporting many marine organisms.

Many saltmarshes are drained by an intricate network of tidal creeks. These creeks and the adjacent marsh function as nursery areas for larval and juvenile finfish, crustaceans, and mollusks, and as a critical fisheries habitat to adult species. Greater than 90% of the commercial and recreational landings in the South Atlantic are composed of estuarine dependent species. The marsh not only provides food, structure, and refuge from predators to fishery organisms, but also regulates the amount of freshwater, nutrient and sediment inputs into the estuary. In addition to its function as an essential fisheries habitat, the marsh plays a vital role in the health and water quality of the estuary. The position of saltmarshes along the margins of estuaries and their dense stands of persistent plants make them valuable for stabilizing shoreline and for storing floodwaters during coastal storms.

3.1.1.1.2 Distribution of Marsh Habitat

Salt and brackish marshes occur in each of the states in the South Atlantic Region. The total area of salt and brackish marshes in this region is approximately 894,200 acres (Field et al. 1991). It is estimated that South Atlantic salt marshes account for 16% of the nation's total coastal wetlands.

South Carolina has the greatest salt marsh acreage (365,900 acres), followed by North Carolina (212,800 acres) and Georgia (213,200 acres). Florida (east coast) has the least salt marsh acreage (106,000 acres). The Albemarle-Pamlico Sound (NC) and the St. Andrews-Simons Sounds are the estuarine drainage areas (EDA) with the greatest marsh habitat.

Environmental Sensitivity Index maps recently completed for the four South Atlantic States present the distribution of wetland habitats and examples are included in Appendix B. More extensive coverages will be available on the Council Habitat Homepage.

Table 1 presents baseline estimates of coastal wetland acreage by estuarine drainage area in the South Atlantic region compiled through a cooperative effort of NOAA and USFWS (NOAA 1991a). Figure 1. shows the estuarine drainage areas in the South Atlantic Region for which the estimates have been compiled. This coastal assessment framework, will ultimately be the spatial frame on which all inshore habitat distribution information will be presented.

Table 1. Coastal wetlands by estuarine drainage area in the south Atlantic (Source: NOAA 1991a).

	(Acres X 100)				
Estuarine Drainage Area[a]	Salt Marsh[b]	Fresh Marsh[b]	Forested and Scrub[b]	Tidal Flats[b]	Total[b]
1 Albemarle/Pamlico Sounds (8)	1,576 (14)	365 (3)	9,062 (80)	311 (3)	11,314
2 Bogue Sound (65)	211 (22)	11 (1)	616 (64)	118 (12)	956
3 New River (46)	41 (16)	5 (2)	203 (81)	45 (1)	252
4 Cape Fear River (13)	90 (6)	97 (6)	1,291 (86)	20(1)	1,498
5 Winyah Bay (30)	124 (2)	308 (5)	5,472 (93)	6 (0)	5,910
6 North and South Santee Rivers (88)	129 (7)	174 (9)	1,613 (84)	1 (0)	1,916
7 Charleston Harbor (10)	268 (14)	169 (9)	1,540 (78)	8 (0)	1,985
8 St. Helena Sound (100)	916 (21)	321 (7)	3,036 (71)	25 (1)	4,299
10 Savannah Sound (100)	322 (11)	141 (5)	2,428 (84)	9 (0)	2,900
11 Ossabaw Sound (82)	245 (10)	40 (2)	2,282 (89)	4 (0)	2,571
12 St. Catherine's/ Sapelo Sounds (29)	352 (40)	46 (5)	461 (53)	13 (2)	872
13 Altamaha River (35)	79 (7)	81 (7)	976 (86)	2 (0)	1,138
14 St. Andrews/ Simmons Sounds (66)	1,134 (20)	157 (3)	4,420 (77)	59 (1)	5,771
15 St. Marys R./Cumberland Sound	N/A	N/A	N/A	N/A	N/A
16 St. Johns River (96)	168 (2)	2,646 (25)	7,665 (73)	2 (0)	10,481
17 Indian River (95)	24 (2)	591 (57)	368 (36)	45 (4)	1,028
18 Biscayne Bay (79)	104 (3)	1,556 (41)	2,059 (55)	49 (1)	3,769
South Atlantic Total	6,666 (11)	6,743 (11)	44,615 (76)	747 (1)	58,770

a. Values in parentheses represent the percent of county grid sampled by NOAA. Areas with less than 100 percent coverage may not be completely mapped by the U. S. Fish and Wildlife Service.
b. Values in parentheses represent the percent of total Estuarine Drainage Area wetlands grid sampled by NOAA.

Salt and brackish marshes occur in the intertidal zone in coastal and estuarine waters. The coastal physiography of the northern and southern part of the South Atlantic Bight (e.g. North Carolina and Florida) is dominated by shallow water lagoons behind sand coastal barrier shoreline. In the central portion (e.g. South Carolina and Georgia) there are depositional marsh-filled lagoons. In both these systems, marshes may occur in vast expanses, in narrow fringing bands, or as small "pocket marshes" interspersed among higher elevation areas. Although marshes may develop in sandy sediments, especially in high energy areas, marsh development typically leads to sediments with fine particle-size (mud) and high organic matter content. In most physical settings, marshes can accrete sediments, and thus maintain their elevation in relation to the rising sea level that is occurring over most of the South Atlantic Coast. Salt marshes persist longest in low-energy protected areas where the rate of sediment accretions is greater than or equal to the rate of subsidence (Mitsch and Gosselink, 1986).

Figure 1. Estuarine drainage areas in the South Atlantic Region (Source: NOAA 1991a).

3.1.1.1.3 Species Composition (Flora)

There are more than one hundred species of vascular flora and algae that compose the various intertidal macrophytic communities that are common to the estuaries of the South Atlantic Bight (SAB) (Beccasio et al. 1980). Most of those communities are tidally influenced marshes and, to a lesser degree, tidally influenced shrub and forest communities. South of the St. John River estuary in northern Florida the wetland communities of the lagoonal estuaries of the lower Florida peninsula gradually change from a marsh dominated landscape to a shrub community dominated by mangroves.

The macrophytes identified in this section are all influenced in their growth characteristics by salinity in the water. Salinities in south Atlantic estuaries generally range from 30.0 parts per thousand (ppt) or above (essentially sea strength) at the mouths of coastal inlets to less than 0.5 ppt at the upper reaches of the estuaries under the influence of freshwater outflow from coastal plain streams and rivers (Odum et al. 1984). The tolerance of salinity in the water column and in the soils that serve as substrate directly influence the composition of the plant community. Salinity in combination with the periodicity of inundation due to tidal action and downstream discharge, soil chemistry, soil type, shading and erosion all result in a predictable model of the zonation of individual species and, at times, discrete plant communities.

Spartina alterniflora or smooth cordgrass is the species that dominates the intertidal landscape in South Atlantic estuaries. *S. alterniflora* is able to tolerate salinities from sea strength to freshwater, as well as the saturated soils that are characteristic of twice-daily tidal inundation. *S. alterniflora*, a true grass, commonly occurs in vast stands growing on the fine grained soils that have been deposited in the low energy coastal lagoons and drowned river valleys behind the barrier islands that fringe the oceanic shoreline. Within the vertical zonation of the tidal amplitude *S. alterniflora* occurs from an elevation that generally equates to mean tide level up to mean high water.

S. alterniflora exhibits three growth forms, tall, medium and short. The tall form dominates the immediate shorelines of the tidal stream banks at an elevation from mean tide level up to slightly below the mean high tide level and to a horizontal depth shoreward of about two meters. The stem height commonly attains one to one and a half meters. The medium form is found from the stream side levee horizontally into the interior of the marsh. Stem density is less dense that the tall form and stem height averages up to about one meter. The short form grows in the interior portion of the marsh where sediments are finer and less well-drained. Stem density can be higher than the medium growth form and stem height averages about 0.2 - 0.3 meters or shorter. This growth pattern is attributed to a combination of periodicity of tidal inundation, soil salinity, soil saturation, nutrient availability and other less predictable factors. The zonation and stem density, however, play a key role in the use of *Spartina* marshes by consumer organisms.

The second most common marsh plant that occurs in the region is *Juncus roemerianus*. *J. roemerianus*, like *Spartina alterniflora,* is found in all of the estuaries of the SAB. Less salt tolerant and not as well adapted to longer periods of inundation as *S. alterniflora*, *J. roemerianus* is found in the higher elevations of tidal coastal marshes. In salinity regimes higher that 15 ppt *J. roemerianus* is found in dense monospecific stands often in a zone between the *Spartina* and high ground. Stem height averages one meter but may approach two meters.

Diversity of the vascular plant community increases at higher tide elevations and at lower salinities. In the outer portions of the estuary, *Spartina patens* or saltmeadow cordgrass, occurs between mean high water and spring high water. Other plants characteristic of the high marsh are *Salicornia virginica* and *Distichlis spicata*. In more brackish portions of the estuary, *S. alterniflora* is replaced by *Spartina cynosuroides* and *Scrirpus olneyii*.

Several species of macroalgae may become abundant within salt marsh tidal creeks and on the marsh surface, particularly in early spring. These include *Ulva*, *Codium, Gracilaria* and *Enteromorpha*. These macroalgal communities, although ephemeral, can provide both refuge and food resources to marsh consumer organisms. Additionally, a diverse community of benthic and epiphytic microalgae inhabit the marsh surface and the stems of marsh plants. This community is composed of diatoms, cyanobacteria, and photosynthetic bacteria, and may represent a significant portion of marsh primary production. The primary production of this algal community also plays an important role in supporting fisheries production in salt marsh habitats.

3.1.1.1.4 Species Composition (Fauna)

Estuarine intertidal marshes provide habitat for species of concern in two SAFMC management plans: the red drum fishery and the shrimp fishery. These marshes also provide fish and wildlife habitat for other fish, shellfish, and other invertebrates, as well as endangered and threatened species, furbearers and other mammals, waterfowl, wading birds, shorebirds and other birds, and reptiles and amphibians. Beyond the estuaries, exported marsh nutrients, detritus, and prey species contained in the food web ultimately add to the ecosystems supporting species of concern in two other management plans, the coastal migratory pelagics fishery and the snapper grouper fishery.

In contrast to freshwater marshes, salt marshes have low species diversity of the higher vertebrates, but high species diversity of invertebrates, including shellfish, and fishes. Table 2 reviews examples of fishes and crustaceans common to southeastern U.S. marshes. These organisms utilize the marsh structure (including the stems of emergent vascular plants, attached macroalgae, substrate materials such as shells and sediments, attached living oysters and mussels, residual tidal pools, and accumulated woody flotsam). Some feed directly on the vegetation, especially decapods and gastropods. Some species, are not found within the marsh, but derive substantial food resources from marsh plants as detritus. The protection afforded by the stem structure and intertidal water levels provides spawning habitat for some fish species, such as killifish, atherinids and gobiids, but most fishes associated with the marsh are recruited as larvae or early juveniles (Boesch and Turner 1984). Taxa spawning in or near the marsh are considered residents, but the most of the fish species (but not necessarily most of the biomass) are seasonally transient (Weinstein 1979). Transients spawn elsewhere, either upstream in freshwater (e.g., striped bass), or downstream in the coastal waters (e.g., flounders) (Schreiber and Gill 1995), and occupy the marsh habitat primarily as juveniles in the warmer months. Some of these species do not penetrate into the marsh, but are strongly linked to it in the adjacent fringing water. Of particular note are penaeid shrimp and red drum, both of which are managed species by the SAFMC. Red drum are critically tied to marshes as juveniles and early adults, feeding on the crustaceans and fishes produced there. Penaeid shrimp (brown, white, and pink) browse at the marsh edge and use the structure for protection (Turner 1977). Estuarine dependant species in the snapper grouper complex include gag, lane snapper, and gray snapper. Spanish mackerel, an important coastal migratory pelagic species, is also dependant on the estuaries during larval and juvenile life stages.

3.1.1.1.5 Habitat Restoration

Efforts to restore or create salt marsh habitat have been underway for over 20 years, as losses of coastal wetlands through erosion, land subsidence, sea level rise and coastal development have increased (Nixon 1980; Matthews and Minello 1994). Restoration or creation of marsh habitat begins with designing a site with the appropriate hydrology, tidal exchange, and sediment properties to support the growth of salt marsh plants. Subsequent to physical modification of the site, plantings are often made of *Spartina alterniflora* or, less frequently, of other marsh plants. Given appropriate site selection and preparation, successful establishment of *Spartina* and/or other marsh species can occur within a few growing seasons.

Table 2. List of select macrofaunal species observed in collections from some marsh habitats located in the southeastern United States (Source: NMFS 1998).

Species	Common Name	Resident Status	Macrophyte Genera	Fisheries Value
FISH				
Anchoa spp.	anchovy	M	Sp, Sc, Ty	P
Anguilla rostrata	American eel	M	Sp, Ju	C/P
Archosargus probatocephalus	sheepshead	M	Sp	R/C/P
Bairdiella chrysoura	silver perch	M	Sp, Sc, Ty, Ju	R/P
Brevootia tyrannus	Atlantic menhaden	M	Sp, Sc, Ty	R/C/P
Cynoscion nebulosus	spotted seatrout	M	Sp, Ju	R/C/P
Cyprinodon variegatus	sheepshead minnow	R	Sp, Ju	P
Dorosoma cepedianum	gizzard shad	F	Sc, Ty	C/P
Eucinostomus sp.	mojarra	M	Sp, Sc, Ty, Ju	P
Fundulus spp.	killifish	R	Sp, Sc, Ty, Ju	R/P
Gambusia affinus	mosquito fish	R	Sc, Ty, Ju	P
Gobiidae	gobies	R	Sp, Sc, Ty, Ju	P
Ictalurus catus	white catfish	F	Sc, Ty	R/C/P
Lagodon rhomboides	pinfish	M	Sp, Sc, Ty, Ju	R/P
Leiostomus xanthurus	spot	M	Sp, Sc, Ty, Ju	R/C/P
Lepomis gibbosus	pumpkinseed	F	Sc, Ty	R/P
Lutjanus griseus	gray snapper	M	Sp	R/C/P
Lutjanus synagris	lane snapper	M	Sp	R/C/P
Lucainia parva	rainwater killifish	R	Sp, Ju	P
Menidia spp.	silversides	R	Sp, Sc, Ty, Ju	P
Micropogonias undulatus	Atlantic croaker	M	Sc, Ty	R/C/P
Micropterus salmoides	largemouth bass	F	Sc, Ty	R/C/P
Morone saxatilis	striped bass	F	Sp, Sc,Ty	R/C/P
Mugil spp.	mullet	M	Sp, Sc, Ty, Ju	R/P
Orthopristis chrysoptera	pigfish	M	Sp	R/P
Paralichthys spp.	flounder	M	Sp, Sc, Ty, Ju	R/C/P
Pogonias cromis	black drum	M	Sp	R/C/P
Pomatomus saltatrix	bluefish	M	Sp, Sc, Ty	R/C/P
Pomoxis nigromaculatus	black crappie	F	Sc, Ty	R/C/P
Sciaenops ocellata	red drum	M	Sp	R/C/P
Sphyraena barracuda	great barracuda	M	Sp	R/P
Symphurus plagiusa	black cheek tonguefish	M	Sp	P
Urophycis spp.	hake	M	Sp	R/C/P
DECOPODS	--			
Callinectes sapidus	blue crab	M	Sp, Sc, Ty, Ju	R/C/P
Menippe mercenaria	stone crab	R	Sp	R/C/P
Palaemonetes spp.	grass shrimp	R	Sp, Sc, Ty, Ju	P
Penaeus spp.	penaied shrimp	M	Sp, Sc, Ty, Ju	R/C/P
Uca spp.	fiddler crabs	R	Sp, Ju	R/C/P

Letter codes for the Life History Type heading are R = resident, M = transient (marine spawner), F = transient (freshwater spawner); for the Macrophyte Genera heading are Sp = *Spartina* spp., Sc = *Scirpus* sp., Ty = *Typha* spp., Ju = *Juncus* spp.; and for the Fisheries Value heading are R = recreational, C = commercial, P = prey species.

An important, and still unanswered, question relative to marsh habitat restoration is how long it takes to restore marsh habitat function, as opposed to simply the replacement of marsh plants; this evaluation of habitat function is complex and time-consuming. Examples of marsh functions to be evaluated are food web support, provision of fishery nursery grounds, and the transformation of nutrients (Smith et al. 1995). Evidence to date suggests that the time it takes a transplanted salt marsh to attain the ecological function of a mature natural marsh may be 10 to 20 years. If the hydrology and tidal elevation of the site are not maintained, then the transplanted marsh may never supply equivalent habitat function as a natural marsh. This is particularly important to recognize in cases where marsh restoration or creation is undertaken to mitigate for the loss of natural marsh via development, dredging, or other permitted activities.

3.1.1.2 Estuarine Shrub/Scrub (Mangroves)

3.1.1.2.1 Description, Distribution and Mangrove Habitat Types.

Mangroves represent a major coastal wetland habitat in the southeastern United States, occupying in excess of 200,000 hectares along the coastlines of all Gulf coast states, Puerto Rico, and the U. S. Virgin Islands; small areas of introduced species are also present in southern California and in Hawaii. Collectively four species comprise the “mangrove” forest: the red (*Rhizophora mangle* L), black (*Avicennia germinans* L. Stearn), the white (*Laguncularia racemosa* L. Gaertn.f.) mangroves and the buttonwood mangrove (*Conocarpus erectus* L.). Figure 2 provides an illustration of some of the characteristics of the first three species. The buttonwood, although frequently referred to as a mangrove, does not meet the strict mangrove definition proposed by Tomlinson (1986). The largest areas of mangrove forests are found along the coastal areas of Florida south of Latitude 28^{o} 00 N. About 90% of this is located in the four southernmost counties of the Florida peninsula: Dade, Monroe, Collier, and Lee Counties (Gilmore and Snedaker 1993). Figure 3 shows the general distribution of mangrove species in Florida.

These species singularly or in combinations occupy wide ranges in the coastal zone from regularly flooded tidal regimes to higher elevations that may receive tidal waters only several times per year or during storm events. The growth of mangroves appears to be limited to estuarine systems and more inland areas that are subject to saline intrusions. A classification system for mangrove types based on gross differences in topography, surface hydrology and salinity exists and is presented in Table 3. A brief description of the mangrove types as summarized from Gilmore and Snedaker (1993), follows. This description is provided because the different forest types have somewhat different functional roles and fauna which utilize them (see next section).

Mangrove fringe forests occur along sheltered coastlines with exposure to open water of lagoons and bays. The tree canopy foliage forms a vertical wall and these forests are almost exclusively dominated by red mangroves. The characteristics of this mangrove habitat type are related to the patterns of tidal inundation through which detrital materials and propagules are exported from the system during ebb tides. These fringe forests commonly have a shoreline berm or an interior wrack line (i.e., build up of detritus). This is a very important habitat type for fishery organisms because of the presence of abundant food and refuge provided by the mangrove prop-roots, and has been more frequently studied relative to its links with adjacent systems than most other mangrove forest types (Thayer and Sheridan In press).

Overwash mangrove islands are ecologically similar to fringe forests because of their high frequency of tidal inundation, but here the entire area is completely covered by tidal waters on almost every tidal cycle. Because of the overwash phenomenon there is an infrequent build up of a detrital berm or the development of a shoreline berm. Gilmore and Snedaker (1993) indicate that there is a high incidence of bird rookeries on overwash islands, presumably due to the limited habitat for predators and scavengers.

Riverine mangrove forests occur in riverine areas that have estuarine water exchange, and is a forest type that is the most productive of the 5 described (Table 3). This high productivity is attributed to the reduced salinity and the fact that freshwater runoff from land provides mineral nutrients required for growth. This high production provides organic detrital material to the adjoining low-salinity system, and also is an important habitat for fishery organisms (Ley 1992).

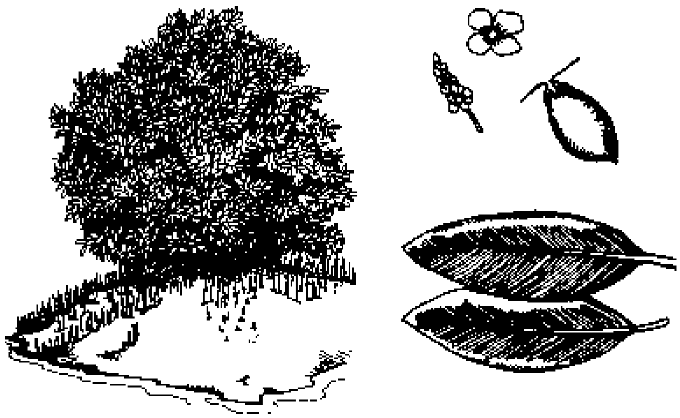
Table 3. Characteristics of Mangrove Forest Type of Southern Florida [a] (Table from Gilmore and Snedaker 1993.)

	Mangrove Types				
Characteristics	Fringe Forest	Overwash Forest	Riverine Forest	Basin Forest	Dwarf Forest
Forest height (m)	7.65	6.37	12.64	12.14	<1.0
Mean stand diameter (cm)	8.31	11.12	19.37	10.53	1.75
Complexity Index [b]					
Trees	26.44	13.17	38.77	18.41	1.5
Saplings	1.54	2.17	22.76	4.09	--
Litter production (mg/ha/yr.)	9.00	9.00	12.98	6.61	1.86

[a] Data are averages.
[b] Complexity Index utilizes tree height, density, and number of species as independentvariables and the sum of present contribution of individual species (Pool et al. 1977).

Basin mangrove forests exist in inland topographic depressions which are not flushed by all high tides. This habitat type may experience seasonal periods of hypersaline soil water which can limit mangrove growth and induce mortality. These habitat types are normally dominated by black mangroves but invasion by Australian pine and Brazilian pepper is very common. Odum et al. (1982) note that this habitat type provides an extreme habitat in which few aquatic species can live because of the commonly low oxygen levels and presence of generally high levels of hydrogen sulfide. However, Gilmore and Snedaker (1993) suggest that because of the large areal extent of the basin mangrove habitat type, they probably contribute the largest absolute quantity of organic detritus to Florida’s nearshore waters, and that this export occurs on a highly seasonal basis.

Dwarf mangrove forests occur in areas where nutrients, freshwater inflow and tidal activity limit the growth of the plant. All of the species can exist in a dwarf form. These marginal habitats have received little attention relative to their role as fishery habitat.



Black Mangrove

White Mangrove

Red Mangrove

Figure 2. Illustrations of red mangroves, black mangroves, and white mangroves with propagules, flowers, and leaves (Source: Odum et al., 1982).

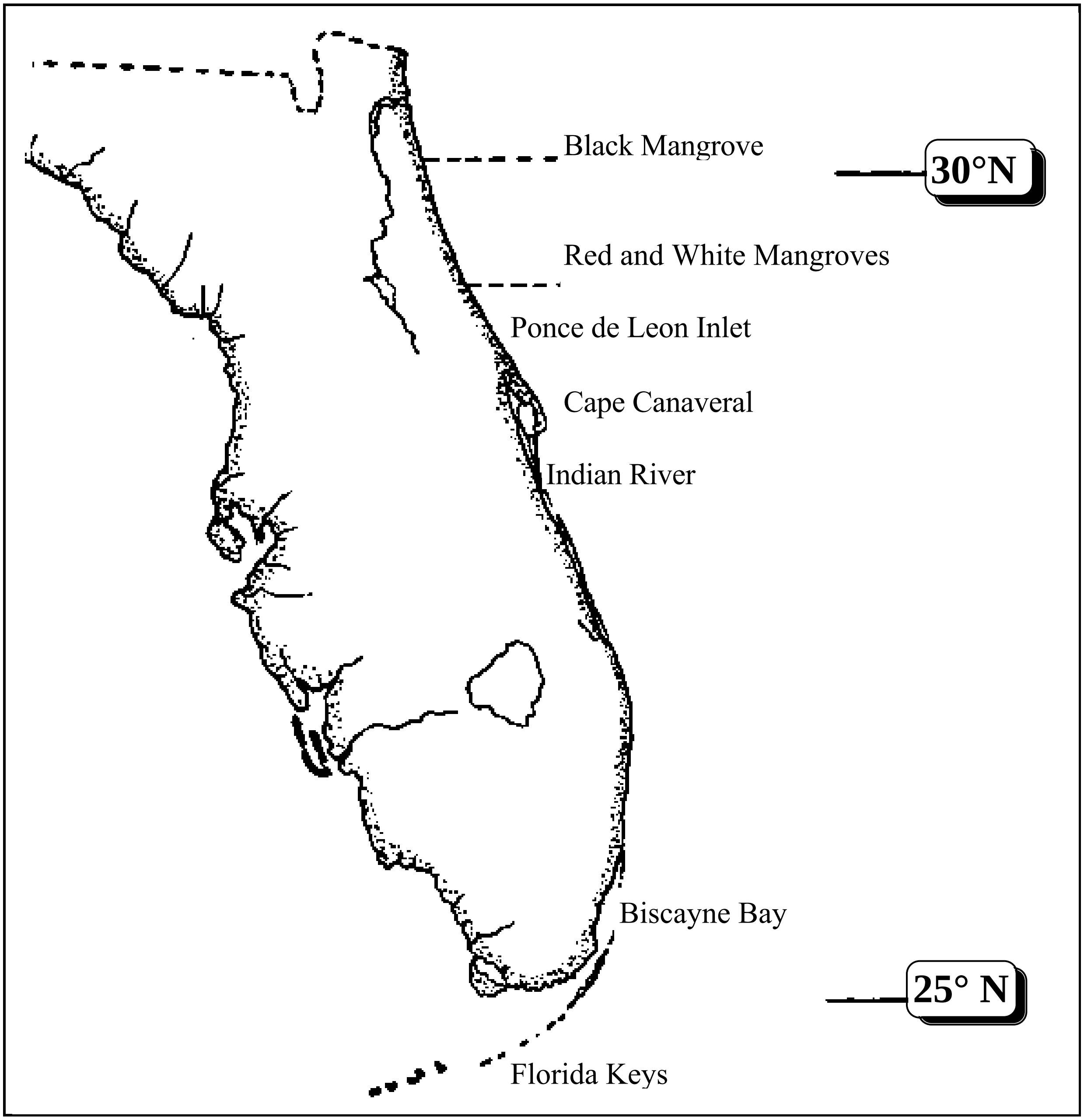


Figure 3. Approximate northern limits for the red mangrove, black mangrove, and white mangrove in Florida (in Odum et al., 1982 based on Savage 1972).

3.1.1.2.2 Stresses on Mangrove Ecosystems

While much of the total U.S, mangrove forest area is protected under the jurisdictions of parks, sanctuaries and refuges (Gilmore and Snedaker 1993, Thayer et al. In press), this coastal habitat and resource is being progressively diminished by a variety of natural and anthropogenic actions such as removal for coastal development, deprivation of freshwater from upland watersheds, severe freezes, clearing for charcoal production, oil spills and water pollution, competitive exclusion by exotic tree species (e.g., Australian pine, Brazilian pepper), illegal cutting or removal, coastal erosion, and mosquito control activities. Most of these aspects have been discussed and/or documented by Odum et al. (1982) and Gilmore and Snedaker (1993), and are discussed under Section 4.0 of this document (Threats to Essential Fish Habitat), and need not be detailed here.

Mangroves are considered resilient and display characteristics of some "pioneer species" in that they have broad tolerances to environmental factors, rapid growth and maturity, continuous or almost continuous flowering and propagule production, high propagule outputs in a wide range of environmental conditions, and adaptations for short and long distance dispersal by tides (Cintron-Molero 1992). Even with these "r-strategist" characteristics mangroves are both sensitive and vulnerable to disturbance. Odum et al. (1982) point out, however, that one of the adaptations of mangroves--the aerial root system, is also one of the plant's most vulnerable components because of their susceptibility to clogging, prolonged flooding, and boring damage from invertebrates. They note that any process that coats the aerial roots with fine sediments or covers them with water for long periods has the potential of being a destructive agent. Diking, impounding and long term flooding, as has occurred in mosquito control situations has caused considerable damage, as have spraying of herbicides and inundation by oil spills. Good discussions of the impacts of urbanization, impoundment and flood control are provided by Gilmore and Snedaker (1993).

3.1.1.2.3 Ecological Roles and Function

Odum et al. (1982) has provided perhaps the most detailed account of the ecology of mangroves and this document and references cited should be referred for detailed descriptions of mangrove habitats. In the interim, however, several publications have appeared (Rooker and Dennis,1991, Cintron-Molero 1992, Gilmore and Snedaker 1993, Thayer and Sheridan In press, Thayer et al. In press) which update ecology, fishery value, and research information needs based on the available and often frequently limited literature base that exists on this habitat type. Cintron-Molero (1992) has provided a succinct summary of the functional values of mangrove ecosystems that is not dissimilar to that presented for seagrass ecosystems (Wood et al. 1969, Thayer et al. 1975). The relatively high primary productivity of mangrove ecosystems and the associated biological processes provide many goods and services which are of direct or indirect benefit to the public and to the urban and industrial environment. In Asia and South America, mangroves have been managed for lumber, firewood and charcoal. Mangrove habitats, particularly riverine, overwash and fringe forests, provide shelter for larval, juvenile and adult fish and invertebrates as will be discussed later and dissolved and particulate organic detritus to estuarine food webs. Because of this linkage, both as habitat and as food resources, mangroves are important exporters of material to coastal systems as well as to terrestrial systems (e.g., through bird use as a rookery and feeding on fish). They help shape local geomorphic processes and are important in the heterogeneity of landforms which provide shelter, foraging grounds and nursery areas for terrestrial organisms. The root system binds sediments thereby contributing to sedimentation and sediment stabilization.

3.1.1.2.3.1 The linkage between mangroves and fishery organisms

Thayer and Sheridan (In press) and Gilmore and Snedaker (1993) have provided syntheses of most recent available information on fishery organism use, in terms of presence, in mangrove habitats; information prior to about 1981 on faunal use is provided by Odum et al. (1982). Based on these publications and references cited, there is little doubt that mangrove habitats provide nursery, feeding and growth, and refuge for both recreationally and commercially important fishery organisms and their food resources when flooded. As noted by

Thayer and Sheridan (In press) and Thayer et al. (1987), while it has long been recognized that mangrove habitats in the southeastern U. S. are important to fishery resources (see Odum et al. 1982), there have been few quantitative studies dealing with the use of these habitat types and their functional value to fishery organisms largely from the lack of available techniques. The prop-root habitat of red and black mangroves has presented a formidable obstacle to evaluation of the temporal and spatial distribution and abundances of fishes and decapod crustaceans using the habitat. However, techniques have evolved to at least provide some information on the abundances and composition of organisms which actually move into and out of these systems when flooded.

Gilmore and Snedaker (1993) have divided mangrove faunal communities into seven spatial guilds that are defined by microhabitat associations, but recognized that these are dynamic groupings with species often moving from one guild to another during ontogeny or with changes in environmental conditions (Table 4). From the standpoint of fish and invertebrate use spatial guilds I, III, IV and V are most relevant, but Guild II, VI and VII cannot be discounted because this contains the arboreal and terrestrial components of the community, many of which are predators or scavengers on the fish and invertebrate fauna of the mangrove community.

The following discussion will deal with the mobile components of mangrove communities, most of which, from a fisheries standpoint interact with the community during flood tides, and the material comes primarily from Gilmore and Snedaker (1993) Thayer and Sheridan (In press) and references cited. Based on the spatial guild scheme seen in Table 4, transient representatives typically are represented by larval and juvenile stages of both invertebrates and fish commonly found using the fringe and overwash island mangrove forests (Guild I), and frequently the adult stage is found in adjacent seagrass meadows or in reef structures. Spiny lobsters (*Panulirus argus*) and pink shrimp (*Penaeus duorarum*) are the most important commercial and recreational invertebrates commonly found among the prop-roots of red mangroves, although Thayer et al. (1987) noted that pink shrimp were conspicuously absent from mangrove habitats sampled in Florida Bay. However, important links in the food linkages--the amphipods, isopods, polychaetes, etc.--are very important invertebrate components of the mangrove prop-root habitat. Snook (*Centropomus undecimalis*), jewfish (*Epinephelus itajara*), tripletail (*Lobotes surinamensis*), leatherjack (*Oligoplites saurus*), gray snapper (*Lutjanus griseus*), dog snapper (*L. jocu*), sailor's choice (*Haemulon parra*), bluestriped grunt (*H. sciurus*), sheepshead (*Archosargus probatocephalus*), black drum (*Pogonias cromis*) and red drum (*Sciaenops ocellata*) also are common to this habitat, using it as refuge and as a ready source of food. Collections in both seagrass beds and mangroves suggest that there is an integral link between these habitats with tripletail, snook, gray snapper, red drum, and jewfish, for example, occurring over seagrass beds or other adjacent bottoms as adults or large juveniles but using the mangrove prop-root during juvenile stages. Spotted seatrout (*Cynoscion nebulosus*), striped and white mullets (*Mugil cephalus*, *M. curema*) and great barracuda (*Sphyraena barracuda*) juveniles also are common inhabitants.

Mangrove tidal creeks and ditches (Guild IV) have received little attention (Ley 1992, Gilmore and Snedaker 1993) but based on the limited data are also utilized extensively by fishery organisms. Large aquatic predators appear to enter this mangrove community through the tidal tributary habitat. Because this habitat type (at least the creek edges) is flooded most of the time, this can serve as habitat for both resident and transient species (Table 4). Predaceous fishes common to this mangrove habitat are juvenile bull sharks (*Carcharhinus leucas*), Atlantic stingray (*Dasyatis sabina*), tarpon (*Megalops atlanticus*), ladyfish (*Elops saurus*), snook

(*Centropomus undecimalis*), jewfish (*Epinephalus itajara*), gray snapper (*Lutjanus griseus*) and red drum (*Sciaenops ocellatus*). Turtles, crocodiles and alligators also forage in these habitats.

The mangrove basin habitat (Spatial Guild V) is the harshest mangrove habitat type (see earlier), and is characterized by separation from tidal water by a berm and seasonal changes in water and thus availability for fishery resources . The more abundant fishes found in this habitat type are cyprinodontiform species such as killifish, mosquitofish and mollies. These species do provide food resources for surrounding habitats during periods of flooding when there is exchange with the adjoining estuary or riverine system.

Table 4. Habitat and Microhabitat Distribution of Organisms Showing an Association with Mangrove Forest Habitats of the Southeastern United States (Source: Gilmore and Snedaker 1993).

Habitat	Species
Sublittoral/Littoral Mangrove Guild: Spatial (Red Mangrove Fringe, Riverine and Overwash	
RESIDENTS-SESSILE	
Tunicates	Black tunicate, *Ascidia niger*
	Mangrove tunicate, *Ecteinascidia*
Crustaceans	Barnacle, *Balanus eburneus*
	Mangrove *Sphaeroma terebans*
Molloscs	Eastern white slipper *Crepidula plana*
	Eastern oyster, *Crassostrea virginica*
	Tree oysters, *Isognomon spp.*
	Broad ribbed *Carditamera*
	Mossy ark, *Arca imbricata*
	Scorched mussel, *Branchidontes*
	Wood boring *Martesia*
RESIDENTS-MOBILE	
Molluscs	Keyhole limpet, *Diodora cayensis*
	Crown conch, *Melogena corona*
	Lightning *Busycon*
	Rock shells, *Thais spp.*
	Oyster drills, *Urosalpinx spp.*
	Pisa snails, *Pisania pusio*
	Ceriths, *Cerithidea spp.*
	Dove snails, *Anachis*
	Turret snails, *Turritella spp.*
	Bubble snails, *Bulla striata*
	Mud snails, *Nassarius spp.*
Crustaceans	Herbst's *Panopeus herbsti*
	Harris mud crab, *Rithropanopeus*
	Broadback mud crab, *Eurytium limosum*
	Snapping shrimp, *Synalpheus*
Teleosts	Sailfin molley, *Poecilia*
	Mosquitofish, *Gambusia*
	Mangrove gambusia, *G. Rhizophorae*
	Inland *Menidia*
	Hardhead *Atherinomorus*
	Skilletfish, *Gobiesox strumosus*
	Florida blenny, *Chasmodes saburrae*
	Highfin blenny, *Lupinoblennius*
	Banded blenny, *Paraclinus*
	Fat sleeper, *Dormitator*
	Notchtongue *Bathygobius*
	Emerald goby, *Gobionellus*
	Naked goby, *Gobiosoma bosc*
	Crested goby, *Lophogobius*
	Clown goby, *Microgobius*

Table 4. Habitat and Microhabitat Distribution of Organisms Showing an Association with Mangrove Forest Habitats of the Southeastern United States (cont.).

Habitat	Species
Sublittoral/Littoral Mangrove Guild: Spatial Guild I (Red Mangrove Fringe, Riverine and Overwash Forests)	
TRANSIENTS	
Molluscs	Squid, *Loligo spp.*
Crustaceans	Spiny lobster, *Panulirus argus*
	Pink shrimp, *Panaeus duorarum*
	Grass shrimp, *Palaemonetes spp.*
	Great land crab, *Cardisoma guanhumi*
	Fiddler crabs, *Uca spp.*
	Swimming crabs, *Callinectes spp.*
Teleosts	Snook, *Centropomus undecimalis*
	Jewfish, *Epinephelus itajara*
	Tripletail, *Lobotes surinamensis*
	Leatherjacket, *Oligoplites saurus*
	Gray snapper, *Lutjanus griseus*
	Dog snapper, *L. jocu*
	Sailor’s choice, *Haemulon parra*
	Bluestriped grunt, *H. sciurus*
	Sheepshead, *Archosargus probatocephalus*
	Striped mojarra, *Eugerres plumieri*
	Yellowfin majarra, *Gerres cinereus*
	Irish pompano, *Diapterus auratus*
	Black drum, *Pogonias cromis*
	Red drum, *Sciaenops ocellata*
	Sergeant major, *Abudefduf saxatilis*
	Checkered puffer, *Sphoeroides testudineus*
Mangrove Arboreal Canopy Guild: Spatial Guild II	
RESIDENTS	
Molluscs	Angulate periwinkle, *Littorina angulifera*
	Latterhorn snail, *Cerithidea scalariformis*
	Coffeebean snail, *Melampus coffeus*
Crustaceans	Sea roach, *Ligia exotica*
	Mangrove crab, *Goniopsis cruentata*
	Mangrove crab, *Aratus pisonii*
	Mangrove crab, *Sesarma curacaoense*
	Gibbes’ pachygrapsus, *Pachygrapsus transversus*
Insects	Moths, *Ecdytolopha spp.*
	Mangrove skipper, *Phocides pigmalion*
	Hairy green caterpillar, *Alaroda slossoniae*
	Red-stripped yellow processionary caterpillar, *Automeris io*
	Puss moth, *Megalopyge opercularis*
	Mangrove scolytid beetles, *Poecilips rhizophorae*
Reptiles	Mangrove snake, *Nerodia fasciata compressicauda*
Birds	Greenbacked heron, *Butorides striatus*
	Belted kingfisher, *Megaceryle alcyon*

Table 4. Habitat and Microhabitat Distribution of Organisms Showing an Association with Mangrove Forest Habitats of the Southeastern United States (cont.).

Habitat	Species
Mangrove Arboreal Canopy Guild:Spatial Guild II (Continued)	
RESIDENTS (Continued)	Cuban yellow warbler, *Dendroica petechia gundlachi*
Birds (Continued)	Florida prairie warbler, *D. discolor paludicola*
	Black-whiskered vireo, *Vireo altiloquus*
	Gray kingbird, *Tyrannus dominicensis*
	Mangrove cuckoo, *Coccyzus minor*
	White-crowned pigeon, *Columba leucocephala*
	Southern crested flycatcher, *Myiarchus crinitus crinitus*
	Florida cardinal, *Cardinalis cardinalis floridana*
TRANSIENTS/DIURNAL MIGRANTS	
Birds	Anhinga, *Anhinga anhinga*
	Double-crested cormorant, *Phalacrocorax auritus*
	Brown pelican, *Pelecanus occidentalis*
	Wading birds, 19 species: *Areidae, Ciconiidae, and Threskiornithidae*
	Osprey, *Pandion haliaetus*
TRANSIENTS/SEASONAL MIGRANTS	
Birds	Warblers, *Emberizidae*
	Vireos, *Vireonidae*
	Loggerhead kingbird, *Tyrannus caudifasciatus*
	Stripe-headed tanager, *Spindalis zena*
Mangrove Benthic and Infauna Community: Spatial Guild III	
RESIDENTS	
Crustaceans	Harris mud crab, *Rithropanopeus harrisii*
	Broadback mud crab, *Eurytium limosum*
	Fiddler crabs, *Uca spp.*
	Giant land crab, *Cardisoma guanhumi*
	Crayfish, *Procambarus alleni*
	Pink shrimp, *Penaeus duorarum*
	Glass shrimp, *Palaemonetes spp.*
Insects	Salt marsh mosquito, *Aedes taeniorhynchus*
	Salt marsh mosquito, *A. solicitans*
	Sand flies, *Culicoides spp.*
	Rivulus, *Rivulus marmoratus*
Mangrove Tidal Creek and Ditch Community: Spatial Guild IV	
Molluscs	Squid, *Loligo spp.*
	Lightning whelk, *Busycon contrarium*
Crustaceans	Pink shrimp, *Penaeus duorarum*
	Glass shrimp, Palaemonetes spp.
	Swimming crabs, *Callinectes spp.*
Elasmobranchs	Bull shark, *Carcharhinus leucas*
	Atlantic stingray, *Dasyatis sabina*

Table 4. Habitat and Microhabitat Distribution of Organisms Showing an Association with Mangrove Forest Habitats of the Southeastern United States

Habitat	Species
	Mangrove Tidal Creek and Ditch Community: Spatial Guild IV (Continued)
Teleosts	Gulf killifish, *Fundulus grandis*
	Striped mullet, *Mugil cephalus*
	Tarpon, *Megalops atlanticus*
	Ladyfish, Elops saurus
	Snook, *Centropomus undecimalis*
	Jewfish, *Epinephelus itajara*
	Gray snapper, *Lutjanus griseus*
	Red drum, *Sciaenops ocellatus*
Reptiles	Soft shelled turtles, *Tionyx spp.*
	Mangrove diamondback terrapin, *Malaclemys terrapin rhizophorarum*
	Green turtles, *Chelonia mydas mydas*
	Mangrove water snake, *Nerodia fasciata compressicauda*
	Florida crocodile, *Crocodylus acutus*
	American alligator, *Alligator mississippiensis*
Birds	Anhinga, *Anhinga anhinga*
	Cormorants, *Phalacrocorax spp.*
	Brown pelican, *Pelecanus occidentalis*
	Surface and diving birds, 29 species: *Anaidae and Rallidae*
Mammals	Manatee, *Trichechus manatus latirostris*
	River otter, *Lutra canadensis*
	Bottlenosed dolphin, *Tursiops truncatus*
	Mangrove Basin Forest Community: Spatial Guild V
RESIDENTS	
Crustaceans	Fiddler crabs, *Uca spp.*
	Glass shrimp, *Palaemonetes spp.*
Insects	Salt marsh mosquito, *Aedes taeniorhynchus*
	Salt marsh mosquito, *A. solicitans*
	Corixids
Fish	Sheepshead minnow, *Cyprinodon variegatus*
	Mosquitofish, *Gambusia affinis*
	Sailfin molly, *Poecilia latipinna*
	Marsh killifish, *Fundulus confluentus*
TRANSIENTS	
Birds	Egrets and herons: *Areidae, Ciconiidae, Threskiornithidae*
Reptiles	Mangrove diamondback terrapin, *Malaclemys terrapin rhizophorarum*
	Mangrove water snake, *Nerodia fasciata compressicauda*
Mammals	White-tailed deer, *Odocoilus virginiana*
	Raccoon, *Procyon lotor*
	Bobcat, Felix rufus
	Gray fox, *Urocyon cinereoargenteus*

3.1.1.2.4 Information/Research Needs.

Thayer et al. (In press) presented a discussion on 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 6 priority areas of information need.

3.1.1.2.4.1 Food web-related information needs.

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 the dissolved organic form 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. 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).

3.1.1.2.4.2 Information needs on productivity and structure of mangroves.

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 characterization of forest structure, successional status and type, remotely. The proportional contribution of mangroves to the total primary production of a given watershed or estuary is not well known. This should include quantification of rates of primary production of respective components and development and testing of predictive models of the factors that control primary production in mangrove estuaries. 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. Coupled with the above is research on the significance of hydrology on successional 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.

3.1.1.2.4.3 Habitat use information needs.

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, and 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.

3.1.1.2.4.4 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.

3.1.1.2.4.5 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.

3.1.1.2.4.6 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.

3.1.1.3 Ecological Value of Seagrasses and Their Function as Essential Fish Habitat

This section is intended to briefly summarize the most important aspects of marine seagrasses which pertain directly to their distribution, abundance and function as essential fish habitat in the South Atlantic region of the United States. For an extensive and comprehensive ecological profile of seagrasses growing in the South Atlantic region we recommend two U.S. Department of Interior Community Profiles: Thayer et al. (1984) and Zieman (1982). A recent symposium on Biodiversity in the Indian River Lagoon published in Volume 57 of the Bulletin of Marine Science (Swain et al. 1995) is an excellent compendium of the biology, ecology and biodiversity of seagrass communities on the east coast of Florida. Another important source document is the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States (Durako et al. 1987). Additionally, three published books on the general biology and ecology of seagrasses have information pertaining directly to use of seagrass habitat by managed species and their food sources (McRoy and Helfferich 1977, Phillips and McRoy 1980, Larkum et al. 1989). Finally, “The relationship of submerged aquatic vegetation (SAV) ecological value to species managed by the Atlantic States Marine Fisheries Commission (ASMFC): summary for the ASMFC SAV Subcommittee” by R. Wilson Laney (1997) provides detailed descriptions and literature citations of seagrass use by species managed by ASMFC and the South Atlantic Council.

3.1.1.3.1 Seagrass Species and Their Geographic Distribution in the South Atlantic Region

Out of the estimated 250,000 flowering plants existing on earth today, only about 60 species have adapted to life in the marine environment (den Hartog 1970). Collectively, we refer to this group of submersed aquatic vascular plants (SAV) as seagrasses. Seaweeds (macroalgae) are often mistakenly referred to as "grasses". Despite the fact that they frequently co-occur and provide similar ecological services, these two plant taxa have distinctly different growth forms and contrasting life requirements. Taxonomically, seagrasses are divided into two families and 12 genera (den Hartog 1971, Phillips and Meinez 1988). At least 13 species of seagrass occur in United States waters, with the exception of Georgia and South Carolina where highly turbid freshwater discharges, suspended sediments and a large tidal amplitude combine to prevent their permanent establishment. In the remainder of the south Atlantic region there are 6 genera of seagrasses represented by 8 species, ranging in size from the three smallest, *Halophila decipiens, Halophila engelmannii* and *Halophila johnsonii,* to the relatively larger genera, *Zostera marina, Ruppia maritima, Halodule wrightii, Syringodium filiforme* and *Thalassia testudinum* (Figures 4 and 5). Maps are included in Appendix C that present general seagrass distribution by estuarine drainage area in the south Atlantic region.

The three seagrass species growing in North Carolina, *Z. marina*, *H. wrightii* and *R. maritima*, are all found within coastal lagoons, protected inland waterways and river mouths protected by barrier islands. There are no known open ocean seagrass meadows in North Carolina. The remaining five species plus *H. wrightii* all occur in Florida and may be found in protected inland waters as well as oceanic environments. In north central, central, and southeast Florida all of the seagrasses occur within protected coastal lagoons and in the Intracoastal Waterway (ICW). Beginning around the Palm Beach area and continuing south through the Florida Keys National Marine Sanctuary (FKNMS), *Halophila decipiens* is found on offshore sandy sediments to a depth of approximately 30 m. Open ocean meadows of *Halodule wrightii, Syringodium filiforme* and *Thalassia testudinum* begin just south of Virginia Key in Biscayne Bay and continue through the FKNMS in water depths up to approximately 30-40 m. The majority of seagrass biomass is distributed in the subtidal zone; however, all of the species, with the exception of *H. decipiens,* can be found growing in the intertidal zone where they may experience periods of exposure and desiccation.

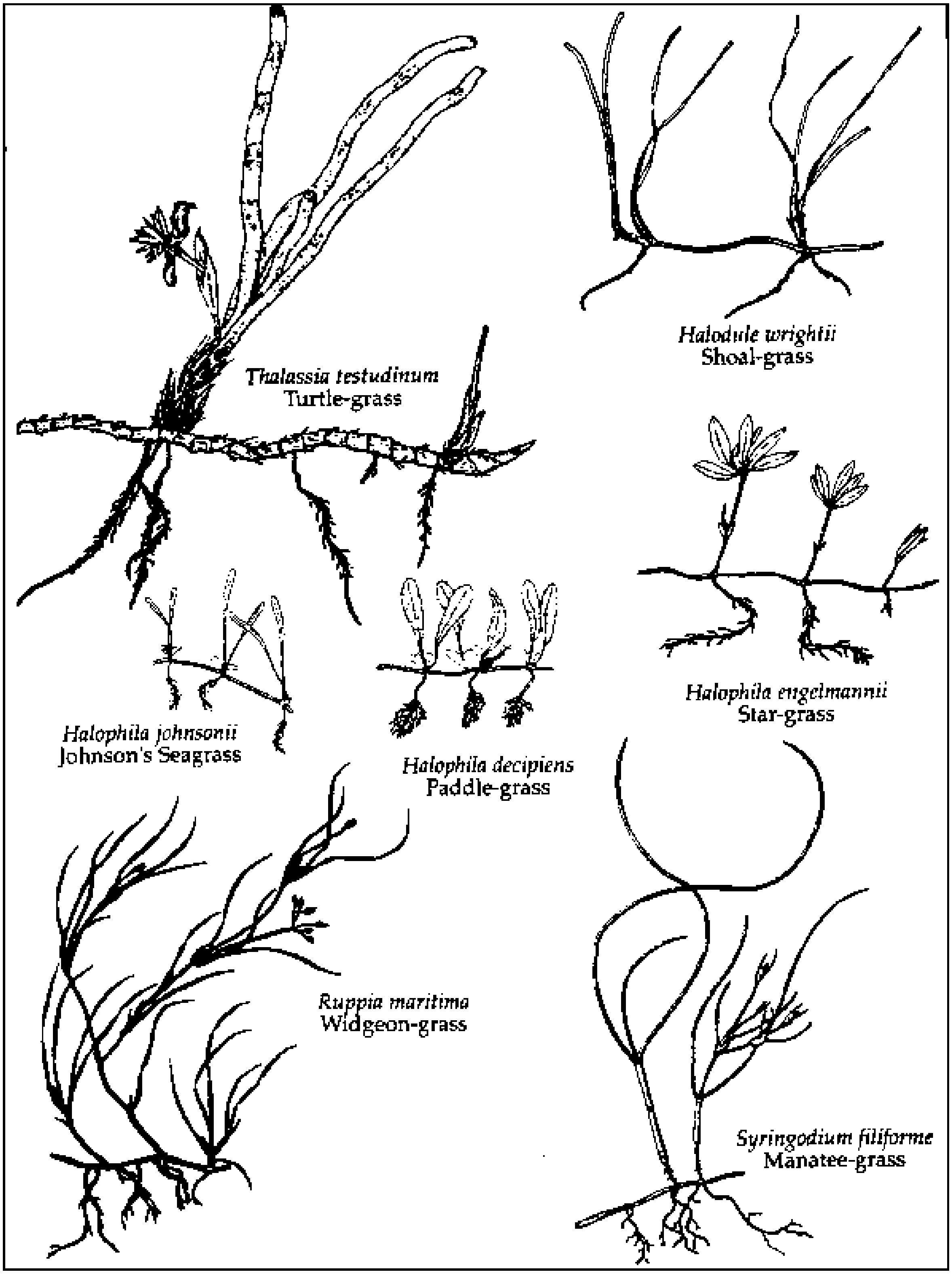
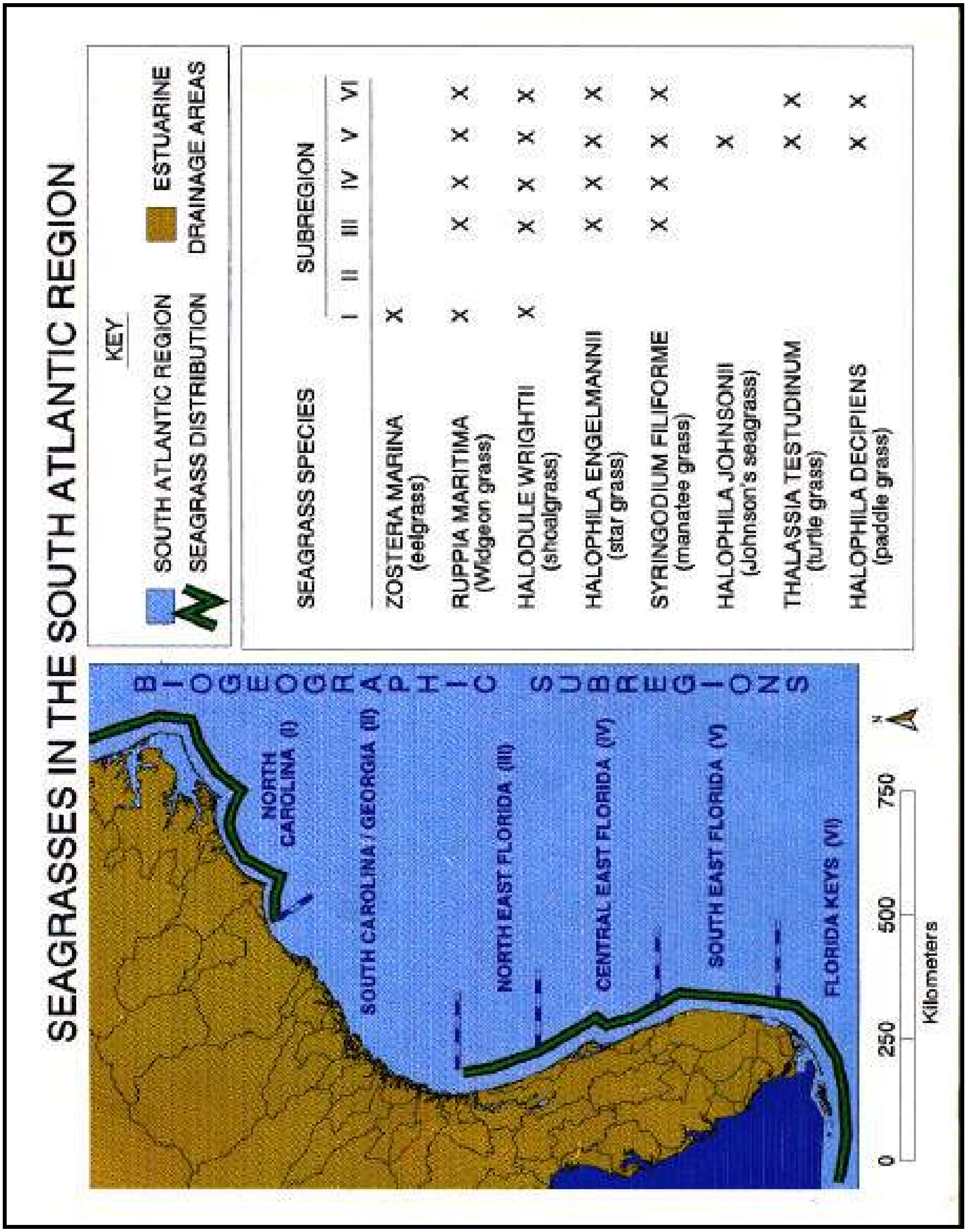


Figure 4. Illustration of seagrass species in the South Atlantic Region (Source: NMFS 1997).

3.1.1.3.2 Seagrass Meadow Dynamics

As in terrestrial grasslands, individual seagrasses and associated species form recognizable biological and physical assemblages known as seagrass meadows. The meadows are usually defined by a visible boundary delineating unvegetated and vegetated substrate and vary in size from small, isolated patches of plants less than a meter in diameter to a continuous distribution of grass tens of square kilometers in area. Seagrass meadows are dynamic spatial and temporal features of the coastal landscape (den Hartog 1971, Patriquin 1975). In the south Atlantic region all seagrasses occur on unconsolidated sediments in a wide range of physical settings and different stages of meadow development leading to a variety of cover patterns, ranging from patchy to continuous. Seagrass beds developing from seed and mature beds in relatively high energy environments may have similar patchy signatures, but very different physical and chemical characteristics (Kenworthy et al. 1982). Depending on the species and the environmental conditions, a meadow may attain full development in a few months (e.g., *Halophila spp.).* Meadows that develop rapidly usually reproduce by seed, forming annual meadows that completely disappear during unfavorable growing conditions. For example, on the east and southeast coast of Florida between Sebastian Inlet in the Indian River Lagoon (IRL) and North Biscayne Bay, *H. decipiens* forms annual meadows in water generally deeper than 1.5-2.0 m (Dawes et al. 1995). These depths are where the winter light levels cannot support the larger perennial species such as *R. maritima, H. wrightii, S. filiforme* and *T. testudinum* (Kenworthy and Fonseca 1996). In the relatively deeper water the smaller opportunistic *H. decipiens* is capable of germinating seeds in summer months when light levels are adequate. This life history strategy, combined with a thin leaf structure, minimal self shading, and relatively low non-photosynthetic biomass make the genus *Halophila* ideally suited for growth in fluctuating and highly disturbed environments (Kenworthy et al. 1989).

These dynamic features of seagrass meadows are not just restricted to the genus *Halophila.* In North Carolina annual meadows of a large bodied species, *Z. marina,* are common in shallow, protected embayments where excessively high (> 30^0 C) summer water temperatures eliminate eelgrass beds that thrive in winter and spring when water temperatures are optimal (Thayer et al. 1984). These shallow embayments are replenished annually by seed stocks of eelgrass, whereas in North Carolina during the summer months when water temperatures exceed 25-30^o C, eelgrass thrives only in relatively deeper water or on tidal flats where water movement is nearly continuous so that the plants are insulated from lethal temperatures and desiccation. In general, whether they are found in the warm temperate coastal waters of North Carolina or the subtropical environment in southeastern Florida, seasonal fluctuations in the abundance of seagrass biomass in the subtidal is normal (Dawes et al. 1995). The range of these seasonal fluctuations tends to increase from south Florida to North Carolina. North Carolina is a special case where seasonal fluctuations may be minimized in water bodies and meadows where *Z. marina* and *H. wrightii* co-occur. These two species are at their southern (eelgrass) and northern (shoalgrass) range limits, and when one species is limited by seasonal thermal extremes the other species may be abundant.



SEAGRASS SPECIES	SUBREGION I	II	III	IV	V	VI
ZOSTERA MARINA (eelgrass)	X					
RUPPIA MARITIMA (Widgeon grass)	X		X	X	X	X
HALODULE WRIGHTII (shoalgrass)	X		X	X	X	X
HALOPHILA ENGELMANNII (star grass)			X	X	X	X
SYRINGODIUM FILIFORME (manatee grass)			X	X	X	X
HALOPHILA JOHNSONII (Johnson's seagrass)					X	
THALASSIA TESTUDINUM (turtle grass)					X	X
HALOPHILA DECIPIENS (paddle grass)					X	X

Figure 5. Illustration and table of the distribution of seagrasses in the South Atlantic Region (Source: NMFS 1998).

Alternatively, meadows formed by the larger bodied species which have either limited or irregular sexual reproduction, may require decades to reach full maturity. For example, the slowest growing species in the south Atlantic region, *T. testudinum,* produces relatively few fruits and seeds at irregular intervals (Tomlinson 1969, Moffler and Durako 1987). When turtlegrass is compared to its' congeners, *H. wrightii* and *S. filiforme,* it has the slowest rate of vegetative expansion (Fonseca et al. 1987). Depending on the environmental conditions, rates of vegetative expansion for *H. wrightii* and *S. filiforme* are normally 4 to 10 times faster than *T. testudinum*. Thus, *T. testudinum* meadows form more slowly than any of the other species, yet if the environmental conditions allow the full development of a turtlegrass meadow its biomass and productivity will usually exceed any other seagrass (Zieman 1982).

Regardless of developmental stage or species composition, small seagrass patches and entire meadows can move, the rate of which may also vary on a scale of hours to decades. These dynamic spatial and temporal features of seagrass meadows are important aspects of fishery habitats. Seagrass habitats must be recognized as including not only continuously vegetated perennial beds but also patchy environments with the unvegetated areas between patches as part of the habitat. In fact, available data show that patchy habitats provide many ecological functions similar to continuous meadows (Murphey and Fonseca 1995, Fonseca et al. 1996). Also, it must be recognized that the absence of seagrasses in a particular location does not necessarily mean that the location is not viable seagrass habitat. It could mean that the present conditions are unfavorable for growth, and the duration of this condition could vary from months to years.

3.1.1.3.3 Threats to Seagrass Systems

Like all other organisms and habitats in estuarine-near shore environments, seagrasses occur at the end of all watershed inputs: the juncture between riverine inflow and oceanic inputs as well as the interface between land and sea. This situation makes them extremely susceptible to perturbations by natural processes as well as being susceptible to damage by human activities.

In the south Atlantic region seagrasses experience natural disturbances such as bioturbation (stingray foraging), storm or wave-related scour (tropical storms and surges), and disease or disease-associated perturbations (*Labyrinthula*), as well as man-related impacts (Short and Wyllie-Echeverria 1996). Especially problematic are excessive epiphytic loads and smothering by transient macroalgae, both of which are often associated with nutrient enrichment. Excessive nutrient discharges and suspended sediments can also disrupt seagrass systems by causing water column algal blooms that diminish the amount of light available for benthic dwelling seagrasses (Dennison et al. 1993). Often, nutrient enrichment will have detrimental effects that cascade up and down the food webs of seagrass meadows by diminishing the dissolved oxygen concentrations, forming toxic concentrations of hydrogen sulfide and diminishing the ability of a meadow to filter and stabilize sediments, thus altering the water column environment for filter feeders and primary producers.

Subtidal seagrasses have suffered little damage from oil spills whereas impacts on intertidal beds have been significant (Durako et al. 1993, Kenworthy et al. 1993). Oil spill-related impacts on the seagrass-associated fauna can range from smothering to lowered stress tolerance, reduced market values and incorporation of carcinogenic and mutagenic substances into the food chain. Other well-known impacts such as dredge and fill operations are no longer a primary cause of major losses of seagrass habitat due to the recognition of their ecological role and vigilance of state and federal regulatory activities relative to permits. This human-related impact, although still present, is now being replaced by that associated with propeller scouring (Sargent et al. 1995) and some fishing gear-related impacts (Fonseca et al. 1984). This physical damage is long-lasting and often results in sediment destabilization and continued habitat loss.

The increasing number of small boats plying estuarine and coastal waters has made the prop-scarring impacts more widespread, and there has been a recognized need in some regions for both enhanced management of these systems and increased awareness by the boating public.

Water quality and, in particular, water clarity is now considered among the most critical, if not the most critical, factor in the maintenance of healthy SAV habitats. In the past few years it has become increasingly evident that, with few exceptions, seagrasses generally require light intensities reaching the leaves of 15-25% of the surface incident light (Kenworthy and Fonseca 1996, Gallegos and Kenworthy 1996, Onuf 1996). However, water transparency standards historically have been based on light requirements of phytoplankton which typically require only 1% of surface light (Kenworthy and Haunert 1991). Many factors act to reduce water column transparency, with excess suspended solids and nutrients being considered to be among the most important and most controllable through watershed management practices.

The loss of seagrasses, regardless of the cause, leads to several undesirable, and often difficult to reverse, situations that reflect on aquatic vascular plant ecological values. Losses can and have led to reduced sediment binding and water motion baffling capability of the habitat allowing sediments to be more readily resuspended and moved (Fonseca 1996). The physical ramification includes increased shoreline erosion (e.g., as occurred in some areas after the seagrass die-off in the 1930's) and water column turbidity. The losses of seagrasses, of course, eliminates all important associated habitat functions pertinent to fisheries use.

3.1.1.3.4 Seagrass As Essential Fish Habitat

Because seagrasses are rooted, they can become nearly permanent, long-term features of coastal marine and estuarine ecosystems coupling unconsolidated sediments to the water column. No other marine plant is capable of providing these properties of seagrasses. Seagrass meadows provide substrates and environmental conditions which are essential to the feeding, spawning and growth of several managed species (see Laney 1997, Zieman, 1982, Thayer et al. 1984). The specific basis of seagrass as fishery habitat is recognized in four interrelated features of the meadows: 1) primary productivity, 2) structural complexity, 3) modification of energy regimes and sediment and shoreline stabilization, and 4) nutrient cycling.

On a unit area basis seagrasses are among the most productive ecosystems in the world (McRoy and McMillan 1977) . High rates of primary production lead to the formation of complex, three dimensional physical structures consisting of a canopy of leaves and roots and rhizomes buried in the sediments. The presence of this physical structure provides substrate for attachment of organisms, shelter from predators, frictional surface area for modification of water flow and wave turbulence, sediment and organic matter deposition, and the physical binding of sediments underneath the canopy. Linked together by nutrient absorbing surfaces on the leaves and roots and a functional vascular system, seagrass organic matter cycles and stores nutrients, and provides both direct and indirect nutritional benefits to thousands of species of herbivores and detritivores.

Primary productivity. Seagrass meadows provide four important sources of primary organic matter, 1) their own tissues, 2) dissolved organic matter released from their tissues during metabolism, 3) the epiphytic microscopic and macroscopic plants that attach to the surfaces of the seagrass leaves, and 4) the plants that live on the sediments among the seagrass shoots. Some fishery organisms consume seagrasses directly, but the majority of the secondary fishery production in the meadows begins with the consumption of epiphyte communities, benthic algae and the utilization of organic detritus. Thus, the food webs supported by seagrass primary production are complex and include many intermediate steps involving microorganisms, meiofauna, small invertebrates such as isopods, amphipods as well as the thousands of species of macroinfauna and epifauna in the sediments on the sediment surface and in the water column.

Structural complexity. Leaf canopies formed by seagrasses range in size from just a few cm (*Halophila spp.*) to more than a meter tall. Where several species co-occur, the three dimensional canopy may take on multiple layers and forms, with long (1.25 m) cylindrical stems and blade surfaces (*S. filiforme)* combined with relatively shorter strap-shaped leaves (*T. testudinum* or *H. wrightii*). No matter what species are present, the existence of leaf surfaces provides structures for attachment of smaller organisms and space between shoots for shelter from predators and adverse environmental conditions. The leaf area in a seagrass meadow may effectively increase the colonizeable substrate per square meter by an order of magnitude compared to an unvegetated substrate. While at the same time, the leaves and stems create a large volume of water column sheltered within the canopy and partially obscured by self shading of the leaves. Within the canopy there is an enormous physico-chemical microenvironment structured and maintained by the seagrasses. This structural influence extends into the sediments where the roots and rhizomes stabilize the substrate and form a large pool organic biomass and a matrix for meiofauna and macrofauna (Kenworthy and Thayer 1984).

Modification of energy regimes and sediment stabilization. The leaf surfaces and the collective structure of the canopy provide frictional drag forces which slows water motion and reduces wave turbulence. This process promotes the deposition of particles in the meadows, including but not restricted to inorganic sediments, dead organic matter and living organisms. The addition of all of these materials enhances the productivity, stability, and biodiversity of coastal systems with seagrasses. By promoting sediment deposition and stabilization, coastal habitats coupled to seagrasses meadows by water movement receive both direct and indirect benefits.

Nutrient cycling. The high rates of primary production and particle deposition make seagrass meadows important sources and sinks of nutrients. During active periods of growth the constant and high rate of leaf turnover and epiphyte growth provides nutrients for herbivores and a mechanism for nutrient export and retention. Temporary and permanent retention of nutrients within seagrass meadows is encouraged by particle deposition and burial as well as the formation of organic matter in the sediments by the roots and rhizomes. Seagrasses are sensitive to the availability and abundance of nutrients in their surrounding environment and often retain nutrient signatures representing environmental conditions they have experienced, both spatially and temporally (Fourqurean et al. 1992). The variation in tissue nutrient composition is an important factor in fishery utilization of seagrass derived organic matter.

3.1.1.3.5 Specific Examples of Seagrass As Essential Fish Habitat

From the standpoint of essential fish habitat, being submerged most if not all of the time, seagrasses are available to fishery organisms for extended periods. There has been a growth of research over the past 30 years trying to understand and quantify functional values of seagrass ecosystems. Experiments and observations have shown that juvenile and adult invertebrates and fishes as well as their food sources utilize seagrass beds extensively. In fact, the habitat heterogeneity of seagrass meadows, the plant biomass, and the surface area enhance faunal abundances. Predator-prey relationships in seagrass beds are influenced by canopy structure, shoot density, and surface area. Blade density interferes with the efficiency of foraging predators and the reduction of light within the leafy canopy further conceals small prey which includes young-of-the-year of many ecologically and economically important species. High density of seagrass shoots and plant surface area can inhibit movement of larger predators, thereby affording shelter to their prey. Additionally, some organisms can orient themselves with the seagrass blades and camouflage themselves by changing coloration. The food availability within grass beds for young stages of managed species may be virtually unlimited. These attributes are particularity beneficial to the nursery function of seagrass beds and while there is continuing debate and research on whether refugia or trophic functions are most important (when and to which organisms), there is little debate that these are important functions provided by this habitat type.

Perhaps seagrass meadows are best known for their source of attachment and/or protection for bay scallops (*Argopectin irradians*) and hard clams (*Mercenaria mercenaria*). Scientific evidence also indicates that blue crabs (*Callinectes sapidus*), pink and brown shrimp *(Penaeus duorarum, P. aztecus*), and lobster (*Panulirus argus*), just to name a few invertebrates, have a strong reliance on seagrass habitats including seagrass-supported trophic intermediaries.

There have been few studies dealing with larval fish settlement and use of seagrass habitats while there have been numerous publications listing juvenile and adult fishes collected in seagrass meadows. One might expect, however that some of the same functions described above hold true for larvae. Seagrass beds are important for the brooding of eggs (for example, silverstripe halfbeak, *Hyporhamphus unifasciatus*) and for fishes with demersal eggs (e.g., rough silverside, *Membras martinica*). Larvae of spring-summer spawners such as anchovies (*Anchoa* spp.), gobies, (*Gobiosoma* spp.), pipefish (*Syngnathus fuscus*), weakfish (*Cynoscion regalis*), southern kingfish (*Menticirrhus americanus*), red drum (*Sciaenops ocellatus*), silver perch (*Bairdiella chrysoura*), rough silverside, feather blenny (*Hypsoblennius hentz*), and halfbeaks are present and use seagrass beds. In regions of North Carolina where there is often year-round cover of seagrass (eelgrass and shoalgrass), larval and early juvenile fishes are present in these beds during much of the year. Lists of these species are presented in referenced literature and policy statements, but it should be pointed out here that larvae and juveniles of important commercial and sportfish such as gag grouper (*Mycteroperca microlepis*), snapper (*Lutjanus griseus*), seatrout or weakfish, bluefish (*Prionotus saltatrix*), mullet (*Mugil* spp.), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonius undulatus*), flounder (*Paralichthys* spp.), herrings (*Clupeidae*), and many other species appear in seagrass beds in spring and early summer. Many of these fish reside only temporarily in grass beds either to forage, spawn, or escape predation. Some species reside there until the fall when they return to the open coastal shelf waters to spawn. As is noted by the SAFMC's SAV protection policy, economically important species use these habitats for nursery and/or spawning grounds (Section 5.2.1.1): including spotted seatrout, grunts (*Haemulids*), snook (*Centropomus* spp.), bonefish (*Albula vulpes*), tarpon (*Megalops atlanticus*) and several species of snapper and grouper.

For the most part, the organisms discussed above utilize the grass bed structure and trophic elements associated with the bed, but many species of herbivorous invertebrates (e.g., urchins *Lytechinus variegatus*, *Tripneustes ventricosus*), birds (e.g., black brant *Branta bernicla*), fishes (e.g., pinfish *Lagodon rhomboides*, parrotfish *Sparisoma radians*), the green turtle (*Chelonia midas*) and the manatee (*Trichechus manatus*) feed directly upon coastal and estuarine seagrasses. Work on green turtles in North Carolina has shown a higher incidence of capture in pound nets set in grass beds than by nets set in unvegetated areas. Grazing can have profound effects on the system, but the consequences are neither uniform nor of similar importance in both tropical and temperate seagrasses (Thayer et al 1984).

The seasonal patterns of reproduction and development of many temperate fishery species coincide with seasonal abundances of seagrasses. It has been concluded in several studies that, although juvenile fish and shellfish can use other types of habitat, the bulk of the shelter in many estuarine systems is provided by seagrasses, and that the loss or reduction of this habitat will produce concomitant declines in juvenile fish settlement. Thus, this habitat type may be essential to many species of commercial, recreational and ecologically important shellfish and finfish.

3.1.1.3.6 Aspects of Conservation and Restoration

The recognition of the ecological role of seagrass habitats has prompted a need to conserve, and more recently protect these habitats by avoiding impacts (i.e., proactive management). This is a less costly and an environmentally sounder means of protecting this important resource than either mitigation or restoration. None-the-less, seagrass habitats have been and continue to be impacted or lost, and restoration efforts have broadened to include development and evaluation of new approaches to seagrass restoration and measurements of recovery of functional values. In addition, programs are being developed at the local level to plant seagrasses for purposes of sediment stabilization, nutrient uptake, and fishery habitat. These programs and projects, which are often volunteer, consult with experts, utilize scientifically based guidelines, and monitor their restoration success. Research continues to evaluate current techniques and develop new approaches (e.g., clonal development). However, we have not found a restoration or mitigation project that has returned seagrass habitat equal to that which has been lost. Much has been written on techniques and evaluation of restoration of seagrasses along the Atlantic coast of the U.S. (Fonseca 1992). Data is showing that if seagrass transplanting is successful we can expect a similar faunal community to return within a few years (2-4 possibly), depending on the geographic area and rate of development of the transplant (Fonseca et al. 1996). There are many uncertainties associated with seagrass mitigation and restoration such as impacts of herbivory, but experience is showing that efforts can be successful if the well-founded guidelines available are followed.

3.1.1.4 Oyster Reefs and Shell Banks

3.1.1.4.1 Introduction

Oyster and shell essential fish habitat in the South Atlantic can be defined as the natural structures found between (intertidal) and beneath (subtidal) tide lines, that are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats, and from wave-formed shell windrows (Bahr and Lanier 1981). Both intertidal and subtidal populations are found in the tidal creeks and estuaries of the South Atlantic. On the Atlantic coast, the range of the American oyster, *Crassostrea virginica*, extends over a wide latitude (20° N to 54° N). The ecological conditions encountered are diverse and the oyster community is not uniform throughout this range. Where the tidal range is large the oyster builds massive, discrete reefs in the intertidal zone. North of Cape Lookout, in North Carolina, the oyster habitat is dominated by Pamlico Sound and its tributaries. In these wind-driven lagoonal systems, oyster assemblages consist mainly of subtidal beds. Throughout the South Atlantic, oysters are found at varying distances up major drainage basins depending upon typography, salinity, substrate, and other variables.

Several terms used to describe the oyster/shell essential fish habitat are oyster reef, bar, bed, rock, ground and planting. The habitat ranges in size from small scattered clumps to large mounds of living oysters and dead shells. Predation and siltation limit oyster densities at the lower portion and outer regions of the reefs. The vertical elevation of intertidal oyster reefs above mean low water is maximal within the central Georgia coastal zone, where mean tidal amplitude exceeds 2 m (Bahr and Lanier 1981).

The existence of shell middens and well defined constructions of shell rings throughout South Carolina, indicates the intertidal oyster has been cultivated and harvested for at least 4,000 years by pre-historic Indians of the coastal plain. In the late 19th and first half of the 20th century, a successful canning industry, taking advantage of the thin, highly irregular clusters of intertidal oysters thrived throughout South Carolina, with nearly 20 canneries in production (Keith and Gracy 1972). In conjunction with industry exploitation, the shellfish resource has, and continues to serve as a critical habitat for ecosystem stability and health. Usually found adjacent to emergent marsh vegetation, *Crassostrea virginica* provides the only three-dimensional structural relief in an otherwise unvegetated, soft-bottom, benthic habitat (Wenner et al. 1996).

Large shell banks or deposits of oyster valves generated by boat wakes are found throughout the South Atlantic, usually along the Atlantic Intracoastal Waterway and heavily traveled rivers. These shell accumulations are usually elongated and conform to the underlying bottom topography from mean low water into the supra littoral zone. Further build-up may result in ridge structures and washovers. In South Carolina, 998 “washed shell” deposits have been located predominantly in the central and southern portion of the State. Washed shell is less resilient, partially abraded oyster shell with a lower specific gravity than recently shucked shells (Anderson 1979).

3.1.1.4.2 Habitat Description and Environmental Requirements

Habitat and environmental conditions are the limiting factors controlling oyster abundance. Optimal salinity and temperature ranges for *Crassostrea virginica* are 12 ppt to 25 ppt and 10° C to 26° C, respectively. Oysters, the typical estuarine animal, tolerate extremes in salinity (5 ppt and 30 ppt), temperature (0°C and 32°C), turbidity and dissolved oxygen. Favorable salinity and temperature regimes are important criteria for successful reproduction and spawning. Spat settlement and survival are best on clean, firm surfaces, such as oyster shell exposed to good water circulation. The oyster reef depends on water currents to provide food and oxygen, remove wastes and sediments, and disperse larvae.

In South Carolina, oysters are predominantly 95% intertidal (Lunz 1952) and this preferred water and exposed habitat is from slightly below mean low water to approximately one meter above MLW (Sandifer et al. 1980). Oysters usually attach to shells on a mud flat, and as other oysters attach in succeeding generations, increased weight may cause them to recede into the mud, but provide a vertical substrate (or shell matrix) for subsequent spatfall (Burrell 1986). Generally, oyster setting in South Carolina occurs from early May through early October (McNulty 1953). Slightly more than 1% of spatfall occurs at other times during the year. Two setting pulses are usually noted each season. The highest settlement occurs from early June through July, and a second and lesser peak takes place during August or early September. Considerable setting intensity may also occur before, between and after the two pulses (McNulty 1953).

Intertidal oyster growth varies significantly with temperature, quantity and quality of food. Oysters grow throughout the year unless exposed to extreme temperatures or other adverse environmental conditions. The eggs, early embryos, and larvae are eaten by protozoans, ctenophores, jellyfishes, hydroids, worms, bivalves, barnacles, larval and adult crustaceans, and fishes (Loosanoff 1965). In South Carolina, oyster predatory studies have been primarily concerned with pests found on natural beds. Lunz (1935, 1940, 1941, 1943) reported the following commonly occurring oyster pests and predators: the boring sponges *Cliona spp*; the oyster drills *Urosalpinx cinerea* and *Eupleura caudata*; the knobbed whelk *Busycon carica*; the annelid worm *Polydora spp.* and the starfish *Asterias forbesii*. Of these, boring sponges probably cause the greatest damage to South Carolina oysters (Lunz 1943).

3.1.1.4.3 Habitat Distribution

The most extensive contiguous intertidal oyster reefs in the South Atlantic region occur in the South Carolina coastal zone. These reefs diminish in size and significance south of Georgia and north of South Carolina (Bahr and Lanier 1981). SCDNR conducted an extensive survey of intertidal oyster resources beginning in 1980 and maintains the data in its Geographic Information System (Anderson, personal comm. 1998) (examples on SAFMC Web page).

North Carolina initiated a GIS mapping program to document distribution of estuarine shell habitats including 7 subtidal and intertidal strata. These and an example of South Carolina detailed ArcView maps are are presented in Appendix D and have been added to the GIS data and map products used to determine EFH.

3.1.1.4.4 Habitat Function

Intertidal oysters have often been described as the “keystone” species in an estuary (Bahr and Lanier 1981) and provide significant surface area as habitat. Sometimes compared to submerged aquatic vegetation in the mid-Atlantic states, the intertidal oyster community has been identified as critical to a healthy ecosystem. Direct and indirect ecosystem services (filtering capacity, benthic-pelagic coupling, nutrient dynamics, sediment stabilization, provision of habitat, etc.) derived from the oyster have been largely ignored or underestimated (Coen and Lukenbach 1998). Oyster reefs can remove, via filter feeding, large amounts of particulate material from the water column, and release large quantities of inorganic and organic nutrients into tidal creek waters (Haven and Morales-Alamo 1970; Dame and Dankers 1988; Dame et al. 1989).

The ecological role of the oyster reef as structure, providing food and protection, contribute to it’s value as a critical fisheries habitat. The three-dimensional oyster reef provides more area for attachment of oysters and other sessile organisms and creates more habitat niches than occur on the surrounding flat or soft bottom habitat. Clams, mussels, anemones, polychaetes, amphipods, sponges, and many species of crabs are part of the oyster reef community. The invertebrates recycle nutrients and organic matter, and are prey for many finfish. Red and black drum, striped bass, sheepshead, weakfish, spotted seatrout, summer and southern flounder, oystertoads, and other fish frequent the oyster reef. Table 5 presents select macrofaunal species observed in collections from oyster habitat located in the southeastern United States. Starfish, sea urchins, and whelks, as well as racoons and wading birds, also come to the reef for food.

Table 5. List of select macrofaunal species observed in collections from oyster habitat located in the southeastern United States (Source NMFS 1997.)

Species	Common Name	Zone	Fisheries Value
CRUSTACEANS			
Balanus spp.	Balanoid barnacles	I	P
Alpheus heterochaelis	snappimg shrimp	I	P
Callinectes sapidus	blue crab	I/S	R/C/P
Crangon septemspinosa	sand shrimp	I	P
Eurypanopeus depressus	flat mud crab	I	P
Mennipe mercenaria	stone crab	I/S	R/C/P
Palaemonetes spp.	grass shrimp	I/S	P
Panopeus herbstii	mud crab	I/S	P
Paguridea	hermit crabs	I	P/C
Penaeus duorarum	pink shrimp	I	R/C/P
Pinnotheres ostreum	oyster crab	I	P
Upogebia affinis	mud shrimp	I	P
MOLLUSCS			
Busycon spp.	whelk	I	R/C/P
Crassostrea virginica	eastern oyster	I/S	R/C/P
Anadara ovalis	blood ark	I	P
Chaetopleura apiculata	common eastern chiton	I	P
Chione cancellata	cross-barred venus	I	R/P
Dinocardium robustum	giant Atlantic cockle	I	R/C/P
Mercenaria mercenaria	hard clam	I	R/C/P
Mytiladae	mussels	I	P
Tagelus spp.	razor clam	I	P
Urosalpix cinerea	oyster drill	I	P
FISH			
Archosargus probatocehalus	sheepshead	I/S	R/C/P
Bairdiella chrysoura	silver perch	S	R/P
Blenniidae	blennies	S	P
Centropristis striata	black sea bass	S	R/C/P
Chaetodipterus faber	spadefish	S	R/C/P
Cynoscion regalis	weakfish	S	R/C/P
Cynoscion nebulosus	spotted trout	S	R/C/P
Fundulus heteroclitus	mummichog	I	P/C
Gobiidae	Gobies	I/S	P
Gobiesox strumosus	skilletfish	S	P
Leiostomus xanthurus	spot	I	R/C/P
Lagodon rhomboides	pinfish	S	R/C/P
Lutjanus griseus	gray snapper	I/S	R/C/P
Micropogonias undulatus	Atlantic croaker	S	R/C/P
Myrophis punctatus	speckled worm eel	I	P
Opsanus tau	oyster toadfish	I/S	P
Orthopristis chrysoptera	pigfish	S	R/C/P
Paralichthys lethostigma	southern flounder	S	R/C/P
Pogonias cromis	black drum	S	R/C/P
Pomatomus saltatrix	bluefish	S	R/C/P
Symphurus plagiusa	black cheek tonguefish	I	P

Letter codes for the Zone heading (in which zone species were collected) are I = intertidal, S = Subtidal; and for the Fisheries Value heading are R = recreational, C = commercial, P = prey species.

3.1.1.4.5 Species Composition

The intertidal oyster habitat consists primarily of the eastern oyster, *Crassostrea virginica*. Another commercially important bivalve, the northern quahog or *Mercenaria mercenaria* often exists sympatrically with *Crassostrea*, which provides predator protection for juvenile clams. Epifauna associated with oyster beds was examined in South Carolina by Hopkins (1956). Beds in high salinity waters exhibited the greatest number (21) of associated species (Sandifer, 1980).

Fouling organisms such as barnacles (*Balanus eburneus*), bryozoans (*Bugula neritina*), sea squirts (*Molgula manhattensis*), and hooked mussels (*Ischadium recurvum*) are commonly observed growing on oysters (Linton 1970). Infestations by mud worms (*Polydora spp.*) are common (Lunz 1940, Grice 1951). In the North Santee River, South Carolina, the boring clam *Martesia sp.* was reported at several stations. A widespread pathogen (*Perkinsus marinus*) "Dermo" and most recently, (*Haplosporidium nelsoni*) "MSX" are both found in South Carolina (Bobo et al. 1997) and may present a problem when transplanting seed oysters. A common oyster commensal or parasite, the pea crab *Pinnotheres ostreum,* is found throughout the estuarine waters of the State. Oyster reefs in high salinity waters are also an important habit for juveniles of several important fish species such as sheepshead, *Archosargus probatocephalus*, gag grouper *Mycteroperca microlepis*, and snapper *Lutjanus spp*., as well as stone crab *Menippe mercenaria* and blue crab *Calinectes sapidus* and other transient and resident species (Wenner et al. 1996).

3.1.1.4.6 Habitat Restoration Efforts

Conservation efforts in South Carolina consist of restoring over fished reef areas and requiring culture permit holders to plant 125 U.S. bushels of oysters or shell for each acre under cultivation. Passive management of 56 State shellfish grounds occurs as designated harvest areas are closed for periods to allow for natural setting and grow out. The State actively manages public shellfish grounds utilizing its R/V Oyster Catcher II, a 50' x 20' vessel to plant seed and shell in 17 areas, averaging 2.3 acres of shellfish habitat, and designated for recreational harvesting only. In addition, quarterly meetings are held with the State's Department of Health and Environmental Control to prioritize shellfish resource areas that would benefit from upgrading water quality.

3.1.1.5 Geographic Distribution and Dynamics of Intertidal Flats in the South Atlantic Region

This section is intended to briefly summarize the most important aspects of tidal flats which pertain directly to their function as essential fish habitat. For a more extensive and comprehensive ecological profile of tidal flats in the South Atlantic region we recommend the U.S. Department of Interior Community Profile, Peterson and Peterson (1979).

3.1.1.5.1 Introduction

Tidal flats are dynamic features of coastal landscapes whose distribution and character may change with shifting patterns of sediment erosion and deposition. Factors that effect the regional character of tidal flats include tidal range, prevailing weather patterns, coastal geography and geology, river influences and human activities. These factors may effect tidal flats as a result of seasonal shifts in tides, winds or river flow and through the influence of storms. Human activities that change flow patterns or sediment supply such as dam and jetty construction, dredging and filling are also important. In areas with a small tide, wind and waves are generally the most important factors in the formation of tidal flats with the exception of locations near tidal inlets (where tidal currents may be important) and river mouths (where river deltas may develop). In areas with moderate to large tidal ranges (>2m), tidal currents are generally the dominant factor in the formation and dynamics of tidal flats.

Variability in the tidal regime along the South Atlantic coast results in considerable regional variability in the distribution and character of the estimated 1 million acres (Field et al. 1991) of tidal flat habitat. Geographic patterns in sediment size on tidal flats result primarily from the interaction of tidal currents and wind energy. The coasts of North Carolina and Florida are largely microtidal (0-2m tidal range) with extensive barrier islands and relatively few inlets to extensive sound systems. In these areas wind energy has a strong affect on intertidal flats. In contrast the coast of South Carolina and Georgia are mesotidal (2-3.3m) with short barrier islands and numerous tidal inlets so that tidal currents are the primary force effecting the intertidal. In both types of systems the substrate of the intertidal flats generally becomes finer with distance from inlets due to the progressive damping of tidal currents and wave energy in the upstream direction. Exposure of flats to wave energy, which resuspends fine particles, may cause the development of sand flats in areas where the wind fetch is sufficient for the development of significant wave energy. On the microtidal coast of North Carolina sandy flats tend to develop due to the large size of the sounds and their orientation relative to prevailing winds. In contrast in Georgia and South Carolina most flats are muddy, as the sounds and estuaries are small so that the importance of wave energy is reduced. These different depositional environments result in development of varied physio chemical environments in and on intertidal flats which in turn cause differences in animal populations that utilize them.

3.1.1.5.2 Tidal Flats as Essential Fish Habitat

Tidal flats are critical structural components of coastal systems that serve as benthic nursery areas, refuges and feeding grounds for a variety of animals (Table 6) and thus provide essential fish habitat. In addition tidal flats play an important role in the ecological function of South Atlantic estuarine ecosystems, particularly in regard to primary production and water quality. The benthic microalgal community of tidal flats consists of benthic diatoms, cyanobacteria, euglenophytes and unicellular algae. Primary production of this community can equal or exceed phytoplankton primary production in the water column, and can represent a significant portion of overall estuarine primary productivity. Benthic microalgae also stabilize sediments and control fluxes of nutrients (nitrogen and phosphorus) between the sediment and the water column. Autochthonous benthic microalgal and bacterial production and imported primary production in the form of phytoplankton and detritus support diverse and highly productive populations of infaunal and epibenthic animals. Important benthic animals in and on the sediments include ciliates, rotifers, nematodes, copepods, annalids, amphipods, bivalves and gastropods. This resident benthos is preyed upon by mobile predators that move onto the flats with the flood tide. These predators do not always kill their benthic prey and many "nip" appendages of buried animals such as clam siphons and polychaete tentacles that can be regenerated. An important aspect of the function of these systems is the regular ebb and flood of the tide over the flats and a corresponding rhythm exists in the animals and microalgae adapted to life in the intertidal zone. The flooding tide brings food and predators onto the flat while the ebb provides residents a temporal refuge from the mobile predators. This constantly changing system provides essential fish habitat as; 1) nursery grounds for early stages of development of many benthically oriented estuarine dependent species 2) refuges and feeding grounds for a variety of forage species and juvenile fishes 3) feeding grounds for a variety of specialized predators. Although it is recognized that tidal flats provide these important ecological functions the relative contribution of intertidal flats of different types and in different locations within coastal systems is not well known.

3.1.1.5.3 Benthic Nursery Function

Many species whose larval stages are planktonic but are benthically oriented as juveniles utilize intertidal flats as primary nursery ground. Intertidal flats are particularly suited for animals to make the shift from a pelagic to benthic existence. During this habitat shift these small animals are expected to be particularly vulnerable to adverse physical forces, predation and starvation, and flats may provide a relatively low energy environment where predation pressure is low and small benthic prey abundant. These animals may develop a tidal rhythm of behavior and move off and on the flat with the ebb and flood of the tide. This provides them an area of retention as currents over the flats are reduced, a refuge from a variety of predators due to the shallow water and excellent feeding conditions as the abundant meiofauna emerge to feed with the flooding tide. A wide variety of important fishes and invertebrates utilize intertidal flats as nurseries (Table 6) including the commercially important paralichthid flounders, many members of the drum family including red drum, and spotted seatrout, the mullets, gray snapper, the blue crab, and penaid shrimps.

3.1.1.5.4 Refuge Function

A variety of pelagic and benthic species utilize the intertidal flats as a refuge from predation and adverse physical conditions (Table 6). Predation pressure in the subtidal, particularly in the vicinity of inlets may increase during the rising tide due to the influx of coastal predators. Intertidal flats provide energetic advantages for animals seeking to maintain their position within the system as current velocities are generally low relative to deeper areas. Schools of planktivores including anchovies, silversides and menhaden and schools of benthic feeding juveniles such as the spot and croaker, pinfish and mojarras, move onto flats with the rising tide to take advantage of the favorable conditions flats provide. More solitary species such as black seabass and gag grouper also appear to utilize flats as a refuge during their emigration from structured estuarine nursery habitats to the sea in the fall. Flats also can provide a refuge from low oxygen levels that may develop in deeper areas of estuaries during summer months.

3.1.1.5.5 Feeding Ground Function

Several groups of specialized feeders utilize intertidal flats as feeding grounds (Table 6). The depositional nature of intertidal flats provide a rich feeding ground for detritivors such as mullet and predators of small benthic invertebrates such as spot and moharra . A variety of invertebrate predators such as whelks and blue crabs feed on tidal flats as do their bivalve prey such as oysters and hard clams, important filter feeding residents of tidal flats. Another group that relies on flats as feeding grounds are predatory fishes such as rays, a wide variety of flatfishes and lizard fish whose form makes them well adapted to feed in shallow water. Other more conventionaly shaped fishes whose prey concentrate on flats use these areas as feeding grounds and red drum can be found hunting blue crabs on flats. Because flats are “dry” much of the time activity is concentrated during high water making tidal flats rich feeding grounds for species adapted to shallow waters.

Table 6. List of common species which utilize intertidal flats in the South Atlantic Region. (Source NMFS 1998.)

Species	Common name	Function	Life stage(s)
Dastatis sayi	bluntnose stingray	F	A
Rhinoptera bonasus	cownose ray	F	A
Angulla rostrata	American eel		J, A
Conger oceanicus	conger eel		A
Myrophis punctatus	speckled worm eel		J
Brevoortia tyrannus	Atlantic menhaden	R	J
Anchoa hepsetus	striped anchovy	R	J, A
Anchoa mitchilli	bay anchovy	R	J, A
Synodus foetens	inshore lizardfish	F	J, A
Urophycis regius	spotted hake	F	J
Membras martinica	rough silverside	R	J, A
Menidia menidia	Atlantic silverside	R	J, A
Centropristis striata	black seabass	R	J
Diplectrum formosum	sand perch	R	J
Mycteroperca microlepis	gag grouper	R	J
Lujanus griseus	gray snapper	N	J
Eucinostomus argenteus	spotfin mojarra	R, F	J, A
Eucinostomus gula	silver jenny	R, F	J, A
Orthopristis chrysoptera	pigfish	R	J
Archosargus probatocephalus	sheepshead	R, F	J
Lagodon rhombodies	pinfish	N, R, F	J, A
Bairdiella chrysura	silver perch		J, A
Cynocion nebulosus	spotted seatrout	N	PL, J
Cynocion regalis	weakfish		J
Leiostomus xanthurus	spot	N, R, F	PL, J, A
Menticirrhus saxatilus	southern kingfish	R, F	J
Micropogonias undulatus	Atlantic croaker	N, R, F	PL, J, A
Sciaenops ocellatus	red drum	N, R, F	PL, J, A
Mugil cephalus	striped mullet	N, R	J, A
Mugil curema	white mullet	N, R	J
Prionotus carolinus	northern searobin		J, A
Citharichthys spilopterus	bay whiff	N, R, F	PL, J, A
Etropus crossotus	fringed flounder	R, F	J, A
Paralichthys albigutta	gulf flounder	N, R, F	PL, J, A
P. dentatus	summer flounder	N, R, F	PL, J, A
P. lethostigma	southern flounder	N, R, F	PL, J, A
Scopthalmus aquosus	windowpane	F	J, A
Trinetes maculatus	hogchoker	N, R, F	PL, J, A
Symphurus plagiusa	blackcheek tonguefish	N, R, F	PL, J, A
Callinectes sapidus	blue crab	N, R, F	J, A
Penaeus aztecus	brown shrimp	N, R, F	PL, J, A
P. duorarum	pink shrimp	N, R	PL, J
P. setiferus	white shrimp	N, R, F	PL, J, A
Busycon spp.	Welk	F	A
Crassostrea virginica	eastern oyster	F	PL, J, A
Mercenaria mercenaria	hard clam	F	PL, J, A

Letter codes for function use are N=benthic nursery function, R=refuge function, and F=feeding ground function. Life stage codes are PL=post-larval, J=juvenile, and A=adult.

3.1.1.5.6 Impacts to Intertidal Flats

Although some activities have direct and dramatic impact on tidal flats, subtler impacts will occur due to activities that effect tidal flats indirectly through alterations in current patterns, wave energy or the supply of sediment. Examples of direct impacts include dredging of flats themselves and contaminant spills. Indirect impacts include dredging that significantly alters current patterns, dam construction that traps sediment, beach re-nourishment projects and jetty construction.

3.1.1.5.7 Conservation of Intertidal Flats

Although intertidal flats are protected by the permitting process that regulate activities impacting the intertidal, the perception that flats are of minor importance relative to vegitated habitats increases pressure on intertidal flats. Flats have the same legal protection afforded vegetated intertidal areas, however; the importance of intertidal flats is not generally recognized and the relative value of intertidal flats is not understood. As a consequence permits may be more easily granted for filling/dredging tidal flats than for salt marshes and salt marsh may be planted on a natural intertidal flat when mitigation for marsh destruction is required. Increased recognition of the ecological value of tidal flats by resource managers and permitting agencies is necessary to preserve these valuable habitats, and research on the different types of intertidal flats and their relative value in coastal systems should be encouraged.

3.1.2 Palustrine Emergent and Forested (Freshwater Wetlands)

3.1.2.1 Introduction

This section briefly describes and summarizes the attributes of tidal fresh- and freshwater marshes (palustrine emergent or riverine emergent classification of Cowardin et al. 1979) and swamp forests (palustrine forested), some of which are also tidal, which pertain to their likely function as EFH. Both habitat types occur in South Atlantic estuarine drainage areas (EDAs) in the tidal fresh portions and freshwater portions of riverine tributaries. The function is deemed as *likely*, rather than definitive at this point for the South Atlantic region.

The review of the literature conducted for this amendment suggests that relatively few studies have been performed in the South Atlantic region to specifically investigate/document use of such habitats by Council-managed species, with the possible exception of white shrimp (*Penaeus setiferus*). Some studies have been performed which document the use of these habitats by important prey species, such as blue crabs, bay anchovies and alosids (alewife and blueback herring). Palustrine emergent, riverine emergent and palustrine forested wetlands in the South Atlantic drainages clearly play an important role in maintaining water quality in downstream areas which are used by Council-managed species as nursery areas. Tidal freshwater marshes are essential fish habitat beacuse they provide nursery habitat for managed species. In addition, palustrine emeregent and forested wetlands support essential fish habitat and the managed species dependant on that habitat through two primary avenues: 1) provision of functional attributes which maintain downstream EFH value by binding substrates, encouraging sediment deposition, nutrient uptake, and generation of detritus in a manner similar to that of intertidal salt marshes; and 2) provision of shelter, spawning habitats and prey for species which serve as important prey for Council-managed species. These prey species include Atlantic menhaden, mullet, alosids, grass shrimp, and others.

Most of the information in this account is derived from Odum et al. (1984) for tidal freshwater marshes; and Wharton et al. 1982 and Hackney et al. 1992 for freshwater marshes and river swamps.

This account employs the terms "tidal fresh marshes" and "freshwater marshes" to describe emergent wetland systems which occur in the tidal and nontidal portions of South Atlantic estuaries and their tributary rivers. For a thorough review of nomenclature used for these types of systems, see Odum et al. (1984, p. 1). In the Cowardin et al. (1979) wetland classification system, such systems could be classified estuarine emergent, riverine emergent or palustrine emergent depending on their position in the landscape with respect to the river channel. Marshes located off the main channel in oxbows or sheltered backwaters or back swamps are more properly termed palustrine; those which are fringing along river edges are classified as riverine (Odum et al. 1984; Cowardin et al. 1979).

Palustrine forested systems are called bottomland hardwoods, in the case of riparian systems (those immediately adjacent to the main channel) which are seasonally flooded, or tidal river swamps, river swamps or back swamps, used for systems which occur in oxbows or more permanently flooded areas landward of the main channel.

3.1.2.2 Description

3.1.2.2.1 Palustrine Emergent (Freshwater Marsh) Wetlands-Geographic Distribution in the South Atlantic Region

Tidal freshwater marshes occur in the uppermost portion of estuaries between the oligohaline (low salinity of 0.5 to 5 ppt) zone and nontidal freshwater wetlands. Combining the physical process of tidal flushing with the plants and animals of the freshwater marsh creates a dynamic, diverse and distinct estuarine community (Odum et al. 1984). Above the influence of the tides, additional freshwater marshes may occur in the backwater areas of river swamps, or in oxbow lakes created in former river channels. The tidal fresh marshes are characterized by: 1) near freshwater conditions (average annual salinity of 0.5 ppt or below except during periods of extended drought); 2) plant and animal communities dominated by freshwater species; and 3) a daily, lunar tidal fluctuation. In the vast lagoonal estuaries of North Carolina, freshwater marshes are probably functionally equivalent to tidal freshwater marshes, but may not experience regular lunar tidal influence, since these areas are dominated by wind-driven tides.

The most extensive development of tidal freshwater marshes in North America occurs on the United States east coast between Georgia and southern New England. The two regions with the greatest area of this wetland habitat type are in the mid-Atlantic states and South Carolina and Georgia. Acreages of freshwater marsh in the four South Atlantic Fishery Management Council states are presented in Table 7 (Odum et al. 1984).

Tidal freshwater marshes are best developed in locations which have: a major influx of freshwater, usually a river; a daily tidal amplitude of at least 0.5 m (1.6 ft); and a geomorphological structure which constricts and magnifies the tidal wave in the upstream portion of the estuary (Odum et al. 1984). As noted above, these conditions are not met in the sounds of NC, thus tidal freshwater marshes are less extensive and are replaced by tidal swamps.

The lower Cape Fear River, NC, and the lower portions of rivers in SC and GA contain numerous and extensive tidal freshwater marshes. Many of these were historically diked, impounded and converted to rice fields during the 18th and first half of the 19th centuries (Odum et al. 1984). Some of these impounded systems remain intact, others are managed to allow ingress and egress of estuarine organisms, including Council-managed penaeid shrimp and red drum, and others whose dikes have deteriorated have reverted to tidal marsh.

The most southern major river system on the coast is the St. Johns River system in Florida. The St. Johns has tidal influence for over 160 km (99 mi) inland; however, due to its unusual morphology (narrow mouth and broad upper reaches) amplitude in the tidal reach is minor, restricting typical plant communities to small areas (Odum et al. 1984).

3.1.2.2.2 Palustrine Emergent Species and Community Structure

Tidal freshwater and freshwater marshes have much greater plant diversity than that found in salt marshes occurring in the more saline portions of estuaries (Odum et al. 1984). Zonation and community types are described in Odum et al. (1984).

Most tidal fresh marsh flora consists of: 1) broad-leaved emergent perennial macrophytes such as spatterdock (*Nuphar luteum*), arrow-arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*) and arrowheads (*Sagittaria* spp.); 2) herbaceous annuals such as smartweeds (*Polygonum* spp.), tear-thumbs (*Polygonum sagittatum* and *P. arifolium*), burmarigolds (*Bidens* spp.), jewelweed (*Impatiens* spp.), giant ragweed (*Ambrosia trifida*), water-hemp (*Anaranthus cannabinus*), and water-dock (*Rumex verticillatus*); 3) annual and perennial sedges, rushes and grasses such as bulrushes (*Scirpus* spp.), spike-rushes (*Eleocharis* spp.), umbrella-sedges (*Cyperus* spp.), rice cutgrass (*Leersia oryzoides*), wild rice (*Zizania aquatica*), and giant cutgrass (*Zizaniopsis miliacea*); 4) grasslike plants or shrub-form herbs such as sweetflag (*Acorus calamus*), cattail (*Typha* spp.), rose-mallow (*Hibiscus moscheutos*) and water-parsnip (*Sium suave*); and 5) a handful of hydrophytic shrubs, including button bush (*Cephalanthus occidentalis*), wax myrtle (*Myrica cerifera*), and swamp rose (*Rosa palustris*).

Marshes of the Mid-Atlantic and Georgia Bight regions can contain as many as 50 to 60 species at a single location, and are comprised of a number of co-dominant taxa (Odum 1978, Sandifer et al. 1980). Among the more conspicuous species which occur in both regions are arrow-arum, pickerelweed, wild rice and cattails. In South Carolina and Georgia, marshes are often nearly a monospecific stand of giant cutgrass or a mixed community dominated by one or more of the species noted above, plus sawgrass (*Cladium jamaicense*), alligatorweed (*Alternanthera philoxeroides*), plumegrass, giant cordgrass (*Spartina cynosuroides*) or soft-stem bulrush (*Scirpus validus*).

Odum et al. (1984) describe eight community types of tidal freshwater marsh based on their synthesis of information from the literature on species dominance in these habitats. The types are:

1) Spatterdock Community: Spatterdock can occur in pure stands, especially in late spring, in areas of marsh adjacent to open water. These areas may be below the level of mean low water, so that the stands are submerged during high tide. They may occur on submerged point bars on the meanders of tidal creeks. Later in the growing season, some of the spatterdock may be overtopped by other species which commonly inhabitat the low intertidal zone, including arrow-arum, pickerelweed and wild rice.

2) Arrow-arum/Pickerelweed Community: Arrow-arum is an extremely cosmolitan species which grows throughout the intertidal zone of many marshes. This species forms its purest stands in the low intertidal portions of the marsh in spring or early summer (Odum et al. 1984). Pickerelweed is equally as likely to dominate or co-dominate this lower marsh zone, although its distribution is usually more clumped than arrow-arum. Both species tolerate long periods of inundation. Other species which may be associated with this community type include burmarigolds and wild rice, and less frequently, arrowhead, sweetflag and smartweeds.

3) Wild Rice Community: Wild rice is conspicuous and distributed widely throughout the Atlantic Coastal Plain. It can completely dominate a marsh, producing plants which exceed 4 m

(13 ft) in height in August and September. It may not be noticeable until mid-summer when it begins to overtop the canopy of the shorter plants, which usually consist of arrow-arum, pickerelweed, spatterdock, arrowhead, smartweed and burmarigolds.

4) Cattail Community: Cattails are among the most ubiquitous of wetland plants and are principal components of many tidal freshwater marshes (Odum et al. 1984). Cattails are mostly confined to the upper intertidal zone of the marsh. They are usually found with one or more associates, including arrow-arum, rosemallow, smartweeds, jewelweed and arrowhead. They will also form dense, monospecific stands, especially in disturbed areas where they may co-occur with common reed (*Phragmites communis*).

5) Giant Cutgrass Community: Giant cutgrass, also called southern wild rice, is an agressive perennial species confined predominantly to wetlands south of MD and VA. It dominates many of the tidal freshwater marshes, excluding other species. If it occurs in a mixed stand, other species present include sawgrass, cattails, wild rice, alligator weed, water parsnip and arrow-arum.

6) Mixed Aquatic Community: The mixed aquatic community consists of an extremely variable association of freshwater marsh vegetation. It generally occurs in the upper intertidal zone of the marsh and is composed of a number of co-dominant species which form a mosaic over the marsh surface. Species present include arrow-arum, rose-mallow, smartweeds, water-hemp, burmarigolds, sweetflag, cattails, rice cutgrass, loosestrife (*Lythrum* spp.), arrowhead and jewelweed.

7) Big Cordgrass Community: Big cordgrass is often seen growing in nearly pure stands in narrow bands along tidal creeks and sloughs, or on levee portions of low-salinity marshes. Arrow-arum and pickerelweed are associated with big cordgrass in these locales, but when stands extend further up onto the marsh, this species will intermix with cattails, common reed, rice cutgrass and wild rice.

8) Bald Cypress/Black Gum Community: The bald cypress/black gum community generally is ecotonal between the marsh itself and wooded swamp or upland forest. Situated in the most landward protions of the tidal freshwater marsh at approximately the level of mean high water, this community consists of a mixture of herbs, shrubs and trees. Additional overstory species present include tupelo gum, red maple and ash, and shrubs such as wax myrtle and buttonbush. The understory may contain typical marsh plants, although they may be reduced in number and quantity due to shading by the canopy.

3.1.2.2.3 Palustrine Emergent Dynamics and Function

Tidal freshwater marsh provides nursery habitat for managed species and is therefore essential fish habitat. Tidal freshwater marsh and likely freshwater marshes as well, are somewhat unique in that the vegetation changes dramatically as the growing season progresses (Odum et al. 1984). First to emerge in the spring are the perennials, spatterdock followed by arrow-arum and pickerelweed as they regenerate from underwater rhizomes beneath the sediments. Interspersed among these species are the seedlings of annuals, consisting of wild rice, burmarigolds, tearthumbs and smartweeds. By early May, arrow-arum, spatterdock and pickerelweed usually dominate the intertidal zone, forming a dense low canopy over the seedlings of the other species. In some places, the canopy may be overtopped by cattail and sweetflag. As the summer progresses, seedlings which germinated earlier begin to overtop the fleshy-leaved perennials, and wild rice and giant cutgrass may reach heights of 3 m (10 ft) by mid-July. Other species follow, and 30 to 50 species may appear in a single marsh location. By late July, the leaves of the arrow-arum and sweetflag begin to yellow, due to dieback from intense summer heat, feeding of herbivores on their leaves, and the canopy of other vegetation shading them. August brings flowering from the giant cutgrass, wild rice and other grasses. Pickerelweed and burmarigolds produce purple and yellow flowers, respectively. Other species also bloom in the fall. As fall deepens, leaves change color, stems collapse and fall over, and by November most of the vegetation begins to decompose. By winter, most of the vegetation is gone, leaving only a barren mudflat until the entire process begins again in the spring.

The organic matter produced by the emergent vegetation, along with the phytoplankton (microscopic plants) and benthic algae in the tidal fresh and freshwater marshes serves as an energy source for various organisms. Much of the live material can be consumed by various insects or other herbivores. Microbial organisms decompose and use a large fraction of the dead plant material which collects on the marsh surface. Animals which feed on this detritus, called detritivores, further fragment plant remains. The ultimate result is that a large amount of the energy present may be exported out of the system. Tidal currents, river currents, and wind energy all act to transport organic carbon downstream to the estuary, which is the nursery area for many of the Council-managed species. Migrating consumers, such as larval and juvenile fish and crustaceans, may feed within the habitat and then move on to the estuary or ocean. While salt marshes export about half of their net primary production to adjacent tidal waters, comparable studies have not been performed for tidal freshwater marshes. However, studies of total net community production in such marshes indicate that values range from 1,000 to over 3,500 $gm/m^2/yr$ (Odum 1978), which is higher than values reported for higher salinity communities.

Decomposition of freshwater marsh plant varies greatly in response to many factors (Brinson, Lugo and Brown 1981). However, there are several general trends with regard to the types of vegetation present and their decomposition rates. The leafy succulent low vegetation types (spatterdock, arrow-arum, burmarigold, pickerelweed, arrowhead, hibiscus leaves and wild rice) decompose extremely rapidly. They have relatively low amounts of resistant compounds (such as hemicellulose, cellulose and lignin) and relatively high amounts of nitrogen. Such plants may completely decompose in 4 to 6 weeks (Van Dyke 1978, Turner 1978).

The plants found in the higher portions of the marsh generally have much slower rates of decomposition. They also in general contain high concentrations of resistant compounds and lower contrations of nitrogen than the rapid decomposers. Consumption of this type of plant material by detrivores is significantly lower than from the fleshy succulent species (Odum et al. 1984).

The differences in decomposition rates and composition of the low and high freshwater marsh plants produce differences in the thickness and duration of the litter layer, erosion rates, and nutrient retention capacity in different sections of the marsh. As a result, depending upon the relative proportions of high and low marsh vegetation at a given site, marshes may vary in their capacity to absorb excess loads of nutrients (i.e. sewage effluent, hog lagoon spills) and therefore provide some measure of water quality benefit for downstream areas.

The overall pattern of nutrient cycling in tidal freshwater marshes appears to be similar to the pattern hypothesized for estuarine marshes (Odum et al. 1984). Oxidized nitrogen and phosphorous compounds are processed within the marsh and reduced compounds are released back into the river. In tidal freshwater marshes, the spring influx of oxidized compounds and the autumn release of reduced compounds may be more prounounced than in estuarine marshes. In addition, most tidal freshwater marshes which have been studied appear to be net exporters of both nitrogen and phosphorous.

3.1.2.2.4 Palustrine Forested Species and Community Types

Tidal freshwater swamps are present along most of the river systems from the Cape Fear River in North Carolina south to Florida. They are often closely associated with tidal freshwater marsh. When they do co-occur, they are landward of the marsh and dominated by trees such as bald cypress (*Taxodium distichus*), red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*) and tupelo gum (*Nyssa aquatica*). They frequently harbor an understory of emergent herbs and shrubs, many of which occur in the marsh. Some of these species are arrow-arum, jewelweed, royal fern (*Osmundia regalis*), lizard's tail (*Saururus cernuus*), Asiatic spiderwort (a.k.a. marsh dewflower, *Murdannia keisak*), wax myrtle and alder (*Alnus* spp.)(Odum et al. 1984).

3.1.2.2.5 Palustrine Forested Dynamics

A transformation similar to that described above for tidal fresh and freshwater marsh also occurs in the herbaceous layer of the swamp forest. Especially during dryer years, barren mud beneath the first and second canopies erupts with a green carpet of herbaceous vegetation in early June, grows to a height of several feet by July/August, and begins to decompose after the first killing frost in October/November. The author observed this transformation first hand in Company Swamp, along the Roanoke River in North Carolina, while completing vegetative sampling during the summer of 1986 (Laney et al. 1988). The lush, herbaceous growth undoubtedly contributes to the production of detrital material which is ultimately flushed from the back swamps and carried by currents to downstream estuaries.

3.1.2.2.6 Distribution by Estuarine Drainage Area

North Carolina

Palustrine emergent freshwater systems occur throughout coastal North Carolina, although as noted above, they are most extensively developed in the Cape Fear River estuary in southeastern NC. Small patches of freshwater marsh occur adjacent to streams in much of northeastern North Carolina, but many of them are too small in extent to have been delineated for most mapping efforts. Such patches of habitat occur in the streams of mainland Dare and Hyde Counties, such as Milltail Creek, Swan Creek and Whipping Creek and their associated "lake" portions. Additional areas of such habitat are also likely present in the smaller tributaries to Albemarle and Pamlico Sounds.

Palustrine forested wetlands are extensively developed in North Carolina. They occur adjacent to most of the northern sounds, and are extensively developed on all the major rivers, including the Chowan, Roanoke, Tar-Pamlico, Neuse, Cape Fear and Waccamaw.

South Carolina

Many of the South Carolina river/estuary systems have more than 200 ha (500 acres) of tidal freshwater marsh. Odum et al. (1984) indicates that the following meet that criterion: Winyah Bay system, including the Sampit, Black, Pee Dee and Waccamaw Rivers; Santee River, Charleston Harbor system, including the Cooper, Wando and Ashely Rivers; Saint Helena Sound system, including the South Edisto, Ashepoo, Morgan, Combahee and Coosaw Rivers; the New and Wright Rivers; and the Savannah River.

Georgia

Systems listed by Odum et al. (1984) which meet the 500-acre palustrine emergent tidal freshwater marsh criterion in Georgia include the Savannah River, Ogeechee River, Altamaha River and Satilla River.

Florida

Palustrine emergent freshwater marsh of unknown extent occurs in the St. Johns River and is likely present in the St. Marys and perhaps the Indian River Lagoon system to some extent.

Table 7. Conservative estimates of acreages of tidal and some nontidal freshwater marshes in the four South Atlantic States (modified after Odum et al. 1984).

State	Estimated Acreage ha (acres)	References
NC	19,800 (49,000)[1]	Wilson (1962), U.S. Army Corps of Engineers (1979)
SC	26,115 (64,531)[2]	Tiner (1977)
GA	19,040 (47,047)[3]	Wilkes (1976), Mathews et al. (1980)
FL	No reliable estimate or observation in Odum et al. (1984).	

[1] Estimate includes 18,600 ha (46,000 acres) of shallow fresh marsh classified by Wilson (1962), which Odum et al. (1984) did not include because they were not tidal; reported area is on the Cape Fear River.

[2] South Carolina also has 28,511 ha (70,451 acres) of coastal impoundments which contain considerable acreage of tidal freshwater marsh.

[3] This estimate may include some tidal swamp as well as non-tidal freshwater marsh.

3.1.2.3 Submersed Rooted Vascular (Aquatic bed-Oligohaline, Tidal Fresh and Freshwater)

3.1.2.3.1 Description

Introduction

This section briefly describes and summarizes the attributes of brackish, tidal fresh and freshwater aquatic beds of submersed rooted vascular vegetation which pertain to their likely function as essential fish habitat (EFH). The function is deemed as *probable*, rather than definitive at this point for the South Atlantic region. The review of the literature conducted for this amendment suggests that relatively few studies have been performed in the South Atlantic region to specifically investigate use of such habitats by Council-managed species or their prey (with the notable exception of the work done in the Northeast Cape Fear River, NC by Dr. Courtney Hackney and students at the University of North Carolina-Wilmington, and in estuarine tributaries of the Pamlico River by faculty and students at East Carolina University).

In other regions, such as the Chesapeake Bay and northern Gulf of Mexico, use of tidal freshwater aquatic beds by Council-managed species and their prey is better-documented. It seems likely therefore that tidal fresh aquatic beds serve directly as EFH in the South Atlantic region because they are used as nursery habitat. Freshwater aquatic beds also provide funtions which support species and other EFH in the South Atlantic region through two primary avenues: 1) provision of functional attributes which maintain downstream EFH value in the estuarine portions of South Atlantic estuarine drainage areas (EDAs), such as binding substrates, facilitating sediment deposition, conducting nutrient uptake, and generating detritus in a manner similar to seagrasses; and 2) providing shelter and forage for species which serve as important prey for Council-managed species, such as Atlantic menhaden *(Brevoortia tyrannus*), mullet (*Mugil* spp.), alosids (*Alosa* spp.), grass shrimp (*Palaemonetes* spp.) and others. Davis and Brinson (1980, 1983) reported that submerged rooted plants are often temporary features of the littoral zone, disappearing and perhaps reappearing with changing environments. They concluded that information on the seasonal and yearly variations in standing biomass of various aquatic macrophytes was needed to assess the potential contribution of these plants to ecosystem structure and function (Davis et al. 1985).

Throughout this section, the term "aquatic bed" is used to describe areas of submersed rooted aquatic vascular vegetation which occur in oligohaline (0.5 to 5 ppt salinity), tidal fresh or freshwater portions of estuaries and their tributary rivers. This term is employed in the Cowardin et al. (1979) classification of wetland and deepwater habitats of the United States, accompanied by the modifier "rooted vascular", to define areas of such vegetation. Such aquatic beds may occur in the estuarine (for beds in oligohaline areas), riverine (tidal fresh or freshwater portions of rivers) or palustrine (oxbow lakes, backswamps) systems as defined in Cowardin et al. (1979). "Aquatic bed" is also the term employed in the land cover classification system developed for use in the national Coastal Change Analysis Program (Clamus et al. 1993) to describe such habitat.

3.1.2.3.2 Freshwater Aquatic Bed Species and Their Geographic Distribution in the South Atlantic Region

The tidal fresh- and freshwater aquatic bed communities are diverse, with numerous plant species that vary in dominance depending upon the influence of salinity, turbidity and other environmental factors. It is likely that such communities occur to some extent in the tidal fresh and freshwater portions of most rivers in the South Atlantic, as far inland as the Piedmont reaches of mainstem rivers and larger tributaries. The aquatic bed communities of a portion (GA, NC, SC) of the states under jurisdiction of the South Atlantic Fishery Management Council (SAFMC) are described in Odum et al.(1984). The aquatic bed communities of southeastern United States Piedmont streams, blackwater streams, medium rivers and low-salinity backbays and lagoons are described to varying degrees in Hackney et al. (1992).

In tidal freshwater, aquatic beds generally grow in a zone extending approximately from mean low water to depths of several meters depending upon water clarity (Odum et al. 1984). This zone often lies adjacent to emergent low marsh and can encompass the entire channel of small, shallow tidal fresh creeks. Most aquatic bed species establish roots in soft benthic muds, and produce herbaceous outgrowths perennially. Stand density and extent are extremely variable, and many species are subject to drastic fluctuations in their populations from year to year, or in some cases within a given season (Southwick and Pine 1975, Bayley et al. 1978)

The presence of aquatic beds appears to diminish in southeastern rivers with distance traveled inland and upstream. They have been rarely reported in Piedmont streams (Mulholland and Lenat 1992); are considered locally abundant in some larger blackwater streams and rivers but rare in small blackwater streams (Smock and Gilinsky 1992); may be abundant in some medium-sized rivers (Garman and Nielson 1992); and can be extensive in some low-salinity (the term "low-salinity as employed herein is synonomous with the term "oligohaline") backbays and lagoons (Moore 1992). Macrophytes may be more abundant in larger rivers of the Piedmont, especially along river margins where sediments are more stable (J.J. Haines, personal communication as cited in Mulholland and Lenat 1992). Larger Piedmont rivers may support a greater variety of plant forms than the smaller streams because of the presence of different substrate types, greater stability of fine-grain sediments and greater light availability.

Water-weeds (*Elodea* spp.), pondweeds (*Potamogeton* spp.) and water-milfoils (*Myriophyllum* spp.) are some of the prevalent species in tidal freshwater wetlands of the Atlantic Coast (Odum et al. 1984 and literature therein). In Virginia, some fresh subtidal aquatic beds are composed of various naiads (*Najas* spp.), wild celery (*Vallisneria americana*) and dwarf arrowhead (*Sagittaria subulata*). Macroscopic algae found growing amid these vascular plants include species of the genera *Nitella*, *Spirogyra* and *Chara*.

In North Carolina, species present in the oligohaline and freshwater portions of Albemarle and Currituck Sounds were recorded by Ferguson and Wood (1994). Species present, in order of frequency of occurrence were: widgeon grass (*Ruppia maritima*), wild celery, Eurasian water-milfoil (*Myriophyllum spicatum*), bushy pondweed (*Najas quadalupensis*), sago pondweed (*Potamogeton pectinatus*) and redhead grass (*Potamogeton perfoloiatus*). The presence of these species and others was also documented by Davis and Brinson (1976) for the Pamlico River estuary. Investigations in the upper portion of the Pamlico River estuary and a tributary, Durham Creek, documented the presence of wild celery, naiad (*Najas* spp.), pondweeds (*Potamogeton foliosus* and *P. perfoliatus*), widgeon grass, and also macroalgal muskgrasses (*Chara* spp. and *Nitella* spp.). Studies indicated that while aquatic beds occurred from 10 to 160 cm in depth, maximum density occurred at 60 cm. Wild celery and pond weed were the dominant species present.

Species present in Florida (St. Johns River) include water milfoil and wild celery (Garman and Nielson 1992) and water weed (*Elodea* spp.) and Hydrilla (freshwater portions of Indian River Lagoon, Gilmore 1977).

Estuarine tributaries of Pamlico Sound, specifically Jacks and Jacobs Creeks of the South Creek system, were surveyed over 17 months for distribution and biomass of submerged macrophytes by Davis, Bradshaw, and Harlan (1985). The rooted macrophytes present were *Ruppia maritima* and *Zannichellia palustris*. *Ruppia* was present primarily during the warm season, while *Zannichellia* was present primarily during the cool season; both species were present in June. Davis et al. (1985) concluded that the contributions of aquatic macrophytes to community structure in these creeks should be highly variable since their biomasses are highly variable.

3.1.2.3.3 Aquatic Bed Meadow Dynamics

Although macrophytes have rarely been reported in Piedmont stream tributaries of EDAs (Mulholland and Lenat 1992), because vascular plants usually do not occur in the shaded portions of Piedmont streams, species such as wild celery may grow in areas exposed to direct sunlight. Some researchers believe that the lack of vascular plants in Piedmont streams is the result of unstable sediments, moderate to high stream gradients, and the large variations in streamflow typical of most Piedmont streams (M.G. Kelly, personal communication as cited in Mulholland and Lenat 1992). An exception to this is the river weed (*Podostemum ceratophyllum*). This species grows attached to rock surfaces and is therefore not dependent on stable sediments. Productivity of river weed was greatest during moderate and stable streamflow, when the stream bed was completely flooded but the water velocities were not great.

In blackwater streams, light intensity is an important limiting factor to aquatic bed growth. Incident light is affected by both canopy development over small streams during the growing season, and by light attenuation in larger rivers (Smock and Gilinsky 1992). Discharge pattern is also probably important. Highly developed macrophyte beds in Upper Three Runs Creek, South Carolina, were attributed to that stream's more constant discharge versus others with more fluctuating discharges (W.R. English, personal communication as cited in Smock and Gilinsky 1992).

Many aspects of the dynamics of aquatic beds in the upper Pamlico River estuary are reviewed in Davis and Brinson (1976). They and other authors (Harwood 1976, Reed 1976a-b, Zamuda 1976a-b, and Vicars 1976a-c) documented the density, depth and distance from shore; seasonal dynamics; growth dynamics; biomass; areal and temporal distribution; macrophyte decay dynamics; and total macrophyte production and nutrient accumulation.

3.1.2.3.4 Aquatic Beds As Essential Fish Habitat

Submersed rooted vascular vegetation in tidal fresh- or freshwater portions of estuaries and their tributaries performs the same functions as those described for seagrasses (see Section 3.1.1.3 of this amendment). Specifically, aquatic bed meadows possess the same four attributes: 1) primary productivity; 2) structural complexity; 3) modification of energy regimes and sediment stabilization; and 4) nutrient cycling. Primary production forms complex, three dimensional physical structures which consist of a canopy of leaves and stems and roots and rhizomes buried in the sediments or attached to rocky substrate (in Piedmont stream tributaries). The physical structure provides substrate for attachment of macroalgae and macroinvertebrates, shelter from predators, frictional surface area for modification of water flow and current turbulence, sediment and organic matter deposition, and the physical binding of sediments. Aquatic bed organic matter, like that of seagrasses, cycles and stores nutrients, providing direct and indirect nutritional benefits to macroinvertebrate herbivores and detritivores.

Two of the potential benefits derived from aquatic beds were tested in field experiments conducted by Rozas and Odum (1988). They conducted studies to determine whether relative predation pressure is less in aquatic beds than in unvegetated areas, and whether fish food availability is greater in aquatic bed than in nearby unvegetated areas. They found that aquatic beds in tidal freshwater marsh creeks not only afford protection from predators, but also provide a rich foraging habitat. By foraging in aquatic bed habitat, fish consume larger prey and may have higher growth rates, lower mortality, and higher fecundity (Rozas and Odum 1988).

While the information on the use of aquatic beds in tidal fresh- and freshwaters appears scant, additional information should be generated in the future due to the development of new techniques (Rozas and Minello 1997). Enclosure devices, including throw traps and drop samplers, generally produce less variability in sampling and their catch efficiency does not appear to vary substantially with the type of habitat. These devices should be employed in aquatic beds to collect additional data to document the role which brackish, tidal fresh and freshwater submersed rooted macrophytes play in sustaining Council-managed species and to clarify their EFH role.

Tidal fresh- and freshwater aquatic beds serve as an important substratum and refuge for macroinvertebrates which serve as prey for fish. In the Middle Oconee River, GA, river weed hosted *Simulium* pupae and *Calopsectra* (*Tarytarsus*) larvae (Nelson and Scott 1962). Nelson and Scott concluded that much of the river weed was not used directly as a food source by invertebrates, but entered the detrital food chain after being dislodged from rock surfaces during high flow or drying out when exposed to air during low flow. Approximately one-half of the total plant detritus on the bottom of this reach of the Middle Oconee was river weed.

The macroinvertebrates upon which some fish species feed exhibit seasonality in Piedmont streams which corresponds to the presence of species of importance to Council-managed species. In Piedmont streams, studies of seasonal fluctuations in macroinverbebrate abundance show peaks in spring and autumn in both density (Stoneburner and Smock 1979, Reisen and Prins 1972) and taxa richness (Lenat 1988). These peaks correspond with the periods when spring-spawning alosids (shads and herrings) and their fall outmigrating juveniles are most likely present. Pre-spawning hickory shad, *Alosa mediocris*, gathering in Albemarle Sound in late winter, commonly eat fish prey, primarily of the Family Clupeidae; hickory shad migrating upstream in the Roanoke River to spawn consume fish and insects (Batsavage and Rulifson 1998).

In some cases, macroinvertebrates may serve not only as a direct source, but also an indirect source of sustenance as well. In blackwater rivers which contain beds of water lily (*Nuphar luteum*), much of the production enter the food chain through grazing by water lily beetles (*Pyrrhalta nymphaea*)(Wallace and O'Hop 1985). At least one investigator believes that the annual cycle of water lily abundance in many Coastal Plain rivers may be the major factor influencing seasonal variation in macroinvertebrate abundance (D.R. Lenat, personal communication as cited in Smock and Gilinsky 1992). Since alosids, herrings in particular, spawn in such beds, spawning adults and emerging larvae may benefit from the availability of prey in the form of macroinvertebrates themselves, or in the form of zooplankton or other species which make use of the detritus produced by invertebrate grazing.

Macroinvertebrate abundance is higher in macrophyte beds and on their fronds or leaves than in sandy substrates (Smock et al. 1985; W.R. English, personal communication as cited in Smock and Gilinsky 1992). This abundance is attributed to the fact that aquatic beds stabilize sediment and are an important substrate, and upon their death, become food for invertebrates, a role similar to that played by seagrasses (see Section 3.1.1.3). Thorp et al. (1997) determined that macroinvertebrate density in Potomac River aquatic beds was two orders of magnitude higher and substantially more diverse than at open water sites. They interpreted their results to support the hypothesis that water-column macroinvertebrates are greatly enhanced in the presence of aquatic bed habitat. Rozas and Reed (1994) found that nekton habitat segregation with depth was largely influenced by submersed aquatic vegetation and salinity as well as water depth. Paller (1987) determined that larval fish assemblages in macrophyte beds were 160 times higher in standing stock than those in adjacent open channels, and that larvae concentrated in the interior of aquatic beds rather than at the ecotone between the aquatic beds and open channels.

Macrophyte beds can also be a source of increased zooplankton prey. Cooper et al. (1994) documented the extent of water lily (*Nuphar lutea*) beds in the lower Roanoke River and their use by larval fishes. They found that the formation of water lily beds is dependent upon water temperature and level of the river but generally begins in early April, with die-back at the end of August or early September. Coverage in the estuary can be substantial; the Roanoke River delta contained about 314,000 m^2 of surface area, representing anywhere from 3% to 40% of river surface area. Cooper et al. (1994) determined that these beds offered important refuge for young fish while allowing them to have access to adjacent open-water zooplankton. *Daphnia*, *Bosmina*, and copepods were found more frequently in adjacent open-water samples, while other cladocerans were more common in water lily beds. Cladocerans and rotifers were the primary prey taxa of larval fishes in water lily beds and cladocera and copepods were the primary taxa in open water. Fish taxa utilizing this habitat included, in order of abundance, sunfishes (centrarchids), shads and herrings (clupeids), minnows (cyprinids), white perch, darters, juvenile menhaden, carp (*Cyprinus carpio*), American eel juveniles (*Anguilla rostrata*), pirate perch (*Aphredoderus sayanus*), Atlantic needlefish (*Strongylura marinus*), brown bullhead (*Ictalurus natalis*) juveniles, striped bass (*Morone saxatilis)*, suckers (*Moxostoma* spp.), inland silverside (*Menidia beryllina*), and yellow perch (*Perca flavescens*).

Overall, macroinvertebrate abundance in blackwater streams is much higher than historically believed (Smock and Gilinsky 1992). Species richness is comparable to other types of southeastern streams previously viewed as more diverse.

Blackwater streams and other Coastal Plain streams and their associated Aquatic beds are important spawning and nursery areas for many fish species, including anadromous species which serve as prey for at least one Council-managed species (bluefish) and likely for others. Use of blackwater streams by anadromous species as spawning sites and as nursery areas is widespread and documented by field observations (Davis and Cheek 1966, Baker 1968, Pate 1972, Gasaway 1973, Frankensteen 1976, Smock and Gilinsky 1992). Highest numbers of fish are present generally from April through June, although fish may arrive earlier in the south and later in the north. Arrival of adults corresponds with the highest flows, thus the greatest area of inundated floodplain (see Section on Palustrine Forested and Emergent Wetlands). Both anadromous and resident species move onto the floodplains to spawn, and those species which have adhesive eggs undoubtedly use aquatic bed vegetation as a substrate.

The life history aspects of anadromous alewife and blueback herring in freshwater along the Atlantic Coast was reviewed by Loesch (1987). The two species occur together (i.e., are sympatric) from New Brunswick and Nova Scotia to upper South Carolina. Alewives alone occur north of Nova Scotia, and bluebacks alone south to Florida. Both species are important prey species for Council-managed species, and both use aquatic bed habitats for spawning in different parts of the range. Where the two species occur together, alewife preferentially uses habitats likely to contain aquatic beds, while blueback use swifter main channel areas. In the South Atlantic, bluebacks use aquatic bed habitats in oxbow lakes and other backwaters. Both species travel far upstream when access permits, increasing the likelihood that they would use riverine aquatic bed habitats. Loesch (1987) does not address microhabitat requirements for spawning, and does not provide any information about whether juveniles use aquatic beds during their nursery residence in freshwaters.

Studies conducted by Rozas and Hackney (1983,1984), and Rozas and Odum (1987a-b), have documented the importance of oligohaline and freshwater creeks and associated aquatic beds as nurseries for species of significance as prey to Council-managed species. Oligohaline wetland habitats were found to be likely of equal importance as higher salinity marshes for two important estuarine species, spot (*Leiostomus xanthurus*) and Atlantic menhaden (*Brevoortia tyrannus*). Additional species significant as prey were also dominant in oligohaline tidal creeks and associated aquatic beds, including grass shrimp (*Palaemonetes pugio*) and bay anchovy (*Anchoa mitchelli*). Recruitment of small juvenile fishes was found to correspond with the period of greatest aquatic bed areal cover. Average densities of fauna were significantly greater in aquatic beds than over nearby unvegetated creek bottoms in the fall. The aquatic beds of tidal freshwater marsh creeks were considered most important as habitat for forage fishes. In experiments where the aquatic bed vegetation was removed from tidal fresh creeks, the number of grass shrimp on adjacent marshes decreased, but the average density of fishes was not reduced. The authors concluded that the proximity of aquatic beds and the depth of adjacent creeks are the most important factors that influence the abundance of nekton on tidal freshwater marshes (Rozas and Odum 1987a).

Anadromous species are also important seasonal components of mainstem rivers which originate in the mountains or Piedmont. These include rivers such as the Roanoke, Tar-Pamlico, Neuse and Cape Fear in NC; Pee Dee, Santee, and Cooper in SC; Savannah, Ogeechee and Ocmulgee in GA, and St. Johns in FL. Other rivers not included in this list primarily drain the Coastal Plain and are blackwater rivers. Since their presence seasonally overlaps with the presence of aquatic beds in these systems, it is likely that adults may use these areas for spawning and perhaps feeding. The eggs, larvae and juveniles which are present in these systems from spring through the fall are much more likely to use aquatic bed habitat for cover and foraging.

The river with the highest potential for EFH designation due to both indirect and direct use by Council-managed species may be the St. Johns in FL (Tagatz 1967, Cox and Moody 1981, Hocutt et al. 1986, Swift et al. 1986, and Garman and Nielson 1992). Tagatz (1967) reported 115 euryhaline species (species which tolerate a wide range of salinity), including clupeids (shads and herrings) and scianids (drums, such as red drum, weakfish, spot, croaker and others). These species occurred at great distances upstream from the river mouth, presumably because of the extended tidal influence due to the St. Johns low gradient, and also to the presence of refugia in the form of salt springs which occur in the river.

Many of the macroinvertebrates which occur in the oligohaline (low salinity) portions of the backbays and lagoons of the South Atlantic region may use the aquatic beds which occur there, especially the crustaceans. These species in some cases constitute important species managed by the Council (e.g. the penaeid shrimps) or are important prey for other Council-managed species (e.g., blue crabs which are prey for red drum, grass shrimp which are prey for many other species). Because many of the shrimps and crabs have well-developed osmoregulatory capabilities (the ability to adjust to changing salinity), the low and often variable salinities that occur in areas such as Currituck Sound, Albemarle Sound, Pamlico Sound, Core and Bogue Sounds, and SC and GA sounds and backbays, do not pose the stress which they do for other organisms (Moore 1992). On the South Atlantic coast, the penaeid shrimp species which appears most likely to use aquatic beds in tidal fresh and freshwater areas is the white shrimp (*Penaeus setiferus*), although it does not apparently penetrate fresh waters as far on the South Atlantic Coast as it does in the Gulf of Mexico (Odum et al. 1984). Although brown shrimp (*Penaeus aztecus*) do occasionally occur in the fresher areas of lagoons such as Albemarle Sound (R. Eager, R.W. Laney, J.W. Kornegay and S.W. Winslow, unpublished data) they are not abundant in such areas.

Perhaps the most abundant macrocrustaceans which may use aquatic beds in tidal fresh and freshwater areas of southeastern EDAs are the grass shrimp, species of the genus *Palaemonetes*. There are four species which occur along the South Atlantic Coast: *P. paludosus*, restricted to freshwaters of rivers and which is abundant in tidal fresh areas; *P. pugio* which occurs in low-salinity areas; *P. intermedius*, also present in low-salinity areas; and *P. vulgaris*, which generally remains in areas of greater than 10 ppt salinity, but which presumably could move into areas occupied by aquatic beds during dry periods when salinities are higher and freshwater flows diminished. Williams (1984) notes that the three estuarine species all occur preferentially in beds of submersed aquatic vegetation, hence the name "grass" shrimp. Freshwater shrimp of the genus *Macrobrachium,* and freshwater crayfish (*Procambarus* spp.) also occur in tidal fresh- and freshwater portions of South Atlantic rivers (Rozas and Hackney 1984); however, their importance in the diet of Council-managed species or their prey is unknown.

Another significant crustacean which occurs in tidal fresh- and freshwater aquatic bed is the blue crab (*Callinectes sapidus*). Fully grown blue crabs, especially males, occur not uncommonly far upstream in coastal rivers and at least one large coastal lake, Lake Mattamuskeet in North Carolina (Moore 1992; Rulifson and Wall 1998). Whether the lake was historically isolated or was connected to the nearby estuary is somewhat in doubt, but it was unquestionably altered in the mid-1800s by the construction of a drainage canal dug by slaves (Lake Landing Canal), and then later in the early part of this century by additional canals which facilitated access by estuarine species (Forrest 1998**.** During one week (April 23-May 2, 1997), over 1,300 blue crabs with an average carapace width of 1.5 inches migrated into the lake, documenting its value as a nursery for this species (Rulifson and Wall 1998). Juvenile blue crabs characteristically occur at the lowest salinities in estuarine ecosystems (Tagatz 1968).

Other euryhaline species which currently use Lake Mattamuskeet and its extensive aquatic bed habitats include Atlantic needlefish (*Strongylura marina*), striped mullet (*Mugil cephalus*) and tidewater silverside (*Menidia menidia*). The anadromous alewife and white perch (*Morone americana*) also use the lake for spawning (Rulifson and Wall 1998).

A study of the functional relationship between economic damages and the loss of submerged aquatic vegetation in Chesapeake Bay demonstrated that loss of aquatic bed area can result in economic losses through diminishing recreational activities and commercial fishing, as a result of the impact of reductions in aquatic bed extent on fish and waterfowl populations (Kahn 1985).

3.1.2.3.5 Distribution by Estuarine Drainage Area

Limited information is available on the distribution and extent of aquatic beds in EDAs of the South Atlantic. Much of the general distribution information in this section is derived from several of the chapters in Hackney et al. (1992), and from Odum et al.(1984). Distribution in EDAs of the South Atlantic region is discussed from the headwaters to the estuaries. Additional information is available from review of National Wetland Inventory (NWI) maps, although much of the aquatic bed habitat may have been overlooked as a consequence of the small size of individual meadows or beds, presence of tree canopy over the stream which precluded detection, or turbid waters present at the time aerial photographs were taken. On those maps which do include aquatic bed, it is mapped as one of the following: Estuarine, intertidal or subtidal aquatic bed in low-salinity backbays and lagoons; riverine, intertidal or subtidal aquatic bed in the tidal fresh portions of rivers; and lacustrine, limnetic aquatic bed in the case of Lake Mattamuskeet (Cowardin et al. 1979).

North Carolina

Ferguson (Ferguson and Wood 1994; and unpublished data) identified species (Table 8) and mapped the distribution and extent of aquatic beds in Currituck, Albemarle, Croatan, Roanoke and Pamlico Sounds in NC. With the exception of Currituck Sound and certain Albemarle Sound sub-estuaries, the shallow portions of the Neuse and Pamlico Rivers and Croatan and Roanoke Sounds are largely devoid of aquatic bed habitat due to physiological stress from variable salinity, chronic turbidity and highly colored water from coastal swamp drainage. Salinities greater than 5 ppt can be too high for low salinity species. Historical meadows of aquatic bed habitat in these low salinity waters are largely missing or reduced in aerial extent, based on anecdotal accounts, having been heavily impacted by development of coastal lands and eutrophication. Total acreage for the low salinity aquatic bed habitat mapped is approximately 11,000 acres, of which 55% is in Currituck Sound. Forty percent is in sub-estuaries associated with Albemarle Sound (R. Ferguson, National Ocean Service, Beaufort, NC, unpublished data).

Table 8. Low Salinity Tolerant and Low Salinity Requiring Species of North Carolina Estuaries (Source: Ferguson and Wood 1994).

Taxonomic Name	Common Name	Salinity Range ------‰-------
Rupia maritima	widgeon grass	0 - 36
Vallisneria americana	wild celery	0 - 10
Myriophyllum spicatum	eurasian water milfoil	0 -10
Najas guadalupensis	bushy pondweed	0 - 10
Potamogeton perfoliatus	redhead grass	0 - 20
Potamogeton pectinatus	sago pondweed	0 - 9
Zannichellia palustris	horned pondweed	0 - 20
Alternantheria philoxeroides	alligatorweed	0 - ?
Nuphar luteum	spatterdock	0 - ?
Ultricularia sp.	bladderwort	0 - ?

(1990) For photographs and general ecological information on thses species. Species of SRV thrive in fresh and oceanic water which has been classified according to salinity by Cowardin et al. (1979). Two species, eel grass (*Zostera marina*) and shaol grass (*Halodule wrightii*) are true seagrasses, requiring salinities _>5.0 ‰ to survive. One species, widgeon grass (*Ruppia maritima*), is euryhaline. The remaining ten species are most frequent at salinities _< 5.0 ‰ (ibid; Batuik et al., 1992)

South Carolina

Species of aquatic bed vegetation recorded in SC blackwater streams include *Sparganium americanum*, which is tolerant of low-light conditions. It is found in fully canopied, second-order Cedar Creek in the Congaree Swamp National Monument, SC. Wild celery and pondweed (*Potamogeton epihydrus*) were common in Upper Three Runs Creek, a tributary of the Savannah River located at the Savannah River Plant site in SC (Morse et al. 1980).

Georgia

Nelson and Scott (1962) reported that river weed (*Podostemum ceratophyllum*) dominated the benthic flora of a rock outcrop reach of the Middle Oconee River, GA.

Free-flowing sections of the Savannah River, GA, hosted *Potamogeton*, *Callitriche*, and *Najas*, as well as *Podostemum*. Aquatic moss, *Fontinalis*, and large growths of the macroalga, *Nitella*, have also been observed in some areas of the Savannah River.

Large beds of macrophytes often occur in the backwaters of large, uncanopied rivers such as the Ogeechee River, GA, and Chowan River, NC (Dennis 1973, Twilley et al. 1985, Wallace and O'Hop 1985).

Florida

Aquatic macrophytes, both aquatic beds and emergent, are abundant and diverse throughout the floodplain of the St. Johns River (Garman and Nielson 1992). Species which dominated the freshwater portions of the river included pondweeds (*Pontederia* spp.), water milfoil (*Myriophyllum*) and wild celery (*Vallisneria*)(Cox et al. 1976).

Freshwater aquatic bed also occurs in the fresh portions of the Indian River Lagoon (Gilmore 1977). Species present included water weed, hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichornia crassipes*), water lettuce (*Pistia stratiotes*) or pickerel weed (*Pontederia lanceolata*).

3.1.3 Estuarine Water Column

This habitat traditionally comprises four salinity categories: oligohaline (< 8 ppt), mesohaline (8-18 ppt), and polyhaline waters (18-30 ppt) with some euhaline water (>30 ppt) around inlets. Alternatively, a three-tier salinity classification is presented by Schreiber and Gill (1995) in their prototype document developing approaches for identifying and assessing important fish habitats: tidal fresh (0-0.5 ppt), mixing (0.5-25 ppt), and sewater (>25 ppt). Saline environments have moving boundaries, but are generally maintained by sea water transported through inlets by tide and wind mixing with fresh water supplied by land runoff. Particulate materials settle from these mixing waters and accumulate as bottom sediments. Coarser-grained sediments, saline waters, and migrating organisms are introduced from the ocean, while finer-grained sediments, nutrients, organic matter, and fresh water are input from rivers and tidal creeks. The sea water component stabilizes the system, with its abundant supply of inorganic chemicals and its relatively conservative temperatures. Closer to the sea, rapid changes in variables such as temperature are moderate compared to shallow upstream waters. Without periodic additions of sea water, seasonal thermal extremes would reduce the biological capacity of the water column as well as reduce the recruitment of fauna from the ocean. While nearby wetlands contain some assimilative capacity abating nutrient enrichment, fresh water inflow and tidal flushing are primarily important for circulation and removal of nutrients and wastes from the estuary.

The water column is composed of horizontal and vertical components. Horizontaly, salinity gradients (decreasing landward) strongly influence the distribution of biota, both directly (physiologically) and indirectly (e.g., emergent vegetation distribution). Horizontal gradients of nutrients, decreasing seaward, affect primarily the distribution of phytoplankton and, secondarily, organisms utilizing this primary productivity. Vertically, the water column may be stratified by salinity (fresh water runoff overlaying heavier salt water), oxygen content (lower values at the bottom associated with high biological oxygen demand due to inadequate vertical mixing), and nutrients, pesticides, industrial wastes, and pathogens (build up to abnormal levels near the bottom from lack of vertical mixing).

Typically, parameters of the following variables can be used to chemically, physically, or biologically characterize the water column: total nitrogen, total organic nitrogen, alkaline phosphatase, total organic carbon, NO_2^-, NO_3^-, NH_4^+, turbidity, total phosphorus, chlorophyll *a* , dissolved oxygen, temperature, and salinity (see Boyer et al., 1997). Composite signatures by these variables can be used to identify the source of the water column. Components commonly used to describe the water column are organic matter, dissolved inorganic nitrogen, dissolved oxygen, temperature, salinity, and phytoplankton. Additional physical descriptors of the water column include depth, fetch, and adjacent structure (e.g., marshes, channels, shoals). Turbidity is quantified by secchi depth, light attenuation, and NTU. Increases in turbidity, resulting from large river flow runoff or strong wind events, affect the distribution and productivity of submerged aquatic vegetation and phytoplankton through reduction of light levels necessary for photosynthesis and changes in nutrient concentrations.

The dynamic, variable, productive, and stressful environment of the estuarine water column provides a rich opportunity for migrating and residental biota to live within the parameters for which they are adapted (Sea Grant, 1976). Many marine-spawning species utilize the estuarine water column as larvae if they are physiologically, thermally, and salinity adapted. For example, during mid-winter, larvae of several important commercial fishes (e.g., menhaden) are transported through inlets into the seemingly inhospitable thermal environment of the shallow estuaries, where they thrive on blooms of plankton and a relative lack of predators. Menhaden and other water column inhabitants utilize the exported production from other estuarine habitats such as marshes, seagrass beds, shell reefs, even though they don't physically occupy these structured environments. While the water column is a relatively difficult component of the estuary to define in terms of essential habitat compared with marshes, seagrass bed, and reefs, it is no less important since it is the medium of transport for nutrients and migrating organisms between river systems and the open ocean.

3.2 Marine/Offshore Habitats

3.2.1 Coral, Coral Reefs, and Live/Hard Bottom Habitats

3.2.1.1 Coral and Coral Reefs

3.2.1.1.1 Geographical Range of Habitat Types

Coral reef communities or solitary specimens exist throughout the geographical areas under Council authority. This wide distribution places corals in oceanic habitats of corresponding variability, from nearshore environments to continental slopes and canyons, including the intermediate shelf zones. Habitats supporting corals and coral-associated species are discussed below in groupings based on their physical and ecological characteristics.

Depending upon many variables (see Section 3.3.7), corals may dominate a habitat (e.g., coral reefs), be a significant component (e.g., hard bottoms), or be individuals within a community characterized by other fauna (e.g., solitary corals). Geologically and ecologically, the range of coral assemblages and habitat types is equally diverse (see, e.g., James, 1977). The coral reefs of shallow warm waters are typically, though not always, built upon coralline rock and support a wide array of hermatypic and ahermatypic corals, finfish, invertebrates, plants, and microorganisms. Hard bottoms and hard banks, found on a wider bathymetric and geographic scale, often possess high species diversity but may lack hermatypic corals, the supporting coralline structure, or some of the associated biota. In deeper waters, large elongate mounds called deepwater banks, hundreds of meters in length, often support a rich fauna compared to adjacent areas. Lastly are communities including solitary corals. This category often lacks a topographic relief as its substrate, but instead may use a sandy bottom, for example.

This discussion divides coral habitats (i.e., habitats to which coral is a significant contributor) into five categories - solitary corals, hard bottoms, deepwater banks, patch reefs, and outer bank reefs (defined below). The order of presentation approximates the ranking of habitat complexity based upon species diversity (e.g., zonation, topographic relief, and other factors). Although attempts have been made to generalize the discussion into definable types, it must be noted that the continuum of habitats includes many more than the five distinct varieties discussed below. However, in compliance with existing knowledge, the following categories will suffice.

To clarify the presentation in this Section and 3.3.7 of this document, corals have been divided into deep-water and shallow-water species, with the 200 m (660 ft) isobath or depth contour arbitrarily chosen as the dividing line since it approximates the edge of the continental shelf.

The following are definitions of selected terminology used throughout this Section and Section 3.3.7 which presents a detailed description of the species and their distribution:

Coral: Species belonging to the Orders Stolonifera, Telestacea, Alcyonacea (soft corals), Gorgonacea (horny corals, sea fans, sea whips), and Pennatulacea (sea pens) in the Subclass Octocorallia; Orders Scleractinia (stony corals) and Antipatharia (black corals) in the Subclass Zoantharia; and the Orders Milleporina (fire corals, stinging corals) and Stylasterina in the Class Hydrozoa.

- Phylum Coelenterata
  - Class Hydrozoa
    - Order Milleporina (fire, stinging corals)
    - Order Stylasterina (hydrocorals)
  - Class Anthozoa
    - Subclass Octocorallia
      - Order Stolonifera
      - Order Telestacea
      - Order Alcyonacea (soft corals)
      - Order Gorgonacea (horny corals, sea fans, whips, precious red coral)
      - Order Pennatulacea (sea pens)
    - Subclass Zoantharia
      - Order Scleractinia (stony corals)
      - Order Antipatharia (black corals)

Stony Corals: For the purpose of this plan, includes species belonging to the Class Hydrozoa (fire corals and hydrocorals) and Class Anthozoa, Subclass Zoantharia (stony corals and black corals).

Octocorals: For the purpose of this plan, includes species belonging to the Class Anthozoa, Subclass Octocorallia (soft corals, horny corals, sea fans, sea whips, sea pens, and others).

Hermatypic (Corals): Corals that contain symbiotic, unicellular zoaxanthallae in their endodermal tissue. Always found in shallow (O to 100 m; O to 330 ft.), warm (15 to 35°C; 60 to 95°F), sun-lit waters. Usually colonial but may be solitary. Often referred to collectively as reef corals, however some species are small and are never found on reefs. Within the discussion on shallow-water corals, this definition has been qualified to exclude some corals with aberrant zooxanthellae relationships, e.g., facultatively symbiotic species (Boschma, 1925; McCloskey, 1970; Duclaux and Lafargue, 1973) and those which appear capable of "bank-building" without the benefit of symbionts (Avent, et al., 1977).

Ahermatypic (Corals): Corals that do not have zooxanthellae. Their distribution is not restricted by depth, temperature, or light penetration. Found from O to 5,880 m (O to 19,000 ft), and O to 35°C (32 to 95°F). Both colonial and noncolonial (i.e., single polyp) species in about equal number. Although often referred to as “deep sea” or “solitary” (see next definition) corals, they often occur in shallow water and many are colonial. Their distribution overlaps that of the hermatypes and is exclusive in waters deeper than about 100 m (330 ft).

Solitary corals: A coral organism composed of a single polyp.

Colonial corals: A coral organism with more than one polyp and which may be part of a coral reef or some other coral assemblage. This may also be referred to as a colony, unit, or individual coral.

Coral Reefs: For purposes of this FMP, coral reefs are defined as the hard bottoms, deepwater banks, patch reefs and outer bank reefs as described below:

1.) Patch reef: Irregularly distributed clusters of corals and associated biota located in the management area only along the seaward (southeast) coast of the Florida Keys. Occur as dome-type patches on the leeward side of outer bank coral reefs (see definition below) or as linear-type patches that parallel bank reefs in arcuate patterns. The latter support flora and fauna, including elkhorn coral (*Acropora palmata*), which more nearly resembles the bank reefs. Patch reefs include hermatypic reef-building corals plus ahermatypic species. Most patch reefs occur 3 to 7 km (1.6 to 3.8 nm) offshore between Miami and the Dry Tortugas on the inner shelf (less than about 15 m or 49 ft depth). Vertical relief ranges from less than 1 m to over 10 m (3 to over 33 ft).

2.) Outer bank reefs: Includes ahermatypic and hermatypic species in a complex assemblage often with greater vertical relief than patch reefs. Located in the Florida reef tract primarily shoreward of the 18 m (60 ft) isobath. Biota always exhibits zonation, with the number and type of zones dependent upon the height of the coral substrate, the location of the reef, and the stresses present. Also referred to as the "outer reef arc" (Davis, 1928) and a "fringing barrier" (Milliman, 1973).

3) Hard bottom: Coral communities lacking the coral diversity, density, and reef development of patch and outer bank reefs. Some hard bottom is more appropriately termed hard banks, organic banks or simply banks. Hard bottom may include some hermatypic corals. Widely distributed in the management area. Biota usually include a thin veneer of live corals, often covering a rock outcrop or a relic reef, and associated benthos (e.g., sponges, tunicates, holothurians) in an assemblage with low relief. Also called live bottom (Struhsaker, 1969), hardgrounds, or pinnacles (when found in a nonbank setting). Hard grounds is not used herein since the term connotes a particular geological sediment structure rather than a biotic community.

4) Deepwater banks: A structure composed primarily of surface-hardened crusts of submarine muddy to sandy carbonate sediments supporting a comparatively diverse assemblage of benthic animals. The ahermatypic corals (*Enallopsammia profunda* and *Lophella prolifera*) may provide framework and promote entrapment and accumulation of sediments and skeletal debris. Similar structures may be called haystacks, deep sea mounds, or lithoherms.

3.2.1.1.1.1 Solitary Corals

Throughout much, if not all, of the management area, research has located bottom communities which include corals as a minor component of biotic diversity [for example Cairns (1979) in the Atlantic]. Although these solitary corals contribute benthic relief and habitat to communities throughout the fishery conservation zone, they apparently comprise a minor percentage of the total coral stocks in the management area.

3.2.1.1.1.2 Hard bottom

Hard bottom constitutes a group of communities characterized by a thin veneer of live corals and other biota overlying assorted sediment types. Hard bottom are usually of low relief and on the continental shelf (Bright, et al., 1981); many are associated with relic reefs where the coral veneer is supported by dead corals.

This grouping of coral habitats is one of the most widely distributed of the five categories identified above, being common throughout the management area. Hard bottom or banks have been described by Goldberg (1973a), Bright, et al. (1981) and Blair and Flynn (1989), off southeastern Florida; off the coasts of southeastern states (Johnston, 1976); off Georgia and South Carolina (Stetson, et al., 1962; Porter, 1978, personal communication; Thomas, 1978, personal communication); and North Carolina (Huntsman, 1984; MacIntyre and Pilkey, 1969).

Ecologically and geologically, hard bottom and hard banks are diverse categories. Both habitats include corals but typically not the carbonate structure of a patch or outer bank coral reef nor the lithified rock of lithoherms, a type of deepwater bank (see discussions below). Diverse biotic zonation patterns have evolved in many of these communities because of their geologic structure and geographic location. Hard bottom is common on rocky ledges, overlying relic reefs, or on a variety of sediment types. In each case, species compositions may vary dependent upon water depth and associated parameters (light, temperature, etc.).

Shelf-edge banks occur off central eastern Florida at depths of 70 to 100 m, with relief up to 25 m and covered with massive, contiguous colonies of *Oculina varicosa* (1 to 2 m in height). Some of the pinnacles are covered entirely with dead *Oculina* debris. At 3 to 50 m depths solitary colonies (<30 cm diameter) of *Oculina varicosa* grow on limestone ledge systems (1 to 3 m relief) that parallel the coast of Florida (Reed, 1980b).

Hard bottom and banks in different geographical areas support different coral assemblages. Near the Florida Keys, hard bottom co-exist as underdeveloped reefs nearshore and seaward of the outer bank reef tract. North of Fowey Rocks off southeastern Florida, hard bottom include all types of corals, though hermatypic species are near their northern limit (see, for example, Goldberg (1973a) and Blair and Flynn (1989). Coral communities from Florida north to North Carolina, are dominated by ahermatypic species (gorgonians, *Oculina*), although some hermatypic species do occur off North Carolina (MacIntyre and Pilkey, 1969), and Georgia (Hunt, 1974). The corals on the hard banks off North Carolina near the 720 and 990 m (2,230 to 2,970 ft) isobaths consist primarily of *Lophelia prolifera* and *Enallopsammia profunda*, but also *Bathypsammia spp.*, *Caryophyllia clavus*, and *Balanophyllia spp.* (Stetson, et al., 1962).

On Florida's east coast, hard bottom of nearshore areas has been characterized in the Florida Keys by Chiappone and Sullivan (1994) and off the mainland by Nelson (1989) and Nelson and Demetriades (1992). Nearshore hard bottom characteristics differ substantially between the mainland coast of east Florida and the Florida Keys. These differences include higher wave energies, fewer corals and grasses, and coarser sediments in nearshore hardbottom of mainland areas (Lindeman, 1997). Additional factors complicate Keys and mainland comparisons of hardbottom. Nearshore hardbottom in the Keys is distributed across more physiographically variable cross-shelf gradients with a greater potential for structural heterogeneity than on the mainland. The presence of over 6000 patch reefs in Hawk Channel (Marszalek et al. 1977), many near shallow hardbottom habitats, introduces additional inter-habitat relationships rarely found in nearshore hardbottom of mainland areas.

3.2.1.1.1.3 Deepwater Banks

The existence of deepwater banks called lithoherms in the Straits of Florida off Little Bahama Bank has been reported in the literature by Moore and Bullis (1960), Neumann, Keller, and Kofoed (1972) and Neumann, Kofoed and Keller (1977). As defined by Neumann, et al. (1977), lithoherms are deepwater structures composed of surface hardened layers of lithified sandy carbonate sediments supporting a regionally diverse array of benthic fauna. Other types of deepwater banks may not be hardened but do support varying amounts of corals.

True lithoherms are located predominantly beyond the outer edge of the continental shelf on the continental slope. Although their distribution is still being delineated, these structures have been identified only in the western south Atlantic region, especially within Bahamian national waters. Some lithoherms do, however, occur near the outer edge of the EEZ. Neumann, et al. (1972, 1977), encountered lithoherms at 600 to 700 m (1,988 to 2,310 ft.) in the northeastern Straits of Florida, along the base of the Little Bahama Banks; Wilber (1976), analyzed the petrology and environmental setting of some banks on the flank of the Little Bahama Bank.

Neumann, et al. (1977), in describing a lithoherm in the Straits of Florida, listed the ahermatypic branching corals, *Lophelia prolifera* and *Enallopsammia profunda*, as the chief contributors to structure and habitats. As noted by James (1977) and others, sponges and other invertebrates also add to bottom relief, species diversity, and total available habitat. Wilber (1976), emphasized the roles of corals, alcyonarians, sponges, and crinoids in baffling, binding, and trapping sediments to the lithoherm.

Deepwater banks may occur in a variety of shapes. Among the formations observed are rocky mounds 30 to 40 m (100 to 133 ft.) high and hundreds of meters long (Neumann et al., 1977); or individual mounds or "haystacks" (Hurley, Siegler and Fink, 1962). Because of accumulated sediments, seismic profiles are often necessary to unmask the true lithified interior of some lithoherms (Wilber, 1976).

Banks have been found to vary greatly in vertical and horizontal dimension. Depending upon age, rates of sedimentation and lithification, currents, and species composition, banks may show a topographical expression ranging from a few meters to as much as 144 m (475 ft), as quoted by Stetson, et al. (1962). These differences alter water flow over the structure and hence biotic zonation (Lang, 1979, personal communication). Within this category of coral assemblages, the word lithoherm is often confused with other terminology. The precise definition of lithoherm identifies banks accumulated by sustained chemical precipitation, i.e., lithification, that is thought to be facilitated by upward-moving, deep, cold water, as on the eastern side of the Straits of Florida.

3.2.1.1.1.4 Patch Reefs

Patch reefs are diverse coral communities typified by the presence of hermatypic (reef-building) and ahermatypic species. Patch reefs differ from consolidated outer bank reefs by their smaller size and lower scale of vertical relief.

These are usually distributed irregularly in clusters nearshore in warm waters like the Florida Keys, (Marszalek, et al., 1977). However, many coral assemblages occurring in the Keys, or north of Miami, are more appropriately called hard bottom communities.

In south Florida, patch reefs as defined herein, have been the subject of studies by Marszalek, et al. (1977) and Jones (1977), among others. More than 6,000 patch reefs occur in the Florida reef tract between Miami and the Marquesas Keys, (Marszalek, et al., 1977); most of those patches occur between Hawk Channel and the outer bank reefs, i.e., in a general strip 3 to 7 km (1.6 to 3.8 nm) offshore. Typically, patch reefs form on coralline rock or another suitable substrate such as coral rubble (Marszalek, et al., 1977).

Geologically, patch reefs tend to form in two patterns - dome and linear - although transitional shapes occur, (Marszalek, et al., 1977). Dome-type reefs are roughly circular to elliptical as viewed from above. Most reefs of this type exhibit well-developed sandy bottom halos around their fringes. Randall (1965), Ogden, Brown and Salesky (1973), and Jones (1977), identified sea grass grazing around coral assemblages by sea urchins [for example, *Diadema antillarum*), parrot fish (family Scaridae) and other biota] plus current scouring as possible causes of halo formation. From above, a trend toward clustering with limited territoriality is easily perceived, i.e., although the domes are grouped, some distance is maintained between individual patch reefs. Most dome patch reefs have less than 5 m (17 ft.) of topographic relief, but some as high as 9 m (30 ft.) do occur. Linear-type reefs are usually situated seaward of dome-type patch reefs parallel to the outer bank reefs. In top view, linear patch reefs appear arcuate to linear, much like the true outer coral reefs of the Florida reef tract. Hence, instead of forming clusters, these patch reefs often occur end-to-end.

The distribution of patch reefs, dome- and linear-type, is uniform in southern Florida waters. Due to the clustering of dome-type reefs, the relationship of the linear-type reefs to coral reefs, and numerous stresses (water temperature and sewage effluents, for example) are most abundant in the upper Keys (Table 9).

Table 9. Patch reef distribution in the Florida reef tract (Source: Marszalek, et al., 1977.)

Area		Approx. no. patch reefs
Fowey Rocks to Broad Creek (Key Largo)		3,975
Broad Creek to Tavernier Creek		1,590
Tavernier Creek to Big Pine Key		50
Big Pine Key to Marquesas Keys		420
	Total	6,035

Patch reefs also exhibit ecological variability. Dome-type assemblages support a diverse array of scleractinians and octocorals, plus numerous benthic invertebrates, algae, and fish (Marszalek, et al., 1977). Except for the noticeable absence of elkhorn coral, *Acropora palmata*, the biota of dome patches resembles that of consolidated outer bank reefs, but usually lacks coral zonation. At Biscayne National Park, however, dome patch reefs display biotic zonation believed related to relief and sedimentation, (Jaap, 1979, personal communication). Octocorals dominate the top interior zones whereas *M. annularis, Diploria spp*., and *Colpophyllia natans* dominate western margins: The dominant coral in this type of patch reef is the small star coral, *Montastraea annularis*, which is often present in single enormous colonies, (see also Shinn, 1963). Linear-type patch reefs support corals and other marine life much like dome-types with the frequent addition of *A. palmata*. When found on a linear patch reef, *A. palmata* colonies are usually smaller, more widely spaced, and oriented differently than when found on an outer bank coral reef (Marszalek, et al., 1977). Of the two types of patch reefs, the linear-type is probably the ecologic transition form between dome patch reefs and outer bank reefs (Marszalek, et al., 1977). One hypothesis classified patch reefs of both types according to their presumed developmental stages of youth, maturity, and senescence (Jones, 1977):

Youth (early development) -- Young patches consist primarily of pioneering scleractinian and alcyonarian species capable of attachment to the sediments. The young patches grow in size by outward expansion and by upward growth on living and dead pioneering corals. Corals in young assemblages on solid substrates are dominated by the star corals *Montastraea annularis* and *M. cavernosa*, and the starlet corals *Siderastrea siderea* and *S. radians*. On less stable bottoms, the brain coral *Diploria* (especially *D. labyrinthiformis*) and the moon coral *Colpophyllia natans*, are major patch forming species. Smaller colonies of *Porites* (*P. astreoides* and *P. porites*), *Favia fragum, Agaricia agaricites, Dichocoenia stokesii*, and Mussidae corals, may grow between coral heads. *Millepora* (*M. alcicornis* and *M. complanata*) aid in cementing the components into a patch reef.

Maturity -- Mature patch reefs are characterized by vertical relief of several meters and a diameter of 10 to 20 m (33 to 66 ft.). Generally, these patches extend upward to the level of lowest low water. Mature patches usually have a horizontal zonation pattern. *Montastraea annularis*, whose large boulders (3 m or 10 ft and more) are the chief contributors to patch structure, usually occur on the eastern and southeastern (windward and seaward) margins (*M. cavernosa* may also occur there); *Diploria* (brain coral) and *Colpophyllia* (moon coral) heads more than one meter in diameter occur on the leeward sides or in eddies; and *Siderastrea* (starlet coral) colonies less than one meter in diameter occupy the center and remaining margins (Jones, 1977). At Biscayne National Park, however, the largest buttresses occur on westward fringes (Jaap, 1979, personal communication).

Senescence -- When coral growth rates are exceeded by mortality in the massive reef-building species, senescence begins (Jones, 1977). This occasion is accentuated by simultaneous increases in growth of alcyonarians. During senescence, the scleractinians such as *Montastraea* and *Siderastrea* may survive due to size and silt resistance. Most of the patch, however, evolves into accretion piles of coral fragments overlain by a thin layer of loose sediment. At least during early senescence, other corals may survive by expanding mucous production (*Porites, Dichocoenia,* some Mussidae), vertical orientation or rapid growth (*Agaricia* and *Millepora*), or branching and vertical growth (*Porites porites*). Unless rejuvenated by new stocks, senescent reefs probably die.

3.2.1.1.1.5 Outer Bank Reefs

Outer bank reefs are restricted geographically to the Florida Keys. Geologically and ecologically, outer bank reefs represent perhaps the oldest, most structurally complex, and diverse type of coral assemblage. Although lithoherms, salt dome hard banks, and other environments that support coral may be older, these reefs are the height of ecological complexity for systems actually formed by corals and their associated organisms.

Outer bank reef distribution is worthy of further discussion. Southeast of the Florida Keys, on the upper shelf, lie the majority of coral reefs in the management area, occurring as a discontinuous arc between Fowey Rocks and the Dry Tortugas.

Florida Reef Tract -- The Florida reef tract is within easy access of the coastal population centers of Miami-Homestead and the entire Keys (Marszalek, et al., 1977). The Florida reefs (outer bank reefs) are a discontinuous arc of skeletons and sediments accumulating in situ.

Although reefs have their origin on sand or other suitable substrate (shells, rocks, fossil reefs, coral debris), their composition is predominantly coral, i.e., limestone or coral rock. Shinn, et al. (1977) and Shinn (1979), concluded that the linearity of these reefs approximately parallel to the Keys is due to underlying bedrock topography, rather than to biological or water quality causes.

The Florida reef tract includes approximately 96 km (52 nm) of outer bank reefs located between Fowey Rocks and the Dry Tortugas, a distance of about 270 km (146 nm) along the 20 m (66 ft.) isobath. A large portion of the reef tract is in the EEZ just beyond Florida's three-mile territorial sea.

As shown by Table 10, these coral reefs are distributed unevenly along that range; most of the reefs are found off the Key Largo area. Marszalek, et al. (1977), best described the reefs as "... typically elongate features of variable vertical relief which occur at the shallow shelf edge between the 5 m and 10 m (16 to 33 ft) depth contours. Their long axes form a discontinuous line of reefs oriented parallel to the shelf edge. The northernmost reefs trend N-S and the reefs near Key West E-W reflecting the change in orientation of the arcuate shelf edge." Most of the outer bank reefs have well-developed spur and groove formations on their seaward faces. Spurs are extensions of coral reef growth seaward up to 30 m (100 ft) or more; grooves occur between adjacent spurs. Spurs and grooves are best developed in the upper and lower Keys. The middle Keys area exhibits some spur and groove formation but the orientation and development is variable (Marszalek, et al., 1977). Shinn (1963), found that spur and groove development in Key Largo Dry Rocks, Florida, is a constructional rather than erosional feature. Shinn, et al. (1981) found that spurs at Looe Key were constructed of *Acropora palmata* and had formed over five meters of carbonate sand. Spurs at Looe Key are no longer accreting due to the extensive die-off of *A. palmata* a few thousand years ago. Robbin (1981) also documented the Keys wide die-off of *A. palmata* at Alligator Reef.

The deep reef at Looe Key is being smothered by migrating carbonate sand. Examination of air photos revealed that carbonate sand that originated to the east and northeast of Looe Key is moving in a westerly direction (Shinn, et al., 1981).

Table 10. Outer bank reef distribution in the Florida reef tract (Source: Marszalek, et al., 1977.)

Area	Outer Bank Reef (km)
Fowey Rocks to Broad Creek	22.2
Broad Creek to Tavernier Creek	34.3
Tavernier Creek to Big Pine Key	16.6
Big Pine Key to Marquesas Key	22.6
Total	95.8

Generally, Florida reefs are smaller in area, less biologically diverse, and lack the vertical relief of most coral reefs of the Bahamas or Caribbean Sea (Marszalek, et al., 1977). However, coral species diversity is still comparable to or greater than reefs bordering nearby countries. Like the patch reefs described above, outer bank reefs may be grouped according to their extent of development, i.e., underdeveloped and well developed (Marszalek, et al., 1977).

Underdeveloped -- Very common throughout the tract, occurring as coral reefs with sparse coral growth and no *Acropora palmata* zone. These reefs may represent relict limestone ridges in the spur and groove arrangement or relatively young reefs with immature biological zonation patterns. Long Reef in the upper Keys is an example of the relic reef case. (See, for example, Shinn, et al., 1977). Small stands of immature coral reef biota often bridge the gaps between more well-developed reefs.

Well-developed -- Marszalek, et al. (1977), characterized these coral reefs by their "reef-flat formed of in situ dead encrusted elkhorn coral, *Acropora palmata*, skeletons and rubble." Colonies of *Acropora*, finger coral *Porites*, and starlet coral *Siderastrea* plus encrusting fire coral *Millepora*, and dozens of benthic species form most of the live reef structure. The typical zonation pattern shows *A. palmata* colonies on the seaward face of the reef to a depth of about 4 m (13 ft.), with *M. complanata* and the colonial zooanthid *Palythoa* in the turbulent shallow zone and a diverse coral assemblage dominated by small star coral, *Montastraea annularis*, heads in the deeper sections (Shinn, 1963). Within the Florida reef tract, Carysfort Reef and Key Largo Dry Rocks (Grecian Rocks) are examples of well developed coral reefs.

3.2.1.1.2 Condition and Trends

Several important impacts on coral health are categorized and discussed below. Present knowledge is not sufficient to establish a definite scale of impact severity.

Many of the man-induced and natural stresses described below possess the capability of temporarily or permanently depressing coral health and stability. Some of the more common responses to stress include polyp retraction, altered physiological or behavioral patterns, and modified energy cycles; the latter may be difficult to observe or quantify but it is a significant component of overall coral health. Another phenomenon, the "shut-down reaction" (SDR), has been studied in the laboratory and observed on rare occasions in the field in stony corals (Antonius, 1977). The SDR appears to be elicited by exposure of sick or diseased corals to a naturally sublethal stress, e.g., predation by the polychaete *Hermodice carunculata*, and proceeds as a rapid disintegration of body tissues resulting in death. Some doubt exists whether the SDR is a real physiological process or a continuation of tissue lysis in the sick coral. Lastly, damaged corals (abraded from anchor chains, storm damaged, etc.) may provide a starting point for infection with the blue-green algae, *Oscillatoria submembranacea*, which can potentially kill entire specimens (Antonius, 1975, 1976).

Generally, these data imply that certain specific areas may be in poorer health than others. Furthermore, the data provide insight for detecting areas with the potential for declining health assuming present stresses continue. Potential problem areas include the upper Florida reef tract where sewage pollution and recreational stresses are escalating.

3.2.1.1.3 Coral Habitat Areas of Particular Concern

The definition and criteria for Coral Habitat Areas of Particular Concern (C-HAPC) are detailed in the Fishery Management Plan for Coral, Coral Reefs, and Live/Hard Bottom Habitat. Pursuant to the MSFCMA the Council is also specifying Essential Fish Habitat - Habitat Areas of Particular Concern (EFH-HAPC). Readers of this plan should understand that although the two designations are closely related, there are conceptual distinctions between the two. EFH-HAPCs are areas of special significance to the managed species (i.e., significant or critical areas, regions or habitats which serve as spawning, nursery, feeding, or refuge areas). C-HAPCs connotes a management concept designed to identify and focus regulatory and enforecment abilities on areas of special significance to the managed species. At the present only one Council designated C-HAPC exists in the South Atlantic region, the Oculina Bank HAPC, located off central eastern Florida. The remainder of this section focuses on the delineation and designation of C-HAPCs. Essential Fish Habitat -HAPCs are discussed and described in Section 3.3.7 of this plan.

As a vital first step in understanding and managing the coral resource, it is necessary to recognize that corals are not spread evenly over the management area. Rather, dense clusters of certain species concentrate at specific geographic locations to form reefs, hard bottoms, etc. Precise understanding of the geographic distribution of major coral habitats has been largely ignored, until recent mapping efforts. As these and other mapping projects are completed, expanded, and refined, they will become an important source of coral HAPC information.

For delimiting specific coral areas, HAPCs are taken only to include localities where large concentrations of adult (sedentary) corals are found. (The open water planktonic life style of larval forms precludes the isolation of specific geographic localities of larval concentration.) On a regional basis, these coral habitats comprise only a very small percentage of the geographical area of authority of South Atlantic Fishery Management Council. Since the focus here is only on coral habitats of particular concern, the area percentage is even smaller.

In order to focus only on coral habitats of particular concern, a set of criteria was developed in the Coral Fishery Management Plan (GMFMC and SAFMC 1982) (see Table 11). These criteria are general guideline statements intended to narrow the full complement of coral habitats down to those representing the most important coral concentrations in the management area.

Table 11. Criteria for identifying Coral Habitat Areas of Particular Concern.

1. Ecological

a. An area that contains an outstanding example of a coral community type found over a broad ocean area. (For example, a deepwater *Lophelia-Enallopsammia* bank, a shallow-water *Acropora* coral reef, patch reefs, etc.).

b. Areas known to possess rare species of coral.

c. Areas whose coral diversity contributes to a highly unusual or unique biologic relationship or ecologic condition.

2. Research

a. Areas with a substantial history of coral research and study. Such areas offer an opportunity to develop a long-term history of corals in their natural setting which should enhance the identification of trends in growth or response to stress - both vital information for coral managers.

b. Areas which display in an especially clear cut fashion, coral habitat features of particular research interest such as spur and groove formations or particular biotic zonation patterns.

3. Exploitation

a. Areas where high concentrations of economically valuable corals subject to harvesting can be found. This might include prime banks of black or pink precious corals, or areas where *Plexaura homomalla* can be abundantly found. These resource areas can then be managed as development areas under optimum yield objectives.

b. Areas where specific man-made development plans, use, or pollution impacts have inflicted, or threaten to inflict, environmental damage including reduced coral species diversity, abundance or health.

4. Recreation

a. Areas that are documented as locations frequented on a regular basis by recreational divers, sports fishermen, or glass bottom boat sightseers.

b. Areas that offer a high but underutilized recreational resource because of their outstanding aesthetic qualities and proximity to population centers or boat access points.

At a minimum, any coral area chosen as an HAPC must meet one or more of the specific criteria presented in Table 11. In addition to these criteria, an effort should be made to ensure inclusion of areas that represent all coral community types found in the management area. Consideration of a geographic factor will provide for a regional system of HAPCs in which the full diversity of important coral habitat sites is included. Particular attention should be given to major coral habitat areas. Foremost of these broad areas is the extensive Florida reef tract which stretches along the Florida Keys. Other such habitat areas include hard bottom communities scattered off North Carolina and South Carolina.

All habitat areas should be mapped on a scale suitable to show the particular resources and associated habitats. A set of geographic coordinates and boundaries should accompany the map to clarify the precise area.

The coral habitat areas described below (Table 12) have been determined to satisfy the criteria and include the important element of geographic distribution. The Council will address, with review by their Scientific and Statistical Committees, nominations for HAPCs periodically and take action as they deem necessary, including public hearings and any other fishery management plan amendment processes.

Table 12. Habitats Meeting Coral HAPC Criteria.

Coral Habitats Meeting Coral HAPC Criteria	Criteria (see Table 11)
Gray's Reef (designated National Marine Sanctuary)	l.c. 2.b, 4.a, and 4.b.
Oculina Bank	1.a, 1.b, l.c. 2.a, 2.b, 3.a, 3.b, 4.a, and 4.b.
Biscayne National Park	1.a, 2.a, 3.b, and 4.a.
Florida Keys National Marine Sanctuary	
Looe Key (incorporated into FKNMS)	1.a, 1.b, 2.b, 3.b, and 4.b.
Key Largo Coral Reef (incorporated into FKNMS)	1.a, 2.a, 2.b, 3.b, and 4.a.

3.2.1.1.3.1 Gray's Reef National Marine Sanctuary

Grays Reef National Marine Sanctuary (GRNMS) is located 17.5 nautical miles east of Sapelo Island, Georgia, and 35 nautical miles northeast of Brunswick, Georgia. Gray's Reef encompasses nearly 32 km^2 at a depth of about 22 meters (Parker et al. 1994). Gray's Reef, has been recognized by the Department of Commerce (OCZM) as an outstanding example of northern live bottom habitat by its designation as a National Marine Sanctuary. Although referred to as a "reef," the 20 m (65 ft) deep area is actually a live bottom composed of a series of rocky ridges running in a southwest-northeast direction and covering an area of about 57 km2 (16.68 n m2). The Sanctuary contains extensive, but patchy hardbottoms of moderate relief (up to 2 meters). Rock outcrops, in the form of ledges, are often separated by wide expanses of sand, and are subject to weathering, shifting sediments, and slumping, which create a complex habitat including caves, burrows, troughs, and overhangs (Hunt 1974). Parker et al. (1994) described the habitat preference of 66 species of reef fish distributed over five different habitat types. Numbers of species and fish densities were highest on the ledge habitat, intermediate on live bottom, and lowest over sand.

Among the benthos at the site are scattered heads of stony corals and a variety of soft corals. The site is visited by scientists, SCUBA divers and commercial and sport fishermen, and is better known. The most authoritative description of the live bottom was prepared by Hunt (1974) on the geology and origin of the area. The Georgia Department of Natural Resources, largely based on information presented by Hunt, nominated the area as a national marine sanctuary (Neuhauser, 1979), and it was designated as such in 1981.

In the 57 km^2 (16.68 nm^2) area bottom alteration activities, trawling and dredging, fish traps, and collection of marine plants, invertebrates, tropical fish, and historic or cultural resources are to be controlled by permits. The status quo activities of anchoring and spearfishing are to be monitored for future consideration. Other fishing activities are to be regulated under plans developed by the South Atlantic Fishery Management Council.

3.2.1.1.3.2 Oculina Bank Habitat Area of Particular Concern

The Oculina Bank Habitat Area of Particular Concern (HAPC) (Figure 6) was established in 1984 by the SAFMC in order to protect a limited area containing *Oculina varicosa* (ivory tree coral, a branching scleractinian coral) reefs. These reefs occur off Ft. Pierce in eastern central Florida. The banks consist of delicately branched *Oculina* coral, growing in spherical, branching, thicket-like colonies stretching several hundred m in length and attaining heights of 0.3-5 meter, covering limestone pinnacles of up to 25 meter-high relief (Reed 1980). In deep water, *Oculina* coral grows slowly, at a rate of less than one-half inch per year. The HAPC is 92 square miles in area and is bounded by longitudes 79°53'W and 80°00'W on the east and west, respectively, and on the north and south by latitudes 27°53'N and 27°30'N. The depth range throughout the HAPC is 70-100 meters.

In shallow water, *O. varicosa* forms small discrete colonies (< 0.5 m) that possess the symbiotic zooxanthellae which aid in coral growth. Paradoxically, in deeper water (> 50 m), the coral forms its massive branching thickets with an extensive calcium carbonate framework while lacking the important symbiont. While *O. varicosa* has been found in water as deep as 128 m (off Cape Lookout, North Carolina) and as far north as Cape Hatteras, North Carolina, the majority of the thickest growth occurs off the east coast of Florida, from Cape Canaveral to Ft. Pierce, in the area of the HAPC.

The diversity of the deepwater ecosystem associated with the Oculina Bank HAPC has been compared to tropical reefs. The strong currents found in this area are thought to contribute to the growth of the coral, trapping fine sand, mud and coral debris and forming the basis of the highly diverse resident invertebrate community, which includes mollusks, crustaceans, echinoderms and amphipods. This dense concentration of invertebrates serves as food for large populations of fishes, including spawning aggregations of gag and scamp (Gilmore and Jones 1992), snowy grouper (juvenile phase), speckled hind, red grouper, warsaw grouper, red porgy, red snapper, and greater amberjack.

The 1984 designation of the Oculina Bank as an HAPC closed the area to mobile fishing gears such as trawls and dredges. The slow growth rate of *Oculina* in deep water as wall as the extremely fragile nature of the coral ensures that contact with fishing gears is extremely destructive to the thickets. The strong currents that are so important in the reef-forming dynamics in the area also ensured that anglers fishing in the area used heavy weights to send their baits to the bottom, causing much damage to the delicate thickets of coral. In 1994, the HAPC was also declared to be the Experimental Oculina Research Reserve (EORR) and was closed to all bottom fishing for a period of 10 years. In 1995 this closure was extended to include all anchoring within the boundaries of the Reserve.

The area encompassed by the EORR was fished extensively by commercial fishermen for calico scallops and rock shrimp as far back as the 1960s. Some fishermen continued to exploit the area with trawls until 1994 (Gregg Waugh, SAFMC, pers. comm.). Reed (1980) described *Oculina* rubble throughout the area. Manned submersible dives in March 1995 found extensive *Oculina* habitat damage throughout the EORR, and only one site, Jeff's Reef, was found where *Oculina* occurred in dense branching thickets. Jeff's Reef comprises a very small portion of the overall reserve area.

The fish community associated with the *Oculina* habitat appears to be greatly reduced after a 15 year period of intensive fishing in the area of the reserve (1980-1994) (Harbor Branch Oceanogr. Inst., unpubl. data). Gilmore and Jones (1992) found spawning aggregations of gag and scamp from 1977-1982. The scamp aggregations were extensive, numbering more than 100 individuals at times. The 1995 submersible dives found no gag aggregations, and those of scamp were reduced to less than 10 individuals (Koenig et al, unpubl.data). In addition, species such as snowy grouper, warsaw grouper, speckled hind, black seabass, red porgy, greater amberjack, little tunny, and blackfin snapper were absent or greatly reduced over levels of the early 1980s. It is thought that decreases in abundance of these important species as well as disappearance of spawning aggregations of gag and scamp are due to both overfishing and extensive habitat destruction.

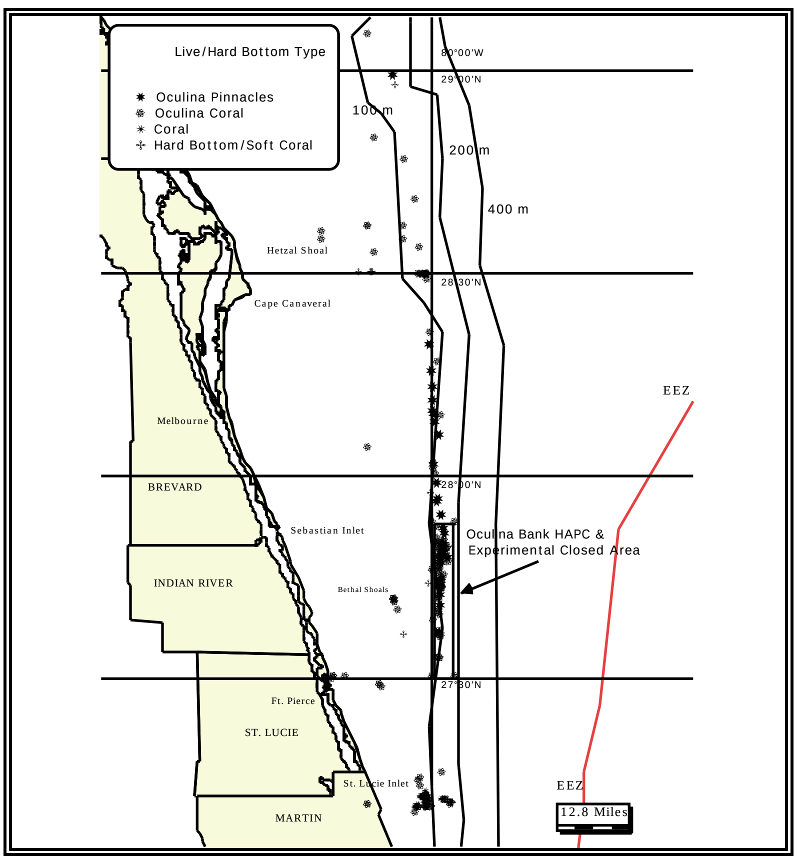


Figure 6. Map of coral (*Oculina varicosa*), coral reef and live/hard bottom habitat distributed along the south Atlantic shelf off the central east coast of Florida (Source: SAFMC 1995).

3.2.1.1.3.3 Biscayne National Park

Biscayne National Park is another HAPC that has been protected at least in part because of the coral resources found on its numerous patch and outer bank reefs. These coral communities are located closer to the Dade County urban areas than Key Largo Coral reefs. The Park is exposed to considerable recreational activity; divers tend to concentrate at four buoyed reefs. This HAPC would include only that portion of the Park located outside state waters.

Coral reef assemblages in this HAPC closely resemble those described for Key Largo; typical zonation patterns exist. Species composition has been studied by Jaap (1979), and Jaap (in preparation). On-going research efforts are described in Biscayne National Park (1978a, b). Most importantly, the Park represents the only sector of the management area and perhaps the world, where all of the data necessary for calculating MSY has been collected.

There are currently no special regulations for the Park. General regulations in Title 36 of the Code of Federal Regulations apply to all units of the national park system. Title 36 includes Part 2 on public use and recreation, Part 3 concerning boating and vessel permits, Part 5 on commercial and private operations, and Part 7 on special regulations.

3.2.1.1.3.4 Florida Reef Tract

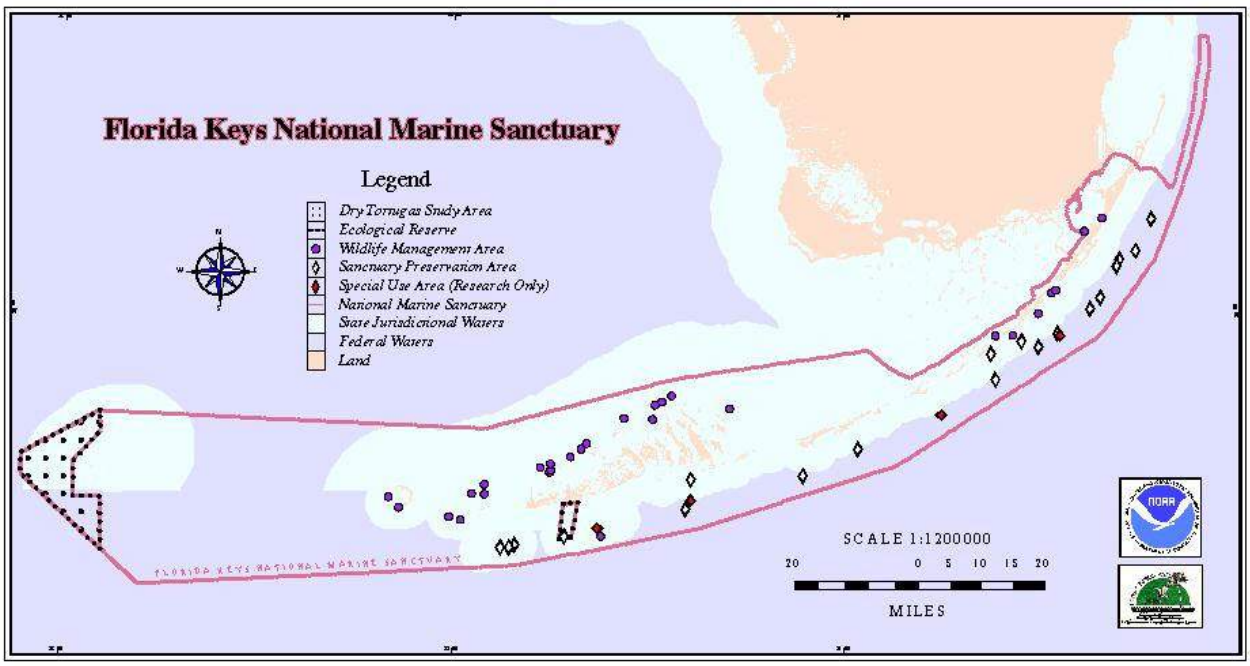
The Florida reef tract contains the continental United States' most extensive coral habitat. Composed of a chain of individual reefs, the tract stretches in a curve of some 370 km (200 nm) from Miami to the Dry Tortugas (DiSalvo and Odum, 1974). The tract is bounded on the shoreward side by the Florida Keys and on the seaward side by the Florida Straits. Its width is about 6.5 km (4 nm) with the seaward edge following the 18 m (60 ft) bathymetric contour. Although Shinn (1963) reports that the tract's flourishing reefs are largely limited to the northern half of the tract particularly off Key Largo, other prospering reefs also exist further south.

For purposes of identifying coral habitats of particular concern along the Florida reef tract, a two areas have been selected: many separate reefs near Key Largo have been selected in the northern reef portion; Looe Key off Big Pine Key is identified from the middle portion. Other tract reefs which were considered, but were not included at this time, are Sand Key off Key West and the Sambo reefs off Boca Chica Key.

The Florida reef tract is exposed to a variety of both natural and man-made threats. Land based pollutants such as sediment, sewage, and various chemicals may be damaging certain reefs. However, the significance and even cause-effect relationships have yet to be clearly established. Perhaps the most significant threat is from recreational use, which exposes the reefs to direct damage by souvenir and specimen collectors and anchor damage.

3.2.1.1.3.5 Florida Keys National Marine Sanctuary

The Florida Keys National Marine Sanctuary (FKNMS) Act (Public Law 101-605, 16 November, 1990) designated 2,800 nm2 (9,500 km^2) as a National Marine Sanctuary encompassing the waters of the State of Florida and the United States (U.S. Dept. of Commerce, 1996). The FKNMS includes the former Key Largo and Looe Key National Marine Sanctuaries. The FKNMS surrounds, but does not include Biscayne and Dry Tortugas National Parks and John Pennekamp Coral Reef State Park. The boundaries of the park extend from seaward of BNP to the beyond the Tortugas Banks, a distance of approximately 220 miles. The offshore boundary corresponds with the 300 ft (91 m) isobath and the inshore boundary follows boundaries of Everglades National Park or the shoreline of the keys. The FKNMS was created to protect highly valued marine biological resources (boundary map shown below). The FKNMS management and coordination is cooperative effort of the Florida Department of Environmental Protection and the National Oceanic Atmospheric Administration. The Governor and Cabinet of the State of Florida and the Secretary of the Department of Commerce approved the FKNMS management plan in 1997. The management plan was developed through a complex process including considerable efforts to include public input. The plan covers boating, fishing, land use, recreation, water quality, zoning, research and monitoring, and education. Action plans are included for each element in the management plan and are phased in over a three-year period, dependent on funding. The most innovative management strategy is the zoning of a marine area for use and conservation. The zoning method was adopted from the Australian Great Barrier Reef Park Authority based on zoning for the Great Barrier Reef.



(Source: http://wave.nos.noaa.gov/nmsp/fknms/)

For coral reefs, the zoning has designated 18 reef areas (30.8 km^2) as Preservation Areas. This zoning is supposed to protect shallow reefs from user resource damages and replenish populations of invertebrates and fish. The zoning designates one area around Western Sambo (30.8 km^2) as an Ecological Reserve (this zone is larger and has more restrictions than in the Preservation Zone). The goal of this zone is to replenish species populations by providing large protected nursery and resident refuge areas. One area has yet to be defined; the proposed replenishment area is a portion of Dry Tortugas. Four restricted Special Use Zones are designated for research only: Conch, Tenneessee, Looe Key, and Pelican Shoal (total area of 1.8 km^2).

The U.S. Environmental Protection Agency was designated in the enactment legislation to conduct an evaluation of the water quality in the FKNMS (this program is designated as the Florida Keys National Marine Sanctuary Water Quality Protection Program). The EPA has reviewed literature, funded monitoring and research to determine the status and trends of water quality and important biotic communities in FKNMS. The monitoring includes water chemistry, sea grasses, and coral reefs and hardbottom communities. The EPA WQPP has also put an emphasis on corrective actions for ground water contamination by onsite sewage disposal systems, cesspits, package plants, surface discharging municipal wastewater treatment plants, and live-aboard vessels (U.S. EPA, 1996).

The goal of the coral reef and hardbottom monitoring project is to develop status and trends of stony coral percent cover and taxonomic diversity of stony coral fauna at 40 sites: 8 hardbottom- nearshore, 9 patch reef, 12 offshore shallow, and 11 offshore deep sites. Sites are distributed between upper Key Largo to west of Key West. Each site is sampled annually. There are four stations at each site. Sampling for coral cover is based on video transects and point counting selected images (N 60 images for each transect, there are 12 transects at a site). Taxonomic diversity (number of different species and/or species complexes found at a station) is determined by a qualitative-timed inventory of each station (44 m2). The information baseline began in 1996. The species inventory data documents that the hardbottom sites and the offshore shallow reef sites had the fewest number of coral species and the patch reef and offshore deep sites have the greatest number of species. Between 1996 and 1997 the number of species observed at an individual site remained relatively similar with the exception of a few sites. The species that occurred in 1996 but not 1997 were typically small and rare species. Video data is still being processed and evaluated.

For additional information on the Santuary refer to the FKNMS internet site (http://wave.nos.noaa.gov/nmsp/fknms/).

3.2.1.1.3.6 Key Largo Coral Reefs (Formerly Key Largo National Marine Sanctuary)

This HAPC has already been recognized by the Department of Commerce (OCZM) as an outstanding example of the patch and outer bank coral reefs found in the Florida reef tract. National recognition and incorporation into the Florida Keys National Marine Sanctuary has intensified public use of the area; resource collection pressures are low but user impacts, such as diver contact injury and recreational boat anchoring, continue. Many of the more prominent reefs are mapped. Sanctuary regulations allow hook and line fishing but prohibit spearfishing and the taking of tropical reef fishes.

The coral reefs within this area comprise the approximate northern limit of reef growth along the mainland coast of the Western Hemisphere. The zonation pattern of the reef structures for the northern Florida reef tract as described by Shinn (1963 and 1979) includes five zones; a back reef, a reef flat, an *Acropora* zone, a *Millepora* zone, and a rubble zone. The coral species composition of reefs off Key Largo are described by the Office of Coastal Zone Management (1979b). Several of the reefs within the area exhibit the spur and groove formation described by Shinn (1963) at the Dry Rocks Reef.

The northern tract reefs have a long history of scientific research. Much of the relevant research has been reviewed by the Office of Coastal Zone Management (1979b). A continuation of this research history is evident in the coral reef resource survey being coordinated by the Office of Coastal Zone Management (1979c) for the then proposed National Marine Sanctuary and an environmental assessment and biological inventory organized jointly by OCZM and the Florida Department of Natural Resources.

3.2.1.1.3.7 Looe Key Reef (Formerly the Looe Key National Marine Sanctuary)

Looe Key HAPC has been recognized by the Department of Commerce (OCZM) as an outstanding example of a submerged coral reef in the lower Florida reef tract. The reef is located 12.4 km (6.7 nm) southwest of Big Pine Key, Florida. From an ecological and topographic point of view, five major zones were described by Antonius, et al. (1978): 1) a patch reef area; 2) a reef flat; 3) a forereef; 4) a deep reef seaward of the forereef; and 5) a deep ridge still further seaward. Each of these zones contains a representative coral species assemblage. Of particular significance, the forereef zone contains a spectacular spur and groove system that is among the best examples in the entire Florida reef tract (Antonius, et al., 1978). The following activities are prohibited: taking or damage to sanctuary resources, including tropical fish and corals; spearfishing; using wire fish traps, poisons, or electric charges; littering; and lobster trapping within the forereef area.

The reef is a diving attraction rapidly growing in popularity with both local residents and tourists (Barada, 1979). Concurrently, it is subject to growing pressure from souvenir hunters and anchor damage (Antonius, et al., 1978). The reef is also used regularly for teaching and recreational purposes by the Newfound Harbor Marine Institute facility on Big Pine Key. The reef was nominated for consideration as a marine sanctuary (see Section 6.4) in November 1975 by the Florida Keys Citizens Coalition and was subsequently designated as such in 1981, and recently incorporated into the FKNMS.

3.2.1.2 Live/Hard Bottom Habitat

Due to substantial biological, climatic, and geological differences between the temperate and tropical componenets of the managed area, the following summary is geographically segregated into two sections: a) Cape Hatteras to Cape Canaveral; and b) Cape Canaveral to the Dry Tortugas. Broadly, these regions represent temperate, wide-shelf systems and tropical, narrow-shelf systems, respectively. The zoogeographic break between these regions typically occurs between Cape Canaveral and Jupiter Inlet (approximately 230 km to the south). Distributions and areal amounts of hard bottom from the Florida/Georgia border to Jupiter Inlet (encompassing portions of both of the regions collated below) have been estimated from the comprehensive GIS assembly of almost all available data records (Perkins et al., 1997).

3.2.1.2.1 Cape Hatteras to Cape Canaveral

Major fisheries habitats on the Continental Shelf along the southeastern United States from Cape Hatteras to Cape Canaveral (South Atlantic Bight) can be stratified into five general categories: coastal, open shelf, live/hard bottom, shelf edge, and lower shelf (Figure 7) based on type of bottom and water temperature. Each of these habitats harbors a distinct association of demersal fishes (Struhsaker 1969) and invertebrates. Most of the bight substrate is covered by a vast plain of sand and mud (Newton et al. 1971) underlaid at depths of less than a meter by carbonate sandstone (Riggs et al. 1996, Riggs et al. 1998). The productivity of this sand- and mud-covered plain is low. Scattered irregularly over the shelf, however, are zones of highly concentrated invertebrate and algal growth, usually in association with marked deviations in relief that support substantial fish assemblages (Huntsman and Mcintyre 1971, Struhsaker 1969). Commonly called "live bottom" areas, they are usually found near outcropping shelves of sedimentary rock in the zone from 15 to 35 fathoms. Live bottom is especially evident at the shelf break, a zone from about 35 to 100 fathoms where the Continental Shelf adjoins the deep ocean basin and is often characterized by steep cliffs and ledges (Huntsman and Manooch 1978). The live bottom areas constitute essential habitat for warm-temperate and tropical species of snappers, groupers, and associated fishes. Exploratory fishing for reef fishes has yielded 113 species representing 43 families of predominately tropical and subtropical fishes off the coasts of North Carolina and South Carolina (Grimes et al. 1982; Table 13). Recently, Parker and Dixon (in press) identified 119 species of reef fish representing 46 families during underwater surveys

44 km off Beaufort, North Carolina (Table 14). Twenty-nine tropical fishes and a basket sponge were new to the study area.Distinct faunal assemblages were associated with two habitats: live/hard bottom on the open shelf; and at the shelf edge. A study of South Atlantic Bight reef fish communities by Chester et al. (1984) confirmed that specific reef fish communities could be identified based on the type of habitat. Bottom topography and bottom water temperatures are the two most important factors which create habitats suitable for warm-temperate and tropical species.

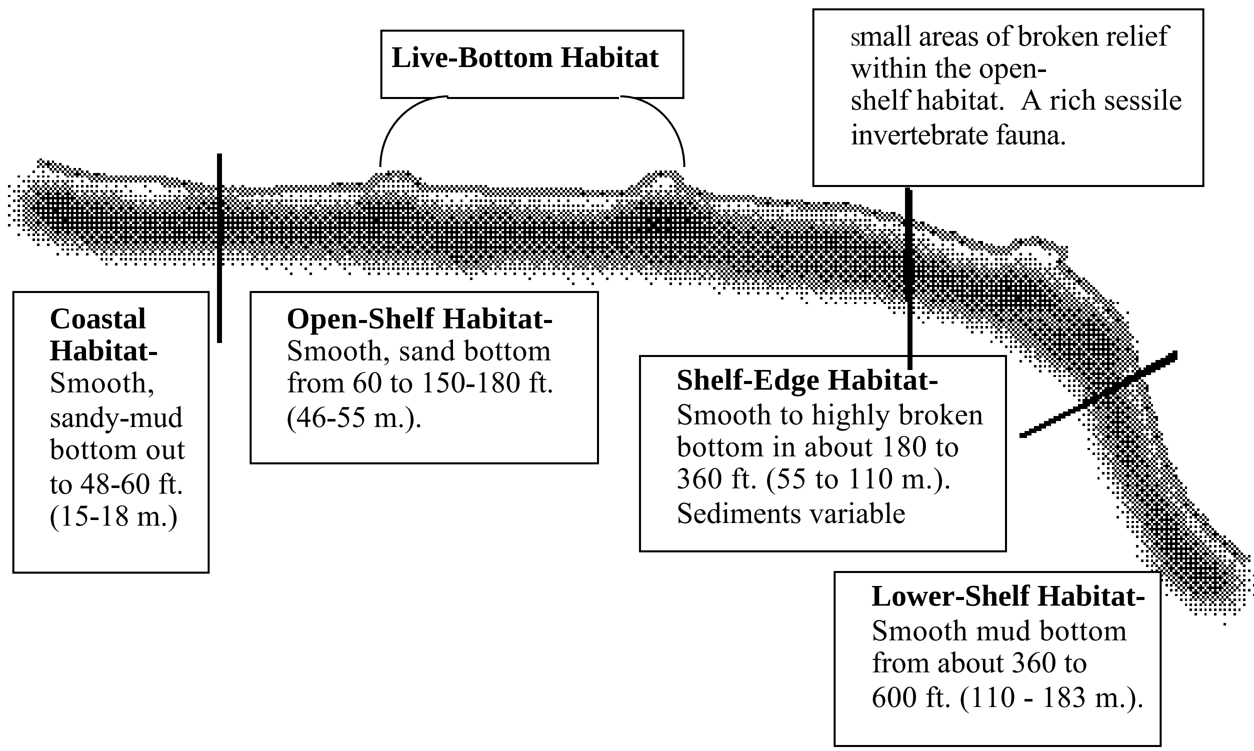


Figure 7. The five major types of habitat on the Continental Shelf off the Southeastern United States North of Cape Canaveral (Source: Struhsaker, 1969).

Table 13. List of fishes occurring at reef and rock outcropping habitats on the outer continental shelf of North Carolina and South Carolina (Source: Grimes et al. 1982).

Family, Genus and Species	Common Name	Collection	Habitat Type
Carcharhinidae			
Carcharhinus falciformis	Silky shark	HL	SE, ILB
Sphyrnidae			
Sphyrna lewini	Scalloped hammerhead	GN	SE
Rhinobatidae			
Rhinobatos lentiginosus	Atlantic guitarfish	TWL	SE
Rajidae			
Raja sp.	Skate	TWL	SE
Dasyatidae			
Dasyatis sp.	Stingray	TWL	SE
Muraenidae			
Gymnothorax nigromarginatus	Blackedge moray	HL	SE, ILB
Muraena retifera	Reticulate moray	HL	SE
Congridae			
Conger oceanicus	Conger eel	HL,T	SE
Paraconger caudilimbatus	Margintail conger	HL	SE
Ophichthidae			
Ophichthus ocellatus	Palespotted eel	HL,SC	SE, ILB
Engraulidae			
Anchoa sp.	Anchovy	SC	ILB
Synodontidae			
Synodus foetens	Inshore lizardfish	HL	ILB
S. synodus	Red lizardefish	TWL	SE
Trachinocephalus myops	Snakefish	HL, TWL	SE,ILB
Batrachoididae			
Opsanus pardus	Leopard toadfish	T	ILB
Antennaridae			
Antennarius ocellatus	Ocellated frogfish	T	ILB
Ogcocephalidae			
Halieutichthys aculeatus	Pancake batfish	TWL	SE
Ogcocephalus sp.	Batfish	TWL, SC	SE
Gadidae			
Urophycis earlii	Carolina hake	HL	ILB
Ophidiidae			
Rissola marginata	Striped cusk-eel	SC, TWL	ILB
Holocentridae			
Holocentrus ascensionis	Squirrelfish	HL	SE
H. Rufus	Longspine squirrelfish	HL	SE
Fistulariidae			
Fistularia villosa	Red cornetfish	HL	SE
Sygnathidae			
Hippocampus erectus	Lined seahorse	SC	SE, ILB
Sygnathus sp.	Pipefish	SC	SE, ILB

Table 13(cont.). List of fishes occurring at reef and rock outcropping habitats on the outer continental shelf of North Carolina and South Carolina.

Family, Genus and Species	Common Name	Collection	Habitat Type
Serranidae			
Centropristis ocyurus	Bank seabass	HL, TWL	ILB
C. Striata	Black seabass	HL, T ,SC	ILB
Dermatolepis inermis	Marbled grouper	HL	ILB
Diplectrum formosum	Sand perch	HL, SC, TWL	ILB
Epinephelus adscensionis	Rock hind	HL	ILB
E. drummondhayi	Speckled hind	HL	SE, ILB
E.flavolimbatus	Yellowedge grouper	HL	SE
E.fulva	Coney	HL	ILB
E. guttatus	Red hind	HL	ILB
E. morio	Red grouper	HL	SE
E.mystacinus	Misty grouper	HL	SE
E. nigritus	Warsaw grouper	HL	SE
E.niveatus	Snowy grouper	HL	SE
Mycteroperca microlepis	Gag	HL	SE, ILB
M. phenax	Scamp	HL	SE, ILB
M. venenosa	Yellowfin grouper	HL	ILB
Ocyanthias martinicensis	Roughtongue bass	TWL	SE
Petrometopon cruenatatum	Graysby	HL	ILB
Paranthias furcifer	Creolefish	HL	SE
Serranus phoebe	Tattler	AC	SE
Grammistidae			
Rypticus saponaceous	Greater soapfish	T	ILB
Priacanthidae			
Pristigenys alta	Short bigeye	TWL	ILB
Priacanthus creuntatus	Glasseye snapper	TRP	ILB
Apogonidae			
Apogon pseudomaculatus	Twospot cardinalfish	TWL	ILB
Branchiostegidae			
Caulolatilus microps	Gray tilefish	HL	SE
C. chrysops	Atlantic golden-eye tilefish	HL	SE
Malacanthidae			
Malacanthus plumieri	Sand tilefish	HL	SE
Rachycentridae			
Rachycentron canadum	Cobia	HL	SE
Carangidae			
Alectis crinitus	African pompano	T	ILB
Caranx ruber	Bar jack	D	ILB
Decapterus punctatus	Round scad	SC, TWL	ILB
Seriola dumerili	Greater amberjack	HL	SE,ILB
S. rivoliana	Almaco jack	HL	SE,ILB

Table 13(cont.). List of fishes occurring at reef and rock outcropping habitats on the outer continental shelf of North Carolina and South Carolina.

Family, Genus and Species	Common Name	Collection	Habitat Type
Ephippidae			
Chaetodipterus faber	Atlantic spadefish	D	ILB
Lutjanidae			
Lutjanus cyanopterus	Cubera snapper	HL	SE
L. buccanella	Blackfin snapper	HL	SE
L. campechanus	Red snapper	HL	SE.ILB
L. synagris	Lane snapper	TWL	ILB
L. vivanus	Silk snapper	HL	SE
Ocyurus chrysurus	Yellowtail snapper	HL	ILB
Rhomboplites aurorubens	Vermilion snapper	HL	SE, ILB
Pomadasydae			
Haemulon aurolineatum	Tomate	SC, HL, TWL	SE, ILB
H. melanurum	Cottonwick grunt	HL	ILB
H. plumieri	White grunt	HL, TWL	ILB
Balistidae			
Aluterus schoepfi	Orange filefish	SC	ILB
Balistes capriscus	Gray triggerfish	HL	SE, ILB
B. vetula	Fringed filefish	TWL	ILB
M. hispidus	Planehead filefish	TWL	ILB
Tetraodontidae			
Sphoeroides dorsalis	++ Marbled puffer	TWL	ILB
S. spengleri	++ Bandtail puffer		

*HL=hook and line, T=trap, TWL= trawl, GN= gill net, SC=stomach contents D=observed by d
*SE= shelf edge, and ILB=inshore live bottom.
++ indicates species not recorded by Strahsaker (1969).
§ indicates species only recorded for southern Onslow Bay and Long Bay.
indicates species not listed by Miller and Richards(1980).

The temperature regimes of the offshore shelf habitats mentioned above are strongly influenced by the Gulf Stream. The Gulf Stream plays an important role in global-scale heat, momentum, and mass flux, as well as circulation patterns throughout its length. Physical, chemical, and biological processes are influenced by the presence of the Gulf Stream. It flows generally northeastward and, with its associated pressure gradient, is responsible for transporting water along the seaward flank of the Sea Slope gyre. The conditions and flow of the Gulf Stream are highly variable on time scales ranging from two days to entire seasons. At all times, the Gulf Stream flows toward the northeast with a mean speed of 1 m/s (2 kt). The location of the Gulf Stream's western boundary is variable because of meanders, attributable to atmospheric conditions, bottom topography, and eddies. These boundary features move to the south-southwest, and transport momentum, mass, heat, and nutrients to the vicinity of the shelf break.

Table 14. Number of dives during which fishes and sponges were observed from October 1975 through March 1980[1,2] and April 1990 through August 1993[1] (of a total of 48 and 31 dives, respectively) on the "210 Rock" off Beaufort, North Carolina (Parker and Dixon (in press)).

Species	**1975-1980**	**%**	**1990-1993**	**%**
Rhincodontidae				
Ginglyostoma cirratum, nurse shark[3]	2	4.2		
Odontaspididae				
Odontaspis taurus, sand tiger			1	2.1
Carcharhinidae				
Carcharhinus leucas, bull shark			1	2.1
C. obscurus, dusky shark			1	3.2
Galeocerdo cuvier, tiger shark			1	2.1
Rhizoprionodon terraenovae, Atlantic sharpnose shark	5	10.4		
Sphyrnidae				
Sphyrna sp., hammerhead			1	2.1
Dasyatidae				
Dasyatis sp., stingray	3	6.3	2	6.5
Muraenidae				
Gymnothorax moringa, spotted moray (S)	5	10.4	5	16.1
G. saxicola, blackedge moray (S)			1	2.1
Muraena retifera, reticulate moray (S)			3	6.3
Ophichthidae				
Myrichthys breviceps, sharptail eel (S)			4	12.9
Congriidae				
Conger sp. or *Paraconger caudilimbatus*, conger (S)	3	6.3		
Clupeidae				
Sardinella aurita, Spanish sardine			2	4.2
Synodontidae				
Synodus foetens, inshore lizardfish (S)			6	19.4
Gadidae				
Urophycis earlli, Carolina hake (S)	9	18.8	2	6.5
Batrachoididae				
Opsanus sp., toadfish[4] (S)			1	3.2
Lophiidae				
Lophius americanus, goosefish (N)			1	2.1
Holocentridae				
Holocentrus ascensionis, longjaw squirrelfish (S)			10	32.3
Aulostomidae				
Aulostomus maculatus, trumpetfish (S)			7	22.6
Fistulariidae				
Fistularia petimba, red cornetfish (S)			2	6.5
Scorpaenidae				
Scorpaena dispar, hunchback scorpionfish (S)	1	2.1		
Serranidae				
**Centropristis striata,* black sea bass (N)	44	91.7	21	67.7
**C. ocyurus,* bank sea bass (S)	44	91.7	30	96.8
Diplectrum formosum, sand perch (S)	1	2.1	6	19.4

Table 14.(cont.) Number of dives during which fishes and sponges were observed on the "210 Rock" off Beaufort, North Carolina.

Species	1975-1980	%	1990-1993	%
**Epinephelus morio*, red grouper (S)	3	6.3	10	32.3
**E. adscensionis*, rock hind (S)			13	41.9
**E. guttatus*, red hind (S)	2	6.5		
**E. cruentatus*, graysby (S)			5	16.1
Hypoplectrus unicolor, butter hamlet (S)			20	64.5
Liopropoma eukrines, wrasse bass (S)	9	18.8	20	64.5
**Mycteroperca microlepis*, gag (S)	48	100.0	30	96.8
**M. phenax*, scamp (S)	20	41.7	30	96.8
**M. interstitialis*, yellowmouth grouper (S)			8	25.8
Rypticus maculatus, whitespotted soapfish (S)	29	60.4	21	67.7
Serranus subligarius, belted sandfish (S)	41	85.4	23	74.2
S. tigrinus, harlequin bass (S)	3	6.3	17	54.8
S. phoebe, tattler (S)	3	9.7		
Priacanthidae				
Priacanthus arenatus, bigeye (S)			18	58.1
P. cruentatus, glasseye snapper (S)			3	9.7
Apogonidae				
Apogon pseudomaculatus, twospot cardinalfish (S)	4	50.0	15	48.4
Rachycentridae				
Rachycentron canadum, cobia			2	6.5
Echeneidae				
Remora remora, remora			1	3.2
Carangidae				
Caranx crysos, blue runner			4	8.3
C. ruber, bar jack	2	4.2	11	35.5
C. bartholomaei, yellow jack			5	16.1
Decapterus punctatus, round scad	26	54.2	5	16.1
**Seriola dumerili*, greater amberjack	41	85.4	28	90.3
**S. rivoliana*, almaco jack	7	14.6	11	35.5
S. zonata, banded rudderfish			4	12.9
Coryphaenidae				
Coryphaena hippurus, dolphin			2	6.5
Lutjanidae				
**Lutjanus campechanus*, red snapper (S)	17	35.4	1	3.2
**L. apodus*, schoolmaster (S)			2	6.5
**Rhomboplites aurorubens,* vermilion snapper (S)			7	14.6
Gerreidae (mojarra)			1	3.2
Haemulidae				
**Haemulon plumieri,* white grunt (S)	45	93.8	30	96.8
**H. aurolineatum,* tomtate (S)	31	64.6	26	83.9
Sparidae				
**Archosargus probatocephalus*, sheepshead (N)			2	4.2
**Calamus leucosteus,* whitebone porgy (S)	25	52.1	18	58.1
**C. nodosus,* knobbed porgy (S)	12	25.0	30	96.8
**Diplodus holbrooki,* spottail pinfish (S)	34	70.8	14	45.2
**Pagrus pagrus,* red porgy (S)	29	60.4	14	45.2
Stenotomus caprinus, longspine porgy (S)			8	16.7

Table 14.(cont.) Number of dives during which fishes and sponges were observed on the "210 Rock" off Beaufort, North Carolina.

Species	**1975-1980**	**%**	**1990-1993**	**%**
Sciaenidae				
Equetus umbrosus, cubbyu (S)	39	81.3	27	87.1
E. lanceolatus, jacknife-fish (S)	5	10.4	11	35.5
E. punctatus, spotted drum (S)			2	4.2
Mullidae				
Mulloidichthys martinicus, yellow goatfish (S)	1	2.1	9	29.0
Pseudupeneus maculatus, spotted goatfish (S)	1	2.1	17	54.8
Kyphosidae				
Kyphosus sp., chub (S)			2	4.2
Ephippidae				
Chaetodipterus faber, Atlantic spadefish	6	12.5	9	29.0
Chaetodontidae				
Chaetodon ocellatus, spotfin butterflyfish (S)	9	18.8	22	71.0
C. sedentarius, reef butterflyfish (S)	2	4.2	13	41.9
C. striatus, banded butterflyfish (S)			6	19.4
Pomacanthidae				
Holacanthus bermudensis, blue angelfish (S)	16	33.3	30	96.8
H. ciliaris, queen angelfish (S)	2	4.2	21	67.7
H. tricolor, rock beauty (S)			2	6.5
Pomacanthus paru, French angelfish (S)			4	12.9
Pomacentridae				
Abudefduf tauras, night sergeant (S)			9	29.0
Chromis multilineata, brown chromis (S)	1	2.1	1	3.2
C. insolata, sunshinefish (S)	1	2.1	14	45.2
C. scotti, purple reeffish (S)	45	93.8	29	93.5
C. cyaneus, blue chromis (S)	3	6.3	7	22.6
C. enchrysurus, yellowtail reeffish (S)	36	75.0	25	80.6
Microspathodon chrysurus, yellowtail damselfish (S)	1	2.1		
Poacentrus partitus, bicolor damselfish (S)	18	37.5	24	77.4
P. variabilis, cocoa damselfish (S)	20	41.7	27	87.1
P. fuscus, dusky damselfish (S)	3	6.3	11	35.5
Sphyraenidae				
Sphyraena barracuda, great barracuda	11	21.6	11	32.4
Labridae				
Bodianus pulchellus, spotfin hogfish (S)	8	16.7	29	93.5
B. rufus, Spanish hogfish (S)	15	31.3	26	83.9
Clepticus parrae, creole wrasse (S)			3	9.7
Halichoeres bivittatus, slippery dick (S)	39	81.3	27	87.1
H. garnoti, yellowhead wrasse (S)	10	20.8	13	41.9
**Lachnolaimus maximus,* hogfish (S)	24	77.4		
**Tautoga onitis*, tautog (N)	17	35.4	13	41.9
Thalassoma bifasciatum, bluehead (S)	9	18.8	21	67.7

Table 14.(cont.) Number of dives during which fishes and sponges were observed on the "210 Rock" off Beaufort, North Carolina.

Species	1975-1980	%	1990-1993	%
Scaridae				
Scarus sp. (S)	11	35.5		
Sparisoma viride, stoplight parrotfish (S)	2	6.5		
Sparisoma sp. (S)			11	35.5
Blenniidae				
Hypleurochilus geminatus, crested blenny (S)			2	4.2
Parablennius marmoreus, seaweed blenny (S)	19	47.1	7	2.4
Gobiidae				
Coryphopterus puntipectophorus, spotted goby (S)	14	29.2	5	16.1
G. oceanops, neon goby (S)	2	4.2	2	6.5
Gobiosoma sp. (S)			2	6.5
Ioglossus calliurus, blue goby (S)	9	18.8	11	35.5
Acanthuridae				
Acanthurus bahianus, ocean surgeon (S)	4	8.3	9	29.0
A. coeruleus, blue tang (S)	2	4.2	17	54.8
A. chirurgus, doctorfish (S)			21	67.7
Scombridae				
**Euthynnus alletteratus*, little tunny			3	6.3
**Scomberomorus cavalla*, king mackerel	10	20.8	1	3.2
Balistidae				
Aluterus scriptus, scrawled filefish (S)	1	3.2		
**Balistes capriscus*, gray triggerfish (S)	18	37.5	13	41.9
Monacanthus hispidus, planehead filefish (S)	28	58.3	29	93.5
Ostraciidae,				
Lactophrys sp., boxfish (S)			1	3.2
Tetraodontidae				
Canthigaster rostrata, sharpnose puffer (S)	1	2.1	3	9.7
Diodon sp., porcupinefish (S)			1	2.1
Sphoeroides spengleri, bandtail puffer (S)	3	6.3	22	71.0
**S. maculatus*, northern puffer (N)	2	4.2	1	3.2
Molidae				
Mola mola, ocean sunfish			2	4.2
Nepheliospongiidae				
Xestospongia muta, basket sponge				X[5]
TOTAL				
SPECIES	119		85	96
FAMILIES	46		34	38

[1] Sampling effort was extended beyond the 3-year study periods in an effort to obtain more winter data.
[2] Some totals differ from the published study because three stations were eliminated for locality comparison, and counting errors were corrected.[3] Nondesignated species were not the main concern of this study (e.g., sharks, jacks, and mackerels).
[4] *Opsanus sp.* is likely an undescribed offshore form.
[5] Although invertebrates usually were not recorded, the first observation of basket sponges was noted during our initial resurvey of the "210 Rock", and basket sponges were the subject of many underwater pictures and notations on cleaning stations throughout the second survey period.
* Target species (important in the recreational and commercial fisheries).
S Tropical species.
N Temperate species.

All of the snapper and grouper offshore shelf habitats referred to above contain hard or live bottom areas, which provide surfaces for the growth of invertebrate organisms and the development of an ecosystem capable of supporting fishes important to commercial and recreational fisheries. In general, the shelf demonstrates a ridge-and-swale (hill-and-valley) topography on the inner part and part of the outer shelf, with ridges having coarser surficial sediments than swales. At the shelf break, the topography is modified by a series of terraces before sloping or dropping off into vast submarine canyons.

The live-bottom habitats are often small, isolated areas of broken relief consisting of rock outcroppings that are heavily encrusted with sessile invertebrates such as bryozoans, sponges, octocorals, and sea fans. These outcrops are the ridges referred to above and are scattered over the continental shelf north of Cape Canaveral, although they are most numerous off northeastern Florida. A study of two live bottom areas off Georgia and South Carolina (Continental Shelf Associates 1979) revealed three hard bottom habitat types: 1) emergent hard bottom dominated by sponges and gorgonian corals; 2) sand bottom underlain by hard substrate dominated by anthozoans, sponges and polychaetes, with hydroids, bryozoans, and ascidians frequently observed; and 3) softer bottom areas not underlain with hard bottom. Along the southeastern United States, most hard/live bottom habitats occur at depths greater than 27 m (90 ft), but many also are found at depths of from 16 to 27 m (54 to 90 ft), especially off the coasts of North Carolina and South Carolina. Bottom water temperatures range from approximately 11^{o} to 27^{o} C (52^{o} to 80^{o}F). Temperatures less than 12^{o}C may result in the death of some of the more tropical species of invertebrates and fishes. Generally, snappers (Lutjanidae), groupers (Serranidae), porgies (Sparidae), and grunts (Haemulidae) inhabit hard bottom habitats off northeastern Florida and the offshore areas of Georgia, South Carolina, and North Carolina. The live bottom areas inshore (at depths of about 18 m; 60 ft) have cooler temperatures, less diverse populations of invertebrates, and are inhabited primarily by black sea bass and associated temperate species.

The shelf edge habitat extends more or less continuously along the edge of the continental shelf at depths of 55 to 110 m (180 to 360 ft). The sediment types in this essential fish habitat zone vary from smooth mud to areas that are characterized by great relief and heavy encrustations of coral, sponge, and other predominately tropical invertebrate fauna. Some of these broken bottom areas (e.g., in Onslow Bay, North Carolina) may represent the remnants of ancient reefs that existed when the sea level was lowered during the last glacial period.

Struhsaker (1969) reported that, as a result of the proximity of the Gulf Stream, average temperatures on the bottom at the shelf edge are higher for a longer duration than those further inshore at other hard bottom areas. Bottom water temperatures at the shelf edge habitat range from approximately 12° to 26° C (55° to 78° F). However, Miller and Richards (1980) found that there is a stable temperature area between 26 and 51 m (85 to 167 ft) where the temperature does not drop below 15°C (59° F). Cold water intrusions may cause the outer bottom temperatures to drop (Avent et al. 1977; Mathews and Pashuk 1977; Leming 1979). Fishes that generally inhabit the shelf edge zone are tropical, such as snappers, groupers, and porgies. Fish distribution is often diffuse in this zone, with fishes aggregating over broken bottom relief in associations similar to those formed at inshore live bottom sites.

The lower shelf habitat has a predominately smooth mud bottom, but is interspersed with rocky and very coarse gravel substrates where groupers (*Epinephelus* spp.) and tilefishes (Malacanthidae) are found. This habitat and its association of fishes roughly marks the transition between the fauna of the Continental Shelf and the fauna of the Continental Slope. Depths represented by this habitat zone range from 110 to 183 m (360 to 600 ft), where bottom water temperatures vary from approximately 11° to 14° C (51° to 57° F). Fishes inhabiting the deeper live or hard bottom areas are believed to be particularly susceptible to heavy fishing pressure and environmental stress.

The exact extent and distribution of productive live bottom habitat on the continental shelf north of Cape Canaveral is unknown. Although a number of attempts have been made, estimations of the total area of hard bottom are confounded due to the discontinuous or patchy nature of this habitat type. Henry and Giles (1979) estimated about 4.3 percent of the Georgia Bight to be hard bottom, but this is considered an underestimate. Miller and Richards (1980) reported that live bottom reef habitat comprises a larger area of the South Atlantic Bight. The method used to determine areas of live bottom involved the review of vessel station sheets from exploratory research cruises to locate sites where reef fishes were collected. Parker et al. (1983) suggested that rock-coral-sponge (live bottom) habitat accounts for about 14 percent, or 2,040 km^2 , of the substratum between the 27 m and 101 m isobaths from Cape Hatteras to Cape Fear. Live bottom constitutes a much larger percentage of the substratum at the above depths from Cape Fear to Cape Canaveral. Parker et al. (1983) estimate that approximately 30 percent, or 7,403 km^2, of the bottom in this area was composed of rock-coral-sponge substrate.

In 1992, the SEAMAP-South Atlantic Bottom Mapping Work Group of the Atlantic States Marine Fisheries Commission began an extensive effort to establish a regional database for hard bottom resources throughout the South Atlantic Bight. The primary objectives of the effort are to identify hard bottom habitats from the beach out to a depth of 200 meters, and to summarize the information into an easily-accessible database for researchers and managers. The Florida Marine Research Institute, as part of the 1998 SEAMAP program deliverables compiled the four state research effort and produced a complete set of ArcView maps presenting available information on hardbottom distribution from Florida to the North Carolina-Virginia border which are included in Appendix E. These coverages were provided to aid in the Council in the identification of essential fish habitat in the South Atlantic. Color versions of these maps are available over the internet at the Councils' Web site (www.safmc.noaa.gov) under essential fish habitat. Examples of the coverages are presented in Figures 8a and 8b.

In addition to the natural hard or live bottom reef habitats, wrecks and other man made structures, such as artificial reefs, also provide suitable substrate for the proliferation of live bottom. However, the combined area of artificial substrates will always be dwarfed compared with the total area of natural, exposed live/hard bottom. The faunal species composition on artificial reefs is similar to that identified on natural hard bottom habitat at the same depth and in the same general area (Stone et al. 1979).

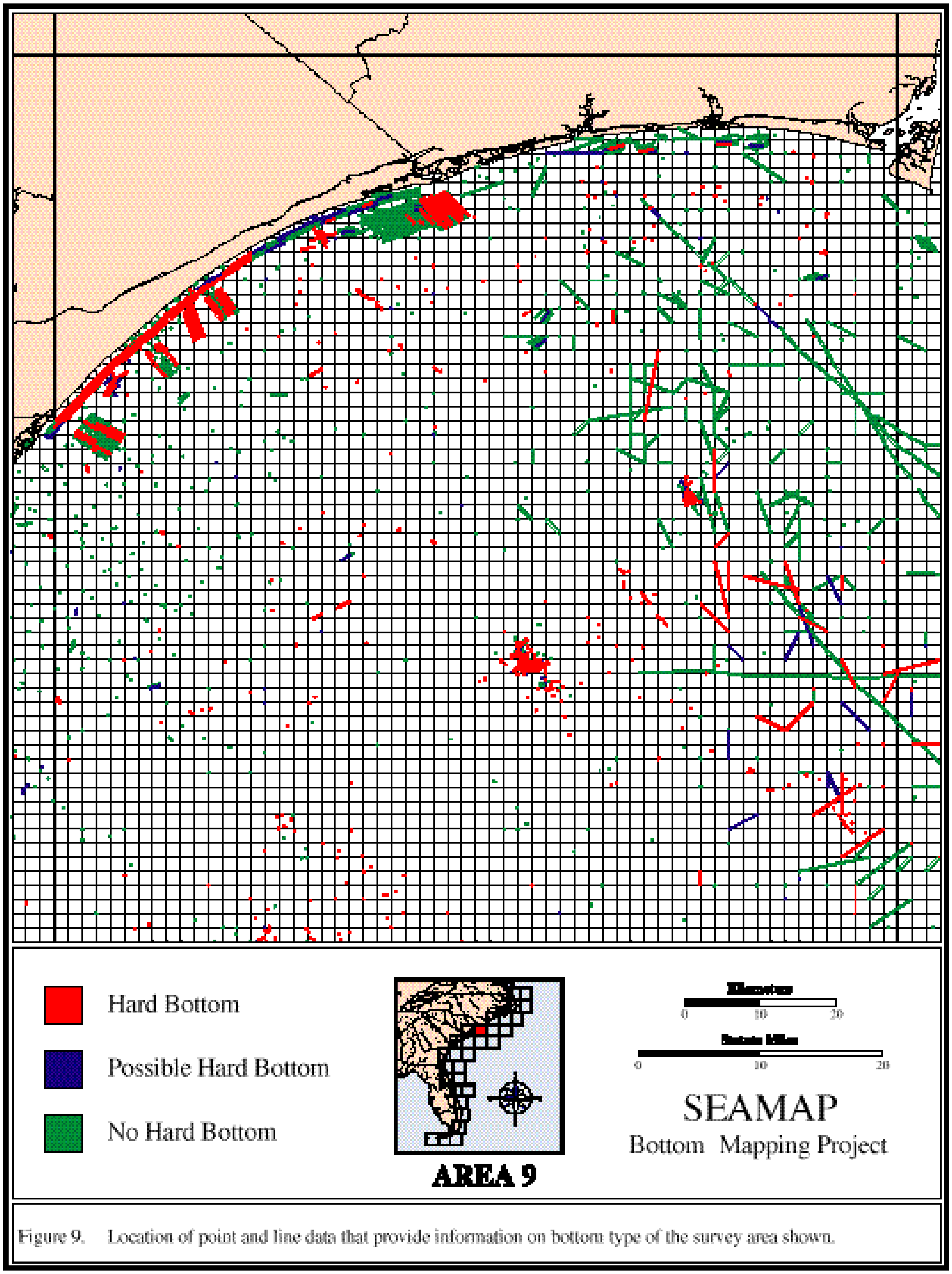


Figure 8a. Hardbottom distribution for Area Offshore of the South Carolina/North Carolina Border (Source: FMRI 1998 SEAMAP Bottom-Mapping Project) (Source: FMRI 1998).

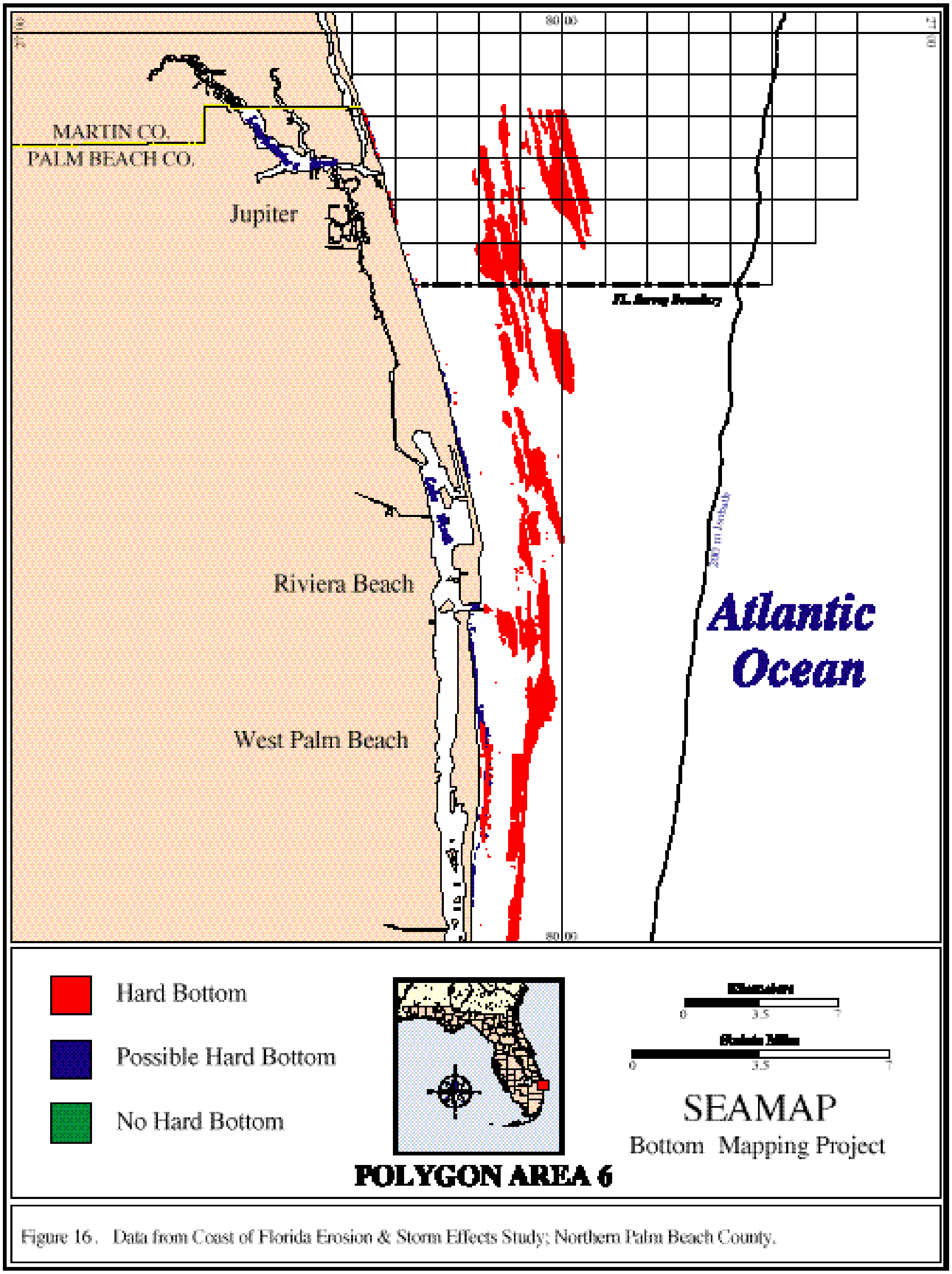


Figure 8b. Hardbottom distribution Offshore Northern Palm Beach County, Florida (1998 SEAMAP Bottom-Mapping Project) (Source: FMRI 1998).

Many fish species that inhabit live bottom reefs are nonmigratory, and are thus residents of specific reef areas for most of their adult lives. Therefore, any activities which result in significant destruction or degradation of reefs would adversely affect the productivity of the species that create important snapper-grouper fisheries. Of potential concern are natural gas/oil drilling activities, which could occur off the coasts of North Carolina, South Carolina, Georgia, and northeast Florida. Increased sedimentation resulting from discharge of drilling muds and byproduct cuttings could bury hard bottom habitats unless currents effectively dispersed the sediments (SC and GA Departments of Natural Resources 1981). Other potential detrimental activities to offshore hard bottom reef habitats include ocean dumping, and bottom contact fisheries. Concern has been expressed that bottom trawling may cause long-term or irreversible damage to animal and plant communities (Tilmant 1979, Wenner 1983) and substrates. A study by Van Dolah et al. (1987) off Georgia evaluated the impacts of a roller trawl on coral and sponge dominated benthic communities. Although some damage was documented for all target species immediately after trawling, recovery of sponge occurred within a year. Even more passive fishing gear and operations, such as bottom longlines and vertical drop lines, and anchoring (Davis 1977) may be damaging to the more fragile reef fish-supporting communities.

3.2.1.2.2 Cape Canaveral to Dry Tortugas

The term hard bottom is applied in two relatively different areas of southeast Florida: the mainland and associated sedimentary barrier islands, and the coral islands and reef tract of the Florida Keys (Hoffmeister, 1974). Therefore, this summary is collated by two subregions: a) mainland southeast Florida; and b) the Florida Keys. The benthic habitat characteristics of the shelf bordering the mainland are not as complex as in the Florida Reef Tract. Within both subregions, non-coralline, hard bottom habitats are present in both nearshore (<4 m) and mid- and outer-shelf areas (>4 m).

3.2.1.2.2.1 Mainland Southeast Florida

Nearshore Hard Bottom - Nearshore hard bottom habitats are the primary natural reef structures at depths of 0-4 m of this subregion. These habitats are derived from large accretionary ridges of coquina mollusks, sand, and shell marl which lithified parallel to ancient shorelines during Pleistocene interglacial periods (Duane and Meisburger, 1969). Currently, the majority of nearshore hardbottom reefs are within 200 m of the shore. However, they are often separated by kilometers of flat nearshore sand expanses. The habitat complexity of nearshore hard bottom is expanded by colonies of tube-building polychaete worms (Kirtley and Tanner, 1968) other invertebrates and macroalgae (Goldberg, 1973; Nelson and Demetriades, 1992). Nelson (1990) recorded 325 species of invertebrates and plants from nearshore hard bottom habitats at Sebastian Inlet. Hard corals are rare or absent due to high turbidities and wave energy. In some areas, the hard bottom reaches heights of 2 m above the bottom and is highly convoluted. The most widespread encrusting organism is the reef-building sabellariid worm, *Phragmatopoma lapidosa* (= *P. caudata*; Kirtley, 1994).

Few quantitative characterizations of nearshore hardbottom fish assemblages are available. Based on visual censusing of three mainland southeast Florida sites over two years, 86 species from 36 families were recorded (Lindeman, 1997). Grunts (Haemulidae) were the most diverse family with 11 species recorded, more than double the species of any other family except the wrasses (Labridae) and parrotfishes (Scaridae) with seven and six species, respectively. The most abundant species were the sailors choice, silver porgy, and cocoa damselfish. Use of hardbottom habitats was recorded for newly settled stages of over 20 species (Lindeman and

Snyder, manuscript). Pooled early life stages (newly settled, early juvenile, and juvenile) represented over 80% of the individuals at all sites. Nearshore hardbottom fish assemblages of this subregion are characterized by diverse, tropical faunas which are dominated by early life stages.

Three studies have included sections on nearshore hard bottom fishes as part of larger project goals. Gilmore (1977) listed 105 species in association with "surf zone reefs" at depths less than two m. Two additional species were added in later papers (Gilmore et al., 1983; Gilmore, 1992). Using visual surveys, Vare (1991) recorded 118 species from nearshore hard bottom sites in Palm Beach County. Futch and Dwinell (1977) included a list of 34 species obtained from several ichthyocide collections on "nearshore reefs". In addition to the species censused in Lindeman (1997), 19 species were qualitatively recorded at the Jupiter and Ocean Ridge sites. Including the prior studies, 192 species within 62 families have now been recorded in association with nearshore hard bottom habitats of mainland southeast Florida (Table 15). At least 90 species are utilized in recreational, commercial, bait, or aquaria fisheries.

Nearshore hard bottom habitats typically had over thirty times the individuals per transect as natural sand habitats (Lindeman, 1997) and newly settled individuals were not recorded during any surveys of natural sand habitats. During 34 visual transects over sand sites in southeast Florida, Vare (1991) recorded seven species (primarily clupeids and carangids). Approximately 15 months of sampling by seine hauls at a nearshore sand site in east-central Florida yielded a total of 22 species (Peters and Nelson, 1987). One species each of engraulid and carangid comprised 70% of the total catch.

Hard bottom habitats are often centrally placed between mid-shelf reefs to the east and estuarine habitats within inlets to the west. Therefore, they may serve as settlement habitats for immigrating larvae or as intermediate nursery habitats for juveniles emigrating out of inlets (Vare, 1991, Lindeman and Snyder, In press). This cross-shelf positioning, coupled with their role as the only natural structures in these areas, suggests nearshore hard bottom may represent important EFH resources.

Offshore Hard Bottom - Several lines of offshore hardbottom reefs, derived from Pleistocene and Holocene reefs, begin in depths usually exceeding 8 m, and in bands that roughly parallel the shore (Goldberg, 1973; Lighty, 1977). The geologic origins and biotic characteristics of these deeper reef systems are different from the nearshore hardbottom reefs (Lighty, 1977), although reefs of both depth strata are lower in relief than reefs of the Florida Reef tract. The tropical invertebrate fauna of several of these mid-shelf reefs are described by Goldberg (1973) and Blair and Flynn (1989). No quantitative examinations of the fish assemblages of these habitats are published. Qualitative characterizations exist in Herrema (1974) and Courtenay et al. (1974; 1980). Using various collecting gears and literature reviews, Herrema (1974) recognized the occurrence of 206 “primary reef” fishes off the mainland southeast coast of Florida. Emphasis was placed on the similarities between this fauna and the reef fish fauna characterized at Alligator Reef in the Florida Keys (Starck, 1968). Lutjanids, haemulids and many other families were represented in both subregions on almost a species by species basis (Herrema, 1974). This information was not contradicted by the faunal characterizations in Courtenay et al. (1974; 1980). Based primarily on offshore records, Perkins et al. (1997) identified 264 fish taxa from the shelf of mainland Florida as hard-bottom obligate taxa.

Table 15. Species of fishes recorded from natural nearshore hardbottom habitats of mainland southeast Florida in the present study (Lindeman, 1997), Gilmore (1977) and Vare (1991). Depths surveyed: present study 1-4m; Gilmore 0-2m; Vare ≤ 4m.

Species	Lindeman	Gilmore	Vare
Rhinocodontidae-Carpet sharks			
Ginglymostoma cirratum	x	x	x
Carcharhinidae-Requiem Sharks			
Carcharhinus brevipinna	x		x
Carcharhinus leucas		x	
Carcharhinus limbatus		x	
Carcharhinus plumbeus		x	
Rhinobatidae-Guitarfishes			
Rhinobatos letiginosus			x
Dasyatidae-Stingrays			
Dasyatis americana			x
Urolophidae-Round stingrays			
Urolophus jamaicensis			x
Muraenidae-Moray eels			
Echidna catenata	x		
Enchelycore carychora			x
Enchelycore nigricans			
Gymnothorax funebris		x	x
Gymnothorax miliaris	x		
Gymnothorax moringa	x	x	x
Ophichthidae-Snake eels			
Ahlia egmontis			
Myrichthys breviceps	x		x
Elopidae-Tarpons			
Megalops atlanticus	x		x
Clupeidae-Herrings			
Harengula clupeola	x	x	
Harengula humeralis		x	
Harengula jaguana	x	x	
Opisthonema oglinum		x	x
Sardinella aurita	x	x	
Clupeid sp.	x		
Engraulidae-Anchovies			
Anchoa cubana		x	
Anchoa hepsetus		x	
Anchoa lyolepis		x	
Gobiesocidae-Clingfishes			
Gobiesox strumosus		x	
Mugilidae-Mullets			
Mugil cephalus	x		x
Mugil curema	x		
Exocoetidae-Halfbeaks			
Hemiramphus brasiliensis	x		
Hyporhamphus unifasciatus		x	
Hyporhamphus sp.		x	
Belonidae-Needlefishes			
Strongylura marina			x
Atherinidae-Silversides			
Membras martinica		x	
Menidia peninsulae		x	
Scorpaenidae-Scorpionfishes			
Scorpaena plumieri	x	x	x
Holocentridae-Squirrelfishes			
Holocentrus adscensionis			x
Holocentrus rufus	x		
Pomacentridae-Damselfishes			
Abudefduf saxatilis	x	x	x
Abudedfuf taurus		x	
Microspathodon chrysurus			x
Pomacentrus fuscus	x		x
Pomacentrus leucostictus	x	x	x
Pomacentrus partitus	x		x
Pomacentrus planifrons			x
Pomacentrus variabilis	x	x	x
Species (cont.)	Lindeman	Gilmore	Vare
Serranidae-Sea Basses and Groupers			
Centropristis striata		x	x
Diplectrum formosum			x
Epinephelus adscensionis			x
Epinephelus itajara		x	
Epinephalus morio		x	
Mycteroperca bonaci	x		x
Mycteroperca microlepis		x	
Serranus subligarius		x	
Grammistidae-Soapfishes			
Rypticus maculatus	x	x	
Rypticus saponaceus			x
Lutjanidae-Snappers			
Lutjanus analis		x	x
Lutjanus apodus	x	x	x
Lutjanus chrysurus	x	x	x
Lutjanus griseus	x	x	x
Lutjanus jocu		x	x
Lutjanus mahogoni		x	
Lutjanus synagris	x	x	x
Haemulidae-Grunts			
Anisotremus surinamensis	x	x	x
Anisotremus viginicus	x	x	x
Haemulon album			?
Haemulon aurolineatum	x	x	x
Haemulon carbonarium	x	x	x
Haemulon chrysargyreum	x	x	x
Haemulon flavolineatum	x	x	x
Haemulon macrostomum	x		x
Haemulon melanurum	x	x	x
Haemulon parra	x	x	x
Haemulon plumieri	x	x	x
Haemulon sciurus	x		x
Haemulon striatum			?
Orthopristis chrysoptera			?
Inermiidae-Bogas			
Inermia vittata			?
Apogonidae-Cardinalfishes			
Apogon		x	
Apogon maculatus	x	x	x
Apogon pseuomaculatus		x	
Astrapogon stellatus			
Phaeoptyx conklin			
Pomatomidae- Bluefishes			
Pomatomus saltatrix		x	
Carangidae-Jacks and Pompanos			
Caranx bartholomaei	x	x	x
Caranx crysos	x	x	x
Caranx hippos	x	x	x
Caranx latus		x	x
Caranx ruber	x	x	x
Chloroscombrus chrysurus	x	x	
Decapterus punctatus	x		
Oligoplites suarus	x	x	x
Selar crumenopthalamus	x		
Selene setapinnis		x	
Selene vomer		x	
Seriola drumerili		x	
Trachinotus carolinus	x		
Trachinotus falcatus	x		
Trachinoyus goodei			x
Mullidae-Goatfishes			
Mulloidicthys martinicus	x		x
Pseudupeneus maculatus	x	x	x

Table 15.(cont.) Species of fishes recorded from natural nearshore hardbottom habitats of mainland southeast Florida in the present study.

Species	Lindeman	Gilmore	Vare
Centropomidae-			
Centropomus undecimalis	x		x
Sparidae-Porgies			
Archosargus probatocephalus	x	x	x
Calamus bajonado		x	x
Diplodus argenteus	x	x	
Diplodus holbrooki		x	x
Coryphaenidae-Dolphins			
Coryphaena equiselis		x	
Sciaenidae-Drums			
Bairdiella sancteluciae		x	
Equetus acuminatus	x	x	x
Equetus lanceolatus			x
Equetus umbrosus		x	
Odontoscion	x	x	x
Umbrina coroides	x		x
Gerreidae-Mojarras			
Eucinostomus argenteus	x	x	x
Eucinostomus gula	x	x	
Eucinostomus sp.	x		
Gerres cinerus	x	x	x
Echeinidae-Remoras			
Echeneis naucrates			x
Priacanthidae-Bigeyes			
Priacanthus arenatus			x
Pempheridae-Sweepers			
Pemphurus schomburgki	x	x	x
Aulostomidae-Trumpetfishes			
Aulostomus maculatus		x	
Fistularidae-Coronetfishes			
Fistularia tabacaria			x
Ephippidae-Spadefishes			
Chaetodipterus faber		x	x
Chaetodontidae-Butterflyfishes			
Chaetodon			x
Chaetodon	x		x
Chaetodon			x
Chaetodon			x
Pomacanthidae-Angelfishes			
Holocanthus bermudensis	x		x
Holocanthus ciliarus		x	
Pomacanthus arcuatus	x	x	x
Pomacanthus paru	x		x
Labridae-Wrasses			
Bodianus rufus	x		x
Dorotonatus megalepis		x	
Halichoeres bivittatus	x	x	x
Halichoeres garnoti			x
Halichoeres maculipinna	x	x	x
Halichoeres poeyi	x	x	
Halichoeres radiatus	x	x	x
Hemipteronotus splendens			x
Hemipteronotus sp.	x		
Lachnolaimus maximus	x		x
Thalassoma bifasciatum	x	x	x
Scaridae-Parrotfishes			
Scarus coelestinus		x	
Scarus guacamaia		x	
Scarus teaniopterus			x
Scarus vetula	x		
Sparisoma atomarium		x	
Sparisoma aurofrenatum	x		
Sparisoma chrysopterum	x		x
Sparisoma radians			x
Sparisoma rubripinne	x	x	x
Sparisoma viride	x		x
Scarid sp.	x		
Synodontidae-Lizardfishes			
Synodus intermedius			x

Species (cont.)	Lindeman	Gilmore	Vare
Sphyraenidae-Barracudas			
Sphyraena barracuda	x	x	x
Sphyraena		x	
Kyphosidae-Sea chubs			
Kyphosus incisor	x	x	
Kyphosus sectatrix	x	x	x
Kyphosus sp.	x		
Scombridae-Mackerels			
Scomberomorus regalis	x		x
Opistognathidae-Jawfishes			
Opistognathus		x	
Dactyloscopidae-Sand Stargazers			
Dactyloscpous		x	
Platygillellus rubrocinctus			
Uranoscopidae-Stargazers			
Astroscopus y-graecum		x	
Oglocephalidae-Batfishes			
Oglocephalus radiatus			x
Labrisomidae-Clinids			
Labrisomus bucciferus	x		
Labrisomus gobio		x	
Labrisomus nuchipinnis	x	x	x
Malacoctenus macropus	x	x	
Malacoctenus triangulatus	x	x	
Paraclinus nigripinnis		x	
Starskia ocellata	x		
Blenniidae-Combtooth Blennies			
Entomacrodus nigricans		x	
Parablennius marmoreus	x		x
Scartella cristata	x	x	
Gobiidae-Gobies			
Coryphopterus glaucofrenum	x		
Gobisoma	x		x
Nes longus	x		
Eleotridae-Sleepers			
Erotelis smaragdus		x	
Triglidae-Searobins			
Prionotus ophryas			x
Acanthuridae-Surgeonfishes			
Acanthurus bahianus	x	x	x
Acanthurus chirurgus	x	x	x
Acanthurus coeruleus	x	x	x
Bothidae-Lefteye Flounders			
Bothus lunatus			x
Balistidae-Triggerfishes			
Balistes capriscus			x
Balistes vetula			x
Canthidermis sufflamen			x
Monocanthidae-Filefishes			
Aluterus scriptus	x		x
Cantherhines pullus	x		x
Monocanthus	x	x	
Ostraciidae-Boxfishes			
Lactophrys trigueter	x	x	x
Lactophrys quadicornis	x		x
Tetrodontidae-Pufferfishes			
Canthigaster rostrata	x		x
Sphoeroides spengleri			x
Diodontidae-Porcupinefishes			
Diodon			x
Diodon hystrix	x		x

1 - Observed, but not censused, in present
2 - Reported only by Futch & Dwinell (1977).
3 - Reported by Gilmore (1992).
4 - Reported by Gilmore et al. (1983).
? Reported but identifiction

3.2.1.2.2.2 Florida Keys and Reef Tract

Nearshore Hard Bottom - Nearshore hard bottom habitats of the Florida Keys can differ both geologically and biologically from mainland areas (Table 16). Florida Keys nearshore hard bottom is semi-continuously distributed among areas with high organic sediments, increased seagrasses, more corals, and reduced wave conditions. Emergent upland components of the Florida Keys are derived from ancient reefs of the Florida Reef Tract and typically do not have sizeable beaches nor a nearshore current regime for delivery of beach-quality sediments. Nearshore hard bottom habitats on the mainland are patchily distributed among large expanses of barren, coarse sediments, commonly possess worm reefs, and show reduced coral diversities (Table 16). In contrast to the Keys, beach systems associated with sedimentary barrier islands are common in mainland areas.

Within the Keys, nearshore hard bottom is widely distributed and shows compositional differences based on proximity to tidal passes (Chiappone and Sullivan, 1994). Near tidal passes, these habitats are dominated by algae, gorgonians and sponges. In the absences of strong circulation, such habitats are characterized by fleshy algae, such as *Laurencia* (Chiappone and Sullivan, 1994). Hard corals are relatively uncommon in nearshore areas, presumably due to greater environmental variability in key parameters (temperature, turbidity, salinity).

Table 16. Geological and biological comparisons between nearshore areas of the east coast mainland and the Florida Keys. Transition areas are given for each attribute. Sources: Kirtley and Tanner (1968), Hoffmeister (1974), present study. From Lindeman (1997).

	Mainland North of Transition	**Geographic** Transition Zone	**Florida Keys** South of Transition
Island Type	Sedimentary Barrier Islands	Key Biscayne-Soldier Key	Coral/Limestone Islands
Bedrock Type	*Anastasia* Limestone	Palm Beach-Broward Counties	Miami or Key Largo Limstone
Sabellariid Worms	Common	Broward Dade Counties	Rare
Shallow Corals	Rare	Key Biscayne Soldier Key	Common
Predominant Type of Sediment	Quartz	Key Biscayne Soldier Key	Calcium Carbonate
Predominant Size of Sediment	Coarse	Key Biscayne Soldier Key	Fine
Seagrasses	Absent	Miami Beach-Fisher Island	Present
Wave Energy	Intermediate to High	Palm Beach-Broward Counties-	Low

Chiappone and Sluka (1996) identified only one study that had quantitatively focused on fishes of nearshore hard bottom areas in the Florida Keys. This work was based on strip transect surveys at two sites in the middle Keys and recorded a total of 30 species within 18 families (Sullivan et al., in prep.). In Jaap (1984) review of Keys reefs, Tilmant compiled a list of 47 fish species occurring on nearshore hard bottom. In contrast, 192 species have been compiled for mainland areas (Lindeman, 1997). The paucity of fish studies on nearshore hard bottom habitats of both the mainland and the Florida Keys render definitive comparisons premature at this stage. Several additional factors further complicate Keys and mainland comparisons. First, nearshore hard bottom in the Keys is distributed across more physiographically variable cross-shelf strata with a greater potential for structural heterogeneity than on the mainland. Second, the presence of over 6000 patch reefs in Hawk Channel (Marszalek et al. 1977), many near shallow hard bottom habitats, introduces additional inter-habitat relationships rarely found in nearshore hard bottom of mainland areas. Characterizing the fish assemblages of the heterogenous nearshore areas of the Keys may be more problematic than for the relatively homogeneous nearshore hard bottom areas of mainland Florida. In both regions, some ecotones and attributes of vertical relief (e.g., sand-hard bottom interfaces and ledges) appear to aggregate some taxa. However, the microhabitat-scale distributions of fishes within nearshore hard bottom habitats remain unquantified.

Offshore Hard Bottom - In a review by Chiappone and Sluka (1996, Table 5), no studies of fishes from hard bottom areas of the outer reef tract or the intermediate Hawk Channel area were identified. Most studies of offshore fish faunas in the Florida Keys have focused on reef formations derived primarily from hermatypic corals. Such areas may contain bedrock outcroppings properly termed hard bottom, however, this is typically not discriminated in the literature. Therefore, characterizations of offshore hardbottom ichthyofauna are not available and literature focused on coral reef fish assemblages of Hawk Channel and the Florida Reef Tract must be consulted (Section 3.2.1.2.2.2).

3.2.1.2.3 Hard Bottom Essential Fish Habitat-Habitat Areas of Particular Concern :

Section 600.815 (a) (9) of the interim final rule on essential fishery habitat determinations recognizes that subunits of EFH may be of particular concern. Such areas, termed Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPCs), can be identified using four criteria from the rule: a) importance of ecological functions; b) sensitivity to human degradation; c) probability and extent of effects from development activities; and d) rarity of the habitat. Hard bottom habitat types which ranked high in terms of these criteria are summarized below.

3.2.1.2.3.1 Charleston Bump and Gyre

The topographic irregularity southeast of Charleston, South Carolina known as the Charleston Bump is an area of productive seafloor, which rises abruptly from 700 to 300 meters within the short distance of about 20 km. The Charleston Bump is located approximately 32° 44' N. Latitude and 78° 06' W. Longitude and at an angle which is approximately transverse to both the general isobath pattern and the Gulf Stream currents (Figure 9). Those areas that contain the highest relief are the only known spawning locations for wreckfish. This species is fished intensively within the relatively small area of high relief, and is one of the few species within the snapper-grouper fisheries complex that has been successfully managed as a sustained fishery (C. Barans, SCDNR, pers. commun.)

The Charleston Gyre is considered an essential nursery habitat for some offshore fish species with pelagic stages, such as reef fishes. The cyclonic Charleston Gyre is a permanent oceanographic feature of the South Atlantic Bight induced by the reflection of rapidly moving Gulf Stream waters by the topographic irregularity (high relief) southeast of Charleston. The gyre produces a large area of upwelling of nutrients, which contributes significantly to primary and secondary production within the SAB region, and is thus important to some ichthyoplankton. The size of the deflection and physical response in terms of replacement of surface waters with nutrient rich bottom waters from depths of 450 meters to near surface (less than 50 meters) vary with seasonal position and velocity of the Gulf Stream currents. The nutritional contribution of the large upwelling area to productivity of the relatively nutrient poor SAB is significant (C. Barans, SCDNR, pers. commu.).

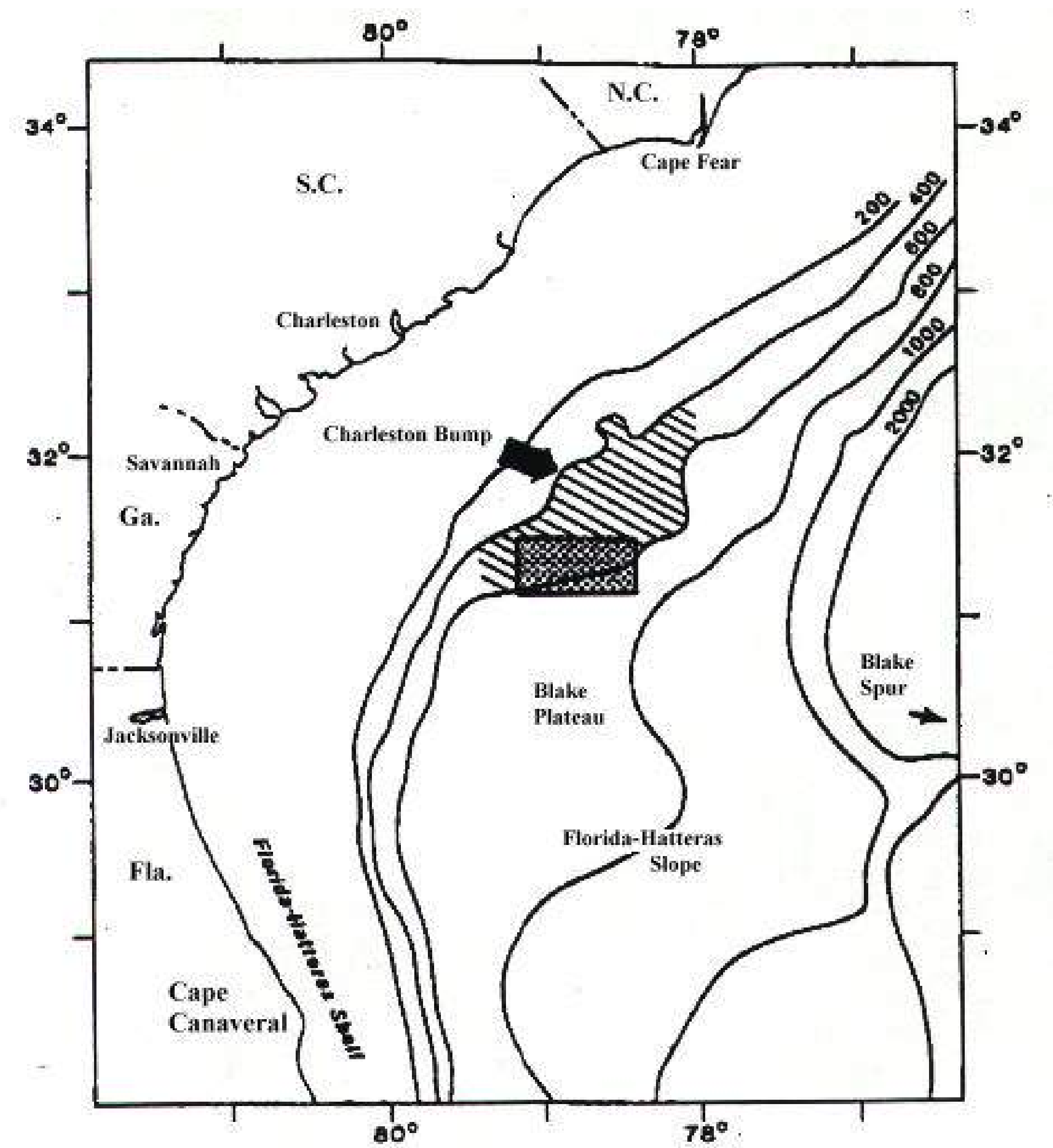


Figure 9. Southeastern U.S. continental shelf and slope, showing major topographic featues (diagnol lines indicate the Charleston Bump) and boundaries of the primary commercial wreckfish grounds (heavy dots). (Source: Sedberry et. al., 1994).

The South Atlantic Bight, the Charleston Bump and Gyre are described in greater detail in "General Oceanographic description of the South Atlantic Bight with emphasis on the Charleston Bump" by Oleg Pashuk (George Sedberry SCDNR pers comm) which follows:

"The continental shelf off the southeastern United States, commonly called the South Atlantic Bight (SAB), extends from Cape Hatteras, North Carolina, to Cape Canaveral, Florida (or according to some researchers, to West Palm Beach, Florida). The northern part of the SAB is known as the Carolina Capes Region, while the middle and southern areas are called the Georgia Embayment, or Georgia Bight. The Carolina Capes Region is characterized by complex topography, and their prominent shoals extending to the shelf break are effective in trapping Gulf Stream eddies, whereas the shelf to the south is more smooth.

Shelf widths vary from just a few kilometers off West Palm Beach, Fla, to a maximum of 120 km off Brunswick and Savannah, Georgia. Gently sloping shelf (about 1m/km) can be divided into the following zones: 1)Inner shelf (0-20 m) which is dominated by tidal currents, river runoff, local wind forcing and seasonal atmospheric changes; 2)Midshelf zone (21-40 m) where waters are dominated by winds but influenced by the Gulf Stream. Stratification of water column changes seasonally: mixed conditions, in general, characterize fall and winter while vertical stratification prevail during spring and summer. Strong stratification allows the upwelled waters to advect farther onshore near the bottom and, at the same time, it facilitates offshore spreading of lower salinity water in surface layer. 3)Outer shelf (41-75 m) is dominated by the Gulf Stream. The shelf break, generally, occurs at about 75-m depth, but is shallower southward.

Oceanographic regime on the continental shelf in the South Atlantic Bight is mainly conditioned by 1)proximity of the Gulf Stream with its frequent meanders and eddies; 2)river runoff; 3)seasonal heating and cooling; and 4)bottom topography. Winds and tides can also modify circulation patterns, especially near shore, or where density gradients are weak. Temperature and salinity of shelf waters widely fluctuate seasonally (from 10° C to 29° C and from 33.0 ppt to 36.5 ppt), whereas warm and salty surface Gulf Stream waters have much less variable properties.

The warming influence of the Gulf Stream is especially notable in the winter near the shelf break where tropical species of fish, corals and other animals are found. A warm band of relatively constant temperature (18-22° C) and salinity (36.0 ppt - 36.2 ppt) water is observed near bottom year-round just inshore of the shelf break, bounded by seasonally variable inshore waters on one side, and by fluctuating offshore waters on the other side, which are subject to cold eddy/upwelling events and warm Gulf Stream intrusions.

Fresh water nearshore is supplied mainly by the Cape Fear, Pee Dee, Santee, Savannah, and Altamaha rivers. River runoff is the highest during late winter-early spring, with maximum in March. The affect of runoff on coastal and shelf waters is most pronounced by April. Seasonal heating and cooling of coastal and shelf waters follow a trend in air temperature's increase and decrease, with a lag of approximately one month also.

Geostrophic southward flow develops on the continental shelf and appears to be seasonal, reflecting river runoff and heating-cooling effects. This counter-current is maximum during summer. In late fall-winter, in general, it is no longer a broad continuous flow, and is restricted to narrow patches mainly in nearshore areas in the vicinity of river mouths.

The fluctuations in the Icelandic Low, the Bermuda-Azores High, and the Ohio Valley High largely govern the mean wind patterns in the SAB. Winds, in general, are from Northeast in fall-winter, and from Southwest in spring-summer, but they can be of different directions during a passage of atmospheric fronts.

Semiduirnal (M_2) tides dominate the SAB. Tidal range varies considerately in the SAB because of varying shelf widths. The maximum coastal tides of 2.2 m occur at Savannah, Georgia, where the shelf is widest, and decrease to 1.3 m at Cape Fear and 1.1 m at Cape Canaveral.

Small frontal eddies and meanders propagate northward along the western edge of the Gulf Stream every 1-2 weeks. They provide small-scale upwellings of nutrients along the shelf break in the SAB. In contrast to transit upwellings, there are two areas in the SAB where upwelling of nutrient-rich deep water is more permanent. One such upwelling is located just to the north of Cape Canaveral which is caused by diverging isobaths. The other, much larger and stronger upwelling occurs mainly between 32° N. Latitude and 33° N. Latitude, and it results from a deflection of the Gulf Stream offshore by the topographic irregularity known as the Charleston Bump.

In general, the Gulf Stream flows along the shelf break, with very little meandering, from Florida to about 32° N latitude where it encounters the Charleston Bump and is deflected seaward forming a large offshore meander. The cyclonic Charleston Gyre is formed, with a large upwelling of nutrient-rich deep water in its cold core. The Charleston Bump is the underwater ridge/trough feature located southeast of Charleston, South Carolina, where seafloor rises from 700 to 300 m within a relatively short distance and at a transverse angle to both the general isobaths pattern of the upper slope, and to Gulf Stream currents. Downstream of the Charleston Bump, enlarged wavelike meanders can displace the Gulf Stream front up to 150 km from the shelf break. These meanders can be easily seen in satellite images.

Although 2-3 large meanders and eddies can form downstream of the Bump, the Charleston Gyre is the largest and the most prominent feature. The consistent upwelling of nutrient-rich deep waters from the depths over 450 m to the near-surface layer (less than 50 m) is the main steady source of nutrients near the shelf break within the entire South Atlantic Bight, and it contributes significantly to primary and secondary production in the region. The Charleston Gyre is considered an essential nursery habitat for some offshore fish species with pelagic stages. It is also implicated in retention of fish eggs and larvae and their transport onshore.

The Charleston Bump and the Gyre can also create suitable habitats for adult fish. For example, the highest relief of the Bump is the only known spawning location of the wreckfish. The Charleston Gyre may be also beneficial to other demersal species of the Snapper-Grouper complex, as well as to pelagic migratory fishes, due to food availability and unique patterns of the currents in this area."

3.2.1.2.3.2 Ten Fathom Ledge and Big Rock

The Ten Fathom Ledge and Big Rock areas are located south of Cape Lookout, North Carolina. The Ten Fathom Ledge is located at 34° 11' N. Latitude 76° 07' W. Longitude in 95 to 120 meter depth on the Continental Shelf in Onslow Bay, North Carolina, beginning along the southern edge of Cape Lookout Shoals. This area encompasses numerous patch reefs of coral-algal-sponge growth on rock outcroppings distributed over 136 square miles of ocean floor. The substrate consists of oolithic calcarenites and coquina forming a thin veneer over the underlying Yorktown formation of silty sands, clays, and calcareous quartz sandstones.

The Big Rock area encompasses 36 square miles of deep drowned reef around the 50-100 meter isobath on the outer shelf and upper slope approximately 36 miles south of Cape Lookout. Hard substrates at the Big Rock area are predominately algal limestone and calcareous sandstone. Unique bottom topography at both sites produces oases of productive bottom relief with diverse and productive epifaunal and algal communities surrounded by a generally monotonous and relatively unproductive sand bottom. Approximately 150 species of reef-associated species have been documented from the two sites (R. Parker, pers. commu.).

3.2.1.2.3.3 Shelf Break Area from Florida to North Carolina

Although the area of bottom between 100 and 300 meters depths from Cape Hatteras to Cape Canaveral is small relative to the more inshore live bottom shelf habitat as a whole, it constitutes essential deep reef fish habitat. Series of troughs and terraces are composed of bioeroded limestone and carconate sandstone (Newton et al. 1971), and exhibit vertical relief ranging from less than half a meter to more than 10 meters. Ledge systems formed by rock outcrops and piles of irregularly sized boulders are common.

Overall, the deep reef fish community probably consists of fewer than 50 species. Parker and Ross (1986) observed 34 species of deepwater reef fishes representing 17 families from submersible operations off North Carolina in waters 98 to 152 meters deep. In another submersible operation in the Charleston Bump area off South Carolina, Gutherz et al. (1995) describe sightings of 27 species of deep water reef fish in waters 185 to 220 meters in depth.

3.2.1.2.3.4 Gray's Reef National Marine Sanctuary

Grays Reef National Marine Sanctuary (GRNMS) is located 17.5 nautical miles east of Sapelo Island, Georgia, and 35 nautical miles northeast of Brunswick, Georgia. Gray's Reef encompasses nearly 32 km^2 at a depth of about 22 meters (Parker et al. 1994). The Sanctuary contains extensive, but patchy hardbottoms of moderate relief (up to 2 meters). Rock outcrops, in the form of ledges, are often separated by wide expanses of sand, and are subject to weathering, shifting sediments, and slumping, which create a complex habitat including caves, burrows, troughs, and overhangs (Hunt 1974). Parker et al. (1994) described the habitat preference of 66 species of reef fish distributed over five different habitat types. Numbers of species and fish densities were highest on the ledge habitat, intermediate on live bottom, and lowest over sand.

3.2.1.2.3.5 Nearshore Hard Bottom of Mainland Southeast Florida.

Extending semi-continuously from Cape Canaveral (28^o30' N) to at least Boca Raton (26^o 20' N), nearshore hard bottom was evaluated in terms of the four HAPC criteria in Section 600.815 of the final interim rule. In terms of ecological function, several lines of evidence suggest that nearshore hard bottom reefs may serve as nursery habitat. The following summary is based on the quantitative information available (Lindeman, 1997, Lindeman and Snyder, manuscript), which also included life stage-specific abundance data. First, pooled early life stages consistently represented over 80% of the total individuals at all sites censused. Second, eight of the top ten most abundant species were consistently represented by early stages. Third, use of hard bottom habitats was recorded for newly settled stages of more than 20 species.

Although suggestive of nursery value, these lines of evidence need to be viewed in the appropriate context. The presence of more juvenile stages than adults does not guarantee a habitat is a valuable nursery. Rapid decays in the benthic or planktonic survival of early stages of marine fishes are common demographic patterns (Shulman and Ogden, 1987; Richards and Lindeman, 1987), insuring that if distributions are homogeneous, all habitats will have more early stages than adults. Are early stages equally distributed among differing habitats or consistently skewed towards particular cross-shelf habitats? The high numbers of early stages on nearshore reefs appear to reflect more than just larger initial numbers of young individuals. Newly settled stages of most species of grunts and eight of nine species of snappers of the southeast mainland Florida shelf have been recorded primarily in depths less than five m, despite substantial sampling efforts in deeper waters. Adults are infrequent or absent from the same shallow habitats. There is habitat segregation among life stages, with the earliest stages using the most shallow habitats in many species of grunts and snappers (Starck, 1970; Lindeman, 1997; Dennis, 1992). Similar ontogenetic differences in both distribution and abundance exist for many other taxa which utilize nearshore hard bottom habitats. Based on this and other evidence, Lindeman and Snyder (manuscript) concluded that at least 35 species utilize nearshore hard bottom as a primary or secondary nursery area. At least ten of these species are managed under the Snapper/Grouper FMP.

Because nearshore areas are relatively featureless expanses of sand in the absence of hard bottom, such structures may also have substantial value as reference points for spawning activities of inshore fishes. Many fishes require three-dimensional structure as a reference point for coarse-scale aggregation and fine-scale behavior during spawning (Thresher, 1984). Using information from the literature, personal observations, and discussions with commercial fishermen, 15 species were estimated to spawn on nearshore reefs (Lindeman, 1997). An additional 20 species may also spawn on or near these reefs. Some are of substantial economic value; these include snook, pompano, and several herring species. At least 90 species known to associate with nearshore hard bottom structures are utilized in South Florida fisheries. The majority of these species are represented primarily by early life stages. Approximately fifty-one species are of recreational value and thirty species are of commercial value. Twenty-two species are utilized for bait and twenty-one species are marketed within the aquaria industry. Based on the demonstrated or potential value of these areas as nurseries and spawning sites for many economically valuable species, nearshore hard bottom habitats were estimated to support highly important ecological functions, the first criterion.

The second and third HAPC criteria, sensitivity and probability of anthropogenic stressors, are interrelated in terms of nearshore hard bottom. They are treated collectively here. Various stretches of nearshore hard bottom have been completely buried by dredging projects associated with beach management activities in this subregion (Section 4.1.2.3). They may also be subjected to indirect stressors over both short and long time scales from such projects. For example, between 1995 and 1998, up to 19 acres of nearshore hard bottom reefs were buried by beach dredging projects at two sites in Palm Beach County. A proposed project may bury an additional hard bottom in 1998 or 1999. Such activities occur within other counties of this subregion as well. The 50-year planning document for beach management in southeast mainland Florida (ACOE, 1996), includes beach dredge-fill projects for over fifteen areas, with renourishment intervals averaging 6-8 years. Given the past and projected future, it is concluded that both the sensitivity of these habitats and the probability of anthropogenic stressors is high.

In terms of the final EFH-HAPC criterion, rarity, nearshore hard bottom also ranks high. In southeast mainland Florida, most shorelines between Dade and Broward Counties (25°30'-26°20' N) lack natural nearshore hard bottom with substantial three-dimensional structure (ACOE, 1996). Although substantial stretches of nearshore hard bottom exist in portions of Palm Beach, Martin, St. Lucie, and Indian River Counties (Perkins et al., 1997) (26°20'-27°15' N) these reefs are often separated by kilometers of barren stretches of sand. Offshore, most mid-shelf areas (5-20 m) are also dominated by expanses of sand despite the variable occurrence of several mid-shelf reef lines. Therefore, there are no natural habitats in the same or adjacent near-shore areas that can support equivalent abundances of early life stages. Absences of nursery structure can logically result in increased predation and lowered growth. In newly settled and juvenile stages, such conditions could create demographic bottlenecks that ultimately result in lowered local population sizes.

Nursery usage of nearshore hard bottom reefs may be a bi-directional phenomenon. Many species utilize these habitats during both newly settled and older juvenile life stages. This suggests that nearshore hard bottom can facilitate both inshore and offshore migrations during differing ontogenetic stages of some species. Their limited availability doesn't necessarily decrease their value. When present, they may serve a primary nursery role as shelter for incoming early life stages which would undergo increased predation mortality without substantial habitat structure. In addition, some species use these structures as resident nurseries; settling, growing-out, and maturing sexually as permanent residents (e. g., pomacentrids, labrisomids). A secondary nursery role may result from increased growth because of higher food availabilities in structure-rich environments. Nearshore hard bottom may also serve as secondary nursery habitat for juveniles that emigrate out of inlets towards offshore reefs. This pattern is seen in gray snapper and bluestriped grunt which typically settle inside inlets and only use nearshore hard bottom as older juveniles (Lindeman, 1997).

In summary, nearshore hardbottom habitats of southeast Florida ranked high in terms of ecological function, sensitivity, probability of stressor introduction, and rarity. Based on the criteria in Section 600.815 (a) (9), it is concluded that they represent Essential Fish Habitat-Habitat Areas of Particular Concern for species managed under the Snapper/Grouper Fishery Management Plan and dozens of other species which co-occur with many species in this management unit.

3.2.2 Artificial/Manmade Reefs

3.2.2.1 Artificial/Manmade Reefs Defined

The National Fishing Enhancement Act of 1984 (Title II of P.L.98-623) defined artificial reefs as "...a structure which is constructed or placed in waters....for the purpose of enhancing fishery resources and commercial and recreational fisheries opportunities." Since the term "artificial reef" tends to promote a misconception that the diverse biotic communities that develop on and around these structures are totally different from those found on natural reefs or live/hard bottom areas, the term "manmade reef" might serve as a better description of these habitats. Considering the long-term nature of the majority of the artificial reefs developed in the South Atlantic Bight since the mid-1960's, possibly the only "artificial" aspect to this type of hard bottom habitat is man's choice of substrate, timing and location selected for development. For this reason, the term "manmade reef" is likely a more accurate description of the resulting habitat and surrounding biological community that results from the establishment of these "artificial" reefs.

For all purposes within this document, manmade reefs are defined as any area within marine waters in which suitable structures or materials have intentionally been placed by man for the purpose of creating, restoring or improving long-term habitat for the eventual exploitation, conservation or preservation of the resulting marine ecosystems that are naturally established on these materials. In this light, manmade reefs should be viewed primarily as fishery management tools. There is no intention to imply that manmade reefs are identical in all respects to naturally occurring hard bottom areas or coral reefs; however, in consideration of the processes that lead to their development the management of the associated living marine resources common on all types of reef communities, they are very similar.

3.2.2.1.1 Function and Ecology of New Hard Bottom Habitats

Hard bottom habitats can be formed when overlying soft sediments are transported away from an area by storms, currents or other forces. The underlying rock or hard-packed sediment which is exposed provides new primary hard substrate for the attachment and development of epibenthic assemblages (Sheer, 1945; Goldberg, 1973a; Jackson, 1976; Osmand, 1977). This substrate is colonized when marine algae and larvae of epibenthic animals successfully settle and thrive. Species composition and abundance of individuals increase quickly until all suitable primary space is used by the epibenthos. At some point, a dynamic equilibrium may be reached with the number of species and number of new recruits leveling off. Competition for space and grazing pressure become significant ecological processes in determining which epibenthic species may persist (Kirby-Smith and Ustach, 1986; Paine, 1974; Sutherland and Karlson, 1977). The reef community itself should remain intact as long as the supporting hard substrate remains and is not buried under too great an overburden of sediment.

Concurrent with the development of the epibenthic assemblage, demersal reef-dwelling finfish recruit to the new hard bottom habitat. Juvenile life stages will use this habitat for protection from predators, orientation in the water column or on the reef itself and as a feeding area. Adult life stages of demersal reef-dwelling finfish can use the habitat for protection from predation, feeding opportunities, orientation in the water column and on the reef and as spawning sites.

Pelagic planktivores occur on hard bottom habitats in high densities and use these habitats for orientation in the water column and feeding opportunities. These species provide important food resources to demersal reef-dwelling and pelagic piscivores. The pelagic piscivores use the hard bottom habitats for feeding opportunistically. Most of these species do not take up residence on individual hard bottom outcrops, but will transit through hard bottom areas and feed for varying periods of time (Sedberry and Van Dolha, 1984).

3.2.2.1.2 Function and Ecology of Manmade Reefs

Manmade reefs are deployed to change habitats from a soft substrate to a hard substrate system or to add vertical profile to low profile (< 1m.) hard substrate systems. These reefs are generally deployed to provide fisheries habitat in a specific desired location that provides some measurable benefit to humans. When manmade reefs are constructed, they provide new primary hard substrate similar in function to newly exposed hard bottom (3.2.2.1.1)(Goren, 1985). Aside from the often obvious differences in the physical characteristics and nature of the materials involved in creating a manmade reef, the ecological succession and processes involved in the establishment of the epibenthic assemblages occur in a similar fashion on natural hard substrates and man-placed hard substrates (Wendt et al., 1989). Demersal reef-dwelling finfish, pelagic planktivores and pelagic predators use natural and manmade hard substrates in very similar ways and often interchangeably (Sedberry, 1988). The changes in species composition and local abundance of important species in a specific area are often seen as the primary benefits of reef deployment activities.

As noted by researchers the physical characteristics of manmade reef habitat may result in differences in the observed behavior of fish species on or around such structures in contrast to behavior observed on equivalent areas of natural hard bottoms (Bohnsack, 1989). Some reef structures, particularly those of higher profile, seem to yield generally higher densities of managed and non-managed pelagic and demersal species than a more widely spread, lower profile, natural hard bottom or reef (Rountree, 1989). The fishery management implications of these differences must be recognized and taken into consideration when planning, developing, and managing manmade reefs as essential fish habitat.

3.2.2.1.3 Function and Ecology of Other Manmade Structures in the Marine Environment

Other manmade hard substrates in marine and estuarine systems provide habitat of varying value to fisheries resources. Coastal engineering structures such as bridges, jetties, breakwaters and shipwrecks provide significant hard substrate for epibenthic colonization and development of an associated finfish assemblage (Van Dolah, 1987). Some of these structures also provide habitat in the water column and intertidal zone which differs significantly from typical benthic reefs. The result of the different ecotones provided by these coastal structures is often higher species diversity than was present before the structure was placed on site. These structures also may provide refuge from predation as well as feeding opportunities and orientation points for juvenile and adult life stages of important finfish species in the South Atlantic region. They differ from manmade reefs as defined above, in that there is generally no direct intention in their design or placement to achieve specific fishery management objectives. However, their impacts should be considered just as any other activity which modifies habitats in the marine environment. It is important to consider that man-made structures often directly or indirectly (through mitigation) replace productive natural habitats.

Pilings vary substantially in their size, shape, and positioning. Those associated with leeward barrier island marinas are typically narrow and placed in shallow, calm water. Combinations of dock pilings and other structures can support sizeable fish assemblages (Iverson and Bannerot, 1984). Pilings associated with bridges are typically much larger, possess more cavities, and are placed in deeper, physically dynamic areas. Bridge pilings in deep channels can possess diverse and abundant ichthyofaunas. A large percentage of the fauna typical to offshore reefs can be found on these habitats, areas where such life stages would not occur under natural conditions. In South Florida, many species reach sizes on inshore bridges that are associated with maturation and have been collected in spawning condition (Lindeman, 1997). While the flat vertical surfaces of seawalls provide little structure for fish usage, many local agencies have added more complex structure in the form of bolders at the bases of seawalls to provide habitat and limit scouring of sediment. Approximately four times as many species have been recorded along seawalls sections with bolders compared to bare sections (Lindeman, 1997).

3.2.2.2 Manmade Reef Development in the South Atlantic Bight

While manmade reefs have been in use along the U.S. South Atlantic Coast since the 1800's, their development in this region was somewhat limited through the mid-1960's. From the late 1960's to the present, reef development off the South Atlantic States (as measured by the number of permitted construction sites) has increased nearly five-fold, with approximately 250 sites now permitted in the coastal and offshore waters of these four states. Roughly half of these sites are in waters off the east coast of Florida alone. Artificial reef locations are considered live/hard bottom habitat and have been included in the SEAMAP Bottom Mapping Project data base and maps presented in Appendix E. In addition, artificial reef locations and structural detail where readily available for select states is presented in Appendix Q.

The total area of ocean and estuarine bottom along the South Atlantic States which has been permitted for the development of manmade reefs at present is approximately 129,000 acres (or 155 nm^2). Due to practical limitations experienced by all artificial reef programs, it is very likely that only a very small percentage of any of these permitted reef sites has actually been developed through the addition of suitable hard substrate. However, since in most cases construction activities may continue indefinitely on these sites, the percentage of hard bottom habitat developed will continue to rise as new materials are added.

Recreational anglers remain the chief user group associated with manmade reefs in this region. Financial resources made available directly or indirectly through a large number saltwater sportfishing interests have been a prominent factor in most reef development projects. Due to favorable environmental conditions throughout most of the year along the South Atlantic States, recreational divers have also been a driving force in the establishment of many manmade reefs in recent years. This relatively new user group will continue to grow as does the popularity of this activity nationwide. While not as significant a user group across the region as the previous two, commercial fishing interests are present on some manmade reefs.

State marine resources management agencies in all four South Atlantic states are actively involved in various aspects of manmade reef planning, development and management in their own waters as well as contiguous federal waters. All four states have, or are in the process of developing, their own state artificial reef management plans. North Carolina, South Carolina and Georgia control all manmade reef development through programs within their respective natural resource management agencies, and hold all active permits for reef development. Florida's reef development efforts are carried out by individual county or municipal programs with a limited degree of oversight conducted by the Florida Department of Environmental Protection. Reef construction permits in Florida are held by state, county and municipal government agencies or programs.

3.2.2.2.1 North Carolina

The North Carolina Division of Marine Fisheries (DMF) has been involved in artificial reef construction since the early 1970's. Responding to interest generated by local fishing club reef projects, the Division began a reef construction program using bundled automobile tires. Hundreds of thousands of tires were deployed on several reefs from Cape Lookout to Brunswick County.

In 1974, three 440-foot Liberty Class ships were cleaned and sunk on reef sites off Oregon Inlet, Beaufort Inlet and Masonboro Inlet. Another Liberty ship was added to the Oregon Inlet site in 1978. These surplus vessels were obtained from the federal government under Public Law 92-402, also known as the Liberty Ship Act. Artificial reef construction continued using tires and smaller surplus vessels until 1986 when the reef program was reorganized.

During 1986 and 1987, twenty-one new reef sites were permitted by the DMF and 210 train cars were deployed on these sites. Use of tires was eliminated in the early 1980's due to stability problems. Reef construction permits which were held by various counties and clubs were transferred to the Division under a general permit issued to DMF by the U.S. Army Corps of Engineers (USACOE).

At present, the DMF maintains 46 artificial reef sites (see Appendix Q). These sites are located from one to 38 miles from shore and are strategically located near every maintained inlet along the coast. In recent years, most of the oceanic and some of the estuarine reefs have received new construction. Materials deployed since 1986 include 30 vessels, 10,000 pieces of large diameter concrete pipe, 210 train cars and over 40,000 tons of concrete pipe, bridge railings and rubble.

In addition to USACOE construction permits, aids to navigation permits are also maintained for the buoys which mark the center point of the artificial reef sites. The reef program uses a 115-foot landing craft for deploying and maintaining buoys, as well as for small construction projects.

Prior to 1990, emphasis was placed on artificial reef construction. With funding provided by the Federal Aid in Sportfish Restoration Program, the reef program has started a monitoring program to evaluate the effectiveness of reef materials, to test designed materials and to monitor fish assemblages on the reef. Aerial surveys are conducted to assess artificial reef usage along the coast and surveys of king mackerel tournament entrants are used to measure reef use, awareness and catch rates.

The DMF maintains one of the most active artificial reef programs in the nation. Adequate state funding and enthusiastic support from many civic and fishing clubs along the coast continues to ensure the success of North Carolina's artificial reef program.

3.2.2.2.2 South Carolina

The use of manmade structures to enhance fishing activities in South Carolina's coastal waters was first documented during the mid-1800's. During the mid-1960's the construction of offshore and coastal artificial reefs for the benefit of saltwater recreational anglers was carried out by numerous private organizations. In 1967 the state provided funding for its first manmade reef construction project, and in 1973 an on-going state-sponsored marine artificial reef program was established. This program is currently maintained by the Marine Resources Division of the South Carolina Department of Natural Resources (SCDNR) within the Division's Office of Fisheries Management Funding for the program consists of state support through the SCDNR budget, federal support through grants from the U.S. Fish and Wildlife Service-managed Sport Fish Restoration Program, and additional support at the state level through the South Carolina Marine Recreational Fisheries Stamp.

The primary focus of the South Carolina Marine Artificial Reef Program (SCMARP) is the coordination and oversight of all activities within the state of South Carolina concerning the management of a viable system of marine artificial reefs in both state and contiguous federal waters. The primary goal of these manmade reefs is the enhancement of hard bottom marine habitats, associated fish stocks and resulting recreational fishing activities that take place on and around them. The SCMARP's responsibilities include reef planning, design, permitting, construction, monitoring, evaluation, research and marking. The program also plays a key role in interfacing with the public in areas related to general fisheries management issues as well as in providing specific reef-related information to user groups.

All manmade reef development and management in South Carolina is guided by the South Carolina Marine Artificial Reef Management Plan, adopted in 1991. As of January 1998, the state's system of marine artificial reefs consisted of 43 permitted sites (12 inside state waters) along approximately 160 miles of coastline. These sites range in location from estuarine creeks to as far as 32 miles offshore. Each manmade reef site consists of a permitted area ranging from several thousand square yards to as much as one square mile. Approximately seven square miles of coastal and open ocean bottom has been permitted, of which less than two percent has actually been developed through the addition of manmade reef substrate.

Saltwater recreational anglers are the primary group associated with marine artificial reef utilization in South Carolina. Their annual fishing activities on manmade reef sites alone account for tens-of-thousands of angler-days, which result in an estimated total economic benefit to the state of over 20 million dollars each year. While some use of permitted artificial reefs by commercial fishing interests has been reported over the past three decades, this activity has been difficult to quantify since these practices do not have popular support with the majority of the fishing public, or may in some cases be illegal. Recreational divers comprise the second most common user group relying on the presence of marine artificial reefs. While sport divers have traditionally not been as large a user group as the saltwater recreational fishing community, significant expansion of the recreational diving industry in the state has resulted in a noticeable increase in this type of usage over the past two decades.

In an attempt to better manage the use of permitted manmade reefs in offshore waters and to ensure their long-term viability, the SCDNR has, through the South Atlantic Fishery Management Council, obtained or applied for Special Management Zone (SMZ) status for 29 of the 31 permitted reef sites located in federal waters. Fishing on those reef sites granted SMZ status is restricted to hand-held hook and line gear and spearfishing (without powerheads). While none exist at the moment, the SCDNR is exploring the feasibility and possible benefits of establishing no-take manmade reefs in nearshore and offshore waters solely for the purpose of stock and habitat enhancement. For additional information refer to Appendix Q and http://water.dnr.state.sc.us/marine/pub/seascience/artreef.html.

3.2.2.2.3 Georgia

The continental shelf off Georgia slopes gradually eastward for 80 miles before reaching the Gulf Stream and the continental slope. This broad, shallow shelf consists primarily of dynamic sand/shell expanses that do not provide the firm foundation or structure needed for the development of reef fish communities, which include popular gamefish such as grouper, snapper, amberjack, and sea bass. Less than 5% of Georgia's adjacent shelf consists of natural reefs (a.k.a., "live bottoms," "hard bottoms"), with most of these located more than 40 miles offshore.

Early artificial reef development efforts off Georgia were initiated by private clubs, who realized that wrecks and similar structures would create enhanced fishing and diving opportunities closer to shore. These sporadic efforts were limited and largely ineffectual. In the late 1960's, the Georgia Department of Natural Resources (GADNR) began experimenting with artificial reef construction in its estuarine waters. These activities were soon expanded in the early 1970's to the state's adjacent federal waters in order to provide increased, more safely accessible opportunities to offshore anglers and recreational divers. Secondary use materials, otherwise known as "materials of opportunity," were primarily used, consisting of tire units, scrap vessels, concrete/steel rubble, culvert, and surplused military vehicles. To date, the state program has constructed 15 artificial reefs from 5-23 miles offshore, as well as 11 estuarine reefs. Most of the offshore artificial reefs and all of the estuarine reefs are buoyed or marked.

Continued expansion of the existing manmade reefs is planned, including the construction of additional offshore and inshore reef sites. Both secondary use and designed materials are currently being used by the program, with an increasing focus on fisheries habitat development. A state artificial reef management plan is expected to be finalized in 1998.

Georgia's artificial reef program is housed within the Marine Fisheries Section of GADNR's Coastal Resources Division. Ongoing artificial reef development and maintenance activities are primarily funded through the Federal Aid in Sport Fish Restoration Program, better known as the Dingell-Johnson/Wallop-Breaux program. Other than in-kind match provided through salaries, direct state funding to date has been sporadic.

Offshore development activities are authorized under a Regional Permit issued to GADNR by the U.S. Army Corps of Engineers, while estuarine development efforts are permitted individually by the Corps of Engineers and the state of Georgia. All buoys and markers are permitted through the United States Coast Guard. Many of Georgia's offshore artificial reefs are also designated Special Management Zones (SMZs), where gear is limited to traditional recreational hook-and-line and spearfishing gear (including powerheads).

Anglers constitute the largest user group on Georgia's offshore and estuarine artificial reefs. Recreational diving at the reefs is limited and primarily restricted to the artificial reefs found well offshore due to improved water visibilities and since these reefs feature the larger wrecks popular with divers. No firm determination has been made regarding the overall contribution of the state's artificial reefs to coastal economies, although rough estimations have suggested a $3-5 million impact annually.

3.2.2.2.4 Florida (East Coast)

Florida leads the nation in the number of public manmade fishing reefs developed. The first permitted artificial reef off Florida was constructed in 1918. Manmade reefs are found in waters ranging from eight feet to over 200 feet with an average depth of 70 feet. No fewer than 595 deployments of manmade reef materials off the Florida East Coast are on record with the Florida Department of Environmental Protection (FDEP). Over the last 40 years the state reef program has experienced a gradual transition in construction materials use, funding sources, and recognition of the importance of measuring effectiveness.

The State's involvement in funding manmade reef construction began in the mid-1960's when the Florida Board of Conservation awarded a limited number of grants to local governments to fund reef development projects. In 1971 a Florida Recreational Development Assistance Program grant was awarded to a local government by the DNR Division of Recreation and Parks for reef construction. Between 1976 and 1980 the DNR Division of Marine Resources received, and oversaw the preparation and placement of five Liberty ships, secured as a result of passage of the Liberty Ship Act, which facilitated the release of obsolete troop and cargo ships for use as artificial reefs.

1978 marked the beginning of a systematic state artificial reef program. The Division of Marine Resources received a large grant from the Coastal Plains Regional Commission for artificial reef development. Rules for disbursing these funds were developed, defining a grants-in-aid program with projects selected through a competitive evaluation of local government proposals. In 1979 the State Legislature appropriated general revenue funds for reef construction which continued on an annual basis, with the exception of one year, through 1990. In 1982, in addition to receiving general revenue funds, the program was officially established as a grants-in-aid program by law (s. 370.25, Florida Statutes). One staff position was assigned responsibility for program administration.

The rapid proliferation of publicly funded artificial reefs in Florida beginning in the mid 1980's is the result of increased levels of federal, state and local government funding for artificial reef development. Prior to that, other state funding sources intermittently provided reef development assistance. In 1966 there were seven permitted artificial reef sites off Florida in the Atlantic Ocean. By 1987, this number had grown to 112. Consistent federal funding for Florida's reef program became available in 1986 as a result of the Wallop-Breaux amendment to the 1950 Federal Aid in Sport Fish Restoration Act (Dingle-Johnson) . During the decade of reef-building activity from 1986-1996, Sport Fish Restoration Funds provided almost three million dollars to complete 164 Florida reef projects.

In January 1990, Florida instituted a saltwater fishing license program. About 5% of the revenue from the sale of over 850,000 fishing licenses annually became available for additional artificial reef projects. Two additional personnel were hired into the state artificial reef program to assist with coordination, information sharing, grant monitoring/compliance and diving assessment of artificial reefs. Saltwater license funds available for reef development have been approximately $300,000 for the past three years. Other revenue sources used for artificial reef projects are variable, however, currently these revenues cumulatively exceed the total annual state/federally funded artificial reef development grant program project budget of $600,000.

Florida is the only southeastern Atlantic coastal state active in artificial reef development which does not have a direct state-managed artificial reef program. For the last 20 years, Florida's artificial reef program has been a cooperative local and state government effort, with additional input provided by non-governmental fishing and diving interests. The state program's primary objective has been to provide grants-in-aid to local coastal governments for the purpose of developing artificial fishing reefs in state and adjacent federal waters off both coasts in order to locally increase sport fishing resources and enhance sport fishing opportunities. All but three active permitted reef sites are held by individual coastal counties or cities.

Reef management expertise at the local government level is variable. Reef programs are found in solid waste management, public works, natural resources, recreation and parks, administrative, and planning departments. Local government reef coordinators range from biologists and marine engineers to city clerks, grants coordinators, planners, and even unpaid volunteers. Reef management and coordination are generally collateral duties for most local government reef coordinators.

Long range systematic planning and general reef management at the local government levels have lagged behind the rate of reef construction in Florida. Site specific projects are planned but the broader areas of program evaluation and actual management have not received much attention. A "State Artificial Reef Development Plan" was drafted in 1992 but there are currently few formal county level or regional artificial reef management plans which tie in with this plan or the National Artificial Reef Plan.

Due to its abundance of coastline, ideal conditions, and large number of academic and research-oriented institutions, a significant quantity of the existing body of field research dealing with manmade reefs has been conducted in waters off Florida. Artificial reef research projects undertaken with over a million dollars in state funding since 1990 have included studies on reef spacing and design, material stability and storm impact studies, long term studies of reef community succession, residency of gag grouper on patch reefs through tagging and radio telemetry, juvenile recruitment to reefs, and impacts of directed fishing.

As with most other artificial reef programs in the U.S., there has been a shift in the types of materials used in the construction of manmade reefs in Florida waters over the past 35 years. Through experience, reef builders have learned which materials work best in providing effective long-lived manmade reefs. Modern construction practices have evolved to a point where reef programs are much more selective in the types of materials they use.

Concrete materials, chiefly culverts and other prefabricated steel reinforced concrete, were the primary reef material in nearly 52% of the 480 public reef deployments in waters off Florida over the past 16 years. Engineered artificial reef units are a small but growing component of the state's manmade reef development efforts. During the last five years no fewer than five prefabricated concrete artificial reef designs have been utilized in 67 publicly funded reef deployments. Most, but not all, units designed specifically for use as artificial reefs have proven to be stable in major storm events. Future requirements for engineering evaluation of modules prior to deployment will be required. Prefabricated units designed specifically for use as manmade reefs have focused on improving upon habitat complexity, stability, and durability, as well as providing a standard design for research and monitoring projects.

Secondary use materials such as obsolete oil platforms and steel vessels have also been used off Florida in the development of manmade reefs. Forty-six percent of the 595 Florida east coast artificial fishing reef structures are sunken vessels. These reefs have catered to fishermen fishing for pelagic species, and a rapidly expanding resident and tourist diving population. The majority of vessels sunk as manmade reefs are concentrated off Dade, Palm Beach, and Broward Counties.

Florida has had a long and diverse history of manmade reef development. Over the last 40 years there has been a shift in emphasis on use of any available material of opportunity which would serve as a three dimensional fish attractor without regard to the longevity or ultimate fate of the material, to emphasis on non- polluting, durable, and storm resistant structures with a life expectancy of at least twenty years. A shift has also taken place during the last two decades from non-governmental control of reef development to cooperative state/county/private partnerships where local governments assume responsibility and manage the permitted reef sites.

3.2.2.3 Manmade Reef Construction Practices

Manmade reefs have been built from a wide variety of materials over the years. As has been the case in almost all artificial reef development activity in the U.S. throughout the present century, most construction materials relied upon in the South Atlantic States have been forms of scrap or surplus; some more suitable for this purpose than others. While many of these materials have been the construction resource of necessity rather than solely of choice, it has become evident in recent years that a total reliance upon scrap or surplus materials for continued reef development activities in most coastal states may not be entirely practical if reef development goals are to be realized and a desirable degree of quality control achieved.

In an effort to decrease dependency of successful reef development on the availability of scrap or surplus materials, and to improve the overall effectiveness and safety of manmade reefs, most artificial reef programs have designed, manufactured and/or evaluated a number of specifically engineered reef habitat structures which may become a more viable option for future reef development projects. Due primarily to improved financial support for most artificial reef programs in the South Atlantic States and a willingness within private industry to develop new and affordable designed reef structures, the use of such reef construction material is now much more feasible.

Whether specifically designed or secondary use materials are utilized to construct manmade reefs, individual state resource management agencies should be able to define particular materials that are deemed acceptable for use as reef structures in their coastal and adjacent offshore waters. The decision to allow or disallow the use of certain materials should be based on existing state and federal regulations and guidelines, as well as any soundly based policies established by a particular state. Materials should only be considered for use if they possess characteristics which allow them to safely meet the established objectives for the manmade reef project under consideration, and present no real risk to the environment in which they are being placed. The document entitled “Guidelines for Marine Artificial Reef Materials,” published by the Gulf States Marine Fisheries Commission, provides detailed information of the experiences, benefits, and drawbacks of past uses of a variety of materials by state resource management agencies. This, as well as other related documents, and the collective experiences of individual artificial reef programs, may be relied upon as the best available data in making decisions regarding the use of certain types of materials in manmade reef development.

3.2.2.3.1 Secondary Use Materials

Most manmade reefs in existence along the South Atlantic States have been constructed from a variety of forms of scrap or surplus materials. Due to their secondary use nature and unpredictable availability, most of these materials can be classified as "secondary use materials" (a.k.a.: "materials of opportunity"). Although past artificial reef development in most states has been directly tied to the availability of these materials due to budgetary constraints, this may not be the most desirable situation for continued planning and development of reef construction efforts in the future. While a total dependency on scrap and surplus materials is not the most effective means of managing reef development activities, some secondary use materials, when available in the proper condition, are very desirable in carrying out manmade reef construction projects and should continue to be utilized to enhance fisheries habitat.

In some cases naturally occurring materials such as quarry rock, limestone, or even shell have been utilized to construct manmade reefs. While these are not by definition scrap materials, their availability is sometimes dictated by a desire to move them from an existing site where for some reason they may no longer be desired. In these cases, they could be classified as a material of opportunity. In other cases, as in the intent to build a reef to provide a rocky bottom substrate, material such as quarry rock or limestone may be the most suitable material available to create the intended habitat, and may be specifically sought after.

In the South Atlantic States individual state artificial reef programs, resource management agencies, or other approved reef programs serve as the central contact and coordination point for evaluating, approving, distributing and deploying secondary use materials on a given state's system of artificial reefs. Before agreeing to approve any materials for use in reef construction, the managing or oversight agency must carefully inspect the items and ensure that they are environmentally safe, structurally and physically stable, needed, practical, and can be deployed in a cost-effective and safe manner. A detailed discussion of the benefits, limitations and problems encountered in using the almost limitless list of secondary use materials that have been employed over the years in the construction of manmade reefs is well beyond the scope of this document. However, both the Atlantic and Gulf State Marine Fisheries Commissions, as well as other individual artificial reef programs have produced publications which cover in great detail, many of the strengths and weaknesses of secondary use materials which have been employed in reef development.

3.2.2.3.2 Designed Habitat Structures

A total reliance on the availability of suitable secondary use materials in attempting to develop a productive system of artificial reefs presents several problems. If an artificial reef program is to function in a manner that is conducive to effective long-term planning and the pursuit of realistic (fishery management driven) reef development goals, it can not continue to base reef construction solely on the unpredictable availability and diminished quantity of acceptable scrap or surplus materials. The only practical solution is to consider the incorporation of manufactured reef structures into planned reef development activities.

Manufactured manmade reef structures can be developed which possess the characteristics desired of a reef substrate for a specific environment, application, or end result. Although the initial costs in procuring these reef materials may be higher than those involved in obtaining many secondary use materials, the transportation, handling and deployment costs are typically about the same, and the lack of expense in having to clean or otherwise prepare these structures can often balance out this difference completely. Being able to engineer into a reef material design specific qualities of stability, durability, structural integrity, transportability and biological effectiveness also gives manufactured reef structures a great advantage over most secondary use materials which are often severely limited in how they can be modified or deployed.

Manufactured reef units can be deployed in any quantity, profile and pattern required, allowing them to provide for maximum efficiency of the materials used in achieving the desired results. Secondary use materials such as ships must be deployed in a single unit, often with a great deal of the total material volume being taken up in vertical profile. The same volume of designed reef materials that would be found in a vessel can be spread over a much larger area of ocean bottom with much less relief, allowing for better access to a larger number of reef users and a “more natural” appearance in the layout of the reef.

One of the most significant advantages offered by the use of designed reef structures is the ability to procure them in any quantity any time they are needed. This allows reef managers to plan ahead and make the best possible use of available funding, as well as predict exact costs needed to accomplish specific reef construction objectives from month to month or year to year. When depending on secondary use materials for reef development, this type of short and long-term planning is rarely available.

3.2.2.3.3 Standards for Manmade Reef Construction

The National Fishing Enhancement Act of 1984 (Title II of P.L.98-623) provides broad standards for the development of manmade reefs in the United States. The purpose of the Act was to “promote and facilitate responsible and effective efforts to establish artificial reefs in the navigable waters of the US and waters superjacent to the outer continental shelf (as defined in 43 USC, Section 1331) to the extent such waters exist in or are adjacent to any State.” In Section 203, the Act establishes the following standards for artificial reef development. "Based on the best scientific information available, artificial reefs in waters covered under the Act...shall be sited and constructed, and subsequently monitored and managed in a manner which will:

(1) enhance fishery resources to the maximum extent practicable;
(2) facilitate access and utilization by US recreational and commercial fishermen;
(3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters;
(4) minimize environmental risks and risks to personal health and property; and
(5) be consistent with generally accepted principles of international law and shall not create any unreasonable obstruction to navigation."

Section 204 of the Act also calls for the development of a National Artificial Reef Plan consistent with these standards. This plan was published by the National Marine Fisheries Service in 1985 and includes discussions of criteria for siting and constructing manmade reefs, as well as mechanisms and methodologies for monitoring and managing such reefs. While the Plan itself lacked any degree of regulatory authority, adopted regulations subsequently developed by the U.S. Army Corps of Engineers for dealing with the issuance of artificial reef construction permits were based on the standards set forth in the Act as well as wording taken from the Plan. The Plan is in the process of being reviewed and revised by the NMFS with significant input being provided by existing state artificial reef programs.

Each state artificial reef program has its own set of standards for the development and management of artificial reefs. In most cases these state standards were developed with the federal standards from the National Fisheries Enhancement Act and the National Artificial Reef Plan in mind. While specific state programs may differ in matters involving technical operation or specific management issues, they are all very similar in their adoption of the national standards that exist.

3.2.2.4 Manmade Reefs in Marine Resource Management

Although manmade reefs may be classified as potentially powerful fishery management tools, it is safe to say at this point that their full potential in this capacity has yet to be realized. This is due in part to a past frequent disassociation between some reef developers and resource management agencies tasked with ensuring the long-term viability of the resources commonly affected by the establishment of additional hard bottom habitat. While this situation has been greatly improved in recent years through the establishment of state artificial reef programs, most of which are now operated by state resource management agencies, the primary limitation to maximizing benefits from manmade reefs has been their singular mode of use. Traditionally in most coastal states, manmade reefs have chiefly been relied upon for one primary purpose - the enhancement of marine recreational fishing activities.

In the past, little thought may have been given to the quantity, quality and degree of long-term success of hard bottom habitat and associated reef communities derived through the establishment of manmade reefs. The primary obtainable measure of success in most reef projects up to this point has been the direct benefit they provide to anglers, the fishing industry and the economy of a given locale. While these are certainly very valid and important benefits achievable through reef development, there are perhaps other benefits which could be realized through the establishment of manmade reefs given a change in focus on the desired end results of reef habitat development efforts.

Not all manmade structures that have been placed in U.S. waters can necessarily be considered essential or even effective fish habitat. In the earlier years of artificial reef construction efforts in this country, poor planning, vague objectives, a lack of experience and basic information resulted in ineffective, and sometimes detrimental reef construction projects being carried out. As with marine resource management in general, technology, expertise and an associated understanding of what works well and what doesn't in developing useful reef habitat, have progressed significantly since that time. Based on the maturing process that the field of manmade habitat development has experienced over the past three decades, the potential uses of these resource management tools should be fully explored. The challenge facing manmade reef development programs today is how best to utilize this technology to most effectively assist in achieving state, regional and national marine resources management goals.

3.2.2.4.1 Fisheries Enhancement

The proper placement of manmade materials in the marine environment can provide for the development of a healthy reef ecosystem, including intensive invertebrate communities and fish assemblages of interest to both recreational and commercial fishermen. The degree of effectiveness of a manmade reef in the enhancement of these harvesting activities varies, dictated by geographical location, species targeted, stock health, and design and construction of the reef. An examination of both the historical and present use of manmade reefs along each of the South Atlantic States reveals a common link to fisheries enhancement as the primary reason for, and benefit from, the establishment of these sites. Manmade reefs have developed an impressive track-record of providing positive results, as measured by harvesting success for a wide range of finfish species. To date, manmade reefs have been chiefly employed to create specific, reliable and more accessible opportunities for primarily recreational anglers. While they have been used to a lesser extent to enhance commercial fishing efforts, this may be due in part to the much smaller size of manmade reefs compared to larger, traditionally relied-upon, naturally occurring “commercial fishing grounds”.

In their present scale and typical design, most manmade reefs, while well-suited for use by recreational anglers, would be unable to withstand intensive commercial fishing pressure, especially for many of the popularly sought-after demersal finfish species, for more than a short period of time. Difficulties experienced in using current commercial gear types and methodologies on and around manmade reef structures may also prove less cost effective than desired. Profit-driven operations would also be less likely to invest in creating a resource which would be open to public use. This, combined with the fact that most manmade reef programs at present receive the majority of their habitat development funding through sources tied directly to recreational fishing interests, make it doubtful that exclusively commercial, or even commercial-scale manmade reefs are likely to be developed in the near future in this country.

3.2.2.4.1.1 Special Management Zones

Conceptualized by the South Atlantic Fisheries Management Council, within the Snapper/Grouper Management Plan, several "Special Management Zones" or "SMZs" have been established in the South Atlantic off South Carolina, Georgia, and Florida to provide gear and harvest regulations for defined locations. The basic premise of this concept is to reduce user conflicts through gear and harvest regulations at locations that feature limited resources that are managed for specific user groups. Generally, manmade reefs have been developed for recreational use utilizing recreational resources. The ability to regulate gear types utilized over the relatively limited area of a manmade reef enables fisheries managers to prevent rapid overfishing of these sites and promote a more even allocation of reef resources and opportunities.

Present SMZ regulations apply to about 30 manmade reef sites off South Atlantic States, with several more proposed. Since regulations concerning the management of SMZs are tied to specific gear restrictions, it is possible that the use of SMZs in the future could be expanded to a point where any possible type of fishing gear could be restricted for a set period of time or indefinitely. This could provide fishery managers with the ability to turn individual manmade reef sites “on or off” as the specific needs of the fishery in question dictate. The ability to have some degree of control over fishing activities on these sites would give manmade reefs more power as a true fishery management tool.

3.2.2.4.1.2 Stock Enhancement Potential

Manmade reefs are known to promote extensive invertebrate communities and enhance habitat for reef fish and other fish species, including cryptic, tropical, and gamefish species, as well as many of commercial or recreational significance. The success of a reef and its contributions to stock enhancement varies geographically, and is determined by a wide range of complex parameters, including existing habitat, physical limitations, material design, reef configuration, reef management, and the health of the targeted species complex, which in turn is reliant on effective fisheries management locally, regionally, and nationally. As evidenced by multi-billion dollar reef development efforts in Japan, an even greater potential for stock enhancement in U.S. waters exists. This potential is further enhanced since domestic reef programs today possess better information and improved technology and are more focused in using this tool towards specific stock enhancement and fishery management needs.

For species which may be to some degree habitat-limited, the establishment of additional suitable habitat targeted to specific life-history stages may improve survival. Additional manmade habitat designed specifically to promote survival of targeted species in "protected" areas could potentially enhance existing ecosystems or create new ones to fill in gaps where essential fish habitat had been damaged, lost, or severely over-fished. Man-made structures also may provide essential habitat while simultaneously acting as a deterrent to illegal fishing practices in specially managed areas (e.g. Florida Oculina Banks).

3.2.2.4.2 Hard Bottom Habitat Enhancement

Habitat enhancement through the construction of manmade reefs can be achieved by converting some other type bottom habitat into a hard bottom community. Mud, sand, shell or other relatively soft bottom habitat can be altered by the addition of hard structure with low to high profile to add to the total amount of hard bottom reef environment in a given area. While it would be difficult and particularly costly to construct man made reefs with an equivalent area of most typical hard bottom found off the Southeastern U.S., substantial areas of ocean bottom can be effectively converted to hard bottom over time given sufficient planning, proper design and adequate resources.

In areas where existing hard bottom habitat is limited spatially, temporally, or structurally, manmade structures may be used to augment what is already in place. Hard bottom with or without a thin veneer of sediment constitutes a preferred substrate for this type of manmade reef development, as opposed to sand and mud bottoms; however, deployment of structures in already productive areas carries a certain degree of risk. Existing hard bottom may be directly damaged or impacted by modified current regimes, movement of materials and potentially increased user pressure. Although sparse, the hard bottom may constitute valuable juvenile habitat and refugia that may be severely compromised by creating additional habitat conducive to predators. On the other hand, a properly planned manmade reef could be constructed without impact to existing resources by utilizing stable materials that are designed to enhance juvenile habitat and survival.

In cases where critical hard bottom habitat is damaged or lost due to natural forces such as severe storms or burial, the addition of manmade reef material could be used to compensate for this loss on site or in adjacent areas. Manmade reef structures can also be used to repair damaged habitat or mitigate for its loss in cases where stable, hard substrate placed on the bottom would provide the closest in-kind replacement as possible, or at least provide the long-term base for the eventual re-establishment of the hard bottom reef community that was originally impacted.

3.2.2.4.3 Manmade Marine Reserves / Sanctuaries

Marine reserves and sanctuaries are a proven management technique that has been implemented successfully worldwide to protect essential fisheries habitat and sustain fisheries stocks and genetic variability. Although the concept of marine reserves / sanctuaries has gained some support in the southeastern United States, the actual application of this management measure has generated resistance among user groups who feel that the establishment of such reserves will adversely impact fishing opportunities by limiting access to existing habitat. For areas with little fisheries habitat, these impacts are viewed as significant.

The potential role that manmade reefs could play in implementing marine reserves and similar management measures remains largely unexplored at present. It is conceivable that effective marine reserves / sanctuaries consisting of manmade structures could be developed in habitat-limited areas to assist specifically in such roles as habitat and stock enhancement. Detailed research needed to measure their effectiveness in these roles is needed. Substantial resources and funds would also be required to develop the large reserve areas proposed, although smaller sanctuaries are entirely feasible. Manmade structures could be utilized to enhance existing marine reserve areas by improving existing habitat or providing additional hard bottom substrate. Manmade reef reserves / sanctuaries could also be used as test platforms to demonstrate to the public the potential effectiveness of such areas, without impacting existing fisheries practices on sites in a given area.

At this time, perhaps the most important contribution that manmade reef technology can provide for fisheries management efforts employing marine reserves / sanctuaries would be to create additional habitat and fisheries to "compensate" user groups for perceived "losses". Coupled with positive effects of adjacent marine reserves, properly sited, more accessible artificial reefs would increase benefits to user groups.

3.2.2.4.4 Enhancement of Eco-Tourism Activities

Along with other eco-tourism activities, recreational diving is one of the fastest growing sports in the United States. Properly planned, manmade reefs can be designed to encourage diving and to reduce spatial conflicts with other user groups, including fishermen. Specific SMZ or other regulations established for a manmade reef could conceivably allow non-consumptive uses only, including diving, underwater photography, snorkeling, and other eco-tourism activities. Recently, designed units were deployed off a Mexican resort to enhance existing reef areas that were viewed via submarine excursions. Materials selected could be designed and deployed to create specific fisheries habitat for tropical, cryptic, and other species targeted by non-consumptive users.

The establishment of additional hard bottom reef communities in areas with thriving dive-related industries could be used to reduce diving-related pressures on existing natural reefs, especially in the case of sensitive coral reefs in the Florida Keys. Finally, a non-consumptive reef would essentially constitute a sanctuary, providing fisheries and the associated habitat with de facto protection.

As with natural reefs, much remains unknown regarding the ecology and functions of manmade reef communities. On the other hand, the use of manmade reefs in management of user groups in fisheries is better known, although this potential has not been fully explored. To date, manmade reefs have been employed to create specific, more accessible opportunities for fishermen and divers, as well as to disperse and redirect pressure from overfished natural habitat.

3.2.2.5 Current Manmade Reef Management Practices

Manmade reefs can be an effective tool used in the management of marine fishery resources if properly developed, maintained and managed. With specific, realistic and measurable objectives in mind, the creation of essential hard bottom habitat can be achieved to benefit a variety of end uses for fisheries managers at federal, regional and state levels. Specific management strategies will depend on the objective(s) of the reef and compliance with existing management or regulating mechanisms, such as regulations mandated as part of the permitting process or the need to conform with existing State, Interstate Marine Fisheries Commission (IMFC), or Regional Fishery Management Council (FMC) fishery management plans (FMPs).

The roles of all parties involved in manmade reef management are found in the National Artificial Reef Management Plan. Since these roles have evolved somewhat since 1985, the current revision of this plan being considered by the NMFS contains the most detailed and up-to-date description of the state of reef management in the U.S. The U.S. Army Corps of Engineers has formalized their specific involvement in manmade reef management through regulations promulgated pursuant to the National Fisheries Enhancement Act of 1984 (33CFR, Parts 320-330). Involvement on a state level varies, with all coastal states in the South Atlantic Region having some degree of control or oversight of artificial reef development in their waters and adjacent Federal waters. All four of these states participate in regional communication and coordination concerning essential manmade reef management activities through the Atlantic States Marine Fisheries Commission. The general consensus of state reef program managers is that manmade reefs are fisheries management tools, and as such, their use constitutes a fisheries issue which must be addressed accordingly.

3.2.2.5.1 Federal Role

The primary Federal role in manmade reef management has been to provide technical assistance, guidance, and regulations for the proper use of artificial reefs by local governments and the private sector in a manner compatible with other long-term needs, and to improve coordination and communication on manmade reef issues between the Federal agencies, States, Regional Fishery Management Councils, Interstate Marine Fisheries Commissions, commercial and recreational fishing industries and interests, diving communities and other interested parties. Generally, the Federal role is carried out by the permit process, and by providing guidelines, services, information, financial aid, and in-kind support, as well as some regulatory functions regarding fishing practices on specially designated artificial reefs (e.g., “Special Management Zone” designation in the South Atlantic Fishery Management Councils’ Snapper/Grouper Fishery Management Plan). See Appendix Q for the locations of designated SMZs.

The Federal Government has been involved in manmade reef activities for several decades, both in research and development sponsored by individual agencies as programs and budgets permitted, and in reviewing and commenting on reef permit applications. There is, however, no overall Federally coordinated program to guide artificial reef activities except through permit review, implementation of regulations, and recommendations in the Plan of 1985. The President's Proclamation of an Exclusive Economic Zone (EEZ) on March 10, 1983 declared a National (Federal) interest in living and non-living resources found within 200 nautical miles from shore. In addition, the National Recreational Fisheries Conservation Plan of 1996 developed pursuant to Executive Order 12962 - Recreational Fisheries, directs specific Federal activities to utilize artificial reefs in implementation of a national recreational fisheries resources conservation plan. The Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Fisheries Act) (P.L. 103-206) of 1993, finds that: “...increasing pressure, environmental pollution, and the loss and alteration of habitat have reduced severely, certain Atlantic coastal fishery resources...and...it is the responsibility of the Federal Government to support...cooperative interstate management of coastal fisheries. Increased use of fisheries resources are expected in the EEZ, and there undoubtedly will be more interest in the use of manmade reefs to enhance these resources and the habitats essential to their proliferation.

Five Federal entities -- the US Departments of the Interior (DOI), Commerce (DOC), Defense (DOD), and Transportation (DOT), and the Environmental Protection Agency (EPA) -- have varying degrees of interest in, and responsibility for, manmade reefs. Detailed discussions of the roles they each play in manmade reef management are found in the National Artificial Reef Management Plan.

3.2.2.5.2 State Role

State resource managers in the South Atlantic Region recognize that manmade reef development involves long-term, if not permanent, alteration of bottom habitat. As such, possible effects on natural resources and the environment must be carefully considered in assessing whether or not to use this management tool in working to achieve specific fishery management-related objectives. Since implementation of the National Artificial Reef Plan of 1985, state resource management agencies in the Southeast Atlantic Region have been active in a variety of roles pertaining to the use of manmade reefs. These include acquiring permits, maintaining liability, financing, constructing, and monitoring marine manmade reefs through state supported programs. Other involvement has ranged from completion of reef construction projects as part of an agency's efforts to improve a specific fishery, to an agency's review and support for other organizations' reef building programs.

State artificial reef programs have adopted state-specific plans based on guidance of the National Artificial Reef Plan of 1985, and tailored to their local regulations, requirements, policies, procedures, and objectives. In effect, the states have been responsible for implementing the National Plan and collecting information necessary for updating guidance in the plan, and for strengthening provisions of the National Fishing Enhancement Act of 1984. There is general consensus among state fishery resource management agencies that manmade reef projects must be considered with fishery management issues in mind.

Species and fisheries associated with manmade reefs typically have been predominant in federal waters. As more of these species become subject to Interstate Marine Fisheries Commission FMP regulations, it is important that state reef programs become more closely linked organizationally with state fishery management programs. In order to achieve the greatest benefits from manmade reefs, it is imperative that appropriate State agencies continue to play a major role in the development of national and site-specific guidelines for their use. The states have utilized the tools given them in a responsible and innovative manner to validate methodologies in reef research on such topics as construction and siting, fishery management, regulatory requirements, and reef biology (including production and aggregation issues). Such validation is essential for effective use of marine artificial reefs in fishery management planning, restoration or development of essential fish habitat, and to demonstrate innovative alternatives for which manmade reef structures can be useful.

3.2.2.5.3 Regional Activities

The Artificial Reef Technical Committee (ATC) of the Atlantic States Marine Fisheries Commission (ASMFC), of which all four South Atlantic states are active members, meets periodically to exchange information and to coordinate activities relevant to common areas of interest. The role of the ATC is to provide an open forum for discussion and debate on issues facing state artificial reef program managers, respective federal agencies, and affected fisheries interests. The committee is composed of the coordinators of the state marine artificial reef programs within the state agencies responsible for marine and coastal resources management. Committee membership also includes representatives from the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the Environmental Protection Agency, and the Regional Fisheries Management Councils. The committee provides critical advice to the ASMFC relative to development of marine manmade reefs, and has served to increase responsiveness and efficiency of coastal reef programs.

Joint committee meetings with the sister-ATC from the Gulf States Marine Fisheries Commission have also served to consolidate individual state efforts along the Gulf and Atlantic Coasts, thus assisting in implementation of key elements of the National Fishing Enhancement Act. Both committees have worked cooperatively to identify and resolve national issues such as standardized criteria for materials used to build artificial reefs. The joint committee forum also has assisted member states in development and implementation of individual state plans and policies responsive to local, regional, and national needs. Coordination of state efforts through the interstate marine fisheries commissions has facilitated a dynamic and positive evolution of national artificial reef efforts. The cooperative efforts of state reef developers have progressed beyond a focus on solely creating access to fisheries utilizing materials of opportunity.

Generally, in marine waters beyond the territorial limit, the South Atlantic Fishery Management Council (SAFMC) determines management strategies for resources or users through specific fishery management plans. Coastal fishery resources which migrate between state, and often federal, jurisdictions may also be regulated through interstate FMPs developed and implemented by the respective Interstate Marine Fisheries Commissions (e.g. as under the Atlantic Coastal Fisheries Cooperative Management Act). Therefore, FMCs and IMFCs should be have an active interest in the development of manmade reefs. These entities also have requirements in their FMPs to designate certain habitat as essential to the management of the species covered under a specific FMP. These entities are a major source of information about the fisheries resources and can help identify areas of potential conflicts or areas of concern in Federal waters, and can identify issues of compatibility of a proposed reef project with management objectives for the effected fisheries. Manmade reefs designated as SMZs offer reef mangers much more flexibility to effectively utilize reefs as fishery management tools by providing a degree of regulatory control which otherwise would not exist. Reefs can be planned, designed and developed with specific management objectives in mind (e.g. stock enhancement of a group of fish species in a particular environment) and be supported by the regulatory language for an SMZ. SMZs or similar regulatory measures allow manmade reefs to be used as non-traditional fishery management tools.

3.2.2.6 Use of Manmade Reefs by Managed Species

Earlier sections have discussed the ways in which manmade reefs are specifically used by both invertebrate and finfish species (3.2.2.1.2, 3.2.2.4.1.2, 3.2.2.4.2). Since manmade reefs are established by marine resource managers throughout the entire South Atlantic Bight, the diversity of species present on and around such structures is extremely wide. Manmade reefs are used in almost every possible marine environment, from shallow-water estuarine creeks to offshore sites up to several hundred feet in depth. Due to the broad distribution of reef sites along the South Atlantic Coastal States, many different species may interact with manmade reefs at different live-stages and at different times.

Since the majority of the manmade reefs constructed along the Southeastern U.S. are in coastal and offshore waters, the species most often present on these sites are predominantly the adult and/or sub-adult stages of virtually all species within the South Atlantic Snapper-Grouper Complex, as well as all species managed within the Coastal Migratory Pelagics. Depending on environmental conditions on a specific reef site, and the behavior patterns of certain fish, species within the Snapper-Grouper group tend to be long to short-term reef residents, while those among the Coastal Pelagics tend to be more transient visitors to the reefs as they migrate up and down the coast. Red drum and spiny lobster, as well as some of the managed shrimp species, may be found on and around specific reef sites at different times of the year, depending on the exact location and design of the reef. While some species of managed corals may occur on reef structures as far north as the Carolina's, the waters off South Florida are the predominant site where such species are found attached to manmade substrate.

3.2.3 Pelagic Habitat

3.2.3.1 Sargassum Habitat

3.2.3.1.1 Description of Sargassum Habitat

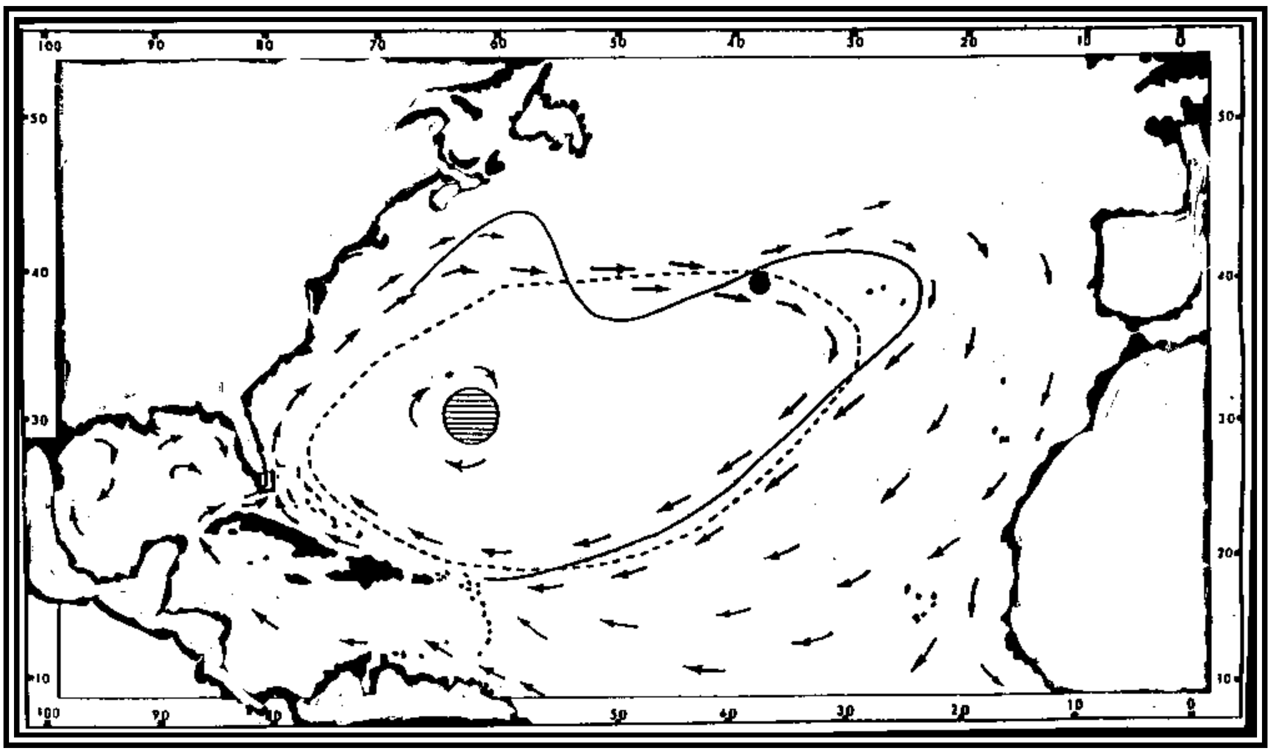
Within warm waters of the western North Atlantic, pelagic brown algae *Sargassum natans* and *S. fluitans* (Phaeophyta: Phaeophyceae: Fucales: Sargassaceae) form a dynamic structural habitat. These holopelagic species are believed to have evolved from benthic ancestors at least 40 million years ago. Evidence supporting this contention include: 1) lack of sexual reproduction characteristic of benthic species, 2) absence of a basal holdfast, 3) endemic faunal elements (10 invertebrates and 2 vertebrates), 4) greater buoyancy than benthic forms, and 5) late Eocene to early Miocene fossil remains from the Carpathian basin of the Tethys Sea (Winge, 1923; Parr, 1939; Friedrich, 1969; Butler et al., 1983; Stoner and Greening, 1984, Luning, 1990). *Sargassum natans* is much more abundant than *S. fluitans*, comprising up to 90% of the total drift macroalgae in the Sargasso Sea. Limited quantities of several benthic species, including *S. filipendula*, *S. hystrix, S. polycertium, S. platycarpum* and *S. pteropleuron*, detached from coastal areas during storms, are also frequently encountered adrift. However, the drifting fragments of these benthic species soon perish (Hoyt, 1918; Winge, 1923; Parr, 1939; Butler et al., 1983).

The pelagic species are golden to brownish in color and typically 20 to 80 cm in diameter. Both species are sterile and propagation is by vegetative fragmentation. The plants exhibit complex branching of the thallus, a lush foliage of lancolate to linear serrate phylloids and numerous berry-like pneumatocysts. Perhaps the most conspicuous features are the pneumatocysts. These small vesicles function as floats and keep the plants positively buoyant. Gas within these bladders is predominately oxygen with limited amounts of nitrogen and carbon dioxide. The volume of oxygen within the pneumatocysts fluctuates diurnally in response, not to diurnal cycles of photosynthesis, but to changes in the partial pressure of oxygen in the surrounding medium (Woodcock, 1950; Hurka, 1971). There are generally a large number of pneumatocysts on a healthy plant: up to 80 % of the bladders can be removed and the plants will remain positively buoyant (Zaitsev, 1971). Under calm sea states the algae are at the surface with less than 0.3% of their total mass exposed above the air - water interface. Experiments indicate that an exposure to dry air of 7-10 min. will kill phylloids, whereas, pneumatocysts and thallomes can tolerate exposures of 20-30 min. and 40 min., respectively. Wetting of exposed parts with seawater at 1 min. intervals, however, is enough to prevent tissue damage (Zaitsev, 1971). In nature, such stress is likely encountered only during the calmest seas or when the algae is cast ashore. Illustrations and descriptions of *S. natans* and *S. fluitans* are given in Hoyt (1918), Winge (1923), Parr (1939), Taylor (1960), Prescott (1968), Humm (1979), Littler et al. (1989) and Schneider and Searles (1991).

Most pelagic *Sargassum* circulates between 20°N and 40°N latitudes and 30°W longitude and the western edge of the Florida Current/Gulf Stream (Figure 10a). The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea (Winge, 1923; Parr, 1939; Ryther, 1956; Dooley, 1972; Butler et al., 1983; Butler and Stoner, 1984; Nierman et al., 1986). Total biomass is unknown, but, estimates obtained from net tows range from 800 - 2000 kg wet weight km^{-2}. Within the Sargasso Sea, this translates into a standing crop of 4 to 11 million metric tons (Parr, 1939; Zaitzev, 1971; Peres, 1982; Butler et al., 1983; Butler and Stoner, 1984; Nierman et al., 1986; Luning, 1990). Stoner (1983) suggested that there had been a significant decline in biomass this century, but later recanted (Butler and Stoner, 1984). Nierman et al. (1986) also calculated that no apparent decline had occurred.

Pelagic *Sargassum* contributes a small fraction to total primary production in the North Atlantic, however, within the oligotrophic waters of the Sargasso Sea, it may constitute as much as 60 % of total production in the upper meter of the water column (Howard and Menzies, 1969; Carpenter and Cox, 1974; Hanson, 1977; Peres, 1982). Estimates of production are typically around 1 mgC m^{-2} d^{-1} with slightly higher values reported from more nutrient rich shelf waters. Production has been shown to double under conditions of nitrogen and phosphorus enrichment (Lapointe, 1986; 1995). Hanisak and Samuel (1984) found *Sargassum* to have low nitrogen and phosphorus requirements, and optimal growth at water temperatures of 24 - 30° C and salinity of 36 ppt. Nitrogen fixation by epiphytic cyanobacteria of the genera *Dichothrix, Trichodesmium,* and *Synechococcus* may enhance production (Carpenter 1972; Carpenter and Cox, 1974; Phlips and Zeman, 1990; Spiller and Shanmugam, 1987). Photosynthesis in both *Sargassum* and the blue-green epiphytes is not inhibited at high light intensities (Hanisak ans Samuel, 1984; Phlips et al., 1986): not surprising in view of the neustonic niche they occupy.

Large quantities of *Sargassum* frequently occur on the continental shelf off the southeastern United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore (Hoyt, 1918; Humm, 1951; Howard and Menzies, 1969; Carr and Meylen, 1980; Winston, 1982; Haney, 1986; Baugh, 1991). During calm conditions *Sargassum* may form large irregular mats or simply be scattered in small clumps. Langmuir circulations, internal waves, and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows collectively termed "windrows" (Winge, 1923; Langmuir, 1938; Ewing, 1950, Faller and Woodcock, 1964; Stommel, 1965; Barstow, 1983; Shanks, 1988; Kingsford, 1990). The algae sinks in these convergence zones when downwelling velocities exceed 4.5 cm sec^{-1}. Buoyancy is not lost unless the algae sink below about 100 m or are held under at lesser depths for extended periods (Woodcock, 1950). A time-at-depth relationship exists which affects the critical depth at which bladder failure ensues (Johnson and Richardson, 1977). If buoyancy is lost, plants slowly sink to the sea floor. Schoener and Rowe (1970) indicate that sinking algae can reach 5000 m in about 2 days. Such sinking events contribute to the flux of carbon and other nutrients from the surface to the benthos (Schoener and Rowe, 1970; Pestana, 1985; Fabry and Deuser, 1991). However, the flux of *Sargassum* to the sea floor has not been quantified and there is no information on the fate of this surface export.



Solid line refers to the outer boundary of regular occurrence; dashed line refers to the area in which there is a> 5% probability of encounter within 1° square; hatched circle represents possible center of distribution

Figure 10a. Distribution of pelagic Sargassum in the Northwest Atlantic. (Source: From Dooley 1972).

3.2.3.1.2 Utilization of Sargassum Habitat

Pelagic *Sargassum* supports a diverse assemblage of marine organisms including fungi (Winge, 1923; Kohlmeyer, 1971), micro-and macro-epiphytes (Carpenter, 1970; Carpenter and Cox, 1974; Mogelberg et al., 1983), at least 145 species of invertebrates (Winge, 1923; Parr, 1939; Adams, 1960; Yeatman, 1962; Weis, 1968; Friedrich, 1969; Fine, 1970; Dooley, 1972; Morris and Mogelberg, 1973; Ryland, 1974; Teal and Teal, 1975; Peres, 1982; Butler et al., 1983; Deason, 1983; Andres and John, 1984; Stoner and Greening, 1984; Morgan et al., 1985;

Nierman, 1986; see Table 1 in Coston-Clements et al., 1991), over 100 species of fishes (Table 1), four species of sea turtles (Smith, 1968; Fletemeyer, 1978; Carr and Meylan, 1980; Redfoot et al., 1985; Ross, 1985; Carr, 1986; 1987a; 1987b; Schwartz, 1988; 1989; Witham, 1988; Manzella and Williams, 1991; Richardson and McGillivary, 1991), and numerous marine birds (Haney, 1986). Many of the organisms most closely associated with *Sargassum* have evolved adaptive coloration or mimic the algae in appearance (Crawford and Powers, 1953; Adams, 1960; Teal and Teal, 1975; Gorelova and Fedoryako, 1986; Hacker and Madin, 1991).

The fishes associated with pelagic *Sargassum* in the western North Atlantic have been studied by a number of investigators (Adams, 1960; Parin, 1970; Zaitzev, 1971; Dooley, 1972; Bortone et al., 1977; Fedoryako, 1980, 1989; Gorelova and Fedoryako, 1986; Settle, 1993; Moser et al., in press). Similar research has also addressed the ichthyofauna of drift algae in the Pacific (Uchida and Shojima, 1958; Besednov, 1960; Hirosaki, 1960b; Shojima and Ueki, 1964; Anraku and Azeta, 1965; Kingsford and Choat, 1985; Kingsford and Milicich, 1987; Nakata et al., 1988). In all cases, juvenile fishes were numerically dominant. Sampling designs and gear avoidance have no doubt contributed to the poorly described adult fish fauna. However, studies by Gibbs and Collette (1959), Beardsley (1967), Parin (1970), Manooch and Hogarth (1983), Manooch and Mason (1983), Manooch et al. (1984; 1985), and Fedoryako (1989) clearly indicate that large pelagic adult fishes utilize *Sargassum* resources. This becomes even more evident when one observes the efforts of fishermen targeting "weedlines".

Many of the fishes found in association with *Sargassum* are not restricted to that habitat and are known to frequent various types of drift material and fish aggregating devices (Besednov, 1960; Mansueti, 1963; Hunter and Mitchell, 1967; Kojima, 1966; Kulczycki et al., 1981; Lenanton et al., 1982; Robertson, 1982; Nakata et al., 1988; Fedoryako, 1989; Rountree, 1989; 1990). Protection, feeding opportunity, cleaning, shade, structural affinity, visual reference, tactile stimulation, historical accident, passive drift and use as a spawning substrate have all been postulated as reasons for such associations (Hirosaki, 1960a; Hunter and Mitchell, 1968; Senta, 1966a; 1966b; 1966c; Dooley, 1972; Helfman, 1981).

The surface residence time, season and geographic location of *Sargassum* affect the species composition and abundance of fishes associated with it. Most of the young fishes that associate with the algae are surface forms (Fahay, 1975; Powles and Stender, 1976) and it is not known if they remain near the alga when it is submerged. Recruitment of fishes to drift algae and flotsam is initially rapid and continues to increase over time (Senta, 1966a; Hunter and Mitchell; 1968; Kingsford and Choat, 1985; Kingsford, 1992). The abundance of larval and juvenile fishes varies seasonally and regionally, both in terms of numbers of fish and fish biomass (Dooley, 1972; Settle, 1993). The invertebrate fauna is similarly variable (Weis, 1968; Fine, 1970; Stoner and Greening, 1984). Regional trends in the mean abundance and biomass of young fish show decrease in abundance across the continental shelf and into the Gulf Stream and Sargasso Sea, and a decrease from spring through winter (Settle, 1993). Species richness is generally highest on the outer shelf during spring and summer and further offshore during the fall and winter. Overall, diversity is greatest in offshore waters (Bortone et al., 1977; Fedoryako, 1980; 1989; Settle, 1993).

The types of *Sargassum* habitats (e.g., individual clumps, small patches, large rafts, weedlines) and the "age" (i.e., growth stage and degree of epibiont colonization) also affects the distribution and abundance of associated fishes. Ida et al.(1967b), Fedoryako (1980), Gorelova and Fedoryako (1986) and Moser et al. (in press) described the spatial distribution of fishes in and around clumps and rafts of *Sargassum*. Juvenile *Diodon, Coryphaena, Lobotes* and the exocoetids occupy the outer periphery, whereas *Canthidermis, Balistes, Kyphosus, Abudefduf,* *Caranx* and *Seriola* are distributed below the algae. Other species such as *Histrio* and *Syngnathus* are typically hidden within the foliage. Larger juveniles and adults occupy nearby waters out to several 10's of meters from the patches. With regard to algal age, Conover and Sieburth (1964) and Sieburth and Conover (1965) suggest that the community could be significantly controlled by the effects of exogenous metabolites on algal epibionts. These substances, which are released during periods of new algal growth, inhibits epibiotic colonization, and could alter the trophic resources available to associated macrofauna, including fish (Gorelova and Fedoryako, 1986). Stoner and Greening (1984) concluded that algal age did affect the macrofaunal composition, but the abundance of carnivores remained stable. However, since their study dealt primarily with the invertebrate fauna, the effects of these substances on other trophic links remains unknown, although similar compounds are known to deter some herbivores (Paul, 1987; Hay and Fenical, 1988; Hay et al., 1988; Steinberg, 1988).

Fish abundance has been found to be positively correlated with *Sargassum* biomass. Correlations were significant over the middle shelf throughout the year. Fish biomass was also positively correlated over the outer shelf during the fall (Settle, 1993). No correlation was observed in the Gulf Stream or Sargasso Sea (Dooley, 1972; Fedoryako, 1980; Settle, 1993). The abundance of motile macrofauna (mostly invertebrates) has also been shown to be related to *Sargassum* biomass (Stoner and Greening, 1984).

There have been well over 100 species of fishes collected or observed associated with the *Sargassum* habitat (Table 17). The carangids and balistids are the most conspicuous, being represented by 21 and 15 species respectively. The planehead filefish, *Monacanthus hispidus*, is clearly the most abundant species in shelf waters off the southeastern U.S. and in the Gulf of Mexico (Dooley, 1972; Bortone et al., 1977; Settle, 1993; Moser et al., in press).

A number of species have direct fisheries value although not all of them are common. However, the seasonal abundances of *Caranx* spp., *Elagatis bipinnulata*, *Seriola* spp., *Coryphaena hippurus*, *Pagrus pagrus*, *Mugil* spp., *Peprilus triacanthus*, and *Balistes capriscus* illustrates the importance of the habitat to the early-life-stages of these species.

The relationships between of a number of fishes and the *Sargassum* habitat remains problematic. The muraenids, gonostomatids, myctophids, apogonids, serranids, gerreids, scarids, lutjanids, chaetodontids, acanthurids, istiophorids, scorpaenids, bothids and several other taxa have been collected in limited numbers. It is likely that many of these fishes are found in convergence zones even in the absence of *Sargassum.*

3.2.3.1.3 Measuring Sargassum Distribution and Abundance

Our current understanding of the seasonal distribution and areal abundance (i.e. biomass per unit area) of pelagic *Sargassum* within the EEZ is poor. Gross estimates of the standing stock for the North Atlantic obtained from towed net samples are highly variable and range between 4 and 11 million metric tons. There is a clear need to improve our understanding of the distribution and abundance of this important habitat. Remote technology could aid to that end. Satellite-based Synthetic Aperture Radar (SAR) offers potential for assessing the distribution of large aggregations over broad swaths of the ocean surface. Coincident ship-based ground-truthing would permit an evaluation of the applicability of routine remote measurements of *Sargassum* distribution and abundance.

Table 17. List of fishes collected or observed in association with pelagic *Sargassum* in the North Atlantic Ocean including the Gulf of Mexico and Caribbean Sea. Life-stages are E=egg, L=larva, J=juvenile and A=adult. Nomenclature follows Robins et al. (1991) (Source: NMFS 1997).

Family Genus and species	Common name	Life-stage(s)
Carcharhinidae	requiem sharks	
Carcharhinus falciformis	silky shark	A
C. limbatus	blacktip shark	A
C. longimanus	oceanic whitetip shark	A
Muraenidae	morays	
Unidentified	moray	L
Clupeidae	herrings	
Sardinella aurita	Spanish sardine	J
Gonostomatidae	lightfishes	
Unidentified	lightfish	L
Myctophidae	lanternfishes	
Unidentified	lanternfish	L
Gadidae	cods	
Urophycis chuss	red hake	L, J
U. earlli	Carolina hake	L, J
U. floridana	southern hake	L, J
U. regia	spotted hake	L, J
Antennariidae	frogfishes	
Histrio histrio	sargassumfish	L, J, A
Exocoetidae	flyingfishes	
Cypselurus furcatus	spotfin flyingfish	E, L, J, A
C. melanurus	Atlantic flyingfish	E, L, J, A
Exocoetus obtusirostris	oceanic two-wing flyingfish	J
Hemirhamphus balao	balao	J
H. brasiliensis	ballyhoo	J
Hirundichthys affinis	fourwing flyingfish	E, L, J, A
Hyporhamphus unifasciatus	silverstripe halfbeak	L, J
Paraexocoetus brachypterus	sailfin flyingfish	E, L, J, A
Prognichthys gibbifrons	bluntnose flyingfish	E, L, J, A
Belonidae	needlefishes	
Tylosurus acus	agujon	L, J
Fistulariidae	cornetfishes	
Fistularia tabacaria	bluespotted cornetfish	J
Centriscidae	snipefishes	
Macroramphosus scolopax	longspine snipefish	J
Syngnathidae	pipefishes	
Hippocampus erectus	lined seahorse	J
H. reidi	longsnout seahorse	J
Microphis brachurus	opossum pipefish	J
Syngnathus caribbaeus	Caribbean pipefish	J
S. floridae	dusky pipefish	J
S. fuscus	northern pipefish	J
S. louisianae	chain pipefish	J
S. pelagicus	sargassum pipefish	E, L, J, A
S. scovelli	gulf pipefish	J
S. springeri	bull pipefish	J

Table 17.(cont.) List of fishes collected or observed in association with pelagic *Sargassum* in the North Atlantic Ocean including the Gulf of Mexico and Caribbean Sea.

Family Genus and species	Common name	Life-stage(s)
Dactylopteridae	flying gurnards	
Dactylopterus volitans	flying gurnard	L, J
Scorpaenidae	scorpionfishes	
Unidentified	scorpionfish	L
Serranidae	sea basses	
Epinephelus inermis	marbled grouper	J
Priacanthidae	bigeyes	
Priacanthus arenatus	bigeye	J
Pristigenys alta	short bigeye	L, J
Apogonidae	cardinalfishes	
Apogon maculatus	flamefish	L
Pomatomidae	bluefish	
Pomatomus saltatrix	bluefish	L
Rachycentridae	cobias	
Rachycentron canadum	cobia	E, L, J, A
Echeneidae	remoras	
Phtheirichthys lineatus	slender suckerfish	J
Carangidae	jacks	
Caranx bartholomaei	yellow jack	L, J
C. crysos	blue runner	L, J
C. dentex	white trevally	J
C. hippos	crevalle jack	J
C. latus	horse-eye jack	J
C. ruber	bar jack	L, J
Chloroscombrus chrysurus	Atlantic bumper	L, J
Decapterus macerellus	mackerek scad	J
D. punctatus	round scad	J
D. tabl	redtail scad	J
Elagatis bipinnulata	rainbow runner	L, J, A
Naucrates ductor	pilotfish	J
Selar crumenophthalmus	bigeye scad	L, J
Selene vomer	lookdown	J
Seriola dumerili	greater amberjack	L, J
S. fasciata	lesser amberjack	J
S. rivoliana	almaco jack	L, J, A
S. zonata	banded rudderfish	J
Trachinotus falcatus	permit	L, J
T. goodei	palometa	J
Trachurus lathami	rough scad	L, J
Coryphaenidae	dophins	
Coryphaena equisetis	pompano dolphin	L, J, A
C. hippurus	dolphin	L, J, A
Lutjanidae	snappers	
Lutjanus sp.	snapper	L
Rhomboplites aurorubens	vermillion snapper	L, J
Lobotidae	tripletails	
Lobotes surinamensis	tripletail	L, J, A
Gerreidae	mojarras	
Eucinostomus sp.	mojarra	L

Table 17.(cont.) List of fishes collected or observed in association with pelagic *Sargassum* in the North Atlantic Ocean including the Gulf of Mexico and Caribbean Sea.

Family Genus and species	Common name	Life-stage(s)
Sparidae	porgies	
Pagrus pagrus	red porgy	L, J
Mullidae	goatfishes	
Mullus auratus	red goatfish	L, J
Unidentified	goatfish	L
Kyphosidae	sea chubs	
Kyphosus incisor	yellow chub	L, J
K. sectatrix	Bermuda chub	L, J
Chaetodontidae	butterflyfishes	
Chaetodon ocellatus	spotfin butterflyfish	J
C. striatus	banded butterflyfish	J
Pomacentridae	damselfishes	
Abudefduf saxatilis	sergeant major	L, J
Mugilidae	mullets	
Mugil cephalus	striped mullet	L
M. curema	white mullet	L
Sphyraenidae	barracudas	
Sphyraena barracuda	great barracuda	A
S. borealis	northern sennet	L, J
Polynemidae	threadfins	
Polydactylus virginicus	barbu	J
Labridae	wrasses	
Bodianus pulchellus	spotfin hogfish	J
Thalassoma bifasciatum	bluehead	J
Scaridae	parrotfishes	
Unidentified	parrotfish	L
Uranoscopidae	stargazers	
Unidentified	stargazer	L
Blenniidae	combtooth blennies	
Hypsoblennius hentzi	feather blenny	L
Parablennius marmoreus	seaweed blenny	L
Gobiidae	gobies	
Microgobius sp.	goby	L
Acanthuridae	surgeonfishes	
Acanthurus randalli	gulf surgeonfish	J
Acanthurus sp.	surgeonfish	L
Trichiuridae	snake mackerels	
Unidentified	snake mackerel	L
Scombridae	mackerels	
Acanthocybium solandri	wahoo	J, A
Auxis thazard	frigate mackerel	J, A
Euthynnus alletteratus	little tunny	A
Katsuwonus pelamis	skipjack tuna	A
Scomber japonicus	chub mackerel	J
Scomberomorus cavalla	king mackerel	A
Thunnus albacares	yellowfin tuna	J, A
T. atlanticus	blackfin tuna	A
Xiphiidae	swordfishes	
Xiphius gladius	swordfish	L, J

Table 17.(cont.) List of fishes collected or observed in association with pelagic *Sargassum* in the North Atlantic Ocean including the Gulf of Mexico and Caribbean Sea.

Family Genus and species	Common name	Life-stage(s)
Istiophoidae	billfishes	
Istiophorus platypterus	sailfish	L, J
Makaira nigricans	blue marlin	L, J, A
Tetrapturus albidus	white marlin	L, J, A
Stromateidae	butterfishes	
Ariomma sp.	driftfish	L
Centrolophus sp.	ruff	J
Cubiceps pauciradiatus	bigeye cigarfish	J
Hyperoglyphe bythites	black driftfish	J
H. perciformis	barrelfish	J
Peprilus triacanthus	butterfish	L, J
Psenes cyanophrys	freckled driftfish	J
Bothidae	lefteye flounders	
Bothus sp.	flounder	L
Cyclopsetta fimbriata	spotfin flounder	L
Balistidae	leatherjackets	
Aluterus heudeloti	dotterel filefish	L, J
A. monoceros	unicorn filefish	L, J
A. schoepfi	orange filefish	L, J
A. scriptus	scrawled filefish	L, J
Balistes capriscus	gray triggerfish	J, A
B. vetula	queen triggerfish	J
Cantherhines macrocerus	whitespotted filefish	J
C. pullus	orangespotted filefish	J, A
Canthidermis maculata	rough triggerfish	J
C. sufflamen	ocean triggerfish	J
Monacanthus ciliatus	fringed filefish	J
M. hispidus	planehead filefish	J
M. setifer	pygmy filefish	J
M. tuckeri	slender filefish	J
Xanthichthys ringens	sargassum triggerfish	J
Ostraciidae	boxfishes	
Lactophrys sp.	cowfish	L
Tetraodontidae	puffers	
Chilomycterus antennatus	bridled burrfish	J
C. schoepfi	striped burrfish	J
Diodon holocanthus	ballonfish	J
D. hystrix	porcupinefish	J
Sphoeroides maculatus	northern puffer	L
S. spengleri	bandtail puffer	L
Unidentified	puffer	L
Molidae	molas	
Mola sp.	mola	J

3.2.3.2 Water Column

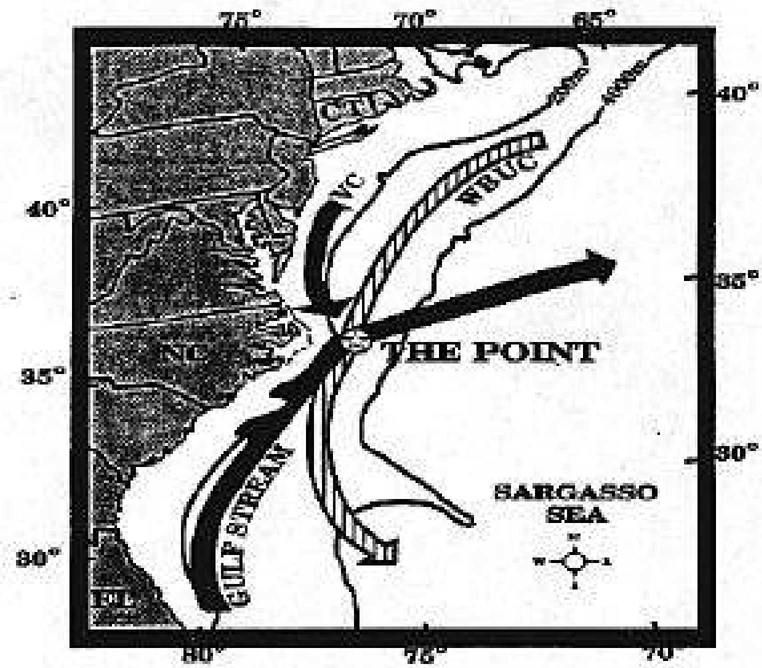
3.2.3.2.1 Description of Water Column Habitats

Specific habitats in the water column can best be defined in terms of gradients and discontinuities in temperature, salinity, density, nutrients, light, etc. These 'structural' components of the water column environment (*sensu* Peters and Cross, 1992) are not static, but change both in time and space. Therefore, there are numerous potentially distinct water column habitats for a broad array of species and life-stages within species.

The continental shelf off the southeastern U.S., extending from the Dry Tortugas to Cape Hatteras, encompasses an area in excess of 100,000 km^2 (Menzel, 1993). Based on physical oceanography and geomorphology, this environment can divided into two regions: Dry Tortugas to Cape Canaveral and Cape Canaveral to Cape Hatteras. The break between these two regions is not precise and ranges from West Palm Beach to the Florida-Georgia border depending on the specific data considered. The shelf from the Dry Tortugas to Miami is ~25 km wide and narrows to approximately 5 km off Palm Beach. The shelf then broadens to approximately 120 km off of Georgia and South Carolina before narrowing to 30 km off Cape Hatteras. The Florida Current/Gulf Stream flows along the shelf edge throughout the region. In the southern region, this boundary current dominants the physics of the entire shelf (Lee et al., 1992; 1994). In the northern region, additional physical processes are important and the shelf environment can be subdivided into three oceanographic zones (Atkinson et al., 1985; Menzel, 1993). The outer shelf (40-75 m) is influenced primarily by the Gulf Stream and secondarily by winds and tides. On the mid-shelf (20-40 m), the water column is almost equally affected by the Gulf Stream, winds and tides. Inner shelf waters (0-20 m) are influenced by freshwater runoff, winds, tides and bottom friction.

Several water masses are present in the region. From the Dry Tortugas to Cape Canaveral, the three water types are: Florida Current Water (FCW), waters originating in Florida Bay, and shelf water. Shelf waters off the Florida Keys are an admixture of FCW and waters from Florida Bay. From Cape Canaveral to Cape Hatteras, four water masses are found: Gulf Stream Water (GSW), Carolina Capes Water (CCW), Georgia Water (GW) and Virginia Coastal Water (VCW). Virginia Coastal Water enters the region from north of Cape Hatteras. Carolina Capes Water and GW are admixtures of freshwater runoff and GSW (Pietrafesa et al., 1985;1994).

Spatial and temporal variation in the position of the western boundary current has dramatic affects on water column habitats. Variation in the path of the Florida Current near the Dry Tortugas, induces formation of the Tortugas Gyre (Lee et al., 1992; 1994). This cyclonic eddy has horizontal dimensions on the order of 100 km and may persist in the vicinity of the Florida Keys for several months. The Pourtales Gyre, which has been found to the east, is formed when the Tortugas Gyres moves eastward along the shelf. Upwelling occurs in the center of these gyres, thereby adding nutrients to the near surface (<100 m) water column. Wind and input of Florida Bay water also influence the water column structure on the shelf off the Florida Keys (Smith, 1994; Wang et al., 1994). Similarly, further downstream, the Gulf Stream encounters the Charleston Bump, a topographic rise on the upper Blake Ridge. Here the current is often deflected offshore, again resulting in the formation a cold, quasi-permanent cyclonic gyre and associated upwelling (Brooks and Bane, 1978). Along the entire length of the Florida Current and Gulf Stream, cold cyclonic eddies are imbedded in meanders along the western front. Three areas of eddy amplification are known: Downstream of Dry Tortugas, downstream of Jupiter Inlet (27°N to 30°N latitude), downstream of the Charleston Bump (32°N to 34°N latitude). Meanders propagate northward (i.e. downstream) as waves. The crests and troughs represent the onshore and offshore positions of the Gulf Stream front. Cross-shelf amplitudes of these waves are on the order 10 to 100 km. Upwelling within meander troughs is the dominant source of 'new' nutrients to the southeastern U.S. shelf and supports primary, secondary and ultimately fisheries production (Yoder, 1985; Menzel 1993). Off Cape Hatteras the Gulf Stream turns offshore to the northeast. Here, the confluence of the Gulf Stream, the Western Boundary Under Current (WBUC), Mid-Atlantic Shelf Water (MASW), Slope Sea Water (SSW) , CCW and VCW create a dynamic and highly productive environment, known as the "Hatteras Corner" or "The Point".



A.
WATER MASSES
OFF CAPE HATTERAS

On the continental shelf, offshore projecting shoals at Cape Fear, Cape Lookout and Cape Hatteras affect longshore coastal currents and interact with Gulf Stream intrusions to produce local upwelling (Blanton et al., 1981; Janowitz and Pietrafesa, 1982). Shoreward of the Gulf Stream, seasonal horizontal temperature and salinity gradients define the mid-shelf and inner-shelf fronts. In coastal waters, river discharge and estuarine tidal plumes contribute to the water column structure.

3.2.3.2.2 Use of Water Column Habitats

Coastal waters off the southeastern U.S. are split into two zoogeographic provinces based on shore fishes and continental shelf invertebrate species. The Caribbean Province includes the Florida Keys and extends northward to approximately the Florida-Georgia border, but its northern boundary is not sharp. The Carolinian Province extends from this border, northwards to Cape Hatteras (Briggs 1974). A similar faunal break is evident in mesopelagic fish fauna. The boundary between the North Sargasso Sea Province and the South Sargasso Sea Province occurs approximately parallel with Jupiter Inlet, Florida (Backus et al. 1977).

The water column from Dry Tortugas to Cape Hatteras serves as habitat for many marine fish and shellfish. Most marine fish and shellfish broadcast spawn pelagic eggs and thus, most species utilize the water column during some portion of their early life history (e.g. egg, larvae, juvenile stages). Larvae of shrimp, lobsters, crabs, and larvae of reef, demersal and pelagic fishes are found in the water column (e.g. Fahay, 1975; Powels and Stender, 1976; Leis, 1991; Yeung and McGowan 1991, Criales and McGowan 1994). Problems with species-level identifications prohibits an exact accounting of the number of fishes whose larvae inhabit the water column, but the number of families represented in ichthyoplankton collections ranges from 40 to 91 depending on location, season and sampling method (Table 18a).

Table 18a. Summary of the number of larval fish families identified from studies conducted off the southeastern coast of the United States. .

Location	**Season**	**No. Families**	**Study**
Florida Keys	Sp	91	Limouzy-Paris et al. (1994)
Cape Canaveral to Cape Lookout	W	48/60[1]	Powles and Stender (1976)
Cape Canaveral to Cape Lookout	Sp	49/56[1]	Powles and Stender (1976)
Cape Canaveral to Cape Lookout	F	40/55[1]	Powles and Stender (1976)
Cape Fear to Cape Lookout	W	74	Govoni and Spach (submitted)
Cape Fear to Cape Lookout	W	66	Powell and Robbins (1994)
Palm Beach to Cape Lookout	Sp-W	51	Fahay (1975)

1 - bongo / neuston data

There are large number of fishes that inhabit the water column as adults. Pelagic fishes in the region include numerous clupeoids, exocoetids, carangids, *Rachycentron*, *Pomatomus*, coryphaenids, sphyraenids and the scombroids (Schwartz, 1989). Some pelagic species are associated with particular benthic habitats (e.g. *Seriola*, *Sphyraena*), while other species are truly pelagic (e.g. *Thunnus*, *Makaira*). Adult meso- and bathypelagic species inhabit the water column in the Gulf Stream (Figure 10b) and adjacent Sargasso Sea (Backus et al. 1977).

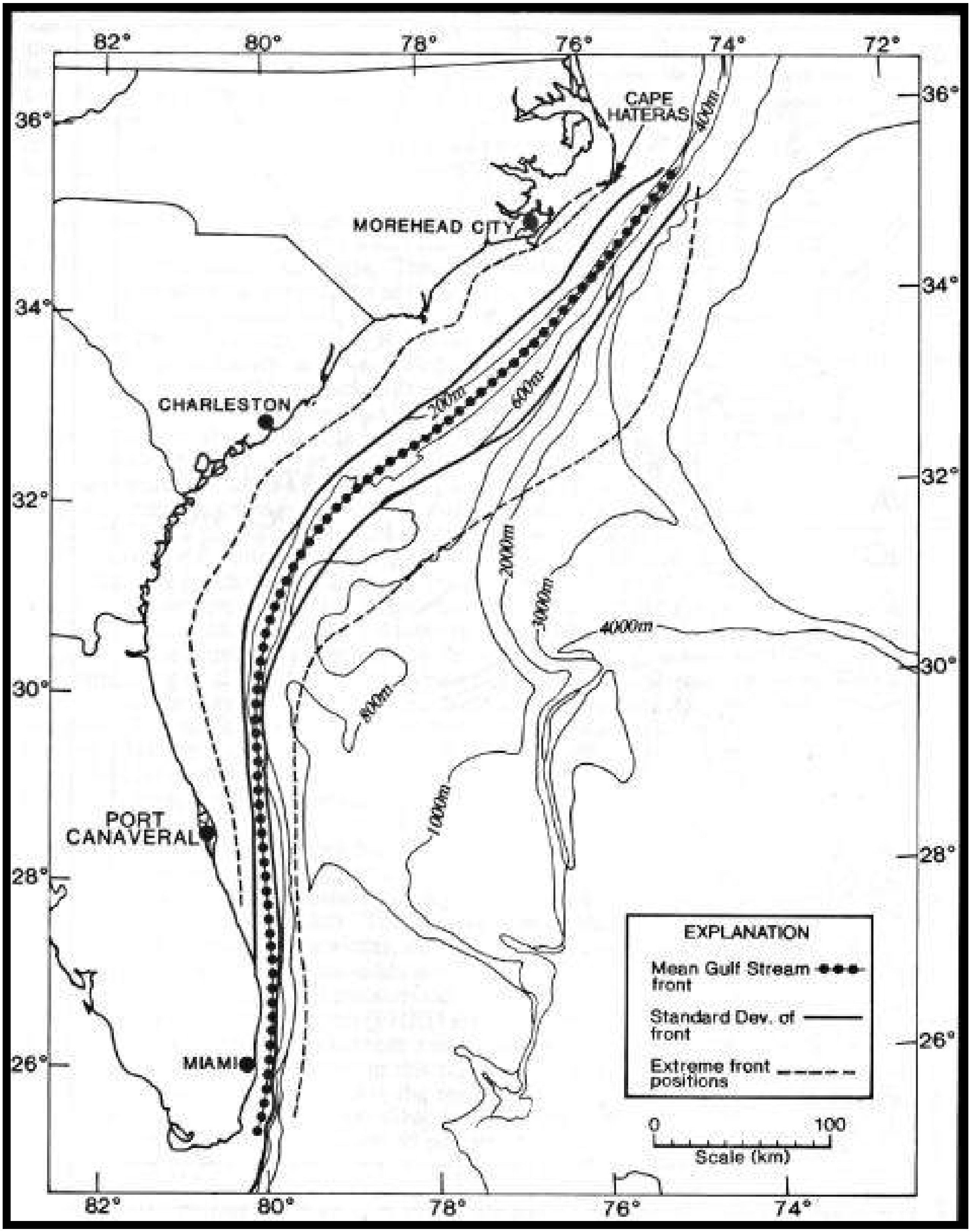


Figure 10b. Gulf Stream front location (Source: MMS 1990).

Species- and life-stage-specific patterns of water column habitat utilization are not well known for most fishes. Some utilize near-shore fronts as feeding or nursery habitats (e.g. *Anchoa*, *Scomberomorus*); others utilize offshore fronts (e.g. *Coryphaena*, *Xiphius*). Important spawning locations include esturaine fronts (e.g. *Cynoscion*, *Sciaenops*), the mid-shelf front (*Micropogonias*, *Leiostomus*, *Paralichthys*), the Gulf Stream front (*Coryphaena*, *Xiphius*). Recent work has shown an accumulation of fish larvae in these shelf fronts (Govoni 1993). Movement of the Gulf Stream front also affects the distribution of adult fishes (Magnuson et al. 1981) and hook and line fisherman and longliners target much of their effort for pelagic species in these frontal zones. In addition, the quasi-permanent gyres which impinge upon the shelf near the Florida Keys and downstream from the Charleston Bump probably serve as important spawning/larval retention habitat for a variety of fishes (Collins and Stender, 1987; Lee et al., 1994). The region known as “Point” off Cape Hatteras supports an unusually high biomass of upper trophic level predators, including many important pelagic fishes. It has been suggested that the area is the most productive sport fishery on the east coast (Ross, 1989).

Due to their important ecological function, at least two offshore pelagic environments discussed above represent essential fish habitat-habitat areas of particular concern (HAPC); the Charleston Bump and The Point. Both regions are productive and highly dynamic oceanic areas. A quasi-permanent, cyclonic eddy with attendant upwelling of nutrient-rich deep water sets-up in the wake of the Charleston Bump. Upwelling results in persistent primary and secondary production that may well result in an important, if not essential feeding environment for the larvae of fishes that congregate to spawn there. The hydrodynamics of the eddy may well serve in the retention of fish propagules that are lost from local populations elsewhere through entrainment into the Gulf Stream. The “Point” off Cape Hatteras is also highly productive due to the confluence of as many as four water masses. Adults of highly migratory species congregate in this area, while the diversity of larval fishes found there is truly astounding (Table 18b).

Table 18b. Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point". (Source: Larry Settle pers comm.)

Family Genus and Species	Common name
Elopidae	tarpons
Elops saurus	ladyfish
Megalops atlanticus	tarpon
Albulidae	bonefishes
Albula vulpes	bonefish
Anguillidae	freshwater eels
Anguilla rostrata	American eel
Moringuidae	spaghetti eels
unidentified	spaghetti eel
Muraenidae	morays
Gymnothorax sp(p).	moray
unidentified	moray
Serrivomeridae	sawtooth eels
unidentified	sawtooth eel
Ophichthidae	snake eels
Apterichtus ansp	academy eel
Apterichtus kendalli	finless eel
Callechelys guiniensis	shorttail snake eel
Callechelys sp.	eel
Echiophis intertinctus	spotted spoon-nose eel
Echiophis punctifer	snapper eel
Gordiichthys ergodes	irksome eel
Myrichthys ocellatus	goldspotted eel
Myrichthys sp.	eel
Myrophis punctatus	speckled worm eel
Ophichthus gomesi	shrimp eel
Ophichthus puncticeps	palespotted eel
Ophichthus sp.	eel
unidentified	snake eel
Nemichthyidae	snipe eels
unidentified	snipe eel
Nettastomatidae	duckbill eels
Saurenchelys cognita	longface eel
unidentified	eel
Congridae	conger eels
Ariosoma sp.	conger eel
Paraconger sp.	conger eel
Rhechias dubia	conger eel
Rhynchoconger gracilior/guppyi	conger
unidentified	conger eel
Clupeidae	herrings
Brevoortia tyrannus	Atlantic menhaden
Etremeus teres	round herring
Sardinella aurita	Spanish sardine
Engrauilidae	anchovies
Anchoa hepsetus	striped anchovy
Engraulis eurystole	silver anchovy
Argentinidae	argentines
unidentified	argentine
Gonostomatidae	lightfishes
Cyclothone sp.	lightfish
Gonostoma elongatum	lightfish
Vinciguerria nimbaria	lightfish
Vinciguerria poweriae	lightfish
Vinciguerria sp.	lightfish
unidentified	lightfish

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Stomiidae	dragonfishes
Stomias sp.	dragonfish
unidentified	dragonfish
Aulopidae	aulopus
unidentified	aulopus
Chlorophthalmidae	greeneyes
unidentified	greeneye
Scopelarchidae	pearleyes
unidentified	pearleye
Synodontidae	lizardfishes
Trachinocephalus myops	snakefish
unidentified	lizardfish
Evermannellidae	sabertooth fishes
unidentified	sabertooth fish
Paralepididae	barrucudinas
Lestidiops affinis	barracudina
Stemonosudis intermedia	barracudina
unidentified	barracudina
Myctophidae	lanternfishes
Benthosema glaciace	glacier lanternfish
Benthosema suborbitale	lanternfish
Benthosema sp.	lanternfish
Ceratoscopelus manderensis	lanternfish
Ceratoscopelus warmingii	lanternfish
Diaphus sp.	lanternfish
Diogenichthys atlanticus	Diogenes lanternfish
Electrona risso	lanternfish
Hygophum benoiti	lanternfish
Hygophum hygomii	lanternfish
Hygophum reinhardtii	lanternfish
Hygophum taaningi	lanternfish
Hygophum sp.	lanternfish
Lampadena luminosa	lanternfish
Lampadena sp.	lanternfish
Lampanyctus ater	lanterfish
Lampanyctus cuprarius	lanternfish
Lampanyctus nobilis	lanternfish
Lampanyctus sp.	lanternfish
Lepidophanes sp.	lanternfish
Myctophum affine	metallic lanternfish
Myctophum obtrusiroste	lanternfish
Myctophum selenops	lanternfish
Myctophum sp.	lanternfish
Notolychnus valdiviae	lanternfish
Notoscopelus sp.	lanternfish
unidentified	lanternfish
Moridae	codlings
unidentified	codling
Bregmacerotidae	codlets
Bregmaceros cantori	codlet
Bregmaceros sp.	codlet
unidentified	codlet
Gadidae	cods
Enchelyopus cimbrius	fourbeard rockling
Merluccius bilinearis	silver hake
Urophycis chuss	red hake

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Urophycis floridana	southern hake
Urophycis regia	spotted hake
Urophycis sp.	hake
Ophidiidae	cusk-eels
Brotula barbata	bearded brotula
Ophidion beani	longnose cusk-eel
Ophidion selenops	mooneye cusk-eel
Ophidion sp.	cusk-eel
Ophididium osostigmum	polka-dot cusk-eel
unidentified	cusk-eel
Carapidae	pearlfishes
unidentified	pearlfish
Lophiiformes (Order)	anglerfishes
unidentified	anglerfish
Ceratoidei (Suborder)	deepsea anglerfishes
unidentified	deepsea anglerfish
Caulophrynidae	deepsea anglerfishes
Caulophryne jordani	deepsea anglerfish
Lophiidae	goosefishes
Lophius americanus	goosefish
Antennariidae	frogfishes
Antennarius sp.	frogfish
Histrio histrio	sargassumfish
Exocoetidae	flyingfishes
Cypselurus melanurus	Atlantic flyingfish
Hemiramphus brasiliensis	ballyhoo
Hirundichthys affinis	fourwing flyingfish
Hyporhamphus unifasciatus	silverstripe halfbeak
Paraexocoetus brachypterus	sailfin flyingfish
Prognichthys gibbifrons	bluntnose flyingfish
unidentified	flyingfish
Belonidae	needlefishes
Tylosurus acus	agujon
unidentified	needlefish
Scomberesocidae	sauries
Scomberesox saurus	Atlantic saury
Atherinidae	silversides
unidentified	silverside
Trachipteridae	ribbonfishes
unidentified	ribbonfish
Trachichthyidae	roughies
unidentified	roughy
Melamphaidae	scalefishes
Melamphaes simus	scalefish
Holocentridae	squirrelfishes
unidentified	squirrelfish
Caproidae	boarfishes
Antigonia capros	deepbody boarfish
Antigonia sp.	boarfish
Fistulariidae	cornetfishes
unidentified	cornetfish
Centriscidae	snipefishes
Marcoramphosus sp.	snipefish
Syngnathidae	pipefishes
Hippocampus erectus	lined seahorse
Hippocampus reidi	longsnout seahorse

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Hippocampus sp.	seahorse
Syngnathus caribbaeus	Caribbean pipefish
Syngnathus floridae	dusky pipefish
Syngnathus pelagicus	sargassum pipefish
Syngnathus scovelli	gulf pipefish
Syngnathus springeri	bull pipefish
Syngnathus sp.	pipefish
unidentified	pipefish
Dactylopteridae	flying gurnards
Dactylopterus volitans	flying gurnard
Scorpaenidae	scorpionfishes
Helicolenus dactylopterus	blackbelly rosefish
unidentified	scorpionfish
Triglidae	searobins
Prionotus carolinus	northern searobin
Prionotus sp(p).	searobin
unidentified	searobin
Chiasmodontidae	swallowers
unidentified	swallower
Serranidae	sea basses
Anthias sp.	sea bass
Centropristis sp.	sea bass
Diplectrum sp.	sea bass
Hemianthias vivanus	red barbier
Liopropoma sp.	sea bass
Plectranthias garrupellus	apricot bass
Psuedgramma gregoryi	reef bass
Rypticus sp.	soapfish
unidentified	sea bass
Priacanthidae	bigeyes
Priancnthus arenatus	bigeye
unidentified	bigeye
Apogonidae	cardinalfishes
unidentified	cardinalfish
Malacanthidae	tilefishes
Lopholatilus chamaeleonticeps	tilefish
Malacanthus plumieri	sand tilefish
Pomatomidae	bluefish
Pomatomus saltatrix	bluefish
Carangidae	jacks
Caranx bartholomaei	yellow jack
Caranx crysos	blue runner
Caranx ruber	bar jack
Caranx spp.	jack
Decapterus macarellus	maclerel scad
Decapterus punctatus	round scad
Decapterus sp.	scad
Elagates bipinnulata	rainbow runner
Hemicaranx amblyrhynchus	bluntnose jack
Selar crumenophthalmus	bigeye scad
Seriola dumerili	greater amberjack
Seriola fasciata	lesser amberjack
Seriola rivoliana	almaco jack
Serioloa zonata	banded rudderfish
Seriola sp(p).	amberjack
Trachinotus carolinus	florida pompano

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Trachinotus falcatus	permit
Trachinotus goodei	palometa
Thachurus lathami	rough scad
unidentified	jack
Coryphaenidae	dolphins
Coryphaena equisetis	pompano dolphin
Coryphaena hippurus	dolphin
Caristiidae	veilfins
Caristius sp.	veilfin
Lutjanidae	snappers
Lutjanus sp(p).	snapper
Rhomboplites aurorubens	vermillion snapper
Lobotidae	tripletails
Lobotes surinamensis	tripletail
Gerreidae	mojarras
Eucinostomus sp.	mojarra
Haemulidae	grunts
unidentified	grunt
Sparidae	porgies
Lagodon rhomboides	pinfish
Pagrus pagrus	red porgy
unidentified	porgy
Sciaenidae	drums
Larimus fasciatus	banded drum
Leiostomus xanthurus	spot
Menticirrhus sp(p).	kingfish
Micropogonias undulatus	croaker
Mullidae	goatfishes
Mullus auratus	red goatfish
unidentified	goatfish
Kyphosidae	sea chubs
Kyphosus sectatrix	Bermuda chub
Chaetodontidae	butterflyfishes
Chaetodon sp(p).	butterflyfish
Pomacentridae	damselfishes
Abudeduf saxatilis	sergeant major
Abudefduf taurus	night sergeant
unidentified	damselfish
Mugilidae	mullets
Mugil cephalus	striped mullet
Mugil curema	white mullet
Mugil sp(p).	mullet
Sphyraenidae	barracudas
Sphyraena barracuda	great barracuda
Sphyraena borialis	northern sennet
Sphyraena sp(p).	barracuda
Labridae	wrasses
Hemipteronotus sp(p).	wrass
unidentified	wrass
Scaridae	parrotfishes
unidentified	parrotfish
Pholidae	gunnels
Pholis sp.	gunnel
Uranoscopidae	stargazers
unidentified	stargazer

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Percophidae	flatheads
unidentified	flathead
Blenniidae	combtooth blennies
Parablennius marmorius	seaweed blenny
unidentified	blenny
Ammodytidae	sand lances
Ammodytes spp.	sand lance
Callionymidae	dragonets
unidentified	dragonet
Gobiidae	gobies
Isoglossus calliurus	blue goby
Microgobius sp.	goby
unidentified	goby
Acanthuridae	surgeonfishes
Acanthurus sp(p).	surgeonfish
Trichiuridae	cutlassfishes
unidentified	cutlassfish
Gempylidae	snake mackerels
Diplosinus multistriates	snake mackerel
Gempylus serpens	snake mackerel
unidentified	snake mackerel
Scombridae	mackerels
Auxis sp(p).	frigate mackerel
Euthynnus alletteratus	little tunny
Katsuwonus pelamis	skipjack tuna
Sarda sarda	Atlantic bonito
Scomber japonicus	chub mackerel
Scomber scomber	Atlantic mackerel
Scomberomorus cavalla	king mackerel
Thunnus albacares/alalunga	yellowfin tuna/albacore
Thunnus thynnus	bluefin tuna
Xiphiidae	swordfish
Xiphias gladius	swordfish
Istiophoridae	billfishes
unidentified	billfish
Stromateidae	butterfishes
Ariomma sp.	driftfish
Hyperoglyphe sp.	driftfish
Nomeus gronovii	man-of-war fish
Peprilus triacanthus	butterfish
Psenes cyanophrys	freckled driftfish
Psenes maculatus	silver driftfish
Psenes pellucidus	bluefin driftfish
Psenes sp.	driftfish
unidentified	butterfish
Bothidae	lefteye flounders
Bothus ocellatus	eyed flounder
Bothus sp(p).	flounder
Citharichthys arctifrons	Gulf Stream flounder
Citharichthys cornutus	horned whiff
Citharichthys gymnorhinus	anglefin whiff
Citharichthys sp(p).	whiff
Cyclopsetta fimbriata	spotfin flounder
Engyophrys senta	spiny flounder
Etropus microstomus	smallmouth flounder
Etropus sp(p).	flounder

Table 18b (cont.). Taxonomic list of larval and early-juvenile fishes from offshore of Cape Lookout to Cape Hatteras including the region known as "The Point".

Family Genus and Species	Common name
Monolene sessilicauda	deepwater flounder
Paralichthys dentatus	summer flounder
Paralichthys lethostigma	southern flounder
Paralichthys oblongus	fourspot flounder
Paralichthys squamilentus	broad flounder
Scophthalamus aquosus	windowpane
Syacium papillosum	dusky flounder
unidentified	flounder
Pleuronectidae	righteye flounders
Glyptocephalus cynoglossus	witch flounder
Pleuronectes ferrugineus	yellowtail flounder
Soleidae	soles
Symphurus sp(p).	tonguefish
Balistidae	leatherjackets
Aluterus heudeloti	dotterel filefish
Aluterus monoceros	unicorn filefish
Aluterus schoepfi	orange filefish
Aluterus scriptus	scrawled filefish
Balistes capriscus	gray triggerfish
Balistes vetula	queen triggerfish
Cantherhines macrocerus	whitespotted filefish
Cantherhines pullus	orangespotted filefish
Cantheridermis maculata	rough triggerfish
Cantherdermis sufflamen	ocean triggerfish
Monacanthus ciliatus	fringed filefish
Monacanthus hispidus	planehead filefish
Monacanthus setifer	pygmy filefish
Monacanthus tuckeri	slender filefish
Xanthichthys ringins	sargassum triggerfish
unidentified	leatherjacker
Ostraciidae	boxfishes
Lactophrys sp(p).	boxfish
Tetraodontidae	puffers
Diodon holcanthus	ballonfish
Sphoeroides spengleri	bandtail puffer
Sphoeroides sp.	puffer
unidentified	puffers
Molidae	molas
unidentified	mola

3.3 Managed Species Distribution and Use of Essential Fish Habitat

The following life history tables (Tables 19a-21b) are based on originals provided by NOAA SEA Division as modified by Council staff and representatives of NMFS SEFSC Beaufort Laboratory. Tabular descriptions of habitat associations by life stage for each species. These tables summarize how each species uses the environment and provides information to assess the relative importance of different habitat types. The three tables developed are: 1) Habitat Associations (Tables 19a & 19b); 2) Biological Attributes (Tables 20a & 20b); and 3) Reproduction Tables (21a & 21b).

Table 19a. Habitat Associations for Select Managed Species (Source: NOAA 1998b, NMFS SEFSC, and SAFMC).

SE EFH		Habitat Associations																																					
		Domain																							Substrate preference									Depth preference				
9/29/98		Freshwater			Estuarine																		Marine											Littoral		Sublittoral		
								Salinity range								Temperature range																						
								NEI			Venice system																												
Species	Life stage	Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Brown shrimp	A				•				•	•		•	•	•	•	•	•	•	•	•	•	•		•		•	•										•	•	
Penaeus	S									•					•				•	•	•			•		•	•											•	
aztecus	J				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•					•	•			•	•			
	L					•			•	•				•	•			•	•	•	•	•		•		•					•			•			•	•	
	E									•					•						•	•		•										•				•	
Pink shrimp	A				•	•	•			•				•	•		•	•	•	•	•	•		•		•	•			•						•	•	•	
Penaeus	S									•					•				•	•	•	•		•		•	•			•						•	•		
duorarum	J						•		•	•		•	•	•	•	•	•	•	•	•	•	•				•	•			•	•	•	•		•	•	•		
	L									•					•					•	•			•	•									•		•	•		
	E									•					•					•	•	•		•	•									•		•	•		
White shrimp	A					•			•	•		•	•	•	•		•	•	•	•	•	•		•		•	•						•				•		
Penaeus	S									•					•				•	•	•			•		•	•										•		
setiferus	J					•	•		•	•		•	•	•	•		•	•	•	•	•	•				•	•				•	•	•		•	•			
	L									•					•			•	•	•	•			•							•			•			•		
	E									•					•				•	•	•			•										•			•		
Black seabass	A				•	•			•	•			•	•	•			•	•	•	•		•	•			•	•	•	•						•	•	•	
Centropristis	S																	•	•	•	•			•										•					
ocyurus	J				•	•			•	•				•	•			•	•	•	•		•	•			•	•	•	•	•					•	•	•	
	L																	•	•	•	•			•										•			•		
	E																	•	•	•	•			•										•					
Gag	A				•				•	•				•	•				•	•	•			•		•	•	•	•	•	•					•	•		
Mycteroperca	S																							•												•	•		
microlepis	J				•				•	•				•	•				•	•	•			•		•	•	•	•	•	•					•	•		
	L																							•												•	•		
	E																							•												•	•		
Cobia	A									•				•	•					•	•	•		•	•									•			•		
Rachycentron	S																			•	•	•		•										•			•		
canadum	J								•	•				•	•					•	•	•	•	•	•		•									•	•		
	L									•				•	•					•	•	•		•										•			•		
	E																			•	•	•		•										•			•		
Mutton snapper	A								•	•				•	•				•	•	•	•		•		•		•	•	•	•					•	•	•	
Lutjanus	S									•				•	•					•	•	•		•		•		•	•	•						•	•	•	
analis	J				•	•	•		•	•			•	•	•				•	•	•	•		•		•		•	•	•	•	•				•	•		
	L								•	•				•	•				•	•	•			•		•					•						•	•	
	E									•				•	•					•	•			•													•	•	
Red snapper	A									•				•	•			•	•	•	•	•		•		•		•	•	•	•					•	•	•	
Lutjanus	S									•				•	•					•	•	•		•		•		•	•	•						•	•	•	
campechanus	J								•	•				•	•				•	•	•	•		•		•		•	•	•	•	•				•	•		
	L								•	•				•	•				•	•	•			•		•					•						•	•	
	E									•					•					•	•			•													•	•	

Table 19a (cont.). Habitat Associations for Select Managed Species.

SE EFH 9/29/98		Habitat Associations																																				
		Domain																							Substrate preference									Depth preferenc				
		Freshwate			Estuarine																	Marine												Littora	Sublittoral			
								Salinity range								Temperature range																						
								NEI			Venice system																											
Species	Life stage	Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Gray snapper	A		•		•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•		•		•		•	•	•	•					•	•	•	
Lutjanus	S									•					•					•	•			•		•		•	•	•						•	•		
griseus	J		•		•	•	•	•	•	•	•	•	•	•	•				•	•	•	•		•		•			•	•	•	•			•	•	•		
	L								•	•		•	•	•	•				•	•	•			•		•					•					•	•	•	
	E									•				•	•					•	•			•												•	•	•	
Lane snapper	A				•	•	•		•	•				•	•				•	•	•	•		•		•		•	•	•	•					•	•		
Lutjanus	S									•				•	•					•	•			•		•		•	•	•		•				•	•		
synagris	J				•	•	•		•	•			•	•	•				•	•	•	•	•	•		•	•	•	•	•	•	•				•	•		
	L								•	•				•	•				•	•	•			•							•					•	•		
	E									•				•	•					•	•			•												•	•		
Yellowtail snapper	A				•	•				•				•	•				•	•	•	•		•		•		•	•	•	•		•			•	•		
ocyurus	S									•				•	•					•	•			•		•		•	•	•						•	•		
chrysurus	J				•	•	•		•	•			•	•	•				•	•	•	•		•		•		•	•	•	•	•				•	•		
	L								•	•				•	•				•	•	•			•							•					•	•		
	E									•				•	•					•	•			•												•	•		
Vermilion snapper	A									•					•				•	•	•	•		•		•		•	•	•							•	•	
Rhomboplites	S									•					•					•	•			•		•		•	•	•							•	•	
aurorubens	J									•					•				•	•	•	•		•		•			•	•							•		
	L									•					•				•	•	•			•													•		
	E									•					•					•	•			•													•		
White grunt	A				•	•			•	•			•	•	•				•	•	•	•		•		•		•	•	•	•					•	•		
Haemulon	S									•				•	•					•	•			•		•		•	•	•						•	•		
plumieri	J				•	•	•		•	•			•	•	•				•	•	•	•		•		•		•	•	•	•	•			•	•	•		
	L								•	•			•	•	•				•	•	•			•		•					•					•	•		
	E									•				•	•					•	•			•												•	•		
Sheepshead	A				•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•		•		•			•	•		•				•	•		
Archosargus	S									•					•					•	•			•												•	•		
probatocephalus	J				•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•					•			•	•	•				•				
	L				•	•	•		•	•			•	•	•					•	•			•							•				•	•	•		
	E									•					•					•	•			•												•	•		
Red drum	A				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•			•						•	•	•	
Sciaenops	S																			•				•										•		•	•		
ocellatus	J				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•			•	•		•		•	•			
	L						•	•	•	•	•	•	•	•	•				•	•	•	•		•		•	•				•		•	•	•	•			
	E						•		•	•				•	•					•	•			•										•		•	•		
Hogfish	A									•					•					•	•	•		•		•		•	•	•	•					•	•		
Lachnolaimus	S									•					•					•	•			•		•		•	•	•						•	•		
maximus	J				•	•	•		•	•			•	•	•				•	•	•			•		•		•	•	•	•	•				•	•		
	L									•					•					•	•			•		•					•					•	•		
	E									•					•					•	•			•												•	•		
Spanish mackerel	A				•					•				•	•					•	•	•	•	•			•						•			•	•		
Scomberomorus	S																			•	•	•		•			•										•		
maculatus	J				•	•	•		•	•			•	•	•			•	•	•	•	•	•	•			•						•			•	•		
	L																		•	•	•			•												•	•		
	E																			•	•	•		•													•		

Table 19b. Habitat Associations for Other Managed and Prey Species Using South Atlantic Estuaries (Source: NOAA 1998).

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1/26/98

		Habitat Associations																																					
		Domain																								Substrate preference									Depth preference				
		Freshwate			Estuarine																		Marine												Littora		Sublittoral		
								Salinity range								Temperature range																							
								NEI			Venice system																												
Species	Life stage	Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Bay anchovy *Anchoa mitchilli*	A		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●								●	●	●		
	S					●	●			●					●					●	●			●										●	●	●	●		
	J		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●	●								●	●	●		
	L					●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●										●	●	●	●		
	E					●			●	●			●	●	●					●	●	●		●										●	●	●	●	●	●
Sheepshead minnow *Cyprinodon variegatus*	A		●			●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●			●					●	●			
	S						●	●	●	●	●	●	●	●	●				●	●	●					●	●			●					●	●			
	J		●			●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●			●					●	●			
	L						●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●			●					●	●			
	E						●	●	●	●	●	●	●	●	●				●	●	●					●	●			●					●	●			
American shad ***Alosa sapidissima***	A		●	●				●	●	●	●	●	●	●	●		●	●	●	●	●	●		●										●		●		●	●
	S		●	●				●	●		●	●						●	●	●							●	●											
	J		●	●				●	●	●	●	●	●	●	●		●	●	●	●	●	●														●			
	L		●	●				●	●		●	●	●																							●			
	E		●	●				●	●		●	●					●	●	●	●							●	●											
Atlantic menhaden ***Brevoortia tyrannus***	A		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●			●										●		●	●	●	●
	S									●				●	●		●	●	●	●				●										●			●	●	●
	J		●		●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●							●	●				●	●	●	●
	L				●	●		●	●	●		●	●	●	●	●	●	●	●	●	●	●		●							●	●				●	●	●	●
	E								●	●			●	●	●		●	●	●	●				●										●			●	●	●

Terms Used in Habitat Association Life History Tables:

Life stage definitions

Life stages were defined in the three life history tables (Habitat Associations, Biological Attributes, and Reproduction) as follows:
A - Adults; mature individuals, but not necessarily in spawning condition.
S - Spawning; adults in spawning condition.
J - Juveniles; not mature but otherwise morphologically similar to adults.
L - Larvae; individuals which have hatched, but not yet attained the characteristic juvenile/adult morphology.
E - Eggs; which have been spawned but not yet hatched.

Terms used
Domain - General habitat of life stages.
• *Freshwater*- Rivers and lakes above head-of-tide; freshwater lentic and lotic habitats.
Lacustrine - Freshwater lentic areas (lakes) with riverine connections to the sea..
Riverine - coastal plain - River portions in the relatively flat land along a coast.
Riverine - inland - River portions away from the coast.
• *Estuarine* - Embayment with tidal fresh, mixing, and seawater zones.
Inlet mouth - The seaward end of an estuary.
Channel - The drowned river channel or tributary channels of an estuary.
Inter- and subtidal flats - Broad, shallow estuarine areas.
Salinity range, NEI - Three salinity zones used by the ELMR program for compilation of distribution and abundance data.
Tidal fresh zone - Salinities of 0.0-0.5 ppt.
Mixing zone - Salinities of 0.5-25.0 ppt.
Seawater zone - Salinities >25 ppt.
Salinity range, Venice system - Five salinity zones according to the Venice system of estuarine classification.
Limnetic - Salinities of 0.0-0.5 ppt.
Oligohaline - Salinities of 0.5-5.0 ppt.
Mesohaline - Salinities of 5-18 ppt.
Polyhaline - Salinities of 18-30 ppt.
Euhaline - Salinities >30 ppt.
Temperature range - The temperatures at which a life stage is typically found, from 0_C to >30_C
• *Marine* - Coastal and offshore
Beach/surf - Shore areas receiving ocean waves and wash.
Neritic - Residing from the shore to the edge of the continental shelf.
Oceanic - Residing beyond the edge of the continental shelf.

Substrate preference - Size of substrate that life stages reside on or in.
• *Mud/clay/silt* - Fine substrates <0.0625 mm in diameter.
• *Sand* - Substrates 0.0625-4.0 mm in diameter.
• *Pebble/cobble/gravel* - Substrates 4-256 mm in diameter.
• *Boulder/rocky outcrop/reef*- Large substrate >256 mm in diameter, exposed solid bedrock, or coral reef.
• *Shell* - Mollusc shell substrate, such as oyster.
• *Submergent vegetation* - Rooted aquatic vegetation that does not grow above the water's surface, e.g., turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*).
• *Emergent vegetation* - Rooted aquatic vegetation that grows above the water's surface, e.g., cordgrass (*Spartina*) and mangrove.
• *Floating vegetation* - Non-rooted aquatic vegetation, e.g., *Sargassum*, and other vegetation that can form floating mats.
• *None* - No known substrate preferences.

Depth preference -
• *Littoral* -
Intertidal - From the high tide mark to depths of 1 m.
Subtidal - At depths of 1-10 m.
• Sublittoral -
Inner shelf (10-50 m) - On or over the continental shelf at depths of 10-50 m.
Middle shelf (50-100) - On or over the continental shelf at depths of 50-100 m.
Outer shelf (100-200 m) - On or over the continental shelf at depths of 100-200 m.

Table 19b.(cont.) Habitat Associations for Other Managed and Prey Species Using South Atlantic Estuaries.

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1/26/98

		Habitat Associations																																			
		Domain																						Substrate preference									Depth preference				
		Freshwate			Estuarine																Marine												Littora		Sublittoral		
							Salinity range								Temperature range																						
							NEI			Venice system																											
Species	Life stage	Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Blue mussel ***Mytilis edulis***	A						●		●	●			●	●	●		●	●	●	●			●	●				●	●	●					●	●	●	●	
	S						●		●	●			●	●	●				●	●			●	●											●	●	●	●	
	J						●		●	●			●	●	●		●	●	●	●			●	●				●	●	●					●	●	●	●	
	L						●		●	●			●	●	●		●	●	●	●			●	●						●	●				●	●	●	●	
	E						●		●	●			●	●	●				●	●			●	●											●	●	●	●	
Bay scallop *Argopecten irradians*	A						●		●	●				●	●		●	●	●	●	●	●		●		●	●				●				●	●	●		
	S						●		●	●				●	●						●			●		●	●				●				●	●	●		
	J						●		●	●				●	●		●	●	●	●	●	●		●		●	●			●	●		●		●	●	●		
	L						●		●	●				●	●				●	●	●			●						●	●	●	●		●	●	●		
	E						●		●	●				●	●				●	●				●										●	●	●	●		
Allantic rangia *Rangia cuneata*	A		●				●	●	●		●	●	●	●			●	●	●	●	●	●				●	●					●	●			●			
	S		●				●	●	●		●	●	●	●					●	●						●	●					●	●			●			
	J		●				●	●	●		●	●	●	●			●	●	●	●	●	●				●	●					●	●			●			
	L		●				●	●	●		●	●	●	●			●	●	●	●	●	●				●	●					●	●			●			
	E		●				●	●	●		●	●	●	●					●	●	●	●												●		●			
Quahog *Mercenaria species*	A						●		●	●			●	●	●	●	●	●	●	●	●	●		●		●	●			●	●		●		●	●	●		
	S						●		●	●				●	●					●	●			●		●	●			●	●		●		●	●	●		
	J						●		●	●			●	●	●	●	●	●	●	●	●	●		●		●	●			●	●		●		●	●	●		
	L						●		●	●				●	●			●	●	●	●	●		●				●	●	●	●				●	●	●		
	E						●		●	●				●	●			●	●	●	●	●		●										●	●	●	●		
Grass shrimp *Palaemonetes pugio*	A		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●								●	●	●	●		●	●			
	S						●		●	●			●	●	●				●	●	●	●											●		●	●			
	J		●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●								●	●	●			●	●			
	L						●		●	●			●	●	●					●	●												●	●	●	●			
	E						●		●	●			●	●	●				●	●	●													●	●	●			

Table 19b.(cont.) Habitat Associations for Other Managed and Prey Species Using South Atlantic Estuaries.

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1/26/98

Species	Life stage	Domain: Freshwater: Lacustrine	Freshwater: Riverine - coastal plain	Freshwater: Riverine - inland	Estuarine: Inlet mouth	Estuarine: Channel	Estuarine: Inter- and subtidal flats	Salinity range NEI: Tidal fresh (0-0.5‰)	NEI: Mixing (0.5-25‰)	NEI: Seawater (>25‰)	Venice system: Limnetic (0-0.5‰)	Venice system: Oligohaline (0.5-5‰)	Venice system: Mesohaline (5-18‰)	Venice system: Polyhaline (18-30‰)	Venice system: Euhaline (>30‰)	Temperature range: 0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Marine: Beach/surf	Marine: Neritic	Marine: Oceanic	Substrate preference: Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Depth preference: Littoral: Intertidal	Littoral: Subtidal	Sublittoral: Inner shelf (10-50 m)	Sublittoral: Middle shelf (50-100 m)	Sublittoral: Outer shelf (100-200 m)
Striped mullet *Mugil cephalus*	A		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●		●	●				●				●	●			
	S																			●				●												●	●		
	J		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●				●				●	●			
	L																		●	●	●			●										●		●	●		
	E																	●	●	●	●	●		●										●		●	●		
Spot *Leiostomus xanthurus*	A				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●			●						●	●	●	
	S									●									●	●				●										●			●	●	
	J		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●					●		●				●	●	
	L									●				●	●				●	●				●										●		●	●	●	
	E									●									●	●				●										●			●	●	
Southern kingfish ***Menticirrhus americanus***	A																																						
	S																																						
	J																																						
	L																																						
	E																																						
Atlantic croaker *Micropogonias undulatus* GM/SE	A		●		●	●		●	●	●	●	●	●	●	●		●	●	●	●	●	●		●		●	●			●						●	●	●	
	S																		●	●				●										●			●	●	
	J		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●	●								●	●	●		
	L				●	●	●		●	●				●	●			●	●	●				●										●				●	●
	E									●					●				●	●				●										●				●	●
Black drum *Pogonias cromis*	A				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●			●							●		
	S				●	●			●	●			●	●	●				●	●				●										●			●		
	J		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●			●					●	●	●		
	L					●	●		●	●			●	●	●			●	●					●										●	●	●	●		
	E					●			●	●			●	●	●				●					●										●		●	●		
Red drum *Sciaenops ocellatus*	A				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●			●						●	●	●	
	S																			●				●										●		●	●		
	J				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●			●	●		●		●	●			
	L						●	●	●	●	●	●	●	●	●				●	●	●	●		●		●	●				●		●	●	●	●			
	E						●		●	●				●	●					●	●			●										●		●	●		

Table 19b.(cont.) Habitat Associations for Select Managed and Prey Species Using South Atlantic Estuaries.

Table 19b.(cont.) Habitat Associations for Select Managed and Prey Species Using South Atlantic Estuaries.

DRAFT SE EFH
1/26/98

		Habitat Associations																																					
		Domain																								Substrate preference									Depth preference				
		Freshwater			Estuarine																		Marine												Littoral		Sublittoral		
								Salinity range								Temperature range																							
								NEI			Venice system																												
Species	Life stage	Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Silversides *Menidia* species	A		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●			●	●	●			●	●			
	S		●				●	●	●	●	●	●	●	●	●				●	●	●	●									●	●			●	●			
	J		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●				●	●			●	●	●			●	●			
	L		●				●	●	●	●	●	●	●	●	●					●	●					●	●			●	●	●			●	●			
	E		●				●	●	●	●	●	●	●	●	●			●	●	●	●	●				●	●			●	●	●			●	●			
Gulf flounder *Paralichthys albigutta*	A						●		●	●			●	●	●		●	●	●	●	●	●		●			●								●	●	●		
	S																		●	●				●			●									●	●		
	J						●		●	●			●	●	●		●	●	●	●	●	●		●			●				●		●		●	●	●		
	L					●	●			●					●				●	●				●										●	●	●	●		
	E									●					●				●	●				●										●		●	●		
Summer flounder *Paralichthys dentatus*	A																																						
	S																																						
	J																																						
	L																																						
	E																																						
Southern flounder *Paralichthys lethostigma*	A		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●		●	●									●	●		
	S								●	●			●	●	●			●	●	●				●										●		●	●		
	J		●		●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●		●		●	●				●		●			●	●		
	L				●	●	●		●	●			●	●	●	●	●	●	●	●	●			●										●		●	●		
	E								●	●			●	●	●		●	●	●	●	●			●										●		●	●		

Table 19b.(cont.) Habitat Associations for Select Managed and Prey Species Using South Atlantic Estuaries.

DRAFT SE EFH
1/26/98

Species	Life stage	Habitat Associations — Domain: Freshwate			Estuarine																		Marine			Substrate preference									Depth preference				
								Salinity range								Temperature range																		Littoral		Sublittoral		
								NEI			Venice system																												
		Lacustrine	Riverine - coastal plain	Riverine - inland	Inlet mouth	Channel	Inter- and subtidal flats	Tidal fresh (0-0.5‰)	Mixing (0.5-25‰)	Seawater (>25‰)	Limnetic (0-0.5‰)	Oligohaline (0.5-5‰)	Mesohaline (5-18‰)	Polyhaline (18-30‰)	Euhaline (>30‰)	0-5°C	5-10°C	11-15°C	16-20°C	21-25°C	26-30°C	>30°C	Beach/surf	Neritic	Oceanic	Mud/silt/clay	Sand	Pebble/cobble/gravel	Boulder/rocky outcrop	Shell	Submergent vegetation	Emergent vegetation	Floating vegetation	None	Intertidal	Subtidal	Inner shelf (10-50 m)	Middle shelf (50-100 m)	Outer shelf (100-200 m)
Ladyfish ***Elops saurus***	A																																						
	S																																						
	J																																						
	L																																						
	E																																						
American eel ***Anguilla rostrata***	A	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●			●						●					●			
	S																		●	●					●									●					
	J		●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●	●				●					●			
	L				●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●	●				●					●	●	●	●
	E																		●	●					●									●					
Blueback herring ***Alosa aestivalis***	A	●	●	●				●	●	●	●	●	●	●	●		●	●	●	●	●	●		●										●			●		
	S	●	●	●				●	●		●	●						●	●	●	●						●	●	●		●	●							
	J	●	●	●				●	●	●	●	●	●	●	●		●	●	●	●	●	●		●		●					●								
	L	●	●	●				●	●		●	●	●					●	●	●	●						●	●	●		●								
	E	●	●	●				●	●		●	●						●	●	●	●																		
Atlantic sturgeon ***Acipenser oxyrhynchus***	A		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●									●	●	●	●
	S		●	●				●	●		●	●						●	●							●	●	●		●	●					●			
	J		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●		●							●	●	●	●
	L		●	●				●	●		●	●						●	●	●	●													●		●			
	E		●	●				●	●		●	●						●	●	●	●							●			●					●			

Table 20a. Biological Attributes of Select Managed Species (Source: NOAA 1998b, NMFS SEFSC, and SAFMC).

DRAFT SE EFH		Biological Attributes																															Value			
		Life Mode					Spatial Strategy					Mobility			Feedi		Prey Items										Longevity									
Species		Epibenthic	Benthic	Demersal	Nektonic	Planktonic	Freshwater resident	Estuarine resident	Marine resident	Coastal migrant	Ocean migrant	Nonmobile	Low mobility	High mobility	Filter feeder	Non-filter feeder	Detritus	Phytoplankton	Zooplankton	Infauna	Epibenthos	Insects	Fish (eggs, larvae)	Fish (juveniles, adults)	Macroalgae	Vascular plants	1 day	1-30 days	1-12 months	1-5 years	5-20 years	>20 years	Recreational	Commercial	Ecological	Indicator of stress
Brown shrimp	A			•					•					•		•	•			•	•				•					•			•	•	•	
Penaeus	S			•					•																											
aztecus	J			•				•						•		•	•		•	•	•		•		•				•				•	•	•	
	L					•		•	•				•			•		•	•									•								
	E			•					•			•															•									
Pink shrimp	A			•				•	•					•		•	•			•	•				•					•			•	•	•	
Penaeus	S			•					•																											
duorarum	J			•				•						•		•	•		•	•	•				•				•					•	•	
	L					•		•	•				•			•		•	•				•					•								
	E			•					•			•															•									
White shrimp	A			•				•	•					•		•	•			•	•				•	•				•			•	•	•	
Penaeus	S			•					•																											
setiferus	J			•				•						•		•	•			•	•				•	•			•				•	•	•	•
	L				•	•			•				•			•		•	•									•								
	E			•					•			•															•									
Black seabass	A			•				•	•	•				•		•				•	•		•	•							•		•	•	•	
Centropristis	S																																			
ocyurus	J			•				•	•	•				•		•				•	•		•							•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Gag	A			•				•	•	•				•		•					•		•	•							•		•	•	•	
Mycteroperca	S			•					•					•																			•	•	•	
microlepis	J	•						•	•	•				•		•			•		•		•	•						•						
	L					•			•				•			•			•																	
	E					•			•			•																								
Scamp	A			•										•																			•	•	•	
Mycteroperca	S			•										•																			•	•	•	
phenax	J	•												•																						
	L					•							•																							
	E					•						•																								
Cobia	A				•				•	•	•			•		•					•			•							•		•	•	•	
Rachycentron	S				•				•																								•	•	•	
canadum	J				•			•	•	•	•			•		•			•		•		•	•						•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Mutton snapper	A			•					•	•				•		•					•			•							•		•	•	•	
Lutjanus	S			•					•	•				•		•					•			•							•		•	•	•	
analis	J	•						•	•	•				•		•					•		•							•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Red snapper	A			•					•	•				•		•					•			•							•		•	•	•	
Lutjanus	S			•					•	•				•		•					•			•							•		•	•	•	
campechanus	J	•							•	•				•		•					•		•							•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									

Table 20a. (cont.) Biological Attributes of Select Managed Species (Source: NOAA 1998b, NMFS SEFSC, and SAFMC).

DRAFT SE EFH		Biological Attributes																															Value			
		Life Mode					Spatial Strategy					Mobility			Feedi		Prey Items										Longevity									
Species		Epibenthic	Benthic	Demersal	Nektonic	Planktonic	Freshwater resident	Estuarine resident	Marine resident	Coastal migrant	Ocean migrant	Nonmobile	Low mobility	High mobility	Filter feeder	Non-filter feeder	Detritus	Phytoplankton	Zooplankton	Infauna	Epibenthos	Insects	Fish (eggs, larvae)	Fish (juveniles, adults)	Macroalgae	Vascular plants	1 day	1-30 days	1-12 months	1-5 years	5-20 years	>20 years	Recreational	Commercial	Ecological	Indicator of stress
Gray snapper	A			•			•	•	•	•				•		•					•			•							•		•	•	•	•
Lutjanus	S			•					•	•				•		•					•			•							•		•	•	•	
griseus	J	•					•	•	•	•				•		•					•		•							•					•	•
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Lane snapper	A			•					•	•				•		•					•			•							•		•	•	•	
Lutjanus	S			•					•	•				•		•					•			•							•		•	•	•	
synagris	J	•						•	•	•				•		•					•		•							•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Yellowtail snapper	A			•					•	•				•		•					•			•							•		•	•	•	
Ocyurus	S			•					•	•				•		•					•			•							•		•	•	•	
chrysurus	J	•						•	•	•				•		•					•		•							•						
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Vermilion snapper	A			•					•	•				•		•															•		•	•	•	
Rhomboplites	S			•					•	•				•		•															•		•	•	•	
aurorubens	J	•							•	•				•		•														•						
	L					•			•				•			•												•								
	E					•			•			•															•									
White grunt	A			•					•	•				•		•					•										•		•	•	•	•
Haemulon	S			•					•	•				•		•					•										•		•	•	•	
plumieri	J	•						•	•	•				•		•					•									•					•	•
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Sheepshead	A				•			•	•					•		•					•			•		•					•		•	•	•	
Archosargus	S				•				•							•																	•	•	•	
probatocephalus	J				•			•						•		•			•		•	•		•		•				•					•	•
	L					•		•	•					•		•			•										•							
	E					•			•					•														•								
Red porgy	A																																			
Red drum	A				•				•					•		•					•			•	•	•						•	•	•	•	•
Sciaenops	S				•											•																	•	•	•	
ocellatus	J				•	•		•	•					•		•					•		•	•	•	•				•						•
	L					•			•				•			•			•									•								
	E					•			•			•															•									
Hogfish	A			•					•	•				•		•																	•	•	•	
Lachnolaimus	S			•					•	•				•		•																	•	•	•	
maximus	J	•						•	•	•				•		•														•						
	L					•			•				•			•												•								
	E					•			•			•															•									
Spanish mackerel	A				•				•	•	•			•		•					•			•							•		•	•	•	•
Scomberomorus	S				•				•																								•	•	•	
maculatus	J				•			•	•	•	•			•		•					•									•						•
	L					•			•				•			•			•		•		•					•								
	E					•			•			•																•								

Terms Used in Biological Attributes Life History Tables:

Life Mode - The usual location within the water column.
• *Benthic* - In the bottom sediments.
• *Epibenthic* - On, but not in, the bottom.
• *Demersal* - In the water column, but near the bottom.
• *Nektonic* - In the water column away from the bottom, and capable of locomotion.
• *Planktonic* - In the water column, but not capable of extensive movements.

Spatial strategy - Use of habitats by life stages.
• *Freshwater resident* - Resides primarily in freshwater (salinity _ 0.5 ppt) habitats.
• *Estuarine resident* - Resides primarily in estuarine habitats (salinity _0.5 and _25 ppt).
• *Marine resident* - Resides primarily in seawater habitats (salinity >25 ppt).
• *Coastal migrant* - Migrates within nearshore waters of the continental shelf.
• *Ocean migrant* - Migrates in ocean waters beyond the continental shelf.

Mobility -
• *Non-mobile* - Sessile, sedentary, or planktonic.
• *Low mobility* - Capable of limited directed movements.
• *High mobility* - Capable of extensive directed movements.

Feeding Type -
• *Filter feeder* - Obtains food items by filtering water or fine sediments.
• *Non-filter feeder* - Obtains food items by other means, such as selective predation.

Prey Items - Food items typically consumed by an organism, such as detritus, phytoplankton, zooplankton, fish, etc.

Longevity - Average lifespan of a particular life stage, from 1 day to >20 years.

Value-
• *Recreational* - Often sought and harvested by sport anglers.
• *Commercial* - Harvested by commercial fishermen for market.
• *Ecological* - Of major importance in aquatic ecosystems as a predator or prey species, etc.
• *Indicator of stress* - Often used in studies of environmental stress.

Table 20b. Biological Attributes of Other Managed and Prey Species Using South Atlantic Estuaries (Source: NOAA 1998, NOAA 1991b).

Life stage
A - Adults
S - Spawning
J - Juveniles
L - Larvae
E - Eggs

Species / life stage		Biological Attributes: Life Mode					Spatial Strategy					Mobility			Feed*		Prey Items										Longevity						Value			
		Epibenthic	Benthic	Demersal	Nektonic	Planktonic	Freshwater resident	Estuarine resident	Marine resident	Coastal migrant	Ocean migrant	Nonmobile	Low mobility	High mobility	Filter feeder	Non-filter feeder	Detritus	Phytoplankton	Zooplankton	Infauna	Epibenthos	Insects	Fish (eggs, larvae)	Fish (juveniles, adults)	Macroalgae	Vascular plants	1 day	1-30 days	1-12 months	1-5 years	5-20 years	>20 years	Recreational	Commercial	Ecological	Indicator of stress
Bay scallop *Argopecten irradians*	A	●						●	●				●		●		●	●	●											●			●	●	●	●
	S	●						●	●																											
	J	●						●	●				●		●		●	●	●										●					●	●	●
	L	●				●		●	●				●		●			●	●									●							●	●
	E			●		●		●	●				●														●									
American oyster *Crassostrea virginica*	A		●					●				●			●		●	●	●												●		●	●	●	●
	S		●					●																												
	J		●					●				●			●		●	●	●										●						●	●
	L		●			●		●				●	●		●		●	●	●									●								
	E					●		●					●														●									
Atlantic rangia *Rangia cuneata*	A		●				●	●				●			●		●	●	●												●			●	●	●
	S		●				●	●																												
	J		●				●	●					●		●		●	●	●											●				●	●	●
	L			●		●	●	●					●				●	●	●									●								
	E			●		●	●	●					●															●								

Table 20b. (cont.) Biological Attributes of Other Managed and Prey Species Using South Atlantic Estuaries (Source: NOAA 1998b, NOAA 1991b).

Life stage
A - Adults
S - Spawning
J - Juveniles
L - Larvae
E - Eggs

Species / life stage		Life Mode					Spatial Strategy					Mobility			Feed*		Prey Items										Longevity						Value			
		Epibenthic	Benthic	Demersal	Nektonic	Planktonic	Freshwater resident	Estuarine resident	Marine resident	Coastal migrant	Ocean migrant	Nonmobile	Low mobility	High mobility	Filter feeder	Non-filter feeder	Detritus	Phytoplankton	Zooplankton	Infauna	Epibenthos	Insects	Fish (eggs, larvae)	Fish (juveniles, adults)	Macroalgae	Vascular plants	1 day	1-30 days	1-12 months	1-5 years	5-20 years	>20 years	Recreational	Commercial	Ecological	Indicator of stress
Hard clam	A		●					●	●			●			●			●	●												●		●	●	●	●
Mercenaria	S		●					●	●																											
species	J		●					●	●				●		●			●	●											●			●	●	●	●
	L	●				●		●	●				●		●			●	●										●							
	E					●		●	●				●														●									
Bay squid	A				●			●	●					●		●					●			●		●				●			●	●	●	
Lolliguncula	S				●			●	●																											
brevis	J				●			●	●					●		●					●			●		●			●				●		●	
	L				●			●	●					●		●			●				●					●								
	E	●						●	●			●																●								
Brown shrimp	A			●					●					●		●	●			●	●				●					●			●	●	●	
Penaeus	S			●					●																											
aztecus	J			●				●						●		●	●		●	●	●		●		●				●				●	●	●	
	L					●		●	●					●		●		●	●									●								
	E			●					●			●				●											●									

Table 21a. Reproductive Attributes of Select Managed Species(Source: NOAA 1998b, NMFS SEFSC, and SAFMC).

SE EFH 9/29/98	Reproduction: Fertilization/ development					Mating type			Spawning strategy					Parent care		Domain			Temporal Schedule												Periodicity				Fecundity								Maturation age					
Species	External	Internal	Oviparous	Ovoviviparous	Viviparous	Monogamous	Polygamous	Broadcast spawner	Andromous	Catadromous	Iteroparous	Semelparous	Batch	Protected	Non-protected	Riverine	Estuarine	Marine	January	February	March	April	May	June	July	August	September	October	November	December	Annual spawning	2 or more per year	2 or more years	Undescribed	<100	100-1,000	1,000-10,000	10,000-100,000	100,000-1 million	1-10 million	>10 million	Undescribed	<6 months	0.5 to 1 Year	1 to 3 Years	3 to 5 Years	> 5 Years	Undescribed
Brown shrimp *Peneaus aztecus*	•		•				•				•			•				•	•	•	•	•	•	•	•	•	•	•	•	•		•							•				•					
Pink shrimp *Peneaus duorarum*	•		•				•				•			•				•				•	•	•	•							•							•				•					
White shrimp *Penaeus setiferus*	•		•				•				•			•			•	•			•	•	•	•	•	•	•	•				•							•				•					
Black seabass *Centropristis ocyurus*	•		•												•			•		0 •	•	•	•	•																						•		
Gag *Mycteroperca mircolepis*	•		•				•	•			•		•		•			•	•	•	•											•							•							•		
Scamp *Mycteroperca phenax*	•		•				•	•			•		•		•			•														•							•									
Cobia *Rachycentron canadum*	•		•				•				•		•		•								•	•	•	•						•								•					•			
Mutton snapper *Lutjanus analis*	•		•				•	•			•		•		•			•			•	•	•	•	•	•	•					•							•							•		
Red snapper *Lutjanus campechanus*	•		•				•	•			•		•		•			•					•	•	•	•	•	•				•							•						•			
Gray snapper *Lutjanus griseus*	•		•				•	•			•		•		•			•				•	•	•	•	•	•	•				•							•						•			
Lane snapper *Lutjanus synagris*	•		•				•	•			•		•		•			•			•	•	•	•	•	•	•					•							•						•			
Yellowtail snapper *Ocyurus chrysurus*	•		•				•	•			•		•		•			•			•	•	•	•	•	•	•	•	•			•							•						•			
Vermilion snapper *Rhomboplites aurorubens*	•		•				•	•			•		•		•			•				•	•	•	•	•	•					•							•						•			•
White grunt *Haemulon plumieri*	•		•				•	•			•		•		•			•	•	•	•	•	•	•	•	•	•	•	•	•		•							•						•			
Sheepshead *Archosargus probatocephalus*	•		•				•	•			•		•		•			•			•	•										•										•			•			
Red drum *Sciaenops ocellatus*	•		•				•	•			•		•		•		•	•	•							•	•	•	•	•		•								•						•		
Hogfish *Lachnolaimus maximus*	•		•				•	•			•		•		•			•	•				•	•	•				•	•		•							•									•
Spanish mackerel *Scomberomorus maculatus*	•		•				•	•			•		•		•			•				•	•	•	•	•	•	•				•								•					•			

Terms Used in Reproduction Life History Tables:

Fertilization/development - Method of egg fertilization and development.
• *External* - Egg fertilization occurs after eggs and sperm are shed into the water.
• *Internal* - Egg fertilization occurs when a male inseminates an egg within a female.
• *Oviparous* - Eggs are laid and fertilized externally.
• *Ovoviviparous* - Eggs are fertilized and incubated internally, and usually released as larvae. Little or no maternal nourishment is provided.
• *Viviparous* - Eggs are fertilized, incubated, and develop internally until birth. Maternal nourishment is provided.

Mating Type - Mate selection strategy.
• *Monogamous* - A single male and a single female pair for a prolonged and exclusive relationship.
• *Polygamous* - A male mates with numerous females or vice-versa.
• *Broadcast spawner* - Numerous males and females release gametes during mass spawning.

Spawning strategy - Spawning mode.
• *Anadromous* - Species spends most of its life at sea but migrates to fresh water to spawn.
• *Catadromous* - Species spends most of its life in fresh water but migrates to salt water to spawn.
• *Iteroparous* - Species reproduces repeatedly during a lifetime.
• *Semelparous* - Species reproduces only once during a lifetime.
• *Batch* - Species spawns (releases gametes) several times during a reproductive period.

Parental Care - Type of egg protection.
• *Protected* - Eggs are protected by parent(s); eggs are buoyant or attached to substrates, or eggs develop in the shelter of a nest.
• *Non-protected* - Eggs are not protected by parent(s).

Domain - Location of spawning.
• *Riverine* - Spawning occurs primarily in fresh water, above head of tide.
• *Estuarine* - Spawning occurs primarily in estuarine waters (to head of tide).
• *Marine* - Spawning occurs primarily in open marine waters.

Temporal Schedule - Months when spawning typically occurs.

Periodicity - Frequency of spawning events.
•*Annual spawning* - Spawning once each year, usually during a restricted season.
•*2 or more per year* - Spawning more than once each year (more than one spawning season).
•*2 or more years* - Spawning events separated by at least two years.
•*Undescribed* - Spawning frequency not documented.

Fecundity - Number of eggs typically produced by a mature female, from <100 to >10 million.

Maturation age - The typical length of time for an individual to reach sexual maturity, from < 6 months to > 5 years.

Table 21b. Reproductive Attributes of Select Managed and Prey Species Using South Atlantic Estuaries (NOAA 1998b, NOAA 1991b).

Species	Reproduction: Fertilization/ development					Mating type			Spawning strategy					Parent care		Domain		
	External	Internal	Oviparous	Ovoviviparous	Viviparous	Monogamous	Polygamous	Broadcast spawner	Anadromous	Catadromous	Iteroparous	Semelparous	Batch	Protected	Non-protected	Riverine	Estuarine	Marine
Spot *Leiostomus xanthurus*	1		1				1	1			1		1		1			1
Pinfish *Lagodon rhomboides*	•		•				•	•			•		•		•			•
Spotted seatrout *Cynoscion nebulosus*	•		•				•	•			•		•		•		•	
Atlantic croaker *Micropogonias undulatus*	•		•				•	•			•		•		•			•
Black drum *Pogonias cromis*	•		•				•	•			•		•		•		•	•
Bluefish *Pomatomus saltatrix*	•		•				•	•			•		•		•			•
Striped mullet *Mugil cephalus*	•		•				•	•			•		•		•			•
Gulf flounder *Paralichthys albigutta*	•		•				•	•			•		•		•			•
Southern flounder *Paralichthys lethostigma*	•		•				•	•			•		•		•			•

Species	Temporal Schedule												Periodicity				Fecundity								Maturation age					
	January	February	March	April	May	June	July	August	September	October	November	December	Annual spawning	2 or more per year	2 or more years	Undescribed	<100	100-1,000	1,000-10,000	10,000-100,000	100,000-1 million	1-10 million	>10 million	Undescribed	<6 months	0.5 to 1 Year	1 to 3 Years	3 to 5 Years	> 5 Years	Undescribed
Spot *Leiostomus xanthurus*	1	1	1	1							1	1		1							1						1			
Pinfish *Lagodon rhomboides*	•	•	•							•	•	•		•						•							•			
Spotted seatrout *Cynoscion nebulosus*		•	•	•	•	•	•	•	•	•				•								•					•			
Atlantic croaker *Micropogonias undulatus*	•	•	•	•	•				•	•	•	•		•								•					•			
Black drum *Pogonias cromis*	•	•	•	•	•						•	•		•								•					•			
Bluefish *Pomatomus saltatrix*			•	•	•				•	•	•			•							•						•			
Striped mullet *Mugil cephalus*	•	•	•							•	•	•		•								•						•		
Gulf flounder *Paralichthys albigutta*	•	•									•	•		•										•			•			
Southern flounder *Paralichthys lethostigma*	•	•									•	•		•					•								•			

Table 21b. (cont.) Reproductive Attributes of Other Managed and Prey Species Using South Atlantic Estuaries (NOAA 1998b, NOAA 1991b).

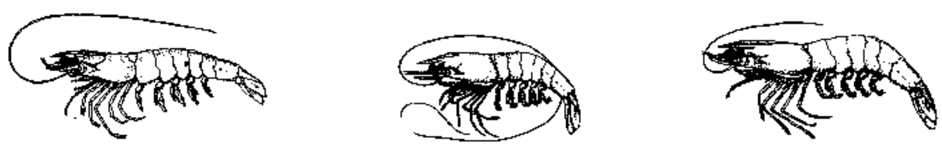
Species	Reproduction: Fertilization/ development					Mating type			Spawning strategy					Parent care		Domain			Temporal Schedule												Periodicity				Fecundity								Maturation age					
	External	Internal	Oviparous	Ovoviviparous	Viviparous	Monogamous	Polygamous	Broadcast spawner	Anadromous	Catadromous	Iteroparous	Semelparous	Batch	Protected	Non-protected	Riverine	Estuarine	Marine	January	February	March	April	May	June	July	August	September	October	November	December	Annual spawning	2 or more per year	2 or more years	Undescribed	<100	100-1,000	1,000-10,000	10,000-100,000	100,000-1 million	1-10 million	>10 million	Undescribed	<6 months	0.5 to 1 Year	1 to 3 Years	3 to 5 Years	> 5 Years	Undescribed
Blue mussel ***Mytilis edulis***	•		•					•				•	•		•		•	•						•	•	•	•	•			•	•								•					•			
Bay scallop *Argopecten irradians*	•		•					•				•	•		•		•	•								•	•	•				•							•					•				
American oyster *Crassostrea virginica*	1		1					1			1		1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1									1		1					
Atlantic rangia *Rangia cuneata*	•		•					•			•				•	•	•				•	•	•	•	•	•	•	•	•			•										•			•			
Quahog *Mercenaria species*	•		•					•			•		•		•		•				•	•	•	•	•	•	•	•				•									•				•			
Grass shrimp *Palaemonetes pugio*	•		•				•				•			•			•			•	•	•	•	•	•	•	•	•				•				•							•					
Blue crab *Callinectes sapidus*		1	1				1				1			1		1	1			1	1	1	1	1	1	1	1	1				1								1					1			
Atlantic sturgeon ***Acipenser oxyrhynchus***	•		•					•	•		•		•		•	•	•			•	•	•	•								•									•							•	
American eel ***Anguilla rostrata***	•		•							•		•			•			•		•	•	•									•									•						•	•	
Blueback herring ***Alosa aestivalis***	•		•					•	•		•				•	•	•				•	•	•	•							•								•							•		
Alewife ***Alosa pseudoharengus***	1		1					1	1		1				1	1	1			1	1	1	1	1							1								1							1		
American shad ***Alosa sapidissima***	•		•					•	•		•				•	•	•		•	•	•										•								•							•		
Atlantic menhaden ***Brevoortia tyrannus***	•		•					•					•		•				•	•	•								•	•									•						•			
Bay anchovy *Anchoa mitchilli*	•		•				•	•			•		•		•		•	•	•	•	•	•	•	•	•	•	•	•	•	•		•					•						•					
Sheepshead minnow *Cyprinodon variegatus*	•		•				•	•			•			•			•			•	•	•	•	•	•	•	•	•				•			•								•					
Silversides *Menidia species*	•		•				•	•			•				•		•		•	•	•	•	•	•	•	•	•	•	•	•		•				•								•				

3.3.1 Penaeid and Deepwater Shrimp

In the southeastern United States, the shrimp industry is based on the white shrimp, *Penaeus setiferus*, the brown shrimp, *Penaeus aztecus*, the pink shrimp, *Penaeus duorarum* and the deeper water rock shrimp, *Sicyonia brevirostri. T*he royal red shrimp, *Pleoticus robustus* occurs in deeper water, and sustains a limited harvest.

3.3.1.1 Description of the Penaied Shrimp Species and Distribution

With the exception of pink shrimp, which is also found off Bermuda, the three *Penaeus* species are restricted to the Atlantic Coast of the U.S. and the Gulf of Mexico. Other common names for the white shrimp (Figure 11) include gray shrimp, lake shrimp, green shrimp, green-tailed shrimp, blue tailed shrimp, rainbow shrimp, Daytona shrimp, common shrimp, and southern shrimp. The brown shrimp (Figure 11) is also known as brownie, green lake shrimp, red shrimp, redtail shrimp, golden shrimp, native shrimp, and also the summer shrimp in North Carolina. Other names for the pink shrimp (Figure 11) include spotted shrimp, hopper, pink spotted shrimp, brown spotted shrimp, grooved shrimp, green shrimp, pink night shrimp, red shrimp, skipper, and pushed shrimp.



Pink shrimp   White shrimp   Brown shrimp

Figure 11. Illustrations of white, brown and pink shrimp.

Juvenile and adult penaeids are omnivorous (eating both plants and animals) bottom feeders with most feeding activity occurring at night although daytime feeding may occur in turbid waters. Food items may consist of polychaetes, amphipods, nematodes, caridean shrimps, mysids, copepods, isopods, amphipods, ostracods, mollusks, foraminiferans, chironomid larvae, and various types of organic debris.

White shrimp appear to prefer muddy or peaty bottoms rich in organic matter and decaying vegetation when in inshore waters. Offshore they are most abundant on soft muddy bottoms. Brown shrimp appear to prefer a similar bottom type and as adults may also be found in areas where the bottom consists of mud, sand, and shell. Pink shrimp are found most commonly on hard sand and calcareous shell bottom. Both brown and pink shrimp generally bury in the substrate during daylight, being active at night. White shrimp do not bury with the regularity of pink or brown shrimp.

Shrimp are preyed on by a wide variety of species at virtually all stages in their life history. Predation on postlarvae has been observed by sheepshead minnows, water boatmen, and insect larvae. Grass shrimp, killifishes, and blue crabs prey on young penaeid shrimp, and a wide variety of finfish are known to prey heavily on juvenile and adult penaeid shrimp.

In Georgia and northern Florida, some white shrimp spawning may occur inshore, although most spawning occurs more than 1.2 miles from the coastline. Off Florida, spawning occasionally takes place inshore, at or near inlets, but most occurs offshore in depths of 6.1-24.4 m (20-80 ft). In South Carolina most spawning occurs within about four miles of the coast. Some shrimp with spermatophores attached have been found inside Charleston harbor (Whitaker, SCWMRD, pers. comm. 1991).

Spawning is correlated with bottom water temperatures and has been reported to occur at bottom temperatures of between 17° and 29° C although spawning generally occurs between 22° and 29° C. White shrimp begin spawning in April in Florida and Georgia and late April or May in South Carolina. Spawning may continue into September or October.

Brown shrimp spawn in relatively deep water. In the Gulf of Mexico, it was concluded that brown shrimp did not spawn in water less than 13.7 m (45 ft) and the greatest percentage of ripe females were at 45.7 m (150 ft). Spawning season for brown shrimp is uncertain, although there is an influx of postlarvae into the estuaries during February and March. Mature males and females have been found off South Carolina during October and November.

Pink shrimp apparently spawn between 3.7 and 15.8 m (12 and 52 ft). Off eastern Florida, peak spawning activity seems to occur during summer. In North Carolina, roe-bearing females are found as early as May, and by June, most pink shrimp are sexually mature.

All three species have eleven larval stages (5 nauplier, 3 protozoan, and 3 mysid) before developing into postlarvae. Duration of the larval period is dependent on temperature, food, and habitat. Records suggest larval periods of 10-12 days for white shrimp, 11-17 days for brown shrimp, and 15-25 days for pink shrimp. Brown shrimp postlarvae appear to overwinter in offshore bottom sediments (Whitaker, SCWMRD, pers. comm. 1991). Postlarval shrimp sizes range from approximately 2.9 to 12 mm (0.1-0.5 in) TL, with pink and white shrimp sizes overlapping and brown shrimp usually being larger.

The mechanism by which postlarvae are brought from distant spawning areas to inside estuaries is not well-known. Shoreward countercurrents north of Cape Canaveral have been suggested as the mechanism for transport of pink shrimp larvae from spawning areas to nursery areas along the northeast Florida coast. Movement of white shrimp postlarvae into the estuary is a result of nearshore tidal currents as white shrimp spawn relatively close to shore. There is some data on brown shrimp that suggest postlarvae may overwinter in offshore waters and migrate into estuaries the following spring. White and pink shrimp move into the estuary during late spring and early summer.

After entering the estuaries, postlarval shrimp occupy nursery areas which offer abundant food, suitable substrate, and shelter from predators. In the South Atlantic these areas are generally dominated by the marsh grass *Spartina alterniflora*.

White and pink shrimp enter the estuaries at about the same time, usually beginning in April and early May in the southern part of their range and in June and July in North Carolina sounds, where white shrimp are uncommon. Large white shrimp begin emigrating out of the estuary to the commercial fishing areas in August and continue through December. Smaller white and pink shrimp may remain in the estuary during winter and are termed overwintering stocks.

In the South Atlantic, juvenile and adult brown shrimp are rarely affected by severe winter weather because most have been captured by fishermen or predators, and others have moved offshore prior to the onset of cold weather.

Pink shrimp bury deeply in the substrate with the onset of cold weather and thus are protected to some extent from winter mortalities. However, pink shrimp can be adversely affected by low temperatures as evidenced by the mass mortalities in North Carolina during the winters of 1976-77 and 1977-78.

Pink and white shrimp that survive the winter grow rapidly in late winter and early spring before migrating to the ocean. The migrating white shrimp, called roe shrimp, make up the spring fishery and also produce the summer and fall crops of shrimp. When a majority of white shrimp do not survive the winter, the North Carolina and South Carolina fisheries are believed to be dependent on a northward spring migration of white shrimp from more southerly areas to form the spawning stock. However, tagging data are inconclusive on the extent of this northward movement.

Spatial and Temporal Distribution and Relative Abundance in Estuarine Habitat

NOAA's Estuarine Living Marine Resource Program (ELMR), through a joint effort of National Ocean Service and NMFS, conducts regional compilations of information on the use of estuarine habitat by select marine fish and invertebrates. A report prepared through the ELMR program (NOAA 1991b) and revised information (NOAA 1998), provided the Council during the Habitat Plan development process, present known spatial and temporal distribution and relative abundance of fish and invertebrates using southeast estuarine habitats. Twenty southeast estuaries selected from the National Estuarine Inventory (NOAA 1985) are included in the analysis which resulted from a review of published and unpublished literature and personal consultations. The resultant information emphasizes the importance and essential nature of estuarine habitat to all life stages of white, brown and pink shrimp. Regional salinity and relative abundance maps for use in determining EFH for white, brown and pink shrimp, were prepared for the Council by NOAA SEA Division. Figures 12-17 present a representative sample of the distribution maps. The entire set of maps in color can be found at the SAFMC web site (www.safmc.noaa.gov) and are included in Appendix F. These maps portray salinity and species relative abundances for estuaries and coastal embayments on state and/or regional maps. Depending on data availability, maps were produced at various scales: 1:24K, 1:80K, and 1:250K. For species relative abundances, these maps were developed only for juveniles of estuarine species (Nelson et al. 1991) showing the highest juvenile relative abundance in any salinity zone by season for each estuary. These maps will eventually be provided to the Council as ArcView shape files with associated data for inclusion into the Councils GIS system.

Rates of growth in penaeid shrimp are highly variable and depend on factors such as season, water temperature, shrimp density, salinity, size, and sex. Adolescent shrimp grow rapidly with estimates ranging from 1.0-2.3 mm per day for white shrimp, 0.5-2.5 mm per day for brown shrimp, and 0.25-1.7 mm per day for pink shrimp. Larger white shrimp may grow more than an inch per month.

Salinity is also a factor determining growth rate in white shrimp. High salinities appear to inhibit growth. Density also affects growth of white shrimp. During years of low densities, the average size is generally larger.

Temperature also affects brown shrimp growth rates, with rates as high as 3.3 mm per day recorded when the temperature exceeded 25° C but less than 1.0 mm per day when water temperature was below 20° C. Salinity also affects growth rates in brown shrimp. Salinities in excess of 10 ppt seems to enhance growth rate.

Pink shrimp in Florida Bay were found to grow 3.5 mm CL (carapace length) in winter and only 1.9 mm CL in spring. In North Carolina, maximum pink shrimp growth rates were recorded in summer.

Distribution

White shrimp range from Fire Island, New York to St. Lucie Inlet on the Atlantic Coast of Florida (Figure 18). Along the Atlantic Coast of the U.S., the white shrimp has centers of abundance in South Carolina, Georgia, and northeast Florida. White shrimp are generally concentrated in waters of 27 m (89 ft) or less, although occasionally found much deeper (up to 270 ft).

On the Atlantic Coast, brown shrimp occur from Martha's Vineyard, Massachusetts to the Florida Keys (Figure 19). While it may occur seasonally along the Mid-Atlantic states, breeding populations apparently do not range north of North Carolina. The species may occur in commercial quantities in waters as deep as 110 m (361 ft), but they are most abundant in water less than 55 m (180 ft).

Pink shrimp occur from southern Chesapeake Bay to the Florida Keys (Figure 20), and around the coast of the Gulf of Mexico to Yucatan south of Cabo Catoche. Maximum abundance is reached off southwestern Florida and the southeastern Golfo de Campeche. Along the Atlantic Coast of the U.S., pink shrimp occurs in sufficient abundance to be of major commercial significance only in North Carolina. Pink shrimp are most abundant in waters of 11-37 m (36-121 ft) although in some areas they may be abundant as deep as 65 m (213 ft). Pink shrimp are common in the estuaries and shallow marine waters surrounding southern Florida and into deep waters (approximately 100 meters) southeast of the Keys, and are the dominant species within the Dry Tortugas shrimping grounds and Florida Bay (Solamon, 1968). Adult pink shrimp congregate in deep water (> 6 fathoms) off the Dry Tortugas to spawn. Larvae can take two routes to the estuarine nursery areas where they spend most of their life cycle. One route is directly to the shallow-water estuaries of the 10,000 Island, Whitewater Bay, and Florida Bay. On the other route, larvae are swept southwesterly into the Florida Current by way of the Loop Current, and are carried northeasterly along the outer edge of the Florida Reef Tract or of east coast of Florida (Ingle et al., 1959).

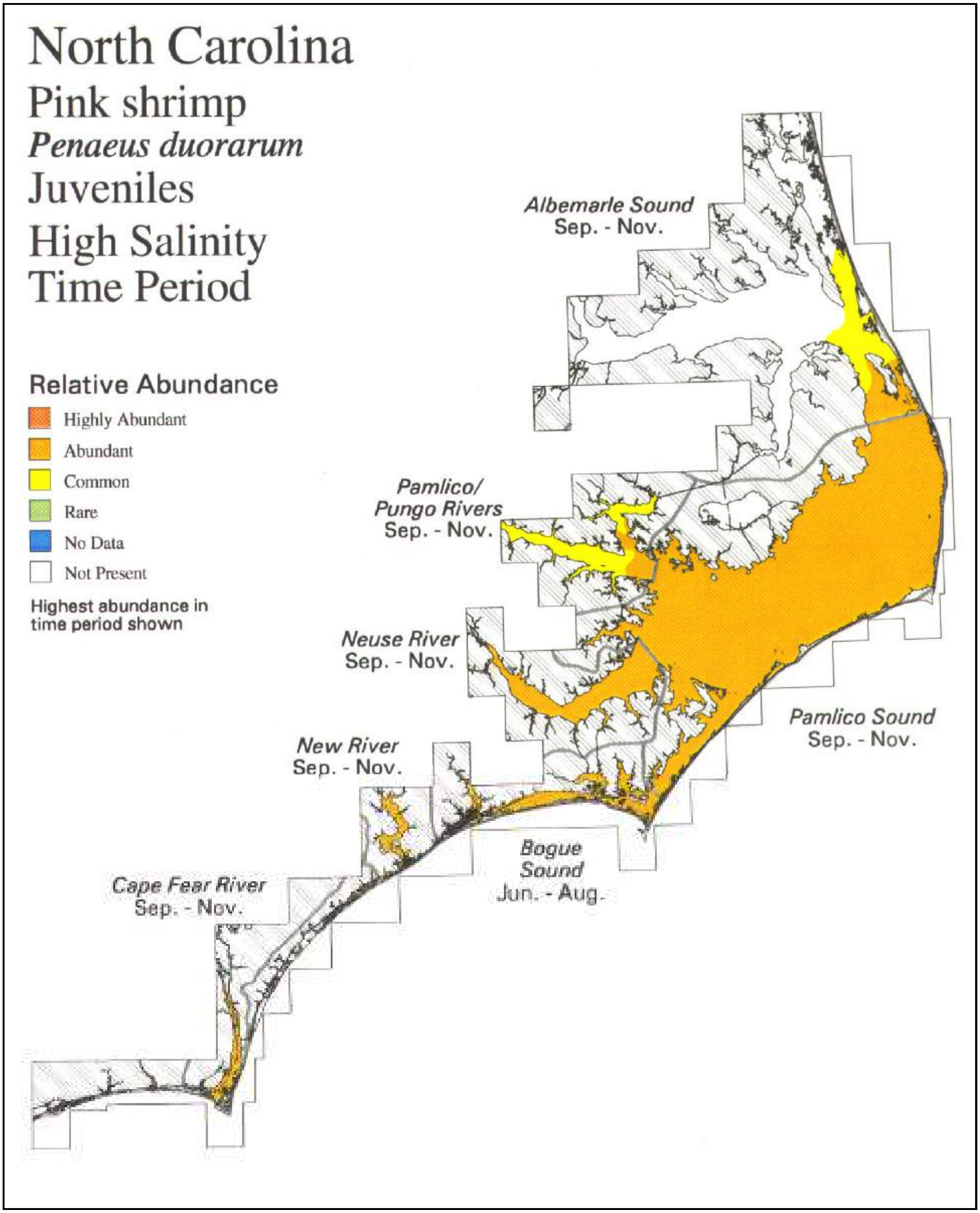


Figure 12. Pink shrimp juvenile distribution in North Carolina estuaries in high salinity time period (Source: NOAA 1998).

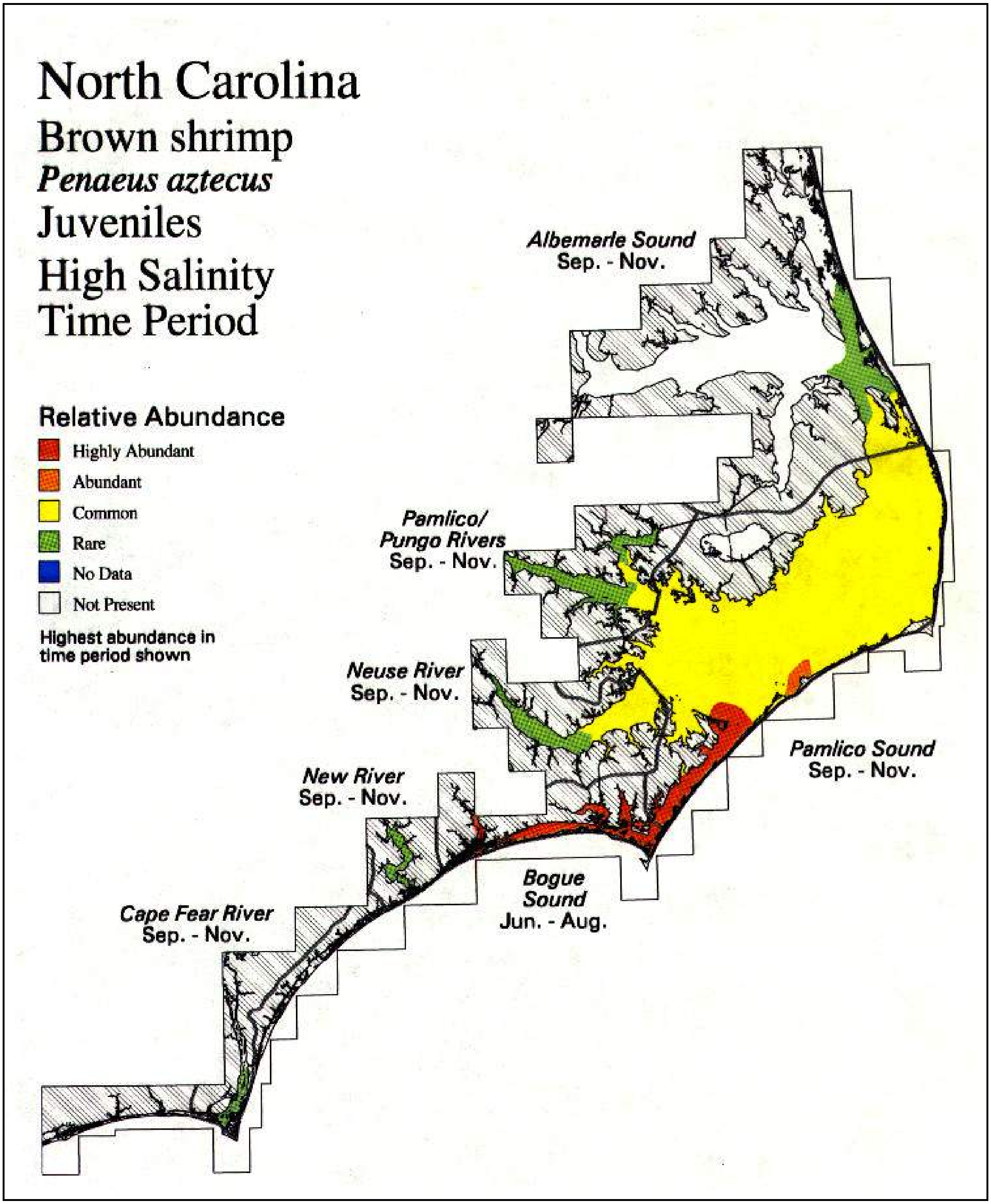


Figure 13. Brown shrimp juvenile distribution in North Carolina estuaries in high salinity time period (Source: NOAA 1998).

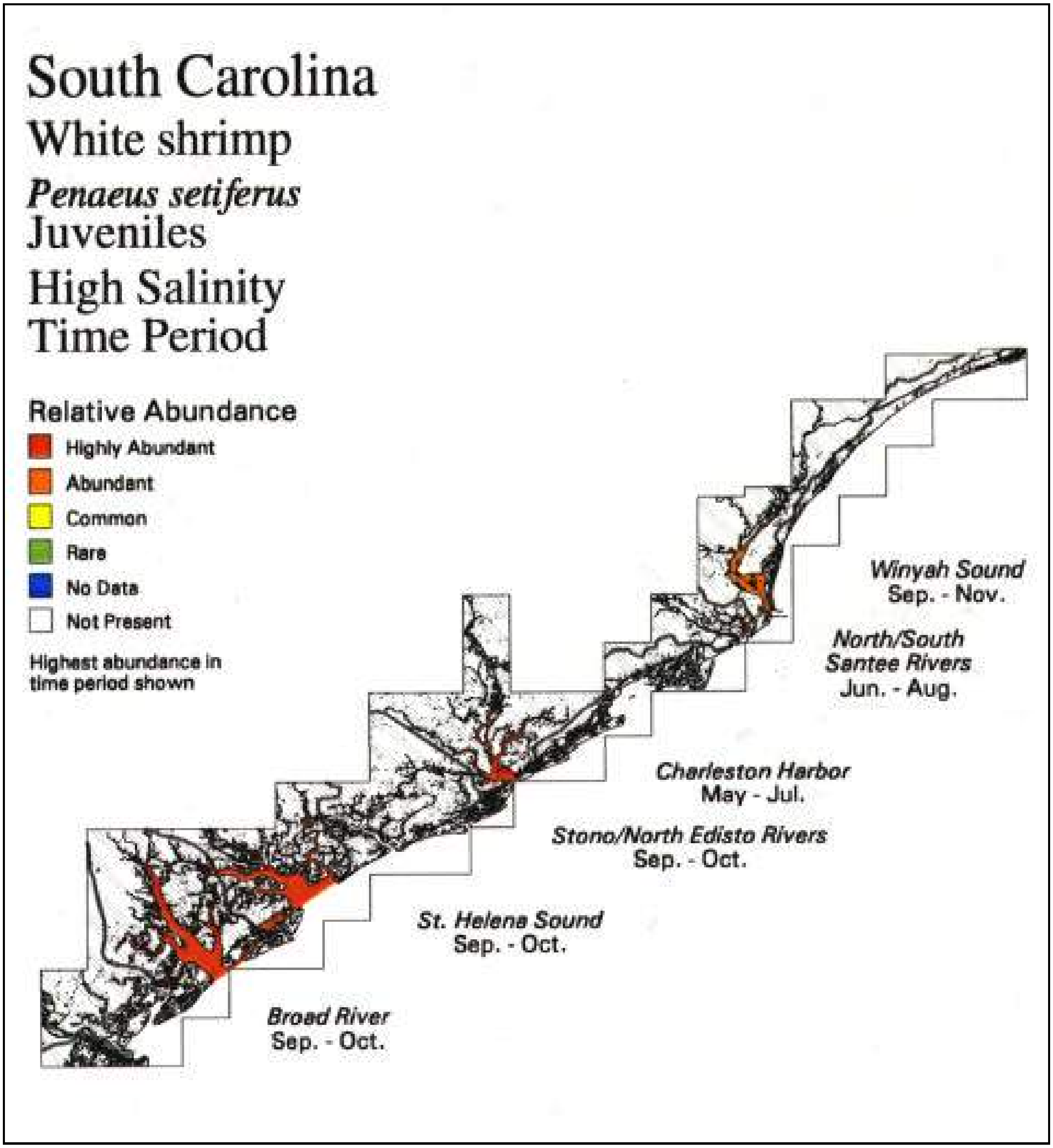


Figure 14. White shrimp juvenile distribution in South Carolina estuaries in high salinity time period (Source: NOAA 1998).

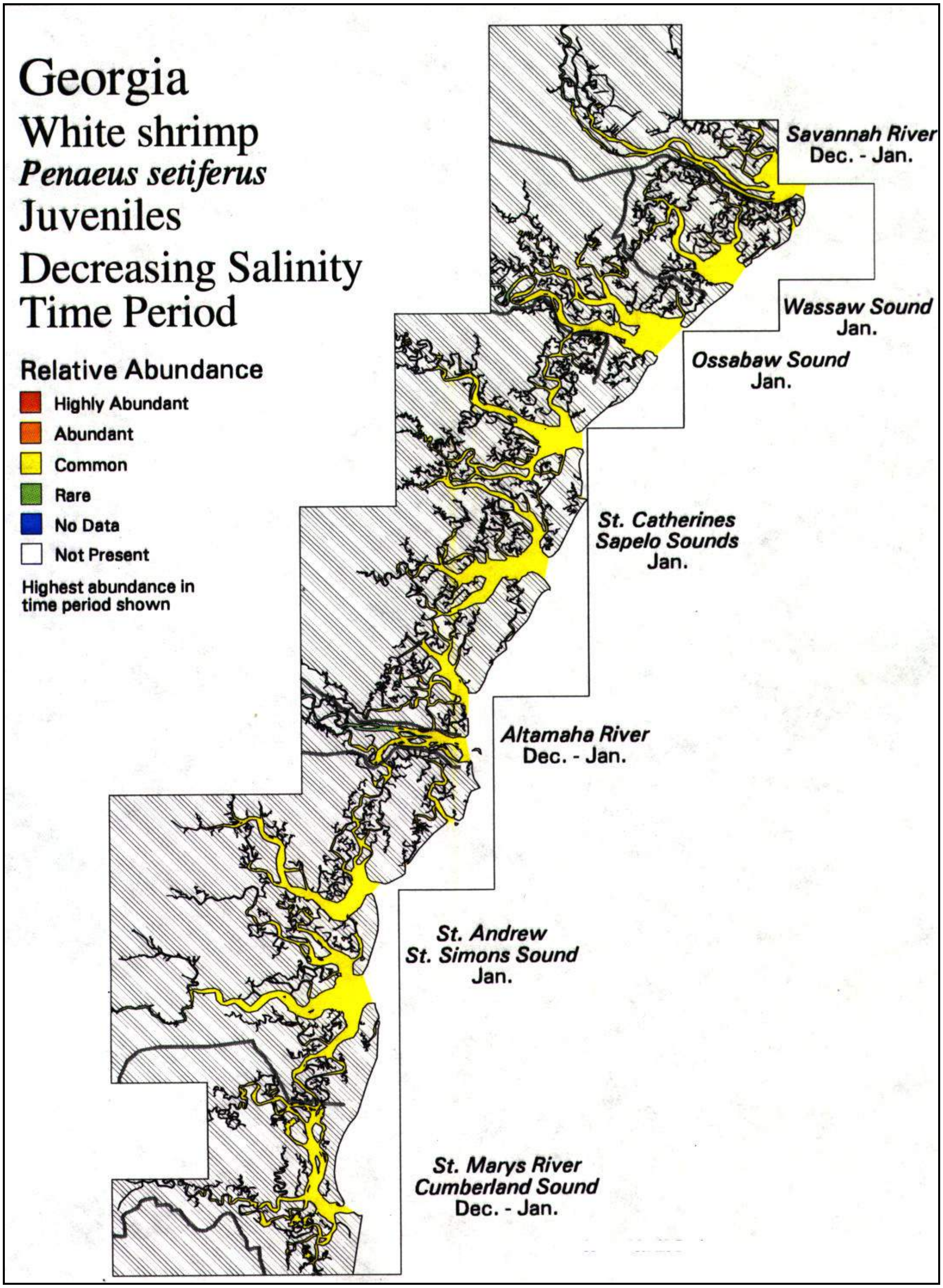


Figure 15. White shrimp juvenile distribution in Georgia estuaries in decreasing salinity time period (Source: NOAA 1998).

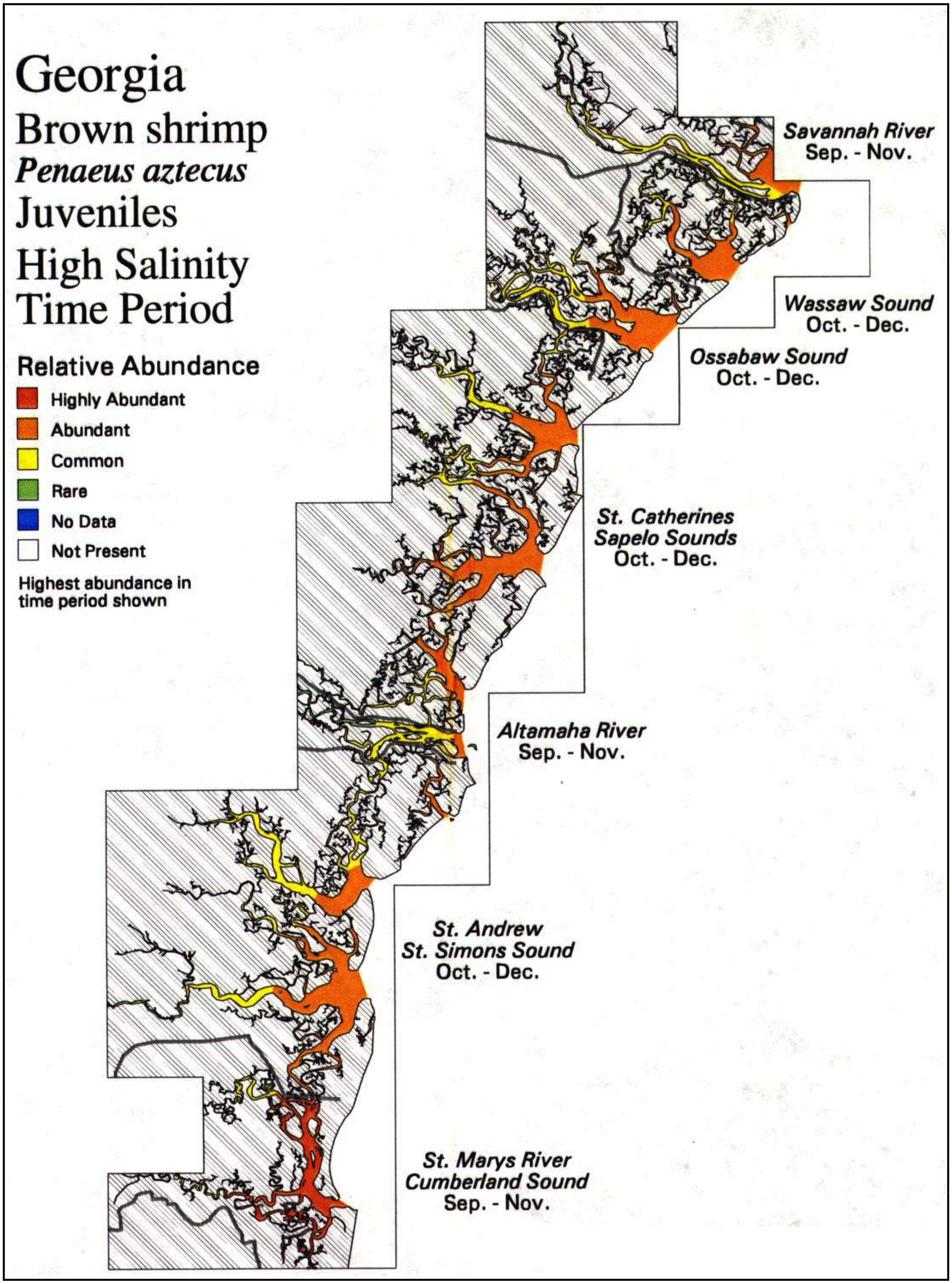


Figure 16. Brown shrimp juvenile distribution in Georgia estuaries in high salinity time period (Source: NOAA 1998).

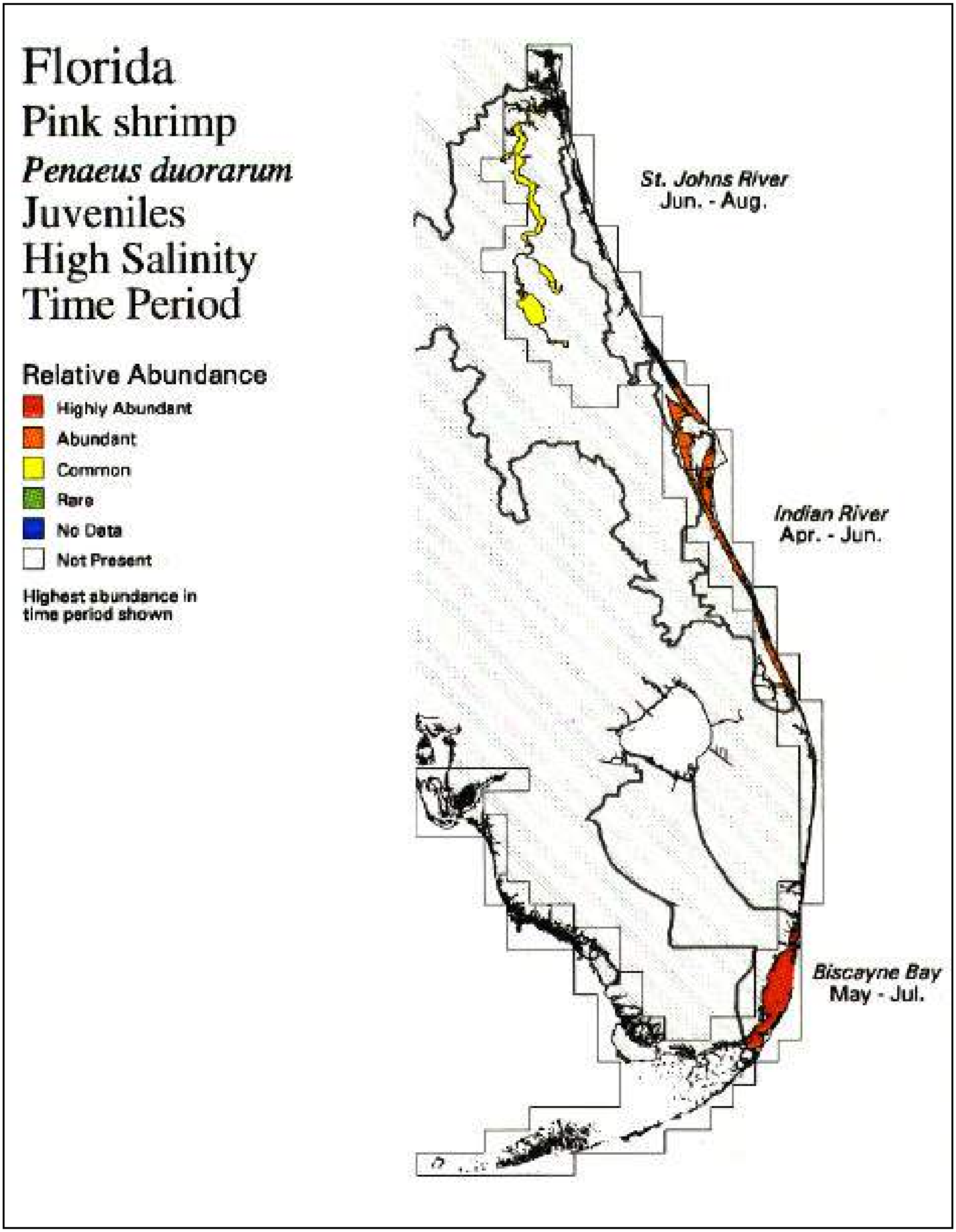


Figure 17. Pink shrimp juvenile distribution in Florida estuaries in high salinity time period (Source: NOAA 1998).

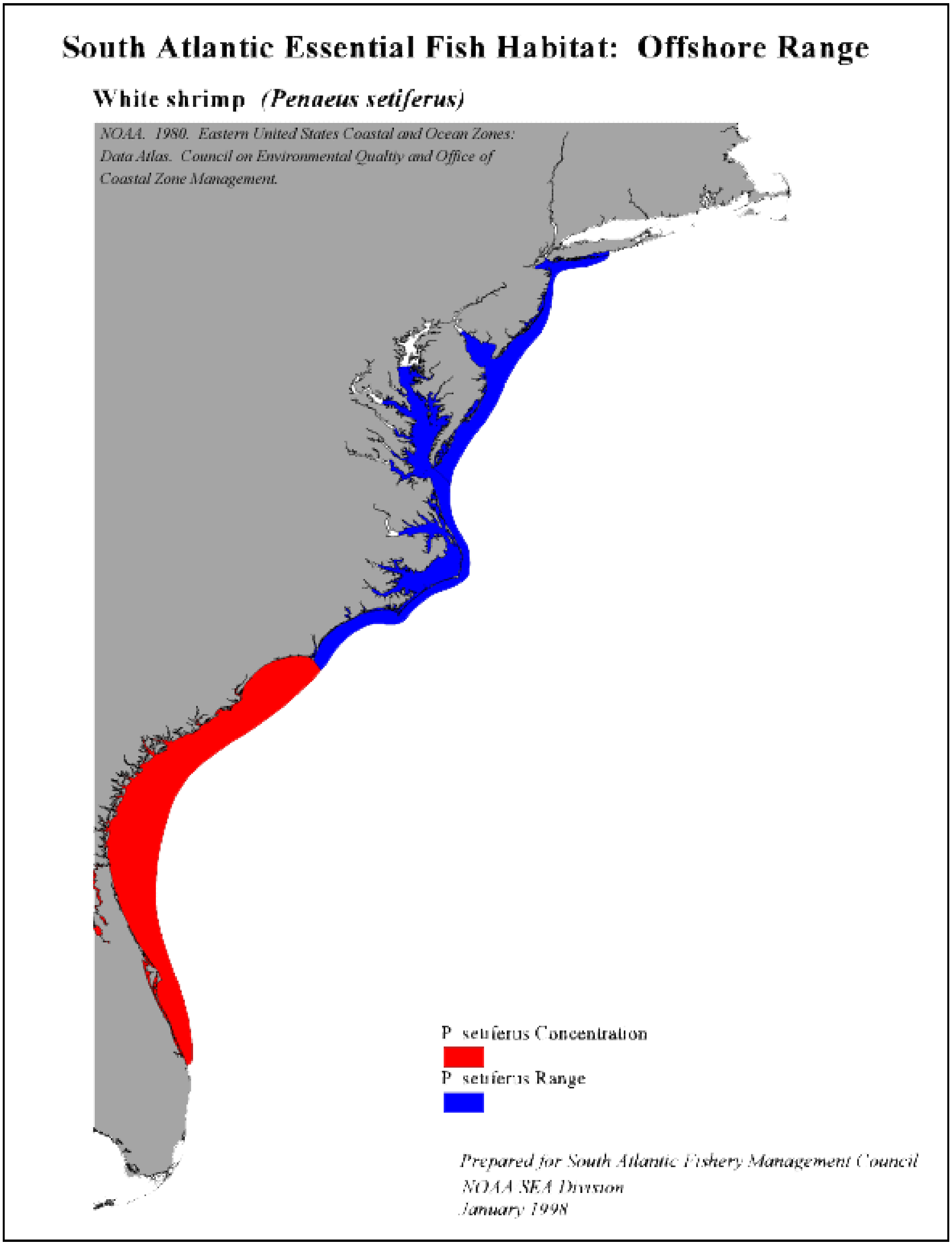

South Atlantic Essential Fish Habitat: Offshore Range
White shrimp (Penaeus setiferus)
NOAA. 1980. Eastern United States Coastal and Ocean Zones: Data Atlas. Council on Environmental Quality and Office of Coastal Zone Management.
P. setiferus Concentration
P. setiferus Range
Prepared for South Atlantic Fishery Management Council
NOAA SEA Division
January 1998

Figure 18. White Shrimp Distribution (Data Source: NOAA 1980).

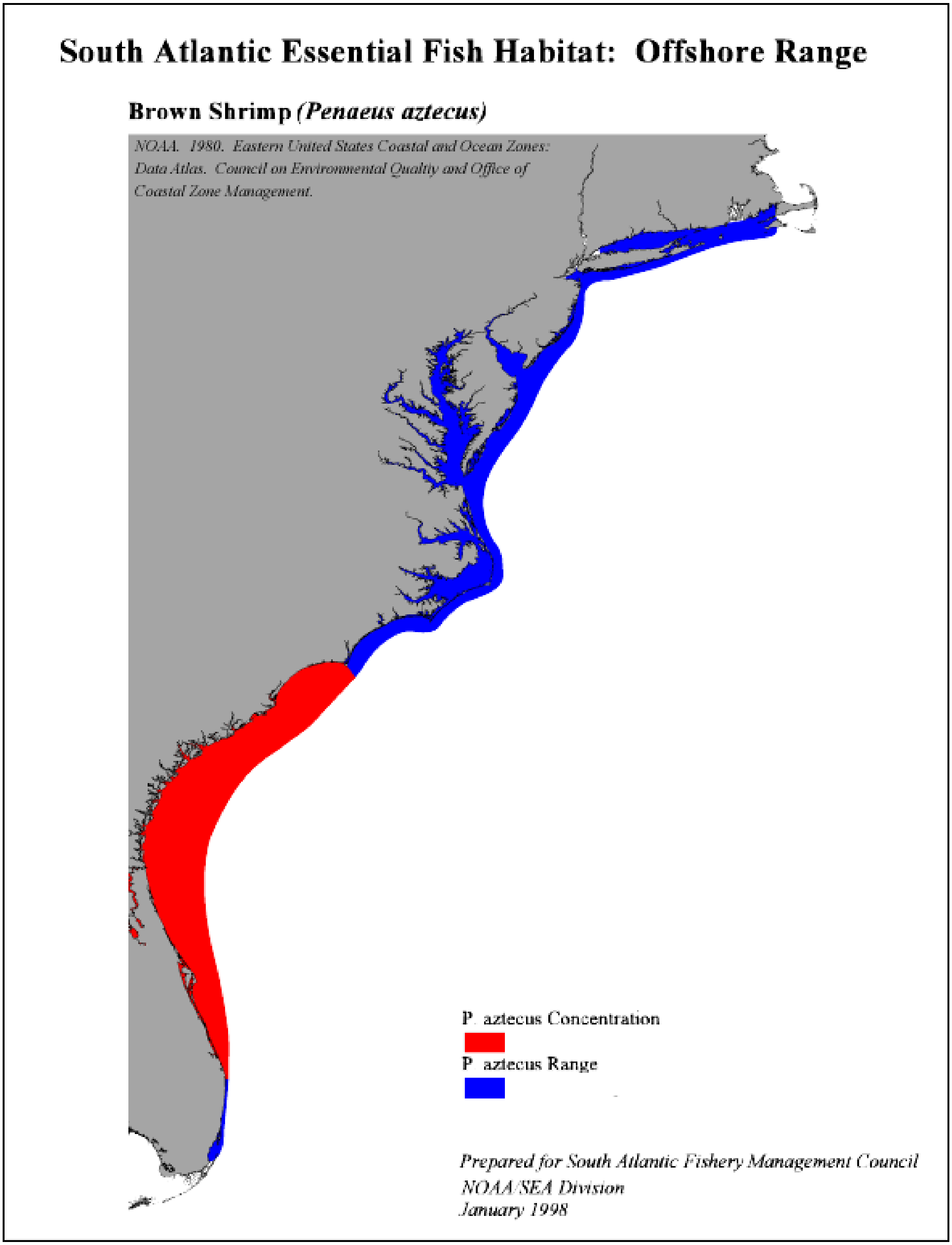


Figure 19. Brown Shrimp Distribution (Data Source: NOAA 1980).

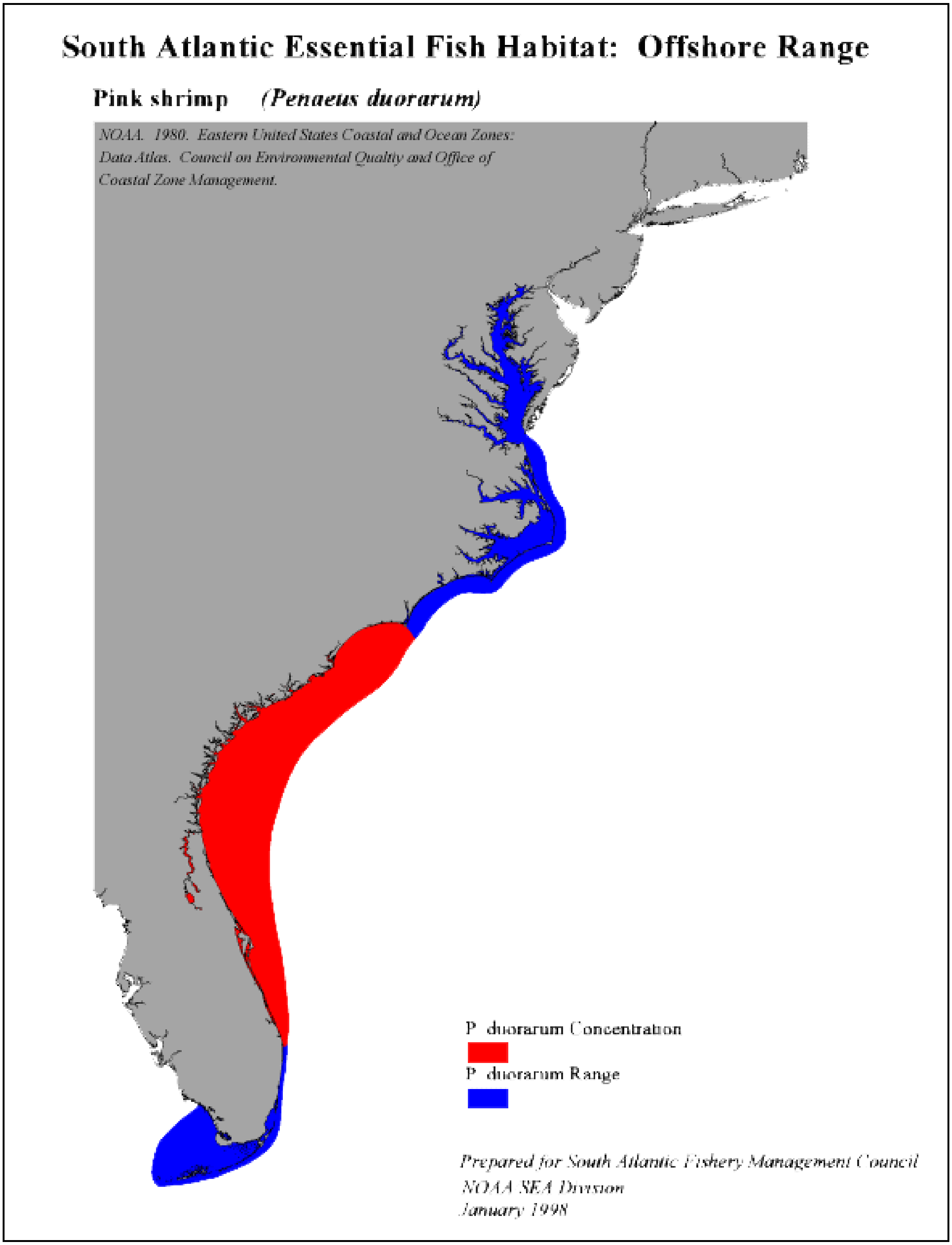


Figure 20 . Pink Shrimp Distribution.

3.3.1.2 Description of the Deepwater Shrimp Species and Distribution

Rock Shrimp

Rock shrimp (Figure 21) are very different in appearance from the three species of *Penaeus*. Rock shrimp can be easily separated from *Penaeus* species by their thick, rigid, stony exoskeleton. The affected environment, including a description of the shrimp fisheries in the south Atlantic region, is presented in detail in the original shrimp plan (SAFMC 1993) and the profile of the shrimp fishery in the south Atlantic (SAFMC 1981). A description of Council concerns and recommendations on protecting shrimp habitat is also included in the original FMP.

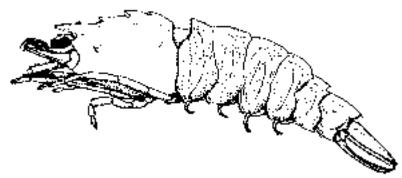


Figure 21. Rock shrimp *Sicyonia brevirostris*.

Biological Characteristics

Rock shrimp are dioecious (separate sexes). Female rock shrimp attain sexual maturity at about 17 mm carapace length (CL), and all males are mature by 24 mm CL. Seasonal temperature initiates maturation. Rock shrimp have ovaries that extend from the anterior end of the cephalothorax to the posterior end of the abdomen. Rock shrimp, as with most shrimp species, are highly fecund. Fecundity most probably, as with penaeids, increases with size. In rock shrimp, copulation is believed to take place between hard shelled individuals. During copulation the male anchors the spermatophore to the female's thelycum by the petasma and other structures and a glutinous material. Fertilization is believed to take place as ova and spermatozoa are simultaneously expulsed from the female. Spawning season for rock shrimp is variable with peak spawning beginning between November and January and lasting 3 months. Individual females may spawn three or more times in one season. Peak spawning activity seems to occur monthly and coincides with the full moon (Kennedy et al. 1977). Five ovarian stages, one more than found in penaeid shrimp, have been identified for rock shrimp (Kennedy et al. 1977): 1) Undeveloped; 2) Developing; 3) Nearly Ripe; 4) Ripe; and 5) Advanced Ripe.

Larval and Postlarval Phases

Kennedy et al. (1977) found rock shrimp larvae to be present year round with no trend relative to depth, temperature, salinity, and length or moon phase. The development from egg to postlarvae takes approximately one month. Subsequently the development from postlarvae to the smallest mode of recruits takes two to three months. The major transport mechanism affecting planktonic larval rock shrimp is the shelf current systems near Cape Canaveral, Florida (Bumpus 1973). These currents keep larvae on the Florida Shelf and may transport them inshore in spring.

Growth Patterns, Mortality, and Recruitment

Rates of growth in rock shrimp are variable and depend on factors such as season, water temperature, shrimp density, size, and sex. Rock shrimp grow about a count a month. Growth is 2 - 3 mm CL per month in juveniles and 0.5 - 0.6 mm CL per month in adults (Kennedy et al. 1977).

Density is thought to also affect growth of rock shrimp. In 1993, the industry indicated that rock shrimp were abundant but never grew significantly over 36/40 count which was the predominant size class harvested during July and August of that year. During years of low densities, the average size appears to be generally larger.

Since rock shrimp live between 20 and 22 months, natural mortality rates are very high, and with fishing, virtually the entire year class will be dead at the end of the season. The intense fishing effort which exists in today's fishery, harvests exclusively the incoming year class. Three year classes were present in sampling conducted between 1973 and 1974 by Kennedy et al. (1977). Fishing mortality in combination with high natural mortality and possibly poor environmental conditions, may be high enough to prevent any significant escapement of adults to constitute a harvestable segment of the population. The better than average rock shrimp production in the 1994 season possibly resulted from better environmental conditions more conducive to rock shrimp reproduction and spawning.

Ecological Relationships

Food, Substrate, and Predation

Along the Florida Atlantic coast, the predominant substrate inside of 200 m depth is fine to medium sand with small patches of silt and clay (Milliman 1972). Juvenile and adult rock shrimp are bottom feeders. Stomach contents analyses indicated that rock shrimp primarily feed on small bivalve mollusks and decapod crustaceans (Cobb et al. 1973). Based on stomach contents of rock shrimp analyzed, Kennedy et al. (1977) found the relative abundance of particular crustaceans and mollusks corresponding to their availability in the surrounding benthic habitat.

Distribution

Recruitment to the area offshore of Cape Canaveral occurs between April and August with two or more influxes of recruits entering within one season (Kennedy et al. 1977).

Keiser (1976) described the distribution of rock shrimp in coastal waters of the southeastern United States. Whitaker (1982) presented a summary of information on rock shrimp off South Carolina. The only comprehensive research to date on rock shrimp off the east coast of Florida was by Kennedy et al. (1977). The following section incorporates some of the more significant findings presented by Kennedy et al. (1977) regarding the biology of rock shrimp on the east coast of Florida.

Rock shrimp (*Sicyonia brevirostris*) are found in the Gulf of Mexico, Cuba, the Bahamas, and the Atlantic Coast of the U.S. up to Virginia (SAFMC 1993) (Figure 22). The center of abundance and the concentrated commercial fishery for rock shrimp in the south Atlantic region occurs off northeast Florida south to Jupiter Inlet (Figure 23). Although rock shrimp are also found off North Carolina, South Carolina, and Georgia and are occasionally landed in these states, no sustainable commercially harvestable quantities of rock shrimp comparable to the fishery prosecuted in the EEZ off Florida are being exploited.

Rock shrimp live mainly on sand bottom from a few meters to 183 m (600 ft), occasionally deeper (SAFMC 1993). The largest concentrations are found between 25 and 65 m (82 and 213 ft).

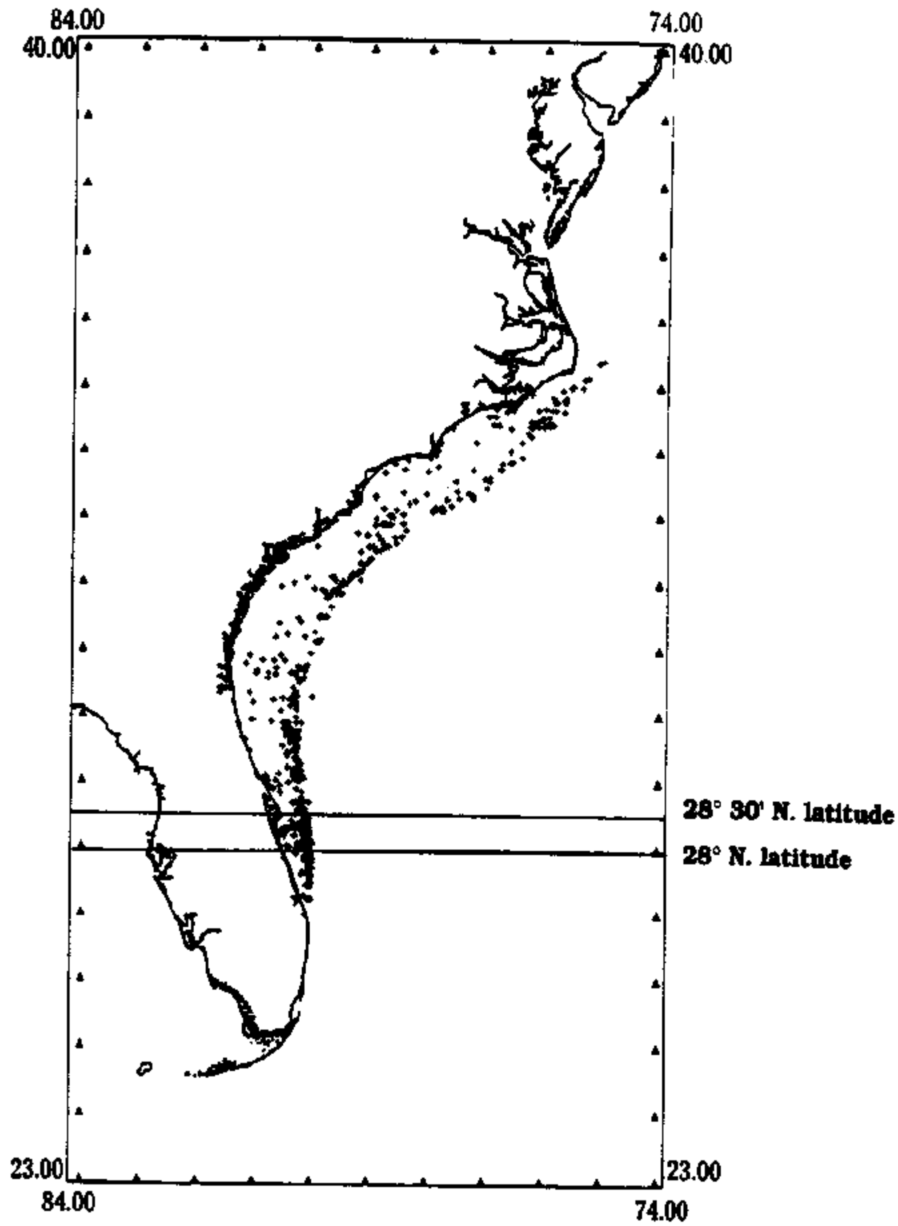


Figure 22. Rock shrimp distribution in the south Atlantic region as indicated from historical research efforts (1956-1991) using finfish and shrimp trawls (Source: NMFS 1994).

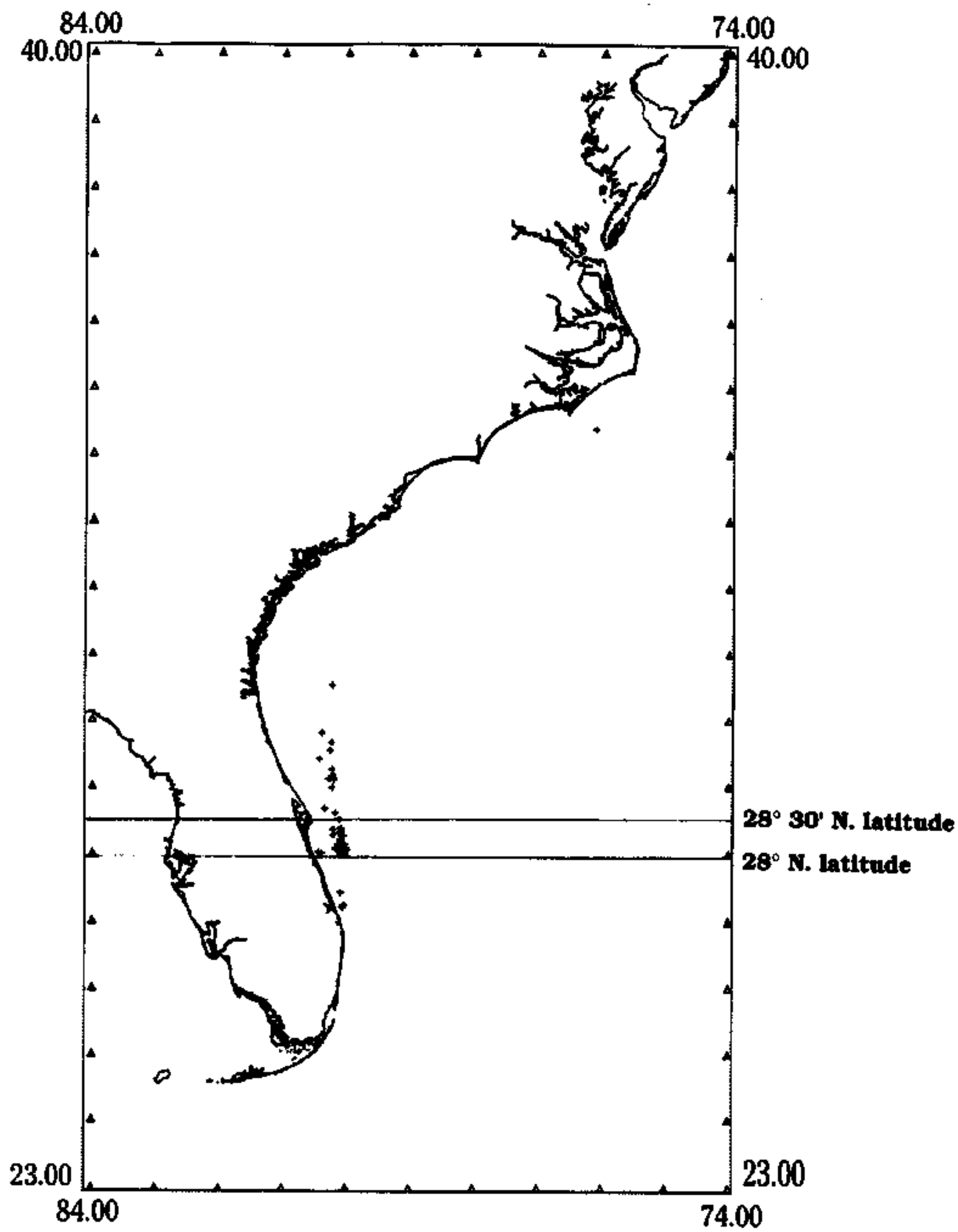


Figure 23. Harvestable rock shrimp distribution in the south Atlantic region as indicated from historic research efforts (1956-1991) using finfish and shrimp trawls (Source: NMFS 1994).

Royal Red Shrimp

Royal red shrimp are found throughout the Gulf of Mexico and South Atlantic area from Cape Cod to French Guiana. In the South Atlantic they are found in large concentrations primarily off northeast Florida. They inhabit the upper regions of the continental slope from 180 m (590 ft) to about 730 m (2,395 ft), but concentrations are usually found at depths of between 250 m (820 ft) and 475 m (1,558 ft) over blue/black mud, sand, muddy sand, or white calcareous mud.

3.3.1.3 Essential Fish Habitat and Environmental Requirements for Penaeid Shrimp

For peneaid shrimp, Essential Fish Habitat includes inshore estuarine nursery areas, offshore marine habitats used for spawning and growth to maturity, and all interconnecting water bodies as described in the Habitat Plan. Inshore nursery areas include tidal freshwater (palustrine), estuarine, and marine emergent wetlands (e.g., intertidal marshes); tidal palustrine forested areas; mangroves; tidal freshwater, estuarine, and marine submerged aquatic vegetation (e.g., seagrass); and subtidal and intertidal non-vegetated flats. This applies from North Carolina through the Florida Keys.

The three commercially important penaeid shrimp of the southeastern United States occupy similar habitats with the greatest differences being in optimal substrate and salinity. Apparently all three species can tolerate a wide range of habitat conditions; however, there appear to be optimal conditions which result in the highest growth rates and greatest survival.

Shrimp have a life cycle which requires a variety of habitats. The habitats can basically be divided into offshore and inshore. The high salinity, oceanic waters serve as habitat for large mature shrimp which will spawn offshore. Brown and pink shrimp apparently move to relatively deep continental shelf water and white shrimp appear to remain nearshore in shallower water (SAFMC 1981).

The relative abundance of the three shrimp species in the South Atlantic may be related to offshore bottom sediment composition. Kennedy and Barber suggest that spawning pink shrimp may be most abundant off Cape Canaveral and Cape Lookout because that species has an affinity for hard, coarse, and particularly calcareous bottom sediments which occur in those areas. They also note that the nearshore soft sediments correlate well with white and brown shrimp distribution from northern Florida to Pamlico Sound, North Carolina.

Offshore water also serves as habitat for larval and postlarval shrimp. These shrimp are planktonic and feed on zooplankton in the water column. There is some evidence that postlarval brown shrimp may overwinter in nearshore bottom sediments (Temple and Fischer, 1967). Aldrich et al. (1968) demonstrated that brown shrimp postlarvae buried in laboratory experiments when water temperature was reduced to 12˚-16.5˚C (54˚-62˚F). For their experiments, they used substrate material taken from Galveston Bay which was 75 percent clay, 22 percent silt and 3 percent sand.

The inshore phase of the life cycle is perhaps the most critical because most of the rapid growth occurs here. This critical habitat is dominated on the Atlantic coast by smooth cordgrass (*Spartina alterniflora*) and *Juncus* (in North Carolina's Pamlico Sound) which produce most of the primary production. Schelske and Odum (1961) stated that up to 10 tons of *Spartina* plant tissues are produced per acre per year. Turner (1977) found a direct relationship between commercial landings to absolute area and type of estuarine-intertidal vegetation. He suggested that the "...measurements of intertidal areas are relative indices of the amount of "edge" in an area and thus indirect measurement of the habitat."

Shrimp enter the inshore habitat as postlarvae and maintain a benthic existence. The areas where juveniles appear most abundant have a mud-silt substrate and intermediate salinities. Gunter et al. (1964) found that juvenile white shrimp were most abundant in waters of salinities less than 10 ppt in Alabama and Texas bays. Truesdale (1970) presented somewhat contradictory information. He concluded that salinity, per se, had no effect on postlarval distribution and abundance in Trinity Bay, Texas except during periods of high river discharge. Zein-Eldin and Aldrich (1965) and Zein-Eldin and Griffith (1970) found that salinity, per se, did not affect the growth of postlarval shrimp.

Apparently white shrimp have a greater tolerance to low salinity than brown shrimp. Gunter (1961) attributes the predominance of white shrimp in Louisiana to the lower estuarine salinities. Conversely, brown shrimp dominate in the waters around the much drier Texas. Gunter points out that the connection between rainfall and Texas white shrimp production was dramatically illustrated in 1957 when a long drought was broken and landings jumped from 2,229,000 pounds in 1957 to 7,370,000 pounds in 1958. Parker (1970) reported brown shrimp in areas where bottom salinity ranged from 0.9 to 36.5 ppt. Gaidry and White (1973) reported that commercial catches of brown shrimp were poor in those years when salinities where less than 15 ppt at the time postlarvae were present in the estuaries. They also stated that years of low commercial landings of brown shrimp were associated with prolonged estuarine temperatures of less than 20˚ C (68˚F) at the time of postlarval immigration into the estuary. Laboratory studies with juvenile and adult brown and white shrimp indicate that white shrimp are better adapted to tolerate low salinity, whereas, brown shrimp are better adapted to higher salinities (McFarland and Lee, 1963). Gunter et al. (1964), found that juvenile white shrimp were more abundant in areas with waters of salinities less than 10 ppt while brown shrimp juveniles were more abundant in salinities between 10.0 and 19.9 ppt.

Juvenile shrimp appear to be most abundant at the *Spartina* grass-water interface. This "estuarine edge" is the most productive zone in many estuaries. Because there is a minimum of wind generated turbulence and stabilization of sediments, rich bands are found that along the edges of marshes (Odum, 1970). Furthermore, Odum (1970) found the percentages of organic detritus in sediments along the shore in the Everglades estuary are several times greater than a few meters offshore. Mock (1967) examined two estuarine habitats, one natural and one altered by bulk-heading. He found a 0.6 m (2 ft) band of rich organic material along the natural shore and very little organic material along the bulkheaded shore. White shrimp were 12.5 times and brown shrimp 2.5 times more numerous in the natural area as in the altered area. Loesch (1965) found that juvenile white shrimp in Mobile Bay were most abundant nearshore in water less than 0.6 m (2 ft) deep containing large amounts of organic detritus. Brown shrimp were congregated in water 0.6 to 0.9 m (2-3 ft) deep where there was attached vegetation.

As shrimp increase in size, they begin migrating toward high salinity, oceanic waters. Parker (1970) observed that size of brown shrimp at the time of emigration is apparently related to density of individuals but smaller individuals tended to concentrate in shallow peripheral zones. St. Amant et al. (1966) observed that as juveniles increased in size they move into deeper, larger bays, through the lower bays and to offshore waters. Lindner and Anderson (1956) stated that shrimp size increased from inside to outside waters. The largest shrimp were in the outside waters where salinity values were highest.

Water temperature directly or indirectly influences white shrimp spawning, growth, habitat selection, osmoregulation, movement, migration, and mortality (Muncy 1984). Spring water temperature increases trigger spawning, and rapid water temperature declines in fall portend the end of spawning (Lindner and Anderson 1956). Growth is fastest in summer and slow or negligible in winter. Water temperatures below 20°C inhibit growth of juvenile shrimp (Etzold and Christmas 1977) and growth is virtually nil at 16°C (St. Amant and Lindner 1966). Growth rates increase rapidly as temperatures increase above 20°C. Increased water temperatures affects molting rate (Perez-Farfante 1969). Good correlation between heating-degree-days and catch/effort ratio for penaeid shrimp was similar to correlations of yield-per-hectare versus latitude (Turner 1977). Temperature and food supply limited the growth of white shrimp postlarvae more than did salinity differences between 2 and 35 ppt (Zein-Eldin 1964).

Severe winters in 1939-40, 1966, 1976-77, and 1977-78 caused mass mortality and reduced catches in the South Atlantic white shrimp fishery (McKenzie 1981; Shipman 1983a; Whitaker 1983a). The Georgia Department of Natural Resources (1983) reported a 34% drop in white shrimp landings in 1981 and a 99% drop in 1981 spring catch of roe shrimp after the unusually cold 1980-81 winter. White shrimp are more tolerant of high temperatures and less tolerant of low temperatures than either brown or pink shrimp (Etzold and Christmas 1977). Among postlarvae, brown shrimp were more resistant than white shrimp to higher temperatures.

White shrimp mortality was reported at water temperatures of 8°C and lower (Joyce 1965). Mortality of white shrimp is total at 3°C or lower, regardless of salinity. White shrimp survival at low temperatures depends on ambient temperature, the rate of temperature decline, the duration of low temperatures and salinity (Joyce 1965). The impact of low water temperature and low salinity on white shrimp was discussed by Music (1979) and Shipman (1983a). Adult white shrimp (>90mm long) may be more susceptible than juveniles to cold temperatures (Whitaker 1983a). Wiesepape (1975) found the 24-h LC_{50} (temperature causing 50% mortality in 24 h) to be 36° and 37°C for white shrimp acclimated at 29° and 34°C, respectively. Postlarvae and 30-mm long juveniles have similar but higher resistance times than 50-mm juveniles.

Adult white shrimp spawn offshore where salinities are at least 27 ppt. The larvae move shoreward and become second-stage postlarvae as they enter estuaries on flood tides. Juvenile white shrimp moved 160 km upstream into water of less than 1.0-ppt salinity waters in the St. Johns River, Florida (Joyce 1965). Juvenile white shrimp have even been recovered from Lake Monroe Power Station filter screens located 270 km from the mouth of the St. Johns River -- especially when low rainfall and low river stages caused reverse tidal flow (Edwin Joyce pers. comm., February 1984). The high calcium ion concentrations in the St. Johns River may explain the relative ease with which marine species enter and remain in low salinity waters (Joyce 1965). The lowest salinity in which white shrimp were recorded in the northern Gulf of Mexico was 0.42 ppt (Perez-Farfante 1969). Although field studies indicate that juvenile white shrimp prefer low salinities, laboratory studies have revealed that white shrimp appear to tolerate a wide range of salinities; they have been successfully reared at salinities of 18 to 34 ppt (Perez-Farfante 1969). McKenzie (1981) cited several studies in which fast growth was reported for white shrimp at salinities of 7 to 15 ppt.

White shrimp in Georgia move toward higher salinity waters as sexual development progresses, and most spawn offshore in the sea (Harris 1974).

Temperature-salinity tolerance ranges for white shrimp vary at different life stages, but the interactions are more pronounced at the extremes of tolerance. For example, Couch (1978) reported that broken-back syndrome (dorsal separation of the third and fourth pleural plates on abdominal) appears after sudden drops in salinity (from 15 ppt to 3 ppt) in cold water (8°C). The critical thermal maxima for white shrimp are influenced largely by acclimation temperatures, and to a lesser extent by salinity and size of test animal (Laney 1973). Freshwater inflow may affect coastal water temperatures, which in turn affect the growth rates (White and Boudreaux 1977) and migration of white shrimp (Shipman 1983b). Spring spawning of white shrimp coincides with a rapid rise in bottom water temperatures in high salinity offshore waters (McKenzie 1981).

White shrimp prefer shallow, muddy-bottom substrate. Landings of shrimp along the Louisiana coast were highest in areas where substrates were highly organic (Barrett and Gillespie 1973; Gaidry 1974). A relative higher linear correlation ($R^2 = 0.69$) between intertidal land area and average annual shrimp catch along Louisiana's inshore regions was reported by Turner (1977). The relation between inshore catches and hectares of vegetated estuarine habitat in the northeastern Gulf of Mexico (Tampa Bay, Florida, to Mobile Bay and Perdido Bay, Alabama) also showed a strong correlation ($R^2 = 0.64$). A direct relationship between commercial shrimp landings and intertidal vegetated areas and degrees latitude was reported by Turner (1977). The annual landings (kg/ha) in 1955-64 were 19.7 in North Carolina, 7.9 in South Carolina, 13 in Georgia, and 22.4 in east Florida. White shrimp undoubtedly composed most of the landings except in North Carolina. Southward fall migration probably account for the high landings from Florida waters. The area of nearshore soft sediments correlate well with white and brown shrimp distribution from Pamlico Sound, North Carolina to northern Florida (McKenzie 1981).

Temporal and spatial shifts by brown, white, and pink shrimp help reduce direct interspecific competition especially for certain substrates (Lassuy 1983). White shrimp burrow less deeply into muddy substrates and are more active in daylight than are brown or pink shrimp. Staggered seasonal recruitment of brown and white shrimp into the south Atlantic estuaries would reduce competition (Baisden 1983).

3.3.1.4 Essential Fish Habitat and Environmental Requirements for Rock Shrimp

For rock shrimp, essential fish habitat consists of offshore terrigenous and biogenic sand bottom habitats from 18 to 182 meters in depth with highest concentrations occurring between 34 and 55 meters. This applies for all areas from North Carolina through the Florida Keys. Essential fish habitat includes the shelf current systems near Cape Canaveral, Florida which provide major transport mechanisms affecting planktonic larval rock shrimp. These currents keep larvae on the Florida Shelf and may transport them inshore in spring. In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse rock shrimp larvae.

A description of shrimp habitat and recommendations to protect habitat were contained in the shrimp management plan (SAFMC 1993). The bottom habitat on which rock shrimp thrive is thought to be limited. Kennedy et al. (1977) determined that the deepwater limit of rock shrimp was most likely due to the decrease of suitable bottom habitat rather than to other physical parameters including salinity and temperature. Cobb et al. (1973) found the inshore distribution of rock shrimp to be associated with terrigenous and biogenic sand substrates and only sporadically on mud. Rock shrimp also utilize hard bottom and coral or more specifically *Oculina* coral habitat areas. This was confirmed with research trawls capturing large amounts of rock shrimp in and around the Oculina Bank HAPC prior to its designation.

Other than Kennedy et al. (1977), no characterization of habitat essential to rock shrimp or bycatch in the rock shrimp fishery has been conducted. A list of species associated with the benthic habitat inhabited by rock shrimp was compiled from research trawling efforts (1955-1991) that captured harvestable levels of rock shrimp. In addition, Kennedy et al. (1977), during research efforts sampling the major distribution area of rock shrimp off the east coast of Florida, compiled a list of crustacean and molluscan taxa associated with rock shrimp benthic habitat.

3.3.1.5 Essential Fish Habitat and Environmental Requirements for Royal Red Shrimp

Essential fish habitat for royal red shrimp include the upper regions of the continental slope from 180 meters (590 feet) to about 730 meters (2,395 feet), with concentrations found at depths of between 250 meters (820 feet) and 475 meters (1,558 feet) over blue/black mud, sand, muddy sand, or white calcareous mud. In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse royal red shrimp larvae.

3.3.1.6 Essential Fish Habitat-Habitat Areas of Particular Concern for Shrimp

Penaeid Shrimp

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for penaeid shrimp include all coastal inlets, all state-designated nursery habitats of particular importance to shrimp (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas), and state-identified overwintering areas.

Estuarine tidal creeks and salt marshes that serve as nursery grounds are perhaps the most important habitats occupied by penaeid shrimp. The major factor controlling shrimp growth and production is the availability of nursery habitat. Remaining wetland habitat must be protected if present production levels are to be maintained. In addition, impacted habitats must be restored if future production is to be increased. Other areas of specific concern are the barrier islands since these land masses are vital to the maintenance of estuarine conditions needed by shrimp during their juvenile stage. Passes between barrier islands into estuaries also are important since the slow mixing of sea water and fresh water are also of prime importance to estuarine productivity.

In North Carolina, essential fish habitat-habitat areas of particular concern include estuarine shoreline habitats since juveniles congregate here. Seagrass beds, prevalent in the sounds and bays of North Carolina and Florida, are particularly critical areas. Core Sound and eastern Pamlico Sound, based on a preliminary aerial survey funded through the Albemarle-Pamlico Estuarine Study, have approximately 200,000 acres of seagrass beds making North Carolina second only to Florida in abundance of this type of habitat (Department of Commerce 1988b). In subtropical and tropical regions shrimp and spiny lobster postlarvae recruit into grass beds from distant offshore spawning grounds (Fonseca et al. 1992).

South Carolina and Georgia lack seagrass beds. Here, the nursery habitat of shrimp is the high marsh areas with shell hash and mud bottoms. In addition, there is seasonal movement out of the marsh into deep holes and creek channels adjoining the marsh system during winter. Therefore, the area of particular concern for early growth and development encompasses the entire estuarine system from the lower salinity portions of the river systems through the inlet mouths.

Rock Shrimp

No essential fish habitat-habitat areas of particular concern have been identified for rock shrimp however, deep water habitat (e.g. the rock shrimp closed area/proposed expanded Oculina Bank HAPC) may serve as nursery habitat and protect the stock by providing a refuge for rock shrimp.

3.3.2 Red Drum

3.3.2.1 Description of the Species and Distribution

Red drum (Figure 24) occur in a variety of habitats distributed from Massachusetts to Key West, Florida on the Atlantic coast (Simmons and Breuer 1962). Red drum historically have been found as far north as Massachusetts with concentrations great enough to support a moderate commercial fishery in New Jersey in the early 1930s. Commercial red drum landings have generally declined along the mid-Atlantic coast with none being reported north of the Chesapeake Bay since 1950 (Yokel 1980). The distribution of red drum along the Atlantic coast in recent years, as indicated from recreational and commercial landings, extends from the Chesapeake Bay area through Florida.

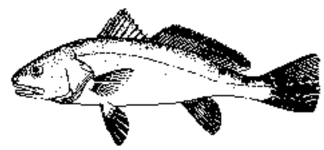


Figure 24. Red Drum, *Sciaenops ocellatus*.

Eggs, Larvae and Juveniles

Red drum spawn in the ocean along beaches and in the vicinity of inlets and passes and possibly in high salinity estuaries. Red drum spawn at night and produce planktonic, spherical eggs between 0.86 mm and 0.98 mm in diameter (Johnson et al. 1977). Eggs are clear with a single, gold-colored oil droplet. Environmental requirements for optimum incubation were determined in the laboratory as a salinity of 25-35 ppt below which the eggs would sink and above which the eggs would clump together. In addition, optimum spawning occurred at temperatures of 22˚-30˚C (Holt et al. 1983). Red drum eggs and larvae are carried through tidal and current movement into estuarine systems. Increased spawning activity is associated with new and full moon periods during the spawning season.

Juvenile red drum have a pronounced seasonal pattern of distribution in Chesapeake Bay and North Carolina moving into deeper areas of estuaries or the ocean in the fall and winter (Yokel 1980). Juveniles have been collected throughout Chesapeake Bay from September to November and through December in North Carolina (Hildebrand and Schroeder 1928; Mansueti 1960). In North Carolina, juvenile one and two year old red drum occur year round in estuaries, both in mainland bays and rivers, and along the grass flats behind barrier islands (Ross et al., 1987). A portion of these cohorts migrate into the ocean after their first year and occur along beaches during the late fall through early spring. Peak recruitment of young fish generally occurs September through November in North Carolina estuaries.

Adults

After maturation, adult red drum spend less time in the estuaries and more time in the ocean (Yokel 1966). They migrate seasonally along the coast, inshore and/or north in spring and offshore and/or south in fall. Chesapeake Bay red drum are taken through October and are most abundant during spring and fall. Large schools of adult red drum were identified during aerial surveys conducted as part of the Atlantic Marine Gamefish Research Program. The annual survey encompassed 12 monthly flights over the continental shelf from Cape Cod, Massachusetts to Miami, Florida to measure sea surface temperature and record sightings of all fish and other surface life. Large schools of adult red drum were identified offshore south of Hatteras, North Carolina in April. Additional sightings of red drum offshore were noted to occur north of Hatteras in May and June. Large numbers of red drum are occasionally gigged in North Carolina sounds in the winter.

Annually, the best catches of large red drum occur around the eastern shore of Virginia and in the lower Chesapeake Bay in May-June and September-October. Largest catches of adult red drum along the Outer Banks are made from late March through May and from October through November (Ross and Stevens 1989). Large schools of red drum have been observed in Pamlico Sound, North Carolina during the summer (Mercer 1984). In winter, red drum have been caught in the trawl fishery and in trawl surveys at depths of 10 to 40 m. Red drum have been reported off South Carolina in 13-26 m of water in the winter and early spring.

In addition, large red drum were captured by shark gillnet fishermen in the EEZ offshore of Folly Beach, South Carolina in May 1989. Recreational fishermen in South Carolina have identified large schools of adult red drum nearshore feeding along bars during rising tides at night. In Georgia, red drum older than four years are generally found along beaches and in offshore waters. Recent sonic tagging studies conducted by Georgia Department of Natural Resources have resulted in field verification of red drum surface schools offshore in the EEZ (Music and Pafford 1984).

Movement Patterns

Adult red drum migrate seasonally along the Atlantic coast (Yokel 1966). Reports from fishermen and menhaden spotter pilots indicate that red drum typically arrive at Cape Hatteras, North Carolina between March and April, some entering Pamlico Sound and others proceeding up the coast. Red drum are expected about a week later at Oregon Inlet and three weeks to a month later in Virginia, some entering Chesapeake Bay. Apparently in times of high abundance and proper environmental conditions, red drum averaging 13-14 kg (33-36 lb) were present along the New Jersey coast from May to October (Welsh and Breder 1923). Red drum leave Virginia in most years by October and fall fishing along the North Carolina coast starts in September and usually ends in November (Yokel 1966).

After their first or second year some red drum move along the barrier island beaches during fall and spend winter in deep holes or sloughs, while others winter in the estuary. As they get older, they spend spring, early summer and fall along the beaches and winter offshore. As spring approaches, these adult fish move from offshore wintering grounds towards the beaches with concentrations showing up around Ocracoke, Hatteras and Oregon Inlets, North Carolina. They occur along beaches near inlets for one to two months and move inside Pamlico Sound in summer. In August they school up around inlets to spawn and remain there and along the beaches through November, then move offshore again.

Red drum also exhibit a north/south movement pattern as follows: A large body of fish moves inshore and north along the beaches in the spring up to the Chesapeake Bay and Virginia barrier islands. Also a large number of fish, generally 5-25 lb, spend their summer around shoals off Cape Hatteras, Cape Lookout and the four inlets north of Cape Lookout.

One consistent pattern that can be drawn from Atlantic coast red drum tagging studies is that red drum tend to stay in the same general estuarine system from post larval stages through their third or fourth year of life. They then move out of the estuarine system into the spawning stock associated with nearshore and offshore areas. Some large fish move into bays, sounds and harbor systems, even after maturity, and are susceptible to capture. The majority of tagging conducted along the Atlantic coast has been directed toward smaller red drum, less than four years old. Large red drum are being tagged through efforts of recreational fishermen participating in sport fish tagging programs conducted by state fishery agencies. Returns of large fish (>32 in TL) have been very low and and many of these returns have occurred at the same general time. Thus movement of these fish can be cited as the minimum distance traveled, not accounting for possible migration and return to spawning grounds (such as specific inlet mouths or bar systems associated with these high energy areas).

Ecological Relationships - Food

A dietary analysis of red drum (5-300 mm SL) stomach contents was conducted by Daniel (1988) Prey varied with fish size. Copepods were predominant prey by volume for fish 5-15 mm SL, representing 27% of the total volume. Mysids comprised 34% of the total volume of prey for fish 16-30 mm. The highest level of fish consumption occurred in juvenile red drum in the 76 and 100 mm size class (72% by volume) found in 70% of the individual samples. Fish were also a major component of juvenile red drum in both the 100-125 mm SL (51% by volume) and the 125-150 mm SL (60% by volume) size classes. A shift in composition of prey species was observed for red drum 200-300 mm SL. The predominant species observed in this size class included decapods (mainly mud crabs and fiddler crabs) accounting for 96% by volume and 95% of the (83) individuals analyzed. Music and Pafford (1984) analyzed the stomach contents of red drum which ranged from 101 mm to 1,100 mm collected in Glynn County Georgia from January 1979 through June 1982. Red drum 300-600 mm in length were found to have 17% fish, 72% arthropods and 11% plant material, with fiddler crabs (16%) and white shrimp (11%) being the predominant food item by occurrence. Red drum 601-1,100 mm in length were found to have 36% fish, 59% arthropods and 5% plant material, with fiddler crabs (14%) and mud crabs (11%) being the predominant food item by occurrence.

3.3.2.2 Essential Fish Habitat and Environmental Requirements

For red drum, essential fish habitat includes all the following habitats to a depth of 50 meters offshore: tidal freshwater; estuarine emergent vegetated wetlands (flooded saltmarshes, brackish marsh, and tidal creeks); estuarine scrub/shrub (mangrove fringe); submerged rooted vascular plants (sea grasses); oyster reefs and shell banks; unconsolidated bottom (soft sediments); ocean high salinity surf zones; and artificial reefs. The area covered includes Virginia through the Florida Keys.

Red drum are distributed along the Atlantic coast, in the ocean and estuarine areas in relation to their stage of maturity. Juvenile red drum utilize the shallow backwaters of estuaries as nursery areas and remain there until they move to deeper water portions of the estuary associated with river mouths, oyster bars and front beaches. Estuarine wetlands are especially important to larval red drum. The types of estuarine systems vary along the Atlantic and subsequently, the preferred juvenile habitat also varies with distribution. Young red drum are found in quiet, shallow, protected waters with grassy or slightly muddy bottoms. Shallow bay bottoms or oyster reef substrates are preferred by subadult and adult red drum. Red drum utilize the oceanic system which is the area of the Atlantic ocean from the beachfront seaward. Large red drum are thought to migrate along the Atlantic coast and are subjected to man's alterations of the natural system. Nearshore and offshore bar and bank areas such as Gaskins and Joiner Banks in South Carolina have been identified as areas where concentrations of red drum could be located. Nearshore artificial reefs along the Atlantic are also known to attract red drum as they make their spring and fall migrations. In the fall and spring red drum concentrate around inlets, shoals, capes, and from the surfzone to several miles offshore, moving among these areas.

The distribution of red drum between estuarine habitat and oceanic waters is dependant mainly on stage of development and temporal and environmental factors. Red drum are euryhaline. Adult and subadult red drum are most often found in diluted/concentrated seawater of 20 to 40 ppt and rarely above 50 ppt, while juveniles range into the freshest parts of estuaries. Eggs and newly hatched larvae require salinities above 25 ppt. Spawning occurs in or near passes of inlets (e.g. "Grillage" at the mouth of Charleston Harbor) with larvae being transported into the upper estuarine areas of low salinity. As larvae develop into juveniles and sub-adults, they utilize progressively higher salinity estuarine and beachfront surf zones. Red drum move out of estuarine areas as adults and occupy the high salinity surf zone nearshore and offshore coastal waters. In North Carolina and Virginia, large adults move into estuaries during summer months.

Red drum are eurythermal, occuring over a temperature range of 2˚-33˚C, although they usually move into deeper water at extremes. Larger juveniles and adults are more susceptible to the effects of winter cold waves than small fish. High red drum mortality during freezes occurs and has the ability to decimate large portions of juvenile year classes. Thermal optimum is dependant on salinity, a characteristic of euryhaline fish.

Spatial and Temporal Distribution and Relative Abundance in Estuarine Habitat

NOAA's Estuarine Living Marine Resource Program (ELMR), through a joint effort of National Ocean Service and NMFS, conducts regional compilations of information on the use of estuarine habitat by select marine fish and invertebrates. A report prepared through the ELMR program (NOAA 1991b) and revised information (NOAA 1998), provided the Council during the Habitat Plan development process, present known spatial and temporal distribution and relative abundance of fish and invertebrates using southeast estuarine habitats. Twenty southeast estuaries selected from the National Estuarine Inventory (NOAA 1985) are included in the analysis which resulted from a review of published and unpublished literature and personal consultations. The resultant information emphasizes the importance and essential nature of estuarine habitat to all life stages of red drum.

Regional salinity and relative abundance maps for use in determining EFH for red drum were prepared for the Council by NOAA SEA Division (Appendix F). Figures 25-28 present a representative sample of the distibution maps for juvenile red drum. The remainder of the coverages and additional information on species and habitat distribution are available over the Internet on the Council web page under the habitat homepage (www.safmc.noaa.gov). These maps portray salinity and species relative abundances for estuaries and coastal embayments on state and/or regional maps. Depending on data availability, maps were produced at various scales: 1:24K, 1:80K, and 1:250K. For species relative abundances, these maps were be developed only for juveniles of estuarine species (Nelson et al. 1991) showing the highest juvenile relative abundance in any salinity zone by season for each estuary. These maps will eventually be provided to the Council as ArcView shape files with associated data for inclusion into the Councils GIS system.

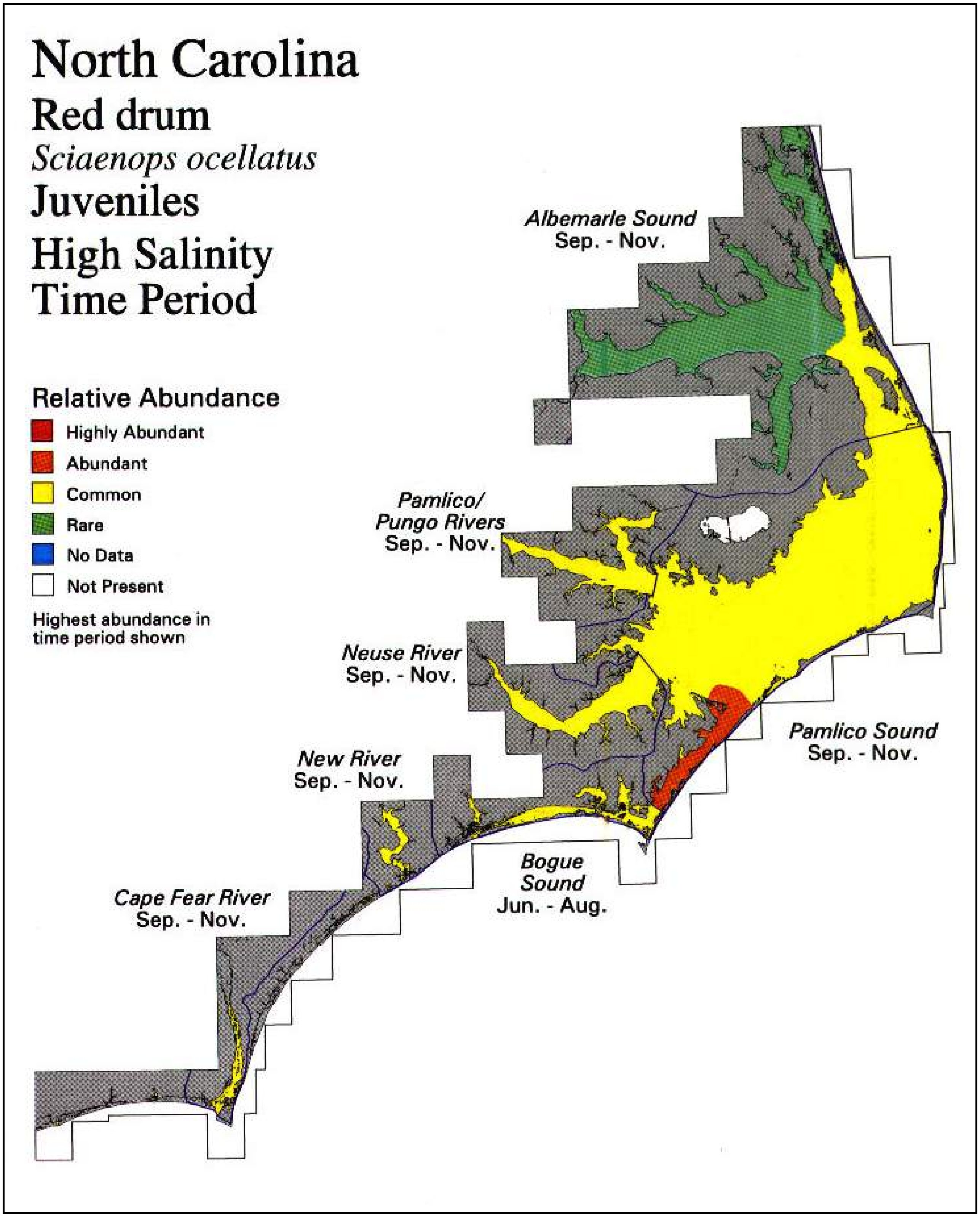


Figure 25. Red drum juvenile distribution in North Carolina estuaries in high salinity time period (Source: NOAA 1998).

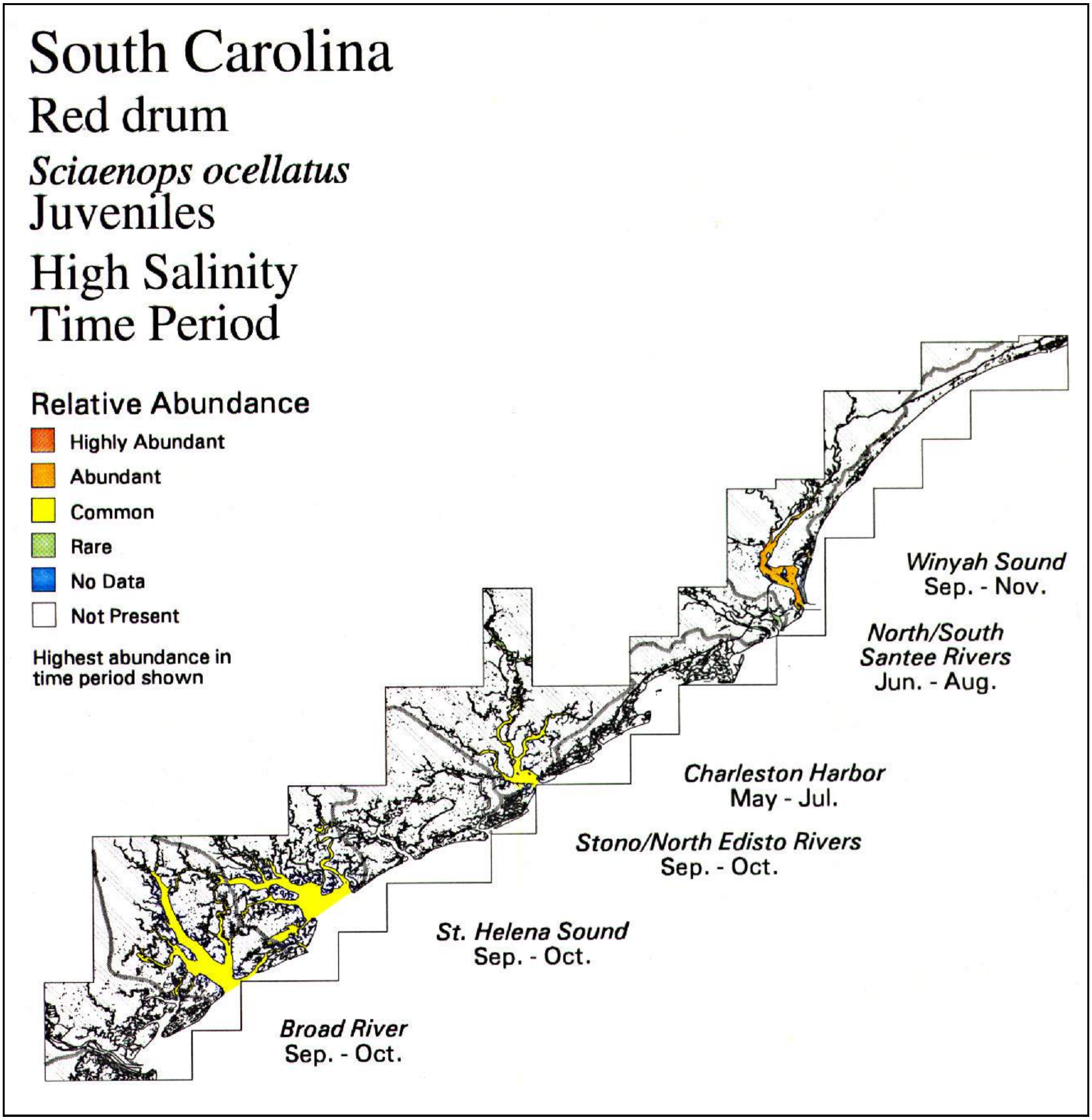


Figure 26. Red drum juvenile distribution in South Carolina estuaries in high salinity time period (Source: NOAA 1998).

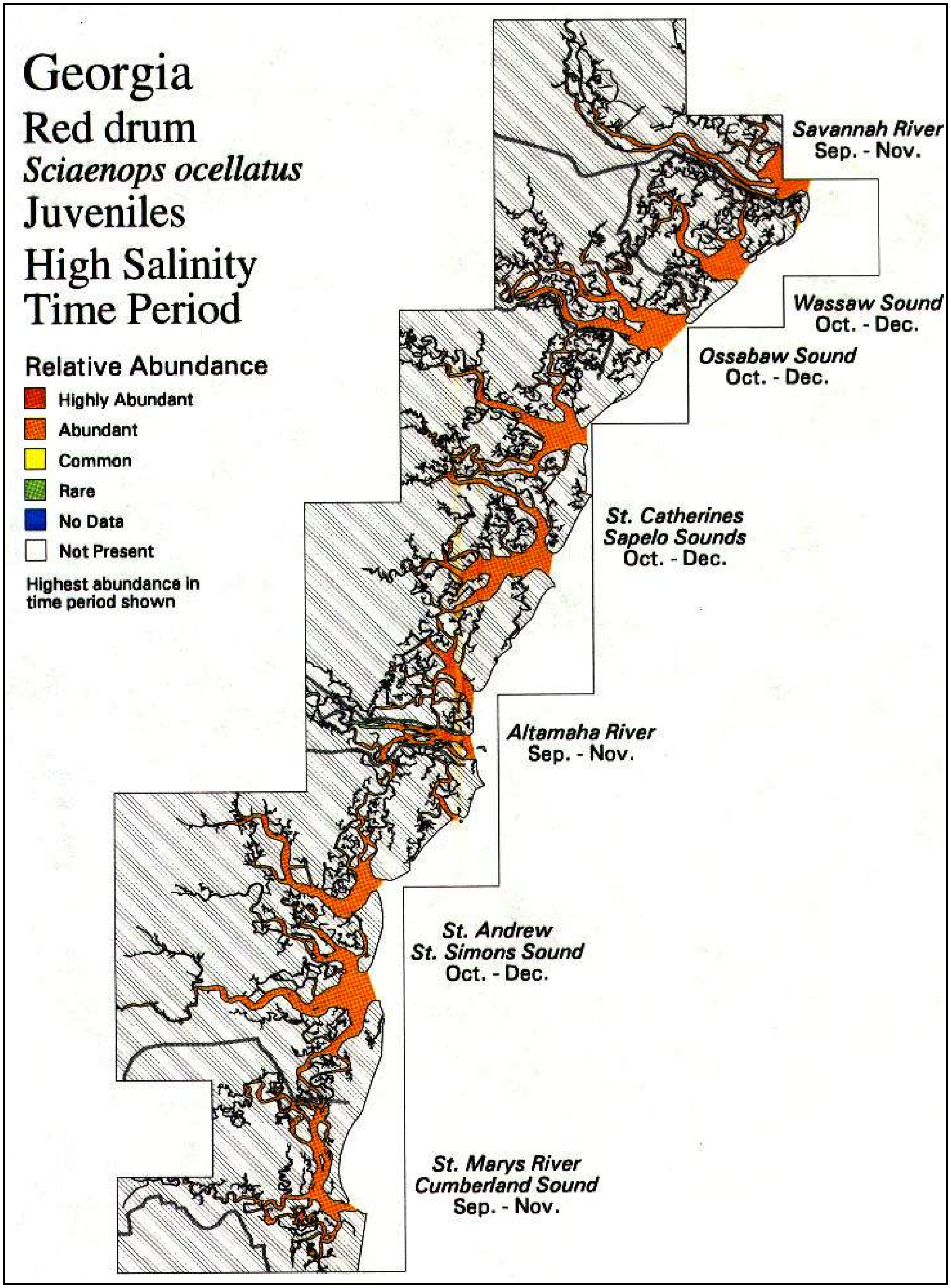


Figure 27. Red drum juvenile distribution in Georgia estuaries in high salinity time period (Source: NOAA 1998).

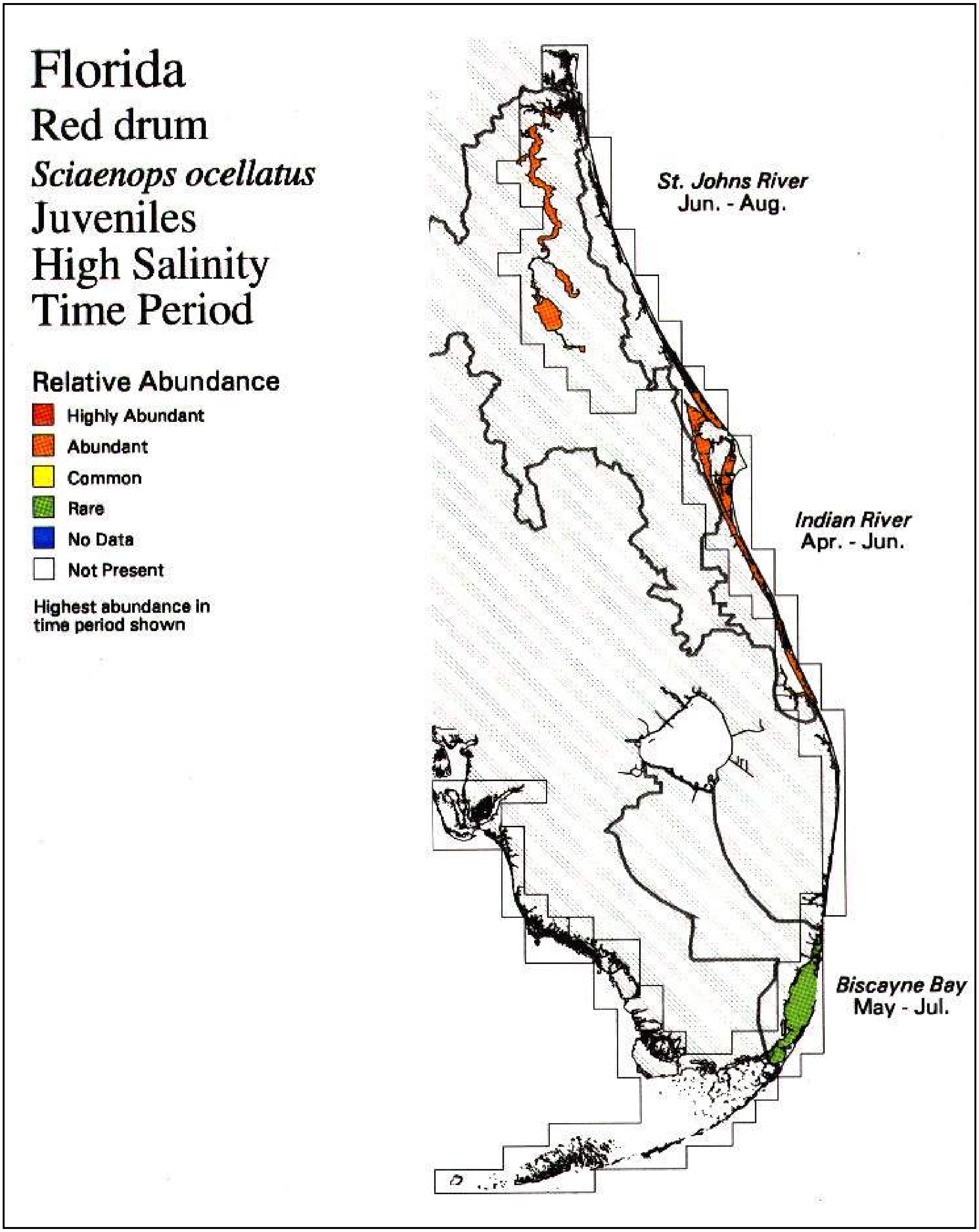


Figure 28. Red drum juvenile distribution in Florida estuaries in high salinity time period (Source: NOAA 1998).

3.3.2.3 Essential Fish Habitat-Habitat Areas of Particular Concern for Red Drum

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for red drum include all coastal inlets, all state-designated nursery habitats of particular importance to red drum (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas); documented sites of spawning aggregations in North Carolina, South Carolina, Georgia, and Florida described in the Habitat Plan; other spawning areas identified in the future; and habitats identified for submerged aquatic vegetation.

These habitats include the most important habitats required during the life cycle of the species, including the spawning areas and estuarine nursery grounds. Other areas of specific concern are barrier islands in each state, as these structures are vital to maintain estuarine conditions needed by larval and juvenile stages. Passes between barrier islands into estuaries also are very important, as the slow mixing of sea water and fresh water is generally regarded as being of prime importance in the productivity of any estuary. A rapid change may cause environmental stresses too great for many estuarine organisms to withstand.

Seagrass beds or submerged aquatic vegetation (SAV) prevalent in the Chesapeake Bay and the sounds and bays of North Carolina and Florida are also critical areas for red drum, particularly for 1 and 2 year old fish (>750 mm or 29.5 in FL). Seagrass beds, shallow areas of estuarine rivers and mainland shorelines, are where many red drum reside during the summer. Based on a preliminary aerial survey in North Carolina there are approximately 200,000 acres of SAV distributed in Core Sound and eastern Pamlico Sound, making North Carolina second only to Florida in abundance of this type of fisheries habitat.

The states of South Carolina and Georgia lack seagrass beds; the preferred habitat of juveniles (<75mm) based on sampling efforts by Daniel (1988) in Charleston, South Carolina, may be high marsh areas with shell hash and mud bottoms. In South Carolina, smaller juveniles remain in the marsh system until they are around 150 mm, moving into the main creeks and river channels and lower harbor areas as they become larger. In addition, there is seasonal movement out of the marsh and into deep holes and creek channel adjoining the marsh system during the winter months. Therefore, the area of particular concern for early growth and development is seasonal and size dependant encompassing the entire estuarine system from the lower salinity portions of the river systems through the inlet mouth or lower harbor areas.

The various inlets, adjoining channels, sounds, and outer bars of ocean inlets are critical areas for spawning activity (see Figure 29 and Appendix S) as well as feeding and daily movements and may be affected by constant dredging, jettying or excessive boat traffic. Adult red drum spend a lot of time in these areas during spring and fall with large concentrations located near the least trafficked inlets.

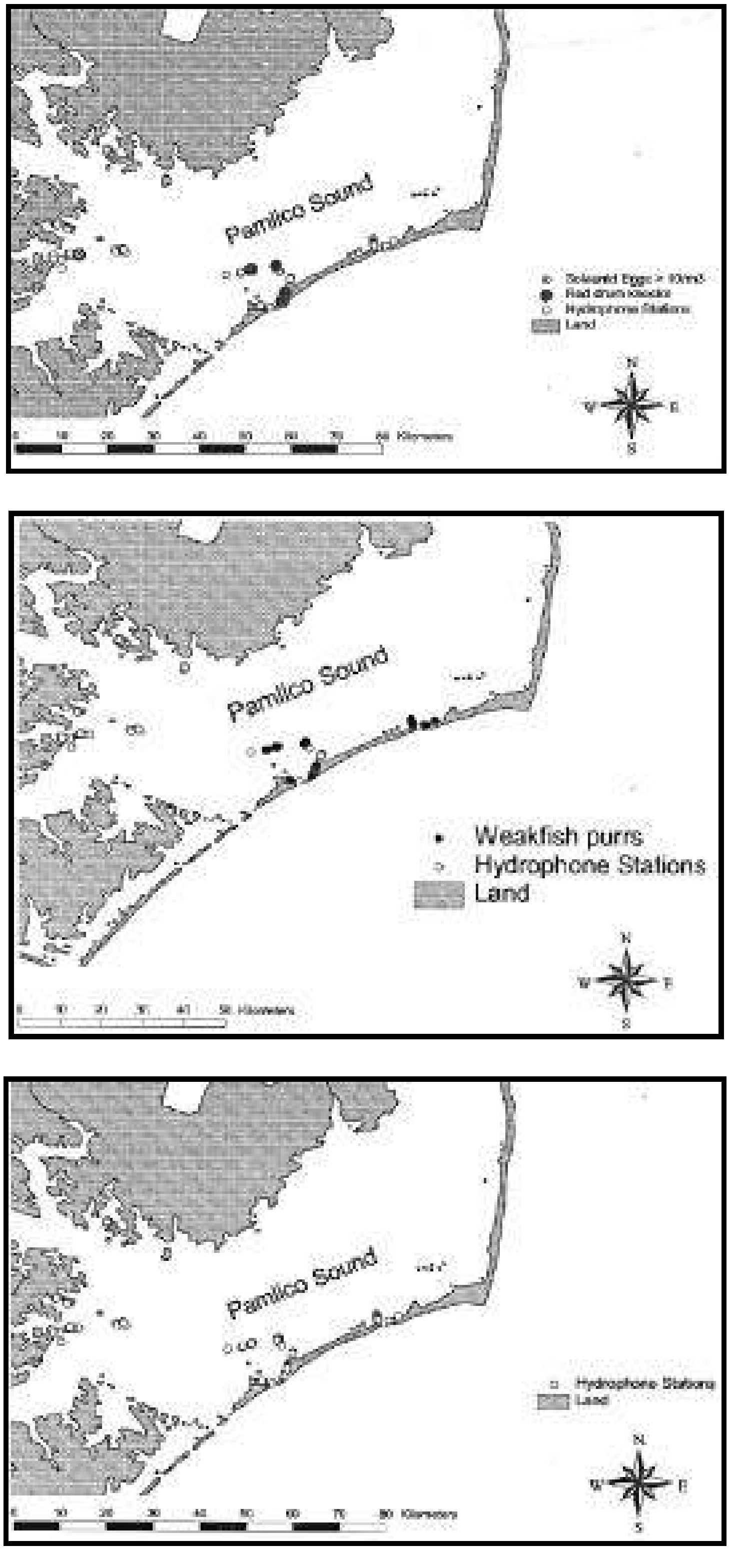


Figure 29. Sites of red drum and weakfish spawning aggregations identified in coastal North Carolina through acoutic sampling conducted by the North Carolina Division of Marine Fisheries (Louis Daniel, pers.comm. 1998).

3.3.3 Snapper Grouper Complex

3.3.3.1 Description of the Species Complex.

Ten families of fishes containing 73 species are managed under the snapper grouper plan (Section 2.2). Their association with coral or hardbottom structure during at least part of their life cycle and their contribution to an interrelated reef fishery ecosystem are the primary criteria for inclusion within the snapper grouper plan (SAFMC, 1983). Phylogenetically, they are diverse and include representatives of two suborders of perciformes (Percoidei and Labroidei), as well as the order Tetraodontiformes. However, sixty-eight of these species are within eight percoid families. There is considerable variation in specific life history patterns and habitat use among the snapper grouper species complex. Seventeen of the 73 species in the FMP are overfished (SPR <30%) according to the most recent NMFS stock assessments and SAFMC SSC analyses. The overfished species include ten groupers, two snappers, two porgies, one grunt, one temperate bass, and one tilefish.

Space constraints in this document limit thorough characterizations of this diverse multispecies complex. To summarize some of the ecological variation among the more valuable species, short biological characterizations are provided below for 18 representative species from seven families. These include the serranid groupers (snowy grouper, yellowedge grouper, warsaw grouper, speckled hind, scamp, and jewfish), the percichthyid temperate basses (wreckfish), lutjanid snappers (gray snapper, mutton snapper, blackfin snapper, red snapper, silk snapper, and vermilion snapper), haemulid grunts (white grunt), sparid porgies (red porgy), carangid jacks (greater amberjack), and malacanthid tilefishes (golden tilefish and blueline tilefish). Seven of these species are overfished. Information on habitat use, biological attributes, and reproduction is provided for many of these and other species in Tables 19a, 20a, 21a, and 21b following the ELMR format used in Nelson et al., (1991).

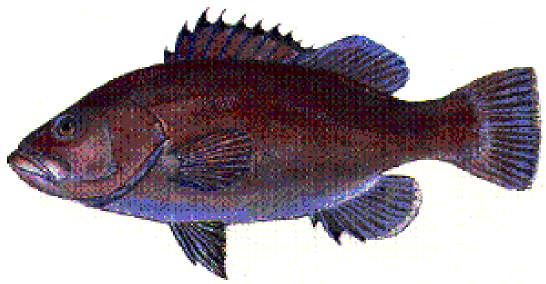
More detailed information is available in the source document for the Snapper Grouper FMP (SAFMC, 1983b) and books summarizing the biology of many of these and co-occurring species, including Munro (1983), Ralston and Polovina (1987), Sale (1991), Claro (1994), and Arreguín-Sánchez (1996). In addition, many publications from areas under, or near, the Council's jurisdiction are available on individual species or species complexes (e.g., Matheson et al., 1986; Grimes et al., 1988; Cuellar et al., 1996; Ault et al., 1998) or specific habitat types (e.g., mangroves - Thayer et al. 1987; seagrasses - Sogard et al., 1987; Florida Keys coral reefs - Bohnsack et al., 1987; Chiappone and Sluka, 1996; nearshore hard bottom - Lindeman and Snyder, in press; deep reefs - Parker and Mays, In press). Many additional summaries of the use of specific habitats by snapper grouper species are enclosed in the habitat characterizations in Section 3.0 of this document.

Groupers (Serranidae):

Snowy Grouper

The snowy grouper (*Epinephelus niveatus*) is a demersal serranid distributed in the western Atlantic from NC and the Gulf of Mexico to Brazil. It also occurs in the eastern Pacific including the Gulf of California, Mexico, and Panama (Fischer, 1978). Juveniles (about 400 mm (TL)) have been observed off NC in depths of 61 m (Parker and Ross, 1986) where bottom water temperatures fluctuate from about 15.0° to 29.0°C. Adults occur to depths of about 180 m, and were common between 116 to 137 m off NC (Roe, 1976; Huntsman and Dixon, 1976; Parker and Ross, 1986), where the habitat contains irregularly sized boulders and ridges of bioeroded limestone with vertical relief up to 10 m interspersed with sand, broken shell, and rock fragments.

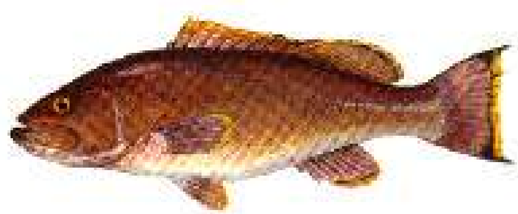
Snowy grouper live at least 27 years, reaching a weight of 29 kg (Moore and Labisky, 1984). Average lengths for fish aged 1 to 17 years are 210, 328, 404, 462, 513, 561, 604, 648, 686, 721, 762, 797, 833, 874, 899, 924, and 958 mm (Matheson and Huntsman, 1984). They feed mostly on crabs, fishes, and cephalopods (Bielsa and Labisky, 1987; Dodrill et al., 1993). Snowy grouper are protogynous hermaphrodites, changing from females to males as they grow older. Fish first reach sexual maturity when about 4 to 5 years old and 450 to 500 mm long (Moore and Labisky, 1984). Spawning occurs April through July, and eggs and larvae are pelagic. This species is considered overfished in the most recent NMFS stock assessment and SAFMC SSC analyses.



Yellowedge Grouper

The yellowedge grouper (*Epinephelus flavolimbatus*) is a large (to 18 kg) grouper that inhabits hard bottom and rocky outcroppings in depths of 190 to 220m (Low and Ulrich, 1983). It ranges from offshore of NC along the continental shelf break to Brazil and the Gulf of Mexico. It is much more abundant in the western Gulf of Mexico than in the Atlantic (Chester et al., 1984).

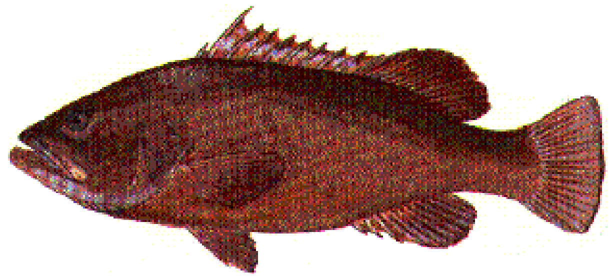
Yellowedge grouper live at least 15 years and grow to 1110 mm. Like their close relative, snowy grouper, yellowedge grouper are believed to be protogynous hermaphrodites. Sex reversal may take place over a wide range of sizes, but has usually occurred by the time a fish reaches 850 mm (Keener, 1984). Yellowedge grouper normally mature between ages five and six (450 to 469 mm). Spawning occurs from April to October with a September peak, and eggs and larvae are pelagic. Adults feed on bottom dwelling animals, including squid, octopus, crabs, eels, lizardfish, seahorses, scorpionfish, and searobins (Manooch and Raver, 1984).



Warsaw Grouper

The warsaw grouper (*Epinephelus nigritus*) is a large serranid distributed from NC to the Florida Keys and Gulf of Mexico to the northern coast of South America. It inhabits irregular bottoms including steep cliffs, notches, and rocky ledges of the continental shelf break in depths of 76 to 219 m (Manooch and Mason, 1987).

Little is known about the reproduction of warsaw grouper but eggs and larvae are thought to be pelagic. Warsaw grouper live at least 41 years and reach lengths of over 2,300 mm and weights of at least 190 kg. Average lengths for fish aged 1, 5, 10, 15, 20, and 24 years are 330, 914, 1,194, 1,295, 1,397, and 1,473 mm (Manooch and Mason, 1987). Fishes and crustaceans are major foods (Manooch pers. obs.). This species is considered overfished in the most recent NMFS stock assessment and SAFMC SSC analyses.

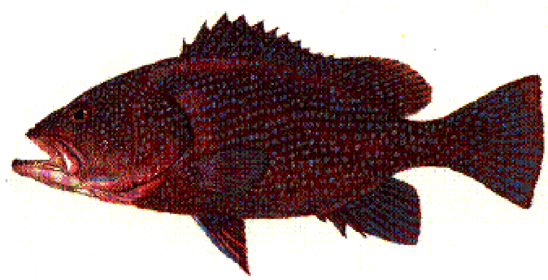


Speckled Hind

The speckled hind (*Epinephelus drummondhayi*) ranges from Bermuda and NC to FL, and throughout the Gulf of Mexico (Smith, 1971; Hoese and Moore, 1977). It inhabits high and low profile hard bottom in depths ranging from 27 to 122 m (Huntsman and Dixon, 1976; Parker, pers. obs.).

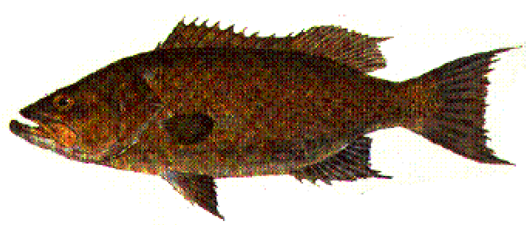
Preliminary investigation indicates that speckled hind are protogynous hermaphrodites (Matheson, 1981). Most of the larger, older fish are males. Sexual maturity is reached in about 5 years (500 mm).

Speckled hind live more than 15 years and can weigh over 20 kg. Average total lengths for fish from NC and SC aged 1 to 15 years are 186, 317, 408, 475, 528, 572, 613,45, 678, 709, 739, 774, 804, 839, and 861 mm (Matheson and Huntsman, 1984). Speckled hind generally engulf their prey whole. The diet includes fishes, shrimp, crabs, squid, and octopus (Bullock and Smith, 1991). This species is considered overfished in the most recent NMFS stock assessment and SAFMC SSC analyses.



Scamp

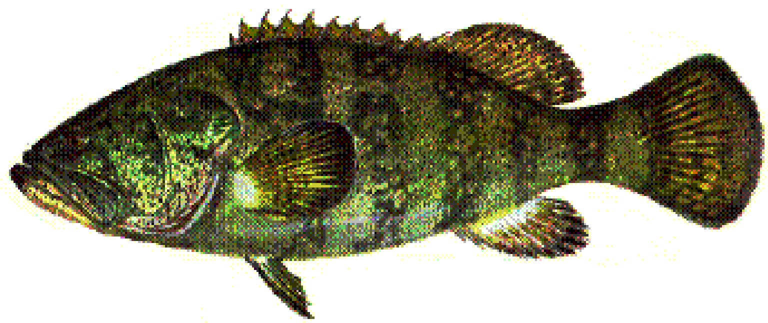
The scamp (*Mycteroperca phenax*) inhabits continental shelf waters from NC to FL and throughout the Gulf of Mexico. The species has been observed over low to high profile rock outcroppings encrusted with soft corals, sponges, hydroids, and bryozoa in waters 20 to 100 m deep (Parker and Ross, 1986).



Scamp spawn from April through August with a peak in May and June (Matheson et al., 1986). They live at least 21 years and grow to 894 mm. Average total lengths (and weights) for fish aged 1, 2, 3, 4, 5, 10, 15, 20, and 21 years are 216 mm (0.15 kg), 333 mm (0.54 kg), 414 mm (1.0 kg), 470 mm (1.4 kg), 516 mm (1.9 kg), 663 mm (3.9 kg), 770 mm (6.9 kg), 884 mm (8.9 kg), and, 894 mm (9.3 kg). Scamp feed mostly on fishes, such as round scad, *Decapterus punctatus*, tomtate, *Haemulon aurolineatum*, and vermilion snapper (Matheson et al., 1986).

Jewfish

The jewfish (*Epinephelus itajara*) is found on both Atlantic and Pacific sides of Central America (Smith, 1971). In the Atlantic, jewfish occur from Brazil throughout the Caribbean, Gulf of Mexico, Bermuda, the Bahamas and Florida (Bohlke and Chaplin, 1968; Smith, 1971; Hoese and Moore, 1977; Robins and Ray, 1986).



In the South Atlantic, jewfish are more abundant off the Florida east coast and in the Florida Keys. Spawning aggregations have been observed in the past off Palm Beach, Florida but do not occur anymore. The occurrence of jewfish north of Florida is rare and the States of Georgia and South Carolina requested jewfish be protected within Special Management Zones around their artificial reefs. This species is considered overfished in the most recent NMFS stock assessments and SAFMC SSC analyses. The Council has since prohibited the harvest or possession of jewfish in the South Atlantic EEZ.

Jewfish are suspected to be protogynous hermaphrodites (born female and changing to male later in life), similar to other groupers. Smith (1971) found evidence of ova remnants in the gonad of a six foot male collected near Bimini, Bahamas. The size or age of sexual transition is unknown and it is possible that some males pass through an immature female stage and mature only as males (L. Bullock, FMRI, FDNR, personal communication). Also, many of the larger fish taken commercially have been females. The ongoing Florida Department of Natural Resources (FDNR) study of jewfish has found no transitional fish among those sampled from the commercial fishery. Thus, it is not conclusive whether jewfish are indeed protogynous hermaphrodites or gonochoristic (sexes separate).

In the eastern Gulf of Mexico, females with ripe ova have been found during July through October with August to mid-October apparently the period of peak reproductive activity (D. DeMaria, SAFMC Snapper Grouper Advisory Panel, personal communication). Spawning aggregations of jewfish have been observed in waters as shallow as 30-40 feet.

In the FDNR study, female jewfish sexually matured at about 50-inches total length (105 pounds in weight). The youngest sexually mature female sampled was ten years of age, assuming one annulus per year. No specific information on fecundity exists. The smallest mature male was 43-inches total length, and the youngest sexually mature male was about five years old (L. Bullock, FMRI, FDNR, preliminary unpublished data).

Jewfish are long-lived and can attain a size of 700 pounds (Smith, 1971). Randall (1968) found fishes, hawksbill turtle, crabs, slipper lobster and most often spiny lobster in the stomachs of jewfish. Smith (1971) reported a large proportion of the jewfish's prey were crustaceans.

Adult and juvenile jewfish inhabit shallow waters and reside around bottom features which provide cover and protection (e.g. shipwrecks, reefs, ledges, piers, bridges and mangrove lined shores) (Godcharles, personal communication; Hoese and Moore, 1977; Robins and Ray, 1986; Smith, 1971; Thompson and Munro, 1978). Juveniles have been found along bulkheads and bridges (Springer and Woodburn, 1960) and in upland canals in Tampa Bay (Lindall et al., 1975). The preferred habitat of adults is the high-relief ledges and wrecks further offshore (Smith, 1976). The habitat preferences of jewfish make them easily accessible to fishermen, and especially vulnerable to spearfishermen. Furthermore, their narrow habitat preference causes this species to be highly susceptible to hypothermia (Gilmore et al., 1978) and red tide (Smith, 1976) induced mortalities. Large numbers of these fish are reported to aggregate around isolated reefs, rock ledges and wrecks in 150 foot depths and less on the southwest and southeast Florida shelf during the spawning season (P. Colin and D. DeMaria, personal communication). Indeed, aggregations up to 24 fish in depths as shallow as 15 feet have been observed in Hobe Sound, Florida (W. Parks, personal communication).

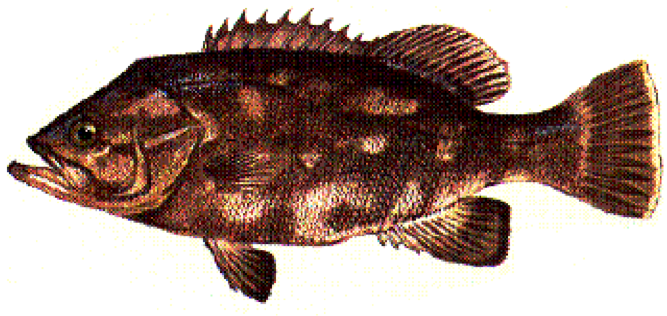
“The jewfish's ecological role in Georgia's offshore live bottom communities is also unknown and subject to conjecture. Based on diver observations, however, it has been suggested that jewfish may slow sandwave inundation of low-relief or isolated outcrops that have been established as residences by this species. Besides maintaining an open substrate for invertebrates, these outcrops also support related live bottom fisheries, including scamp, black seabass, snapper and other reeffish. In light of the low occurrence of live bottoms off Georgia, this type of function could be important in maintaining some of the state's offshore live bottoms” (D. Harris, personal communication).

Temperate Basses (Percichthyidae):
Wreckfish

The wreckfish (*Polyprion americanus*), has a wide geographic distribution but little is known of its biology and fisheries potential. Hardy (1978) reported the distribution of *Polyprion americanus* in the western Atlantic as extending from Grand Banks, Newfoundland to La Plata River, Argentina. The available literature consists primarily of occurrence records or behavioral observations (Roberts, 1977; Ryall and Hargrave, 1984; Schroeder, 1930), with limited life history data (Roberts, 1989). Wreckfish are pelagic for the first several years of their life (up to 30 cm length), often associated with floating debris (Roberts, 1989), the habit responsible for their common name. They grow to large size (100 kg weight, 2 m length), and are commercially fished in portions of their range (Roberts, 1989). The shallowest reported demersal populations of *Polyprion* in the western Atlantic were reported off Argentina in depths of 66-84 m (Menni and Lopez, 1979). The maximum reported depth for wreckfish is 1000 m (Lythgoe and Lythgoe, 1971). The presence of fishable concentrations of wreckfish in the northwestern Atlantic was unknown until 1987, when a fishery began to develop on the Blake Plateau, adjacent to South Carolina and Georgia.

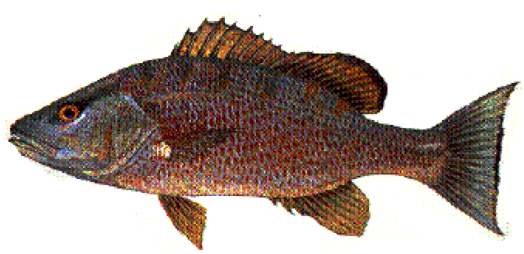
The fishing grounds and known distribution of wreckfish comprise an area of the Blake Plateau of approximately 50-75 square nm, characterized by a rocky ridge system having a vertical relief of >50 m and a slope of >15 degrees. The depth range in this area is 450-600 m.

The substrates in areas of the Blake Plateau exhibiting significant relief are generally characterized as composed of manganese - phosphate pavements, phosphorite slabs and coral banks (Pratt and McFarlin, 1966: Stetson et al, 1979). Bottom samples obtained from commercial fishermen indicate that wreckfish concentrations occur primarily on the manganese-phosphate bottoms. Prior observations from the research submersible, Johnson Sea-Link I, showed low densities of wreckfish associated with coral mounds or banks [C. A. Wenner (SCWMRD), personal communication]. There has been some exploratory efforts by commercial vessels but most of the fishing effort occurs on the initially discovered grounds of the Hoyt Hill area. This species is considered overfished in the most recent NMFS stock assessment and SAFMC SSC analyses.



Snappers (Lutjanidae):
Gray Snapper

One of the most commonly caught marine fishes in Florida, the gray snapper (*Lutjanus griseus*) occurs in marine and estuarine waters from North Carolina and Bermuda through Brazil (Robins and Ray, 1986). Spawning activity occurs offshore and peaks during the summer and early fall (Grimes, 1987; García-Cagide et al., 1994, Domeier et al., 1996). Eggs and larvae are planktonic and occur offshore (Bortone and Williams, 1986). Flexion of the caudal fin occurs at 4.2 mm (Richards and Saksena, 1980). Planktonic larval duration is estimated to range from at least 25 to 40 days, with a mean of 33 days postfertilization based on otolith microstructure (Lindeman et al., MSa). Settlement sizes range from approximately 10 to 20 mm (Starck, 1970). Larvae appear competent to settle at ages from approximately three to five weeks. The mean growth rate estimated for early juveniles is 0.92 mmd^{-1} (Lindeman et al., MSa). Maturity is reached at about 200 mm TL, probably during the third year (Starck, 1970). A variety of adult growth data are summarized in Claro and Garcia (1994). Based on literature reviews, Ault et al. (1998) estimated gray snapper reach a maximum size of .72 meters and a maximum age of 10 years.



The majority of western Atlantic snappers are easily distinguished as adults and larger juveniles. However, newly settled stages (<25 mm SL) of *Lutjanus griseus, L. apodus, L. jocu,* and *L. cyanopterus* can co-occur in shallow water, have essentially identical fin meristics, lack dorsolateral spots, and can be difficult to distinguish. Diagnostic methods for these species and other snappers at settlement are summarized in Richards et al. (1994) and Lindeman (1997).

Juvenile gray snapper are euryhaline and occur at salinities from 0-37 ppt (Tabb et al., 1961; Starck, 1970; Rutherford et al., 1983; Bortone and Williams, 1986). Exposure to freshwater pulses caused no mortality in laboratory experiments with juveniles (Serafy et al., 1997). Lower lethal temperature have been estimated at 11-14^{o} C (Starck, 1970) and several authors report mortality at low water temperatures caused by freezes (Tabb and Manning, 1961; Starck, 1970; Gilmore et al., 1978). Gray snapper are carnivorous at all life stages. Juveniles primarily prey on crustaceans, but can also consume fish, mollusks and polychaetes (Starck, 1970; Hettler, 1989). Adults are typically nocturnal predators, consuming mostly fish, but also taking shrimp and crabs (Longley and Hildebrand, 1941; Starck and Davis, 1966; Randall, 1968; Starck, 1970; Moe, 1972). Adults may show seasonal spawning migrations (Starck, 1970; Domeier and Colin, 1997).

In contrast to most snapper species, there is a substantial literature on habitat use in juvenile stages of gray snapper. Most information is from south or central Florida. Starck (1970) summarized information available through the 1960s for the Florida Keys and concluded that settlement stages and early juveniles primarily used grassbeds before migrating to hard structure in deeper waters with growth. In the Florida Bay area, gray snappers have been examined indirectly or directly in various studies, including Odum and Heald (1972), Thayer et al. (1987), Sogard et al. (1987), Hettler (1989), Chester and Thayer (1989), and Rutherford et al. (1989). These studies found gray snapper to be the most abundant lutjanid in the northern and eastern areas of this complex estuary, with hundreds of turbid basins and limited flushing. In grassbeds of the Indian River Lagoon, gray snapper was the most frequently occurring and second most abundant snapper collected (Gilmore, 1988). Work in high-salinity, low-turbidity mangrove habitats in Cuba (Claro and García-Arteaga, 1993) and Puerto Rico (Rooker and Dennis, 1991) also recorded gray snapper as the most abundant lutjanid.

Based on reviews of 40 years of surveys, and new sampling, in the Biscayne Bay area, newly settled stages commonly occurred in grassbeds, were consistently absent from mangrove and hardbottom habitats, and were uncommon or rare from all habitats exceeding 5 m in depth (Lindeman et al., In press). Early juvenile stages (2.5-7 cm) were more widely distributed, particularly on the habitat scale, occurring among a variety of hard structures as well as mangroves and grassbeds. The absence of newly settled life stages from hardbottom and mangrove habitats may result from the older resident fauna and more concentrated predation pressures in these habitats (Lindeman, 1997).

In summary, early stages can occur in estuaries and shallow marine areas (Hildebrand and Schroeder, 1928; Reid, 1954; Loftus and Kushlan, 1987; Bohlke and Chaplin, 1968; Randall, 1968; Starck, 1970; Chester and Thayer, 1989). Bottom types of high value include seagrass flats (*Thalassia*, *Syringodium*, and *Halodule*); soft marl bottoms, fine marl mud with shell and rock outcrops; mangrove roots; hardbottom structures; and shallow basins with seagrasses adjacent to mud banks (Bortone and Williams, 1986, Starck, 1968, Hildebrand and Schroeder, 1928, Starck 1970, Gunter, 1957, Chester and Thayer 1989). Adults are primarily marine and utilize deeper waters than juveniles, but can occur in estuaries and rivers. Adults are euryhaline, ranging from 0-47 ppt waters (Croker, 1960, Hardy, 1978, Briggs, 1958) and have been reported from depths of 77 m (Rivas, 1970). Bottom types of high value for adults are diverse and include coral reefs and hardbottom offshore, ledges of channels, artificial structures, mangroves and grassbeds, alcyonarians, and sponges (Starck and Davis, 1966, Gunter, 1957, Hildebrand and

Schroeder, 1928, Kilby, 1955, Moe, 1972, Springer and Woodburn, 1960; Starck, 1970; Bohnsack et al., 1987).

Mutton Snapper

A premier demersal fishery species, the mutton snapper (*Lutjanus analis*), ranges from Florida and Bermuda to Brazil (Robins and Ray, 1986). Unlike the gray snapper, mutton snapper are not appreciably present north of central Florida or in the northern Gulf of Mexico. Spawning activity occurs offshore and may peak during the summer and fall (Grimes, 1987; Garcia-Cagide et al., 1994). Sizeable aggregations can be formed during spawning (Domeier and Colin, 1997). Eggs and larvae are probably planktonic and occur offshore (Richards et al., 1994). Planktonic larval duration is estimated to range from at least 27 to 37 days, with a mean of 31 days postfertilization (Lindeman et al., MSa). Settlement sizes range from approximately 10 to 20 mm (Starck, 1970). The mean growth rate estimated for early juveniles is 0.68 mmd^{-1} for winter-spawned individuals (Lindeman et al., MSa). Adult growth data are summarized in Claro and Garcia (1994). Based on literature reviews, Ault et al. (1998) estimated that mutton snapper reach a maximum size of .94 meters and a maximum age of 14 years.

Mutton snapper are recorded from salinities of 4.5-37.3 ppt (Christensen 1965) and temperatures of 18.5-30^{o} C (Roessler, 1970). Mortality from hypothermal stress has been documented at 6-13^{o} C (Gilmore et al., 1978). Larvae and newly settled stages are presumed to be planktivorous and benthic invertebrate foragers, respectively. Large juveniles and adults feed predominately on a wide array of crustaceans and fishes, although gastropods and octopii may also be consumed (Randall 1967; Starck, 1970; Parrish 1987).

In contrast to the gray snapper, there is little literature on habitat use in early stages of nutton snapper. Eggs and larvae probably utilize water column habitats over the continental shelf, based on similar lutjanids (Grimes 1987; Leis 1987). Recruitment of early juveniles 10-25 mm SL to the Indian River Lagoon occurs principally from June to November; however, juveniles <20 mm SL have been captured in July, and October through January (Gilmore, unpubl data). From 1974 to 1977 the largest single collections of juveniles consistently occured in November, but the wide distribution of early juveniles through the summer, fall and winter indicates a prolonged spawning and recruitment period for southeast Florida mutton snapper populations (Gilmore, unpubl. data).

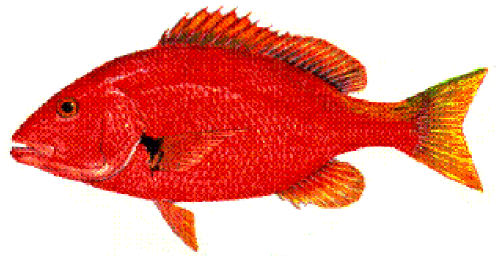
Newly settled stages occur in seagrass meadows (10-15 mm SL at settlement, with size ranges of 10-200 mm SL, n = 250; Gilmore, unpubl. data) and generally use mangrove prop roots or adjacent shallow rock and coral reef formations as larger juveniles (>100 mm SL; Gilmore, unpubl. data). Christensen (1965) captured 297 juveniles, 15-176 mm SL in seagrass meadows at Jupiter Inlet in the southern terminous of the Indian River Lagoon, while Springer and McErlean (1962) captured 67 individuals 16-66 mm SL in nearshore seagrass meadows of the Florida Keys. Ocean inlet seagrass meadows are preferred habitat for mutton snapper juveniles in the Indian River Lagoon although they occurred at all seagrass stations from Sebastian Inlet to St. Lucie Inlet (Gilmore 1988; Gilmore unpublished data).

Adults utilize a variety of deeper reef environments over reef, sand and mud substrates and can occur to depths of 100 m (Starck, 1970; Rivas, 1970; Gilmore 1977; Claro, 1981). Adult may make migrations to spawning sites (Domeier and Colin, 1997). Adults are generalized top predators on a variety of reef invertebrates and fishes, particularly slow-moving or sedentary benthic and epibenthic prey species. Feeding predominately takes place near the bottom during the day or night (Randall, 1968; Parrish, 1987).

Blackfin Snapper

The blackfin snapper (*Lutjanus buccanella*) occupies shelf edge habitat from Cape Hatteras, NC to the Caribbean Antilles, and in the Gulf of Mexico (Böhlke and Chaplin, 1993). While juveniles and subadults sometimes inhabit hard bottom at shallow depths (12 to 40 m), adult fish usually occur from 40 to 300 m (Rivas, 1970*;* Nagelkerken, 1981).

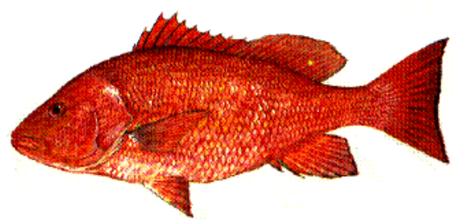
Male fish grow larger (to 740 mm) than females but are less common (Boardman and Weiler, 1980). Adult fish more commonly reach 500 mm on a diet of fish and crustaceans (Nagelkerken, 1981).



Red Snapper

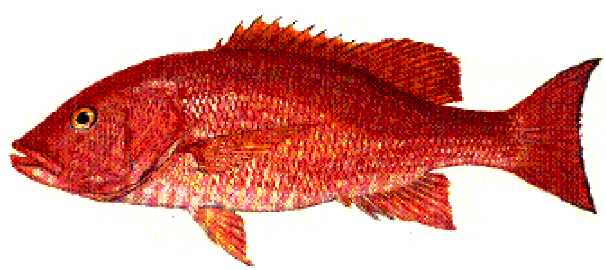
The red snapper (*Lutjanus campechanus*) ranges from Cape Hatteras, NC to FL and throughout the Gulf of Mexico. It is found over rocky bottom at depths from 10 to 190 m and feeds on fishes and invertebrates, i.e. shrimp, cephalopods, and worms (Fischer, 1978).

Red snapper mature after 3 years (Bradley and Bryan, 1975) and spawn throughout the warmer months. Eggs and larvae are pelagic. Red snapper lives at least 16 years and grow to 1,025 mm. Average total lengths for fish aged 1, 2, 3, 4, 5, 10, and 15 are 224, 379, 453, 536, 577, 845, and 1,025 mm (Nelson and Manooch, 1982).



Silk Snapper

The silk snapper (*Lutjanus vivanus*) ranges from Cape Hatteras, NC to Brazil and in the Northern Gulf of Mexico along the continental shelf edge, 64 to 242 m in depth (Böhlke and Chaplin, 1993). This shelf edge habitat consists of algal limestone cliffs and ledges interspersed with shell hash and sandstone (Grimes, 1976).

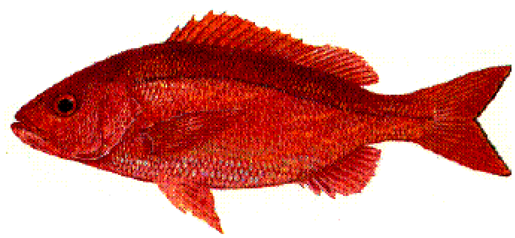


Young adult and juvenile fish occupy shallower depths than adult fish, to as shallow as 12 m where preferred bottom type occurs (Nagelkerken, 1981). Fish and crustaceans make up the majority of the diet.   Silk snapper reach sexual maturity by 500 to 555 mm and grow to 750 mm. Thought to travel in loose schools, silk snapper aggregate year round for spawning with apparent peaks in July through September and October through December. Female fish outnumber males (Boardman and Weiler, 1980).

Vermilion Snapper

The vermilion snapper (*Rhomboplites aurorubens*) occurs over rough bottom from Bermuda and NC to Brazil, including the West Indies (Bohlke and Chaplin, 1993). Their diet consists mostly of small pelagic crustacea (ostracods, copepods, stomatopods, amphipods, shrimp, and crabs), cephalopods, pelagic gastropods, and small fish (Dixon, 1975; Grimes, 1979).

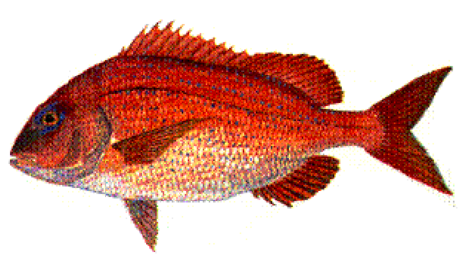
Vermilion snapper mature in 3 to 4 years, and spawn April through September off NC (Grimes, 1976) and year around off Puerto Rico (Boardman and Weiler, 1980). Ovaries contain 100 thousand to 1.8 million eggs (Grimes, 1976). Eggs and larvae are pelagic. Vermilion snapper live at least 10 years and grow to 618 mm (Grimes, 1978). This species is considered overfished in the most recent NMFS stock assessments and SAFMC SSC analyses.



Porgies (Sparidae):
Red Porgy

In the western Atlantic the red porgy (*Pagrus pagrus*) occurs from NC to Argentina over rough bottom at depths from 18 to 280 m (Murray and Hjort, 1912), but has not been reported from the Caribbean (Manooch and Huntsman, 1977). Red porgy are protogynous hermaphrodites; most fish longer than 457 mm are males. Females mature in 2 to 4 years and may spawn 47,000 to 500,000 eggs.

Spawning occurs from January through April and eggs and larvae are pelagic (Manooch, 1975). Red porgy live up to 15 years. Average lengths for ages 1 to 12 years are 238, 290, 341, 382, 419, 451, 483, 505, 527, 543, 558 and 604 mm. The red porgy feeds on crabs, snails, worms, sea urchins, and occasionally small fishes such as round scad and tomtate (Manooch, 1977). This species is considered overfished in the most recent NMFS stock assessments and SAFMC SSC analyses.



Grunts (Haemulidae):
White Grunt

The white grunt (*Haemulon plumieri*) ranges from North Carolina to Brazil. Eggs and early larvae are pelagic (Johnson, 1978). Juveniles and adults are found from the shore to at least 35 m (Fischer, 1978), occupying a variety of habitats including reefs and hardbottom, grass flats, and mangrove habitats (Gilmore, 1977; Darcy, 1983). They are often found individually or in small groups, but can also form large schools over reefs and gorgonians, particularly during the day (Longley and Hildebrand, 1941; Gilmore, 1977; Darcy, 1983; Christensen, 1965). Spawning occurs over much of the year with one or more peaks in warmer months (Garcia-Cagide, 1994).

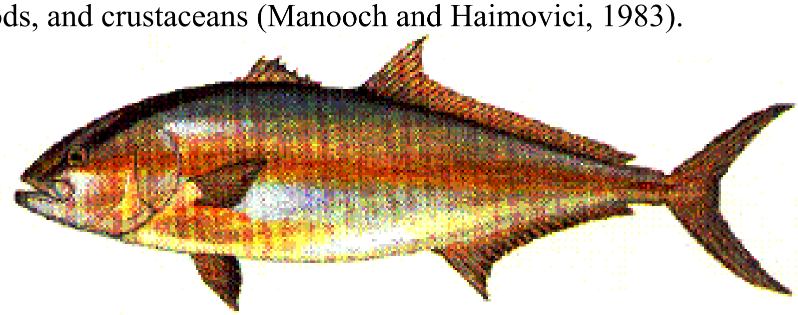
Larvae reared in the laboratory grew at a rate of 0.32 mm/d (Saksena and Richards, 1975). Otolith increment deposition has been validated as daily and the mean growth rate of field-collected early juveniles has been estimated at 0.38 mm/d (Lindeman et al., MSa). Adults tagged on the Florida west coast showed a growth rate ranging from 1.4 to 3.6 mm/month (Moe 1966). Maximum length is estimated at 450 to 460 mm (Hoese and Moore, 1977; Robins et al., 1986; Evermann and Marsh 1902; Breder, 1948).

White grunt are fished commercially and recreationally throughout their range (Manooch, 1976; Fernando, 1966). They are important in energy exchange between reef and seagrass communities because of nocturnal foraging migrations (Darcy, 1983). Newly settled stages feed on plankton directly from the water column during the day (Ogden and Ehrlich, 1977). Adults are generalized carnivores which feed mainly on benthic invertebrates (Manooch, 1976). These include echinoderms, polychaetes, majid crabs, alpheid shrimp, isopods, other shrimp, crabs, and small fish (Bebe and Tee-Van, 1928; Davis, 1967; Fischer, 1978; Darcy, 1983). Because of their abundance, they are probably important prey for many larger species of groupers and snappers (Darcy, 1983).

Jacks (Carangidae):
Greater Amberjack

The greater amberjack (*Seriola dumerili*) occurs in the western Atlantic from Nova Scotia and Bermuda to Brazil, including the West Indies and Gulf of Mexico (Fischer, 1978). Greater amberjack probably spawn year around but are reproductively most active from March through June (Burch, 1979). Spawning concentrations occur in southeast FL and the Keys.

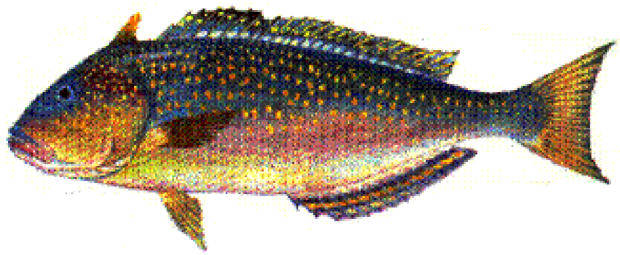
The relatively new (since 1985) commercial fishery, especially that conducted by divers with spearguns, focuses on these aggregations. Greater amberjack have been aged to 17 years; they reach a weight of at least 30.5 kg and a length (FL) of 1,552 mm (Manooch and Potts, in press). Average lengths for fish aged 1 to 10 years are 407, 643, 908, 1000, 1094, 1169, 1218, 1333, 1397, and 1435 mm (Burch, 1979). Amberjacks are voracious feeders; major foods are fishes, cephalopods, and crustaceans (Manooch and Haimovici, 1983).



Tilefishes (Malacanthidae):
Golden Tilefish

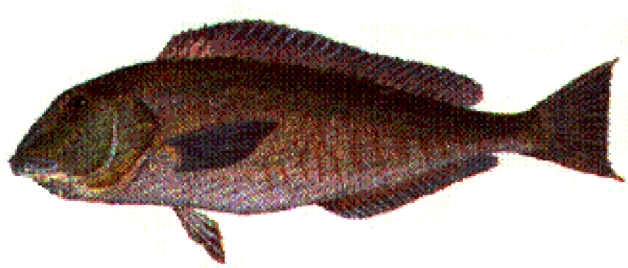
The golden tilefish (*Lopholatilus chamaeleonticeps*) is a demersal malacanthid species that inhabits the outer continental shelf and upper continental slope along the entire east coast of the United States and the Gulf of Mexico south to Venezuela. It is a bottom dweller, living in burrows in clay substrate at depths from 76 to 457 m (Freeman and Turner, 1977) in water temperatures from 9 to 14%C (Grimes et al., 1986).

Fifty percent of males mature by age 5 (450 mm) while 50% of females mature by age 6 (500 mm) (Erickson and Grossman, 1986). Females spawn 1 to 10 million eggs, and spawn fractionally from March to November (Grimes et al., 1988). Golden tilefish live at least 33 years and mean sizes for fish aged 5, l0, l5, 20, 25 and 30 years are 471, 554, 689, 790, 883 and 852 mm (Harris and Grossman, 1985). Adult tilefish feed on fish, crabs, shrimp, squid, worms, sea cucumbers, anemones, tunicates, and sea urchins (Freeman and Turner, 1977). This species is considered overfished in the most recent NMFS stock assessment and SAFMC SSC analyses.



Blueline Tilefish

The blueline tilefish (*Caulolatilus microps*) occurs from Cape Charles, VA to the Campeche Banks, Mexico in water depths between 68 and 236m, but is found principally south of Cape Hatteras (Dooley, 1978). The species frequents irregular bottom comprised of troughs and terraces inter-mingled with sand, mud, or shell hash bottom along the continental shelf break. This habitat is commonly shared with some of the deep water snappers and groupers, especially snowy grouper. Blueline tilefish have been observed hovering near and entering burrows under rocks (Parker and Ross, 1986). Water temperatures typically range from 15 to 23 ^{o}C (Ross, 1978). These tilefish are epibenthic browsers, often feeding upon crabs, shrimps, snails, worms, sea urchins, and fish (Ross, 1982; Bielsa and Labisky, 1987).



Long lived and slow growing, blueline tilefish may attain 820 mm in 17 years (Ross, 1978; Ross and Huntsman, 1982; Labisky et al., 1983). They commonly reach 150 mm by the end of year one. Labisky et al. (1983) reported average lengths for age 1-15 fish of 165, 279, 358, 414, 464, 505, 544, 576, 607, 632, 655, 676, 693, 709, and 726 mm respectively.

Some females mature at age 1, all are mature by age 6. Large females spawn up to 4 million pelagic eggs between April and September, with peak spawning in May and September (Ross and Merriner, 1982). Early researchers believed that blueline tilefish might be protogynous hermaphrodites; however, a recent study indicates normal sexual dimorphism (Labisky et al., 1983).

3.3.3.2 Distribution and Use of Inshore/Estuarine Habitat.

Snapper grouper species utilize both pelagic and benthic habitats during their life cycle. Planktonic larval stages live in the water column and feed on zooplankton. Juveniles and adults are typically demersal and usually associate with hard structures on the continental shelf that have moderate to high relief; i.e., coral reefs, artificial reefs, rocky hard-bottom substrates, ledges and caves, sloping soft-bottom areas, and limestone outcroppings. More detail on these habitat types is found in Sections 3.2.1 and 3.2.2. However, juveniles of some species, such as *Lutjanus analis*, *L. griseus*, *L. jocu*, *L. synagris*, *Ocyurus chrysurus*, *Epinephelus itajara*, *E. morio*, *Mycteroperca microlepis* , *M. venenosa*, *C. faber,* and *L.maximus* may occur in inshore seagrass beds, mangrove estuaries, lagoons, and bay systems. In many species, various combinations of these habitats may be utilized during diurnal feeding migrations or seasonal shifts in cross-shelf distributions.

NOAA's Estuarine Living Marine Resource Program (ELMR) has compiled regional information on the use of estuarine habitats by select marine fish and invertebrates. A report prepared through the ELMR program (NOAA 1991b) and revised information (NOAA 1998), provided to the Council during the Habitat Plan development process, summarizes known spatial and temporal distributions and relative abundances of fish and invertebrates using southeast estuarine habitats. Twenty southeast estuaries selected from the National Estuarine Inventory (NOAA 1985) are included in an analysis based on a review of published and unpublished literature and expert consultations.

Detailed information on the distribution and seasonal use of estuarine habitat by gray snapper exists in the NOAA ELMR program. This information emphasizes the importance and essential nature of estuarine habitats to gray snapper. Since it is the only estuarine dependant species under the Snapper Grouper FMP in the ELMR data set, it is used here as a proxy for other estuarine dependent snapper grouper species. As information is compiled on other estuarine dependent species, such as gag, spatial coverages of juvenile distribution and use of inshore habitat essential to the species will be spatially portrayed on maps. Figures 30-32 present a representative sample of the distibution maps for juvenile gray snapper. The remainder of the coverages and additional information on species and habitat distribution are available over the Internet on the Council web page under the habitat homepage (www.safmc.noaa.gov). These maps portray salinity and relative abundances for estuaries and coastal embayments on state and/or regional maps. Depending on data availability, maps were produced at various scales: 1:24K, 1:80K, and 1:250K. These maps will eventually be provided to the Council as ArcView shape files with associated data for inclusion into the Council's GIS system.

3.3.3.3 Offshore Habitat

3.3.3.3.1 Distribution and Use of Offshore Habitat

The principal snapper grouper fishing areas are located in live bottom and shelf-edge habitats. Temperatures range from 11° to 27° C over the continental shelf and shelf-edge due to the proximity of the Gulf Stream, with lower shelf habitat temperatures varying from 11° to 14° C. Depths range from 54 to 90 feet or greater for live-bottom habitats, 180 to 360 feet for the shelf-edge habitat, and from 360 to 600 feet for the lower-shelf habitat.

The exact extent and distribution of productive snapper grouper habitat on the continental shelf north of Cape Canaveral is unknown. Current data suggest that from 3 to 30 percent of the shelf is suitable bottom. These hard, live-bottom habitats may be low relief areas supporting sparse to moderate growth of sessile invertebrates, moderate relief reefs from 1.6 to 6.6 feet, or high relief ridges at or near the shelf break consisting of outcrops of rock that are heavily encrusted with sessile invertebrates such as sponges and sea fans. Live-bottom habitat is scattered irregularly over most of the shelf north of Cape Canaveral, but is most abundant off northeastern Florida. South of Cape Canaveral the continental shelf narrows from 35 to 10 mi and less off the southeast coast of Florida and the Florida Keys. The lack of a large shelf area, presence of extensive, rugged living fossil coral reefs, and dominance of a tropical Caribbean fauna are distinctive characteristics.

Rock outcroppings occur throughout the continental shelf from Cape Hatteras, NC to Key West, FL (MacIntyre and Milliman, 1970; Miller and Richards, 1979; Parker et al., 1983). Generally, the outcroppings are composed of bioeroded limestone and carbonate sandstone (Newton et al., 1971) and exhibit vertical relief ranging from <0.5 to over 10 m. Ledge systems formed by rock outcrops and piles of irregularly sized boulders are common. Parker et al. (1983) estimated that 24% (9,443 km^2) of the area between the 27 and 101 m isobaths from Cape Hatteras to Cape Canaveral is reef habitat. Although the area of bottom between 100 and 300 m depths from Cape Hatteras to Key West is small relative to the shelf as a whole, it constitutes prime reef fish habitat according to fishermen and probably contributes significantly to the total amount of reef habitat.

Man-made artificial reefs are also utilized to attract fish and increase fish harvests. Research on man-made reefs is limited and opinions differ as to whether or not artificial structures actually promote an increase of biomass or merely concentrate fishes by attracting them from nearby natural areas.

The distribution of coral and live hard bottom habitat as presented in the SEAMAP Bottom Mapping Project is a proxy for the distribution of the species within the snapper grouper complex. The methodology used to determine hard bottom habitat relied on the identification of reef obligate species including members of the snapper grouper complex. ArcView maps were prepared for the four-state project by FMRI (FDEP) showing the best available information on the distribution of hard bottom habitat in the south Atlantic region. The maps which consolidate known distribution of coral, hard/live bottom and artificial reefs as hard bottom are included in Appendix E. These maps are also available over the Internet on the Council web page under the habitat homepage (www.safmc.noaa.gov). General snapper grouper species distribution maps are available for black sea bass and red porgy (Figures 34a and 34b).

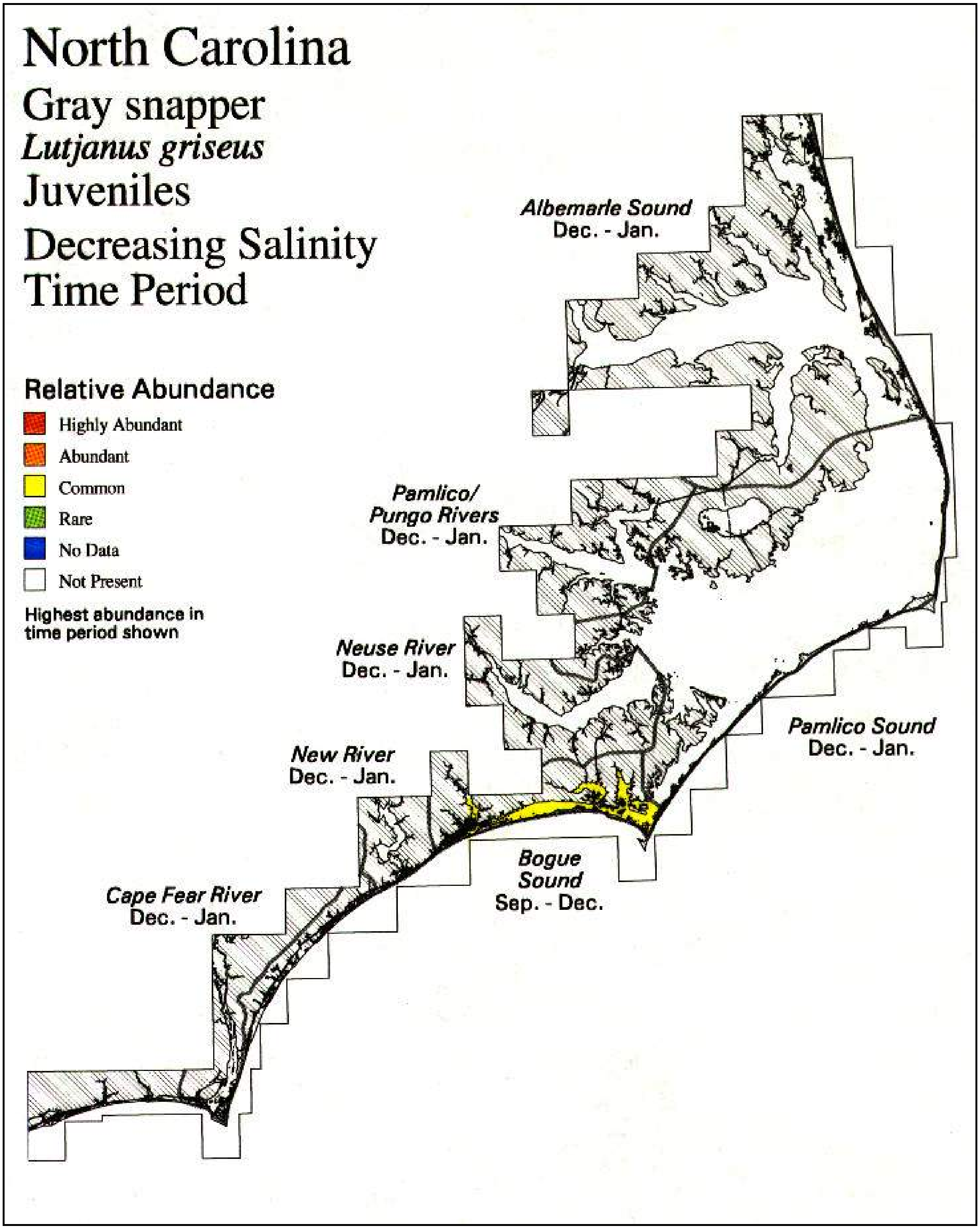


Figure 30. Gray snapper juvenile distribution in North Carolina estuaries in high salinity time period (Source: NOAA 1998).

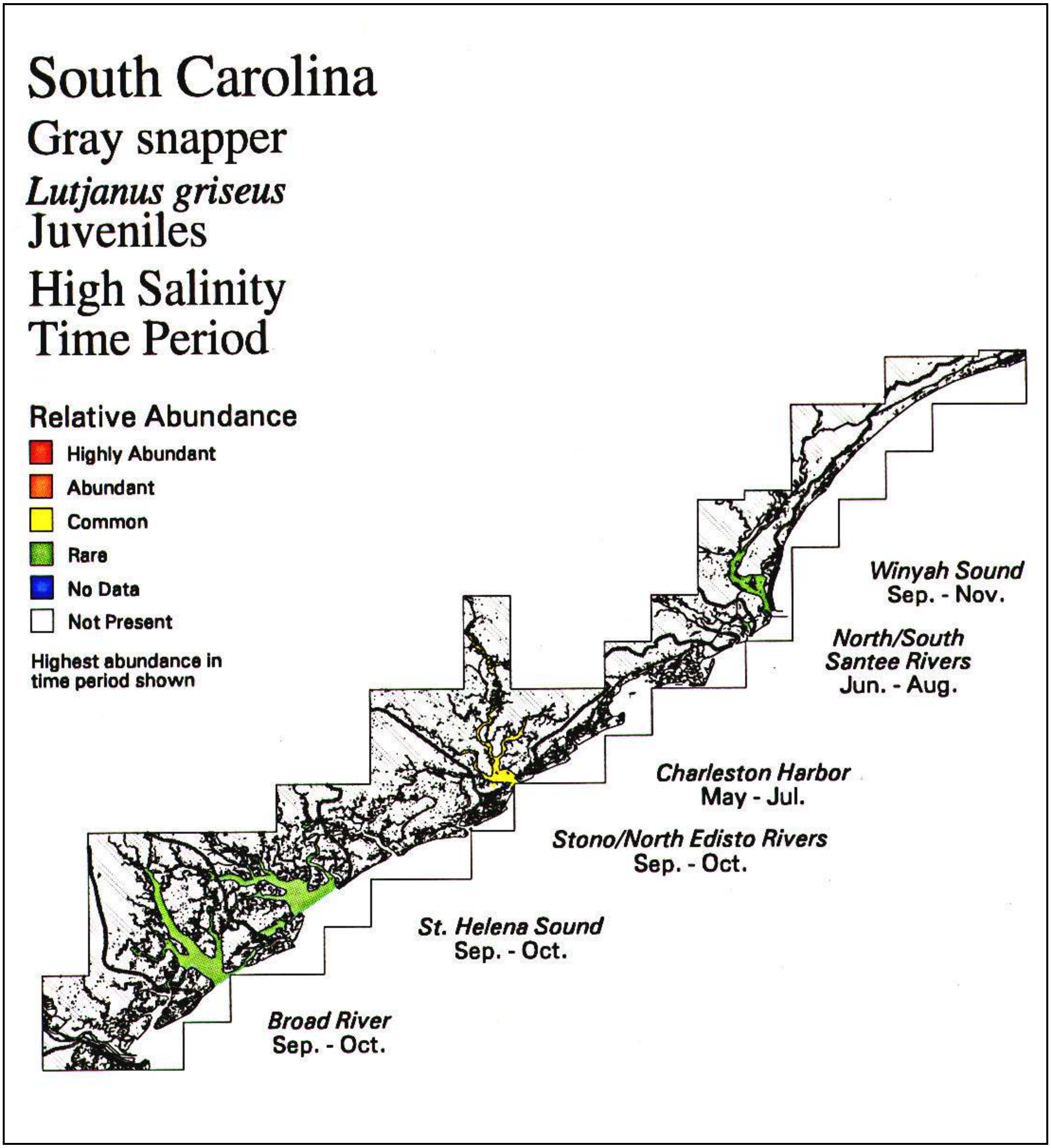


Figure 31. Gray Snapper juvenile distribution in South Carolina estuaries in high salinity time period (Source: NOAA 1998).

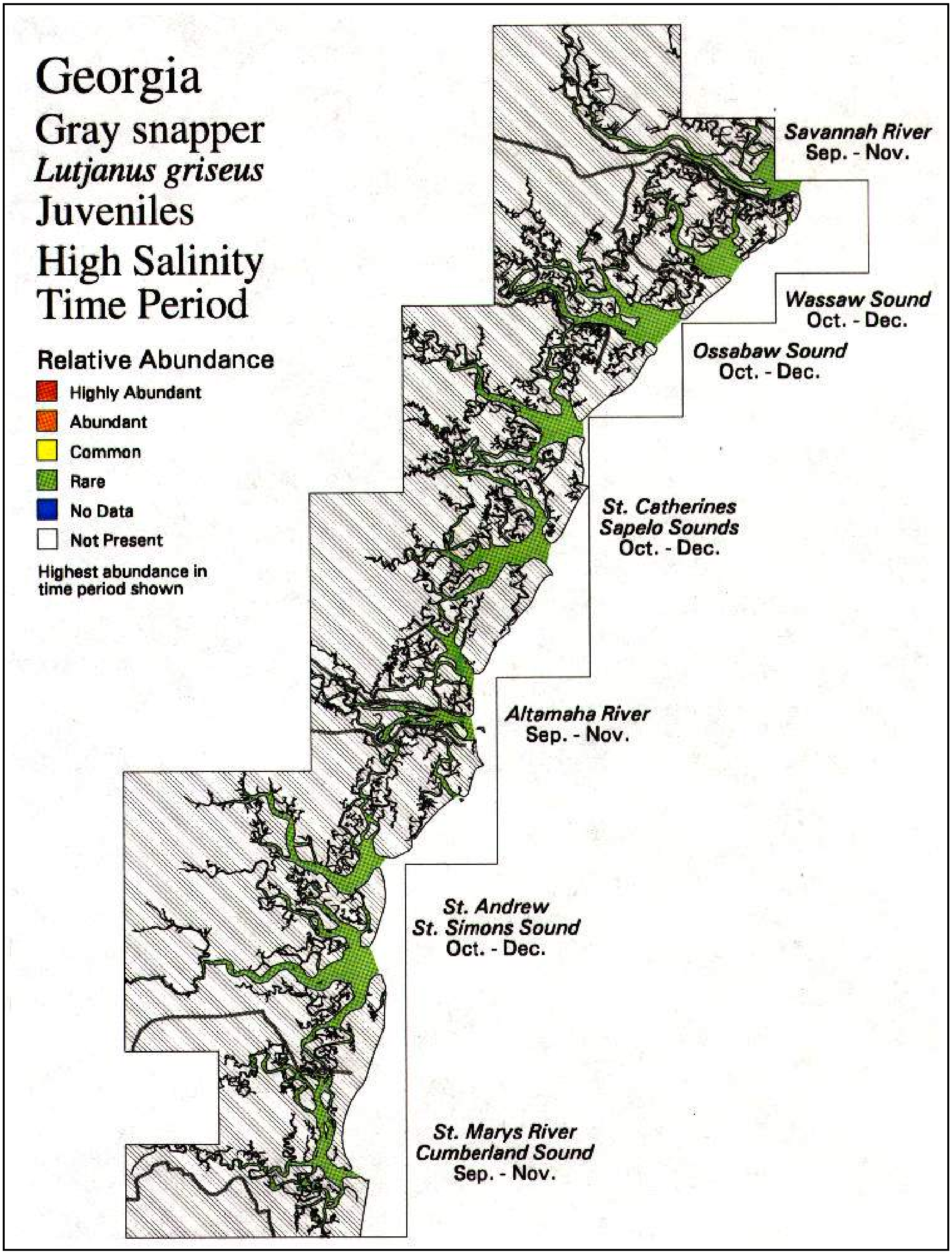


Figure 32. Gray Snapper juvenile distribution in Georgia estuaries in high salinity time period (Source: NOAA 1998).

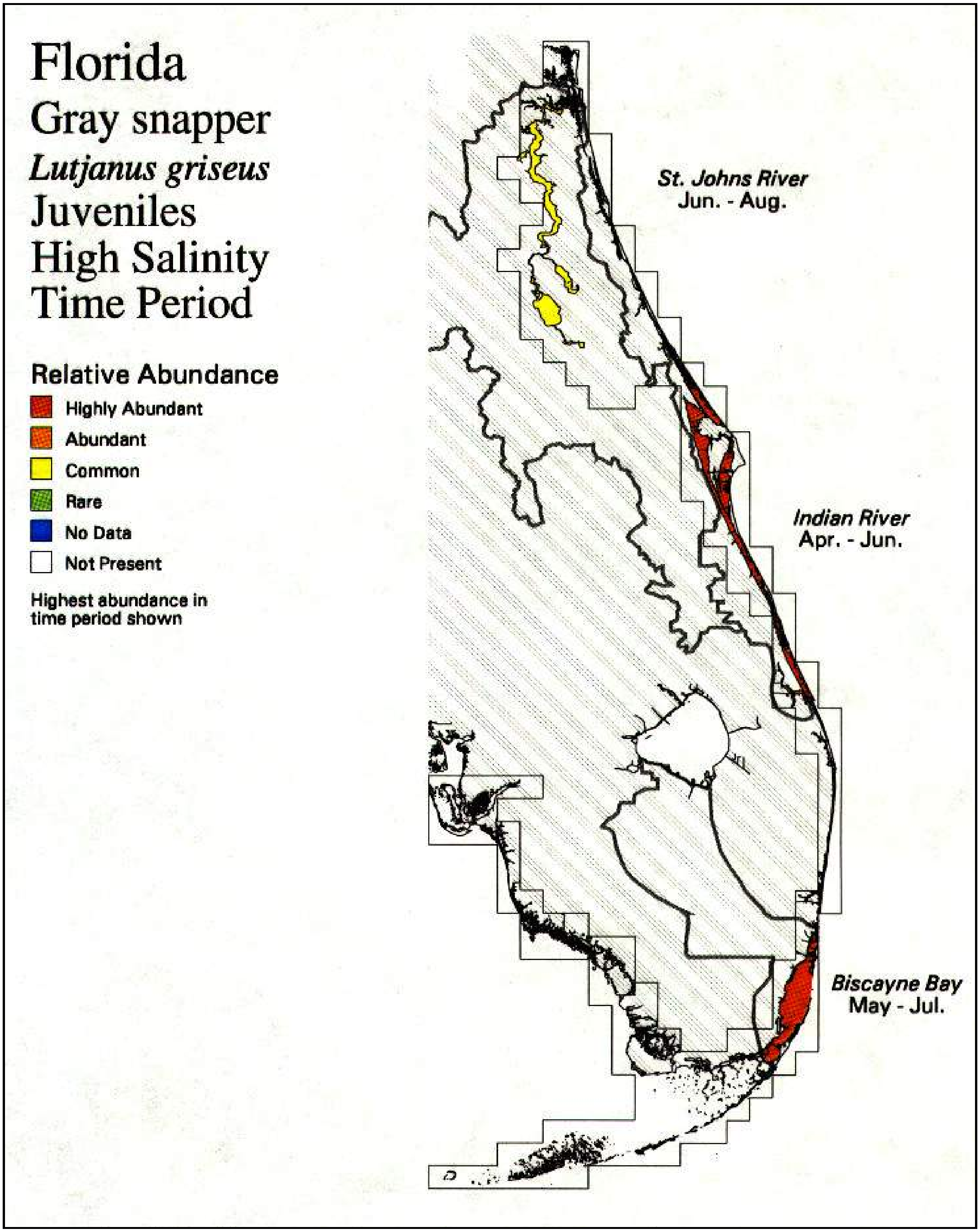
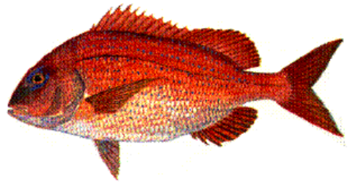
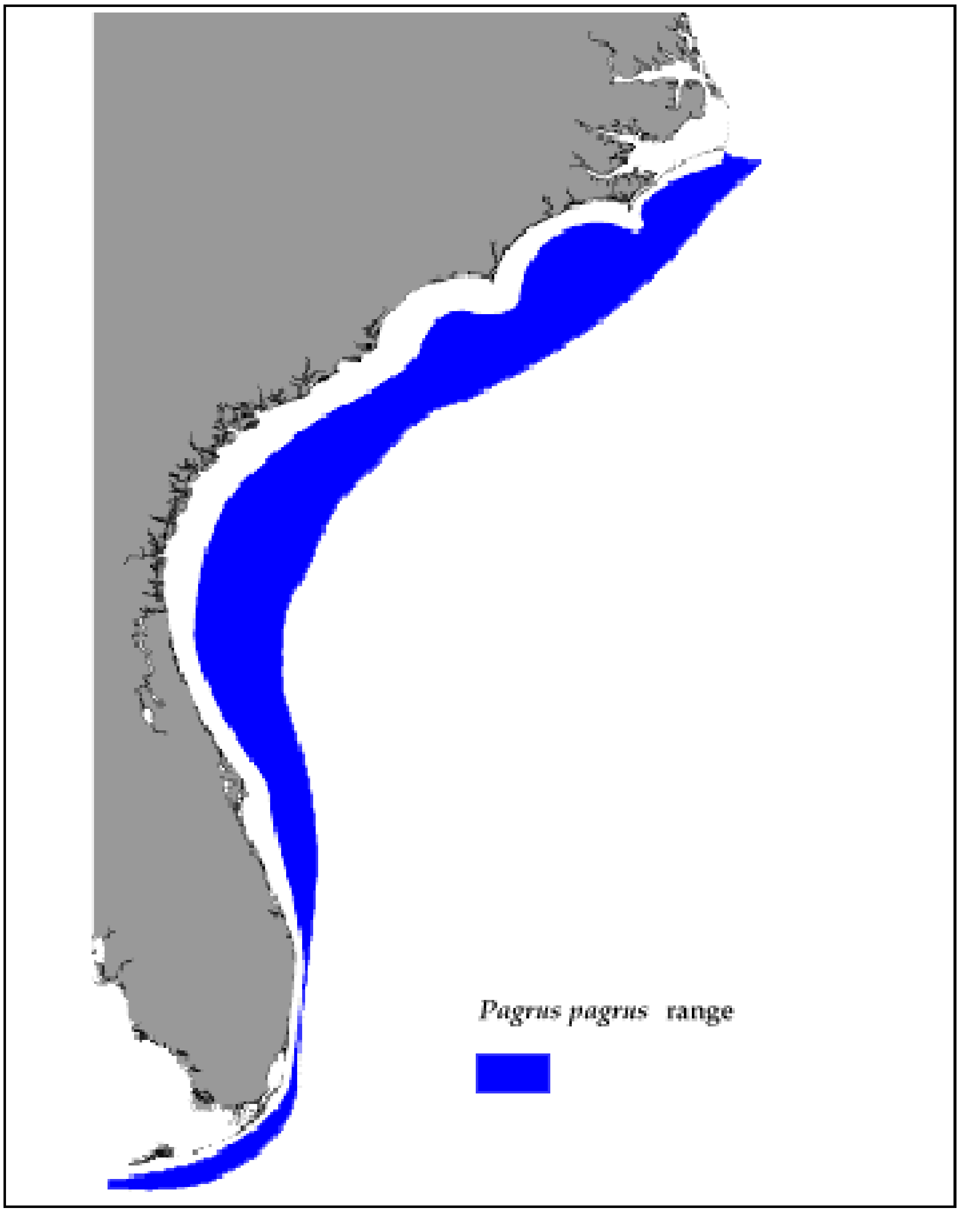
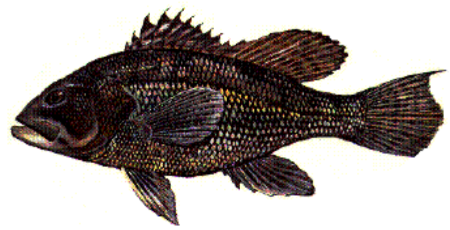


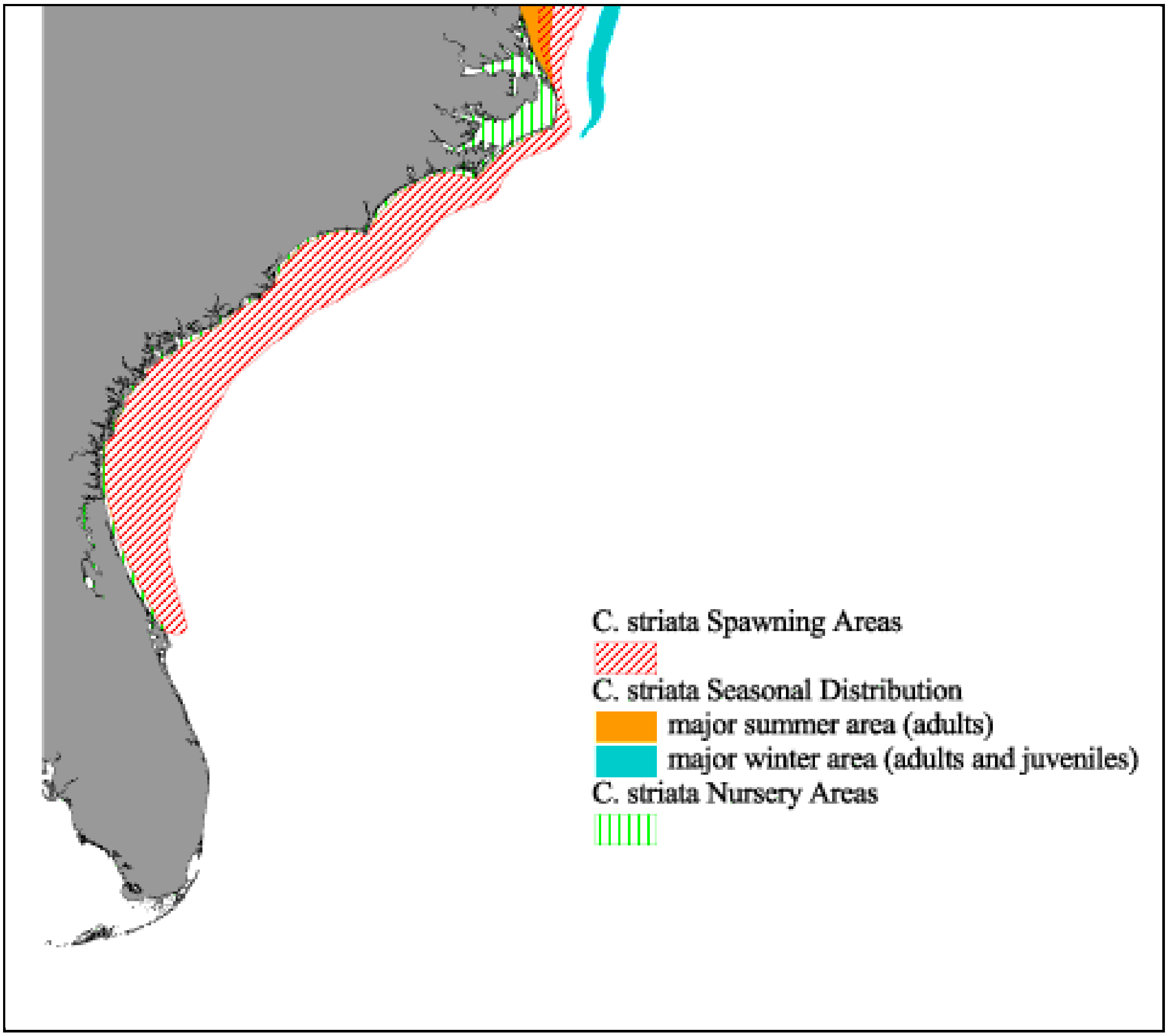
Figure 33. Gray Snapper juvenile distribution in Florida estuaries in high salinity time period (Source: NOAA 1998).





Figures 34a.   Red porgy distribution (Adapted from: NOAA 1980 and NOAA 1998).





Figures 34b.   Black sea bass distribution in the South Atlantic region (Adapted from NOAA 1980 and NOAA 1998).

Additional information on managed species use of offshore fish habitat was generated cooperatively by the South Carolina Department of Natural Resources, NOAA/Biogeographic Characterization Branch, and the South Atlantic Fishery Management Council. Plots of the spatial distribution of offshore species were generated from the Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP) data (Figures 35-41) .

This fishery-independent survey program has been collecting data in the South Atlantic Bight region since 1973. The program began 25 years ago as an ichthyoplankton and groundfish survey of shelf and upper slope waters from Cape Fear to Cape Canaveral, however, since 1978, efforts of the South Carolina MARMAP program have concentrated on fishery-independent assessments of reef fish abundance and life history. The spatial distribution of sampling effort has varied considerably by gear type. Traps, which have constituted the bulk of the sampling effort (n=7458), were deployed randomly on confirmed hard bottom habitat during 1979-1997. Longline sampling (n=445) has usually been restricted to the deepest regions in the sampling area. Sampling strategy for trawls (n=2249) varied during 1973-1987. From 1973-winter 1977, a stratified random sampling strategy was employed. During summer 1977 to 1980, trawling was conducted over sand bottom habitat along offshore transects. From 1978 to 1987, a trawl survey targetted only live bottom areas at known hard bottom locations. MARMAP also conducted a trawl survey in 1982 to 1983 and 1985-1987 at depths < 18 m. Sampling effort with the different gear types varied seasonally, increasing during spring Months (n=205) to a peak in June (n=2301) and then declining by October (n=454) through the winter months.

Maps portraying the distribution of offshore species were created with this temporal and spatial variability in fishing effort in mind (Figures 36-42). The marine species EFH products requested by the SAFMC were catch-density plots. No attempt was made to interpret seasonal or habitat-specific catch distributions for individual species due to the low number of observations for many species and the sampling bias towards summer months and hard bottom habitat. Therefore, catch data for each species were pooled across all years, months, and gear types for each species and then plotted against regional bathymetry. Catch distributions for each species are a function of spatio-temporal distribution of sampling effort for each gear and susceptibility of individual species to each gear. Therefore, each plot should not be interpreted as a comprehensive portrayal of an individual species' distribution. Certainly, many of the species presented here exhibit seasonal trends in abundance while others are more residential (Grimes et al. 1982; Chester et al., 1984; Sedberry and Van Dolah, 1984; Wenner and Sedberry, 1989). Instead, the plots should be considered as point confirmation of the presence of each species within the scope of the sampling program. As importantly, the plots identify the occurrence of the snapper grouper complex over hard bottom habitats. These plots, in combination with the hard bottom habitat distributions presented in Appendix E, can be employed as proxies for offshore snapper grouper complex distributions in the south Atlantic region.

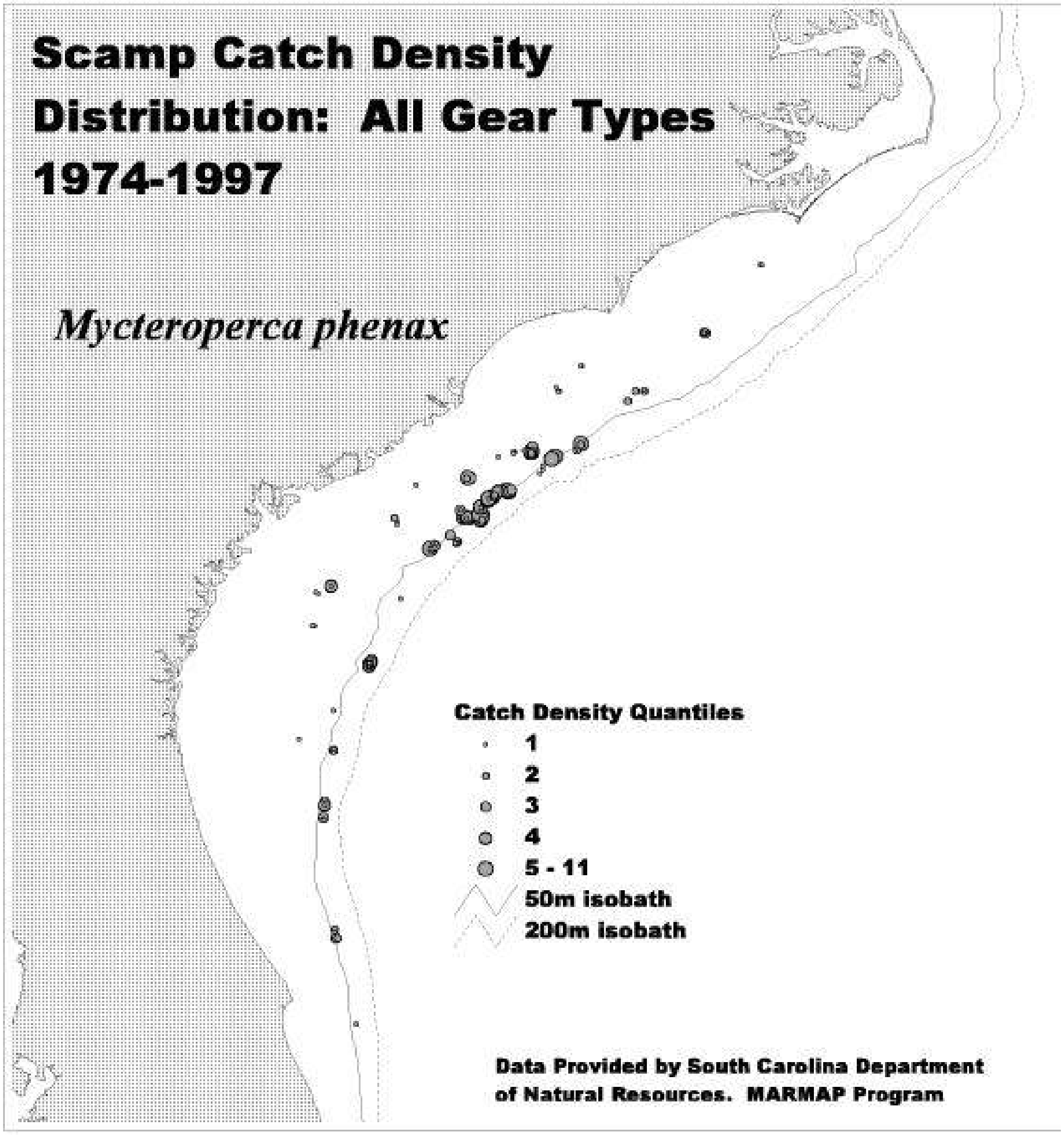


Figure 35. Scamp catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

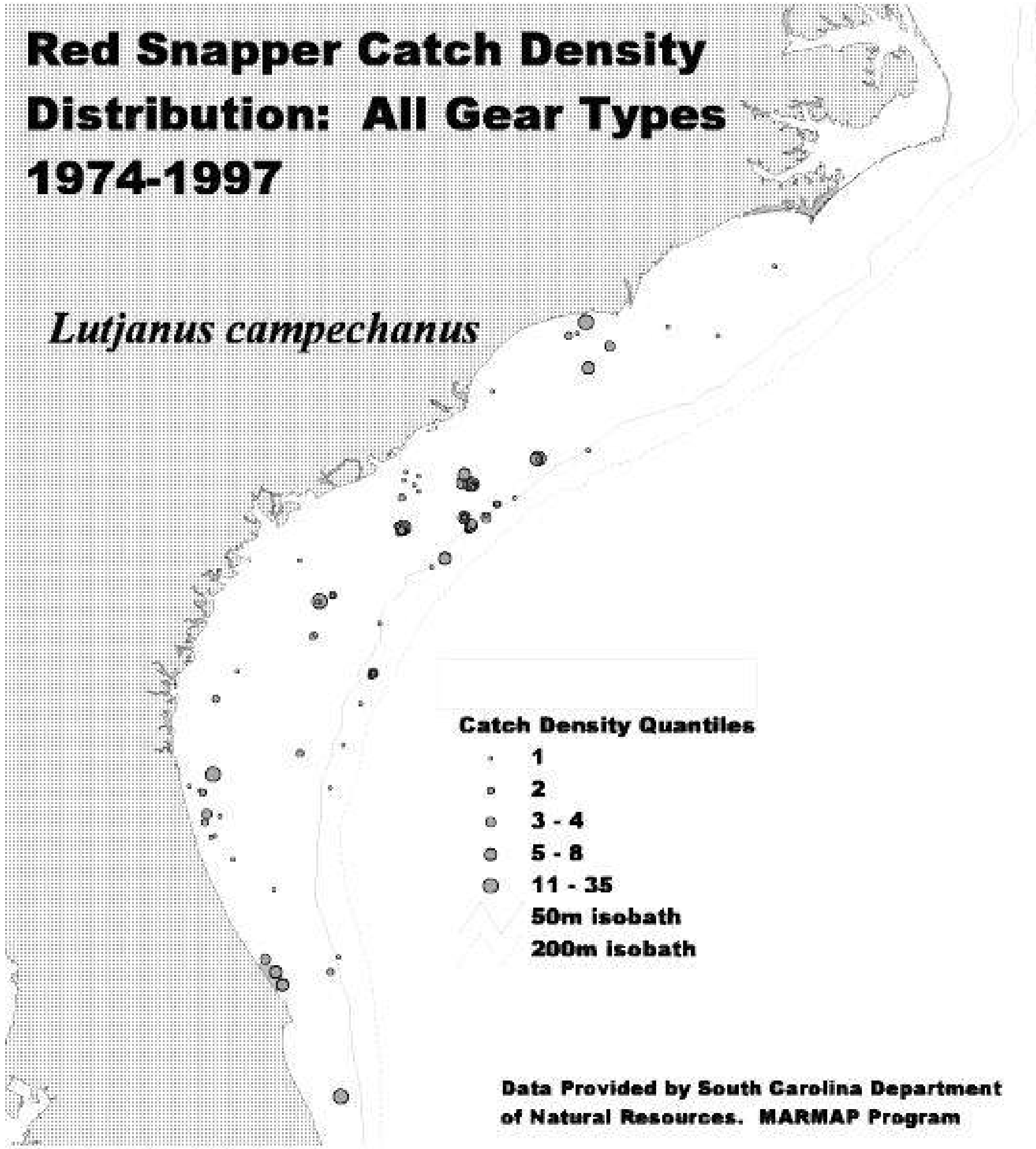


Figure 36. Red snapper catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

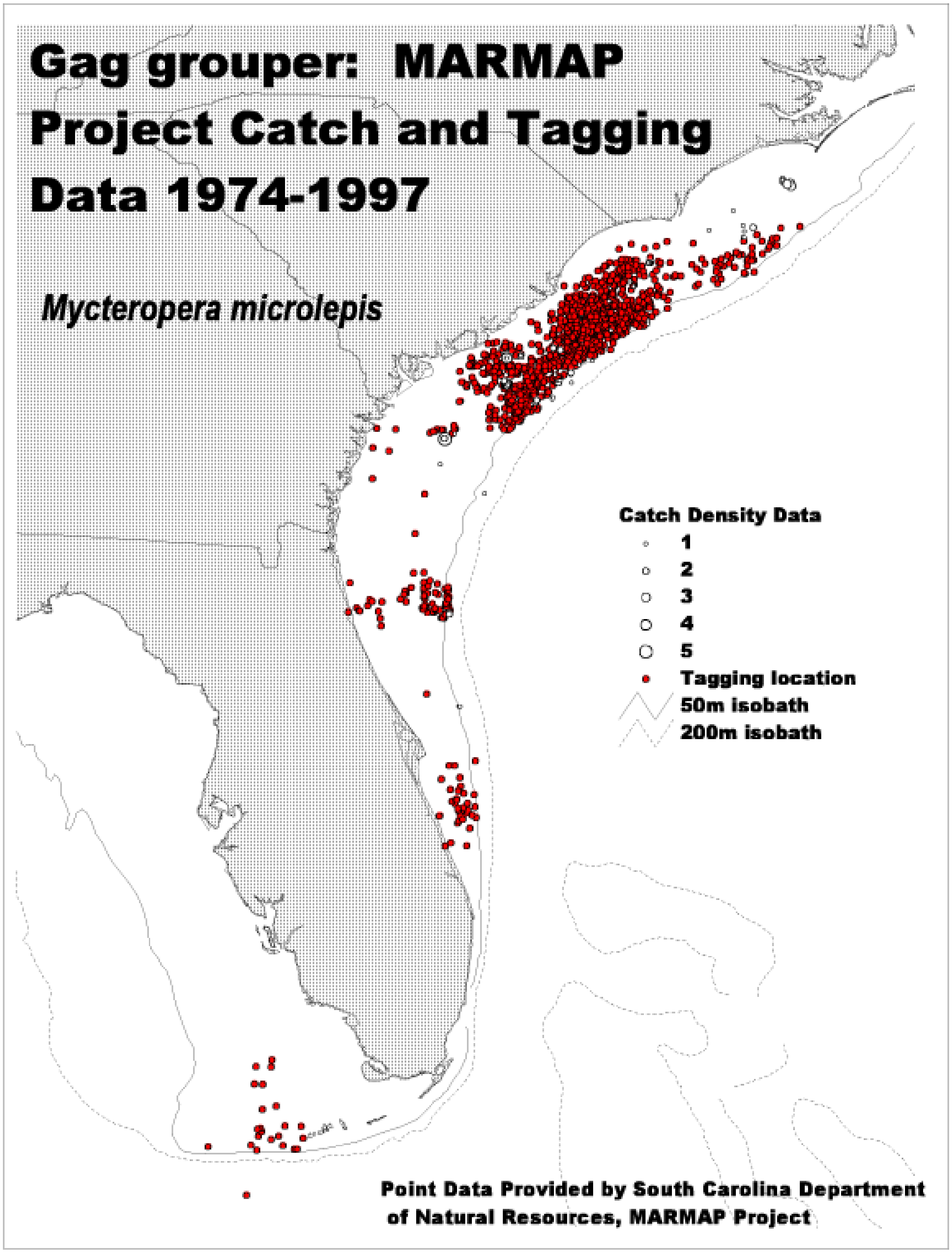


Figure 37. Gag catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

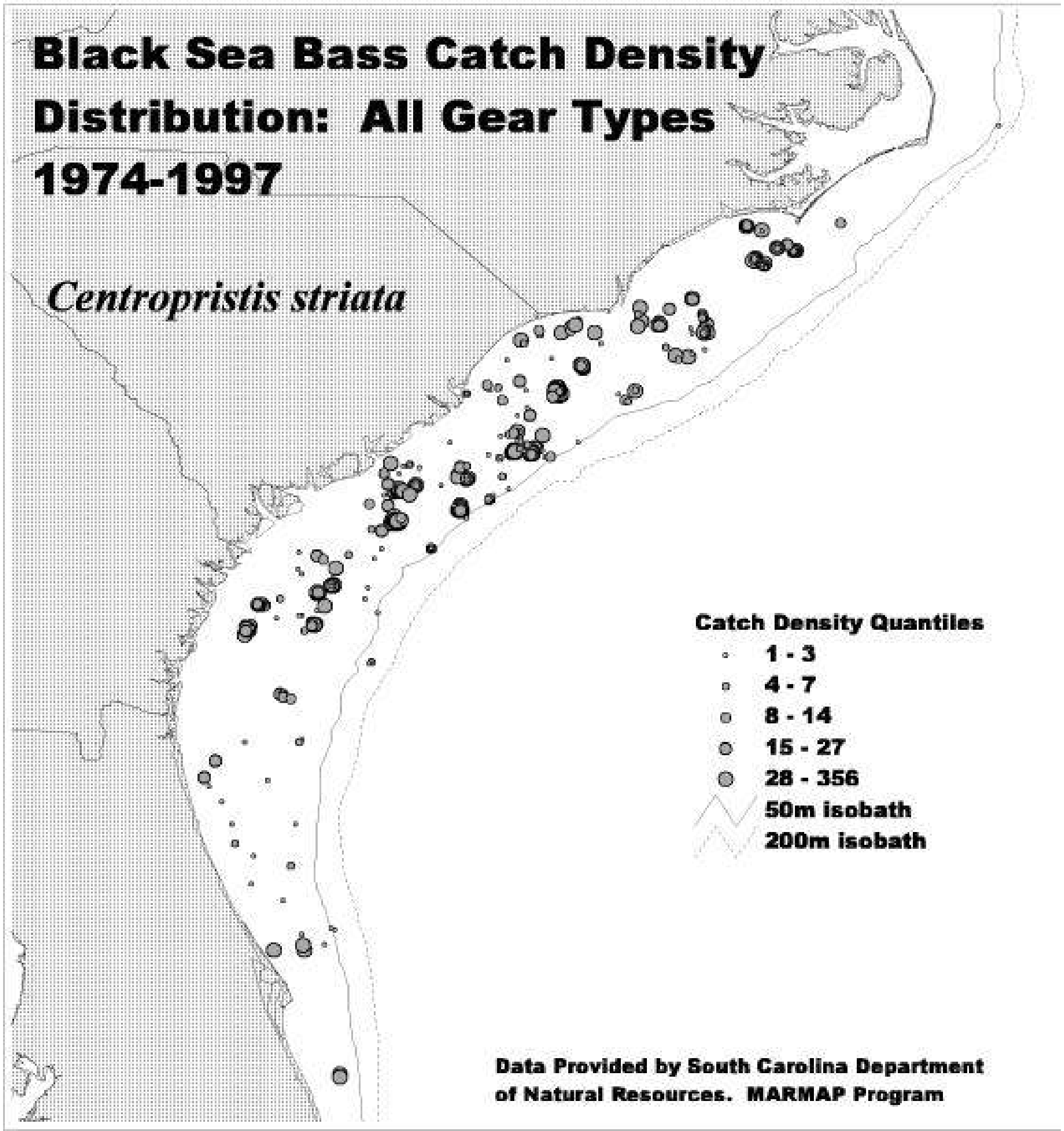


Figure 38. Black Sea Bass catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

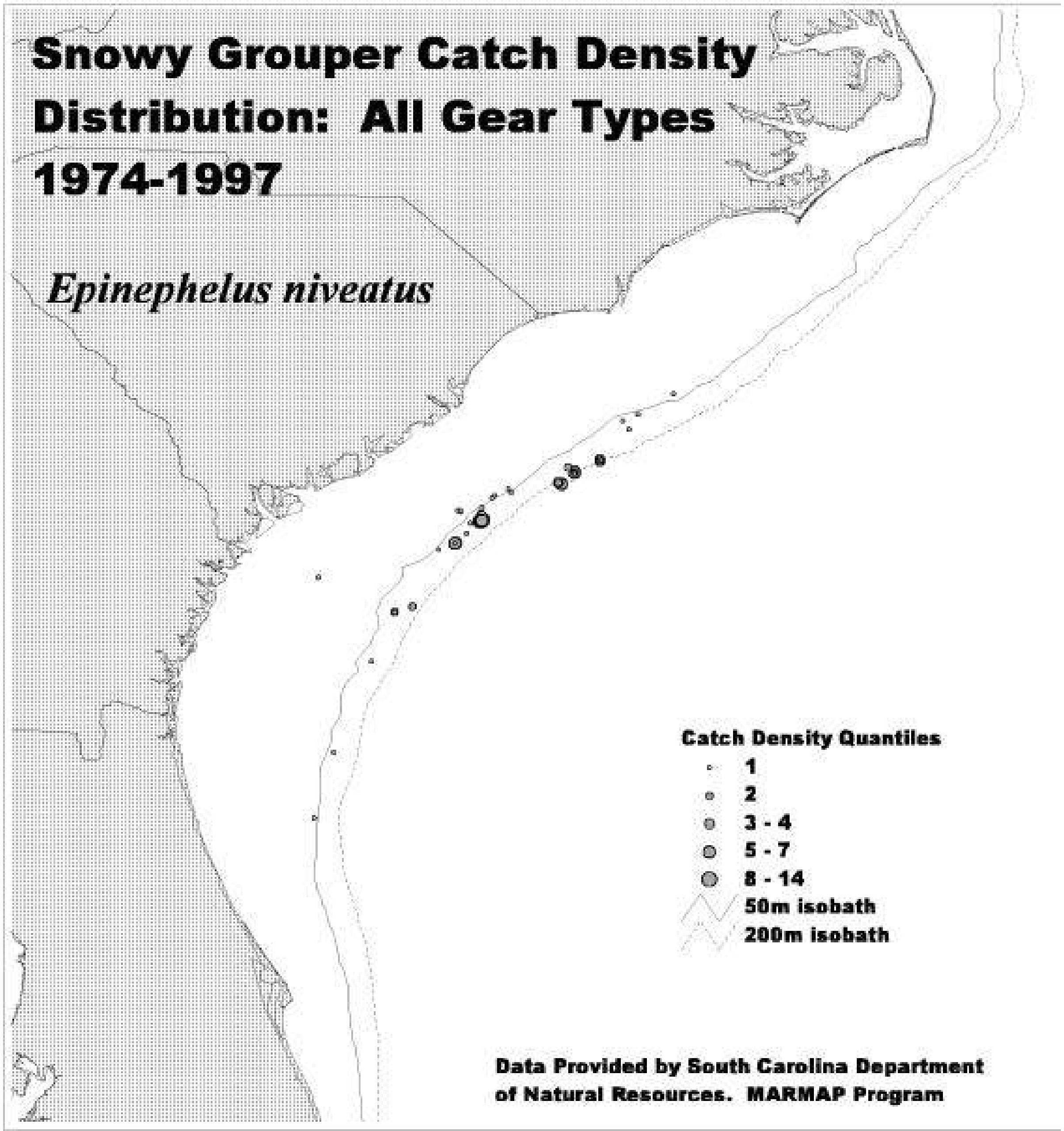


Figure 39. Snowy Grouper catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

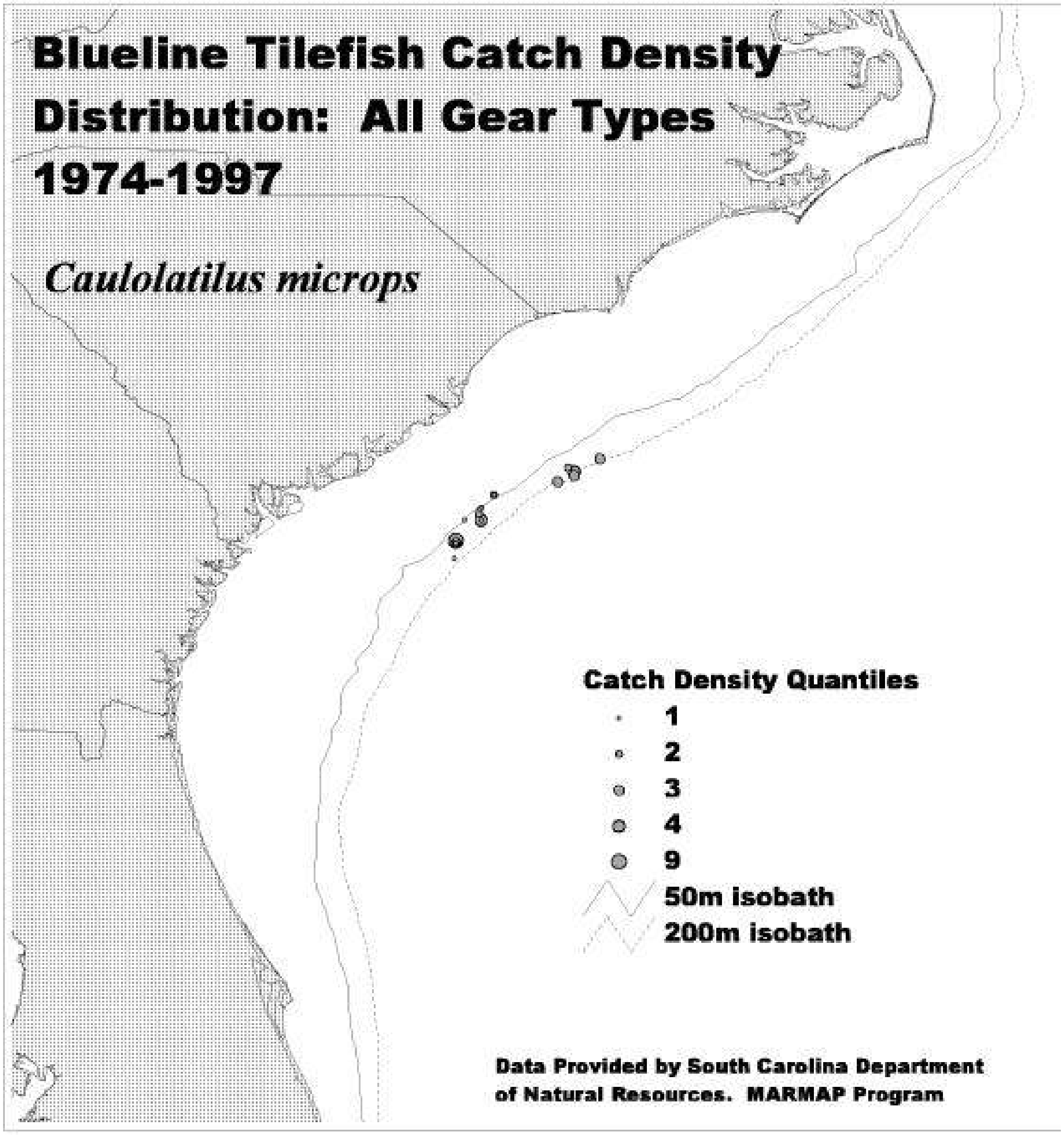


Figure 40. Blueline Tilefish catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

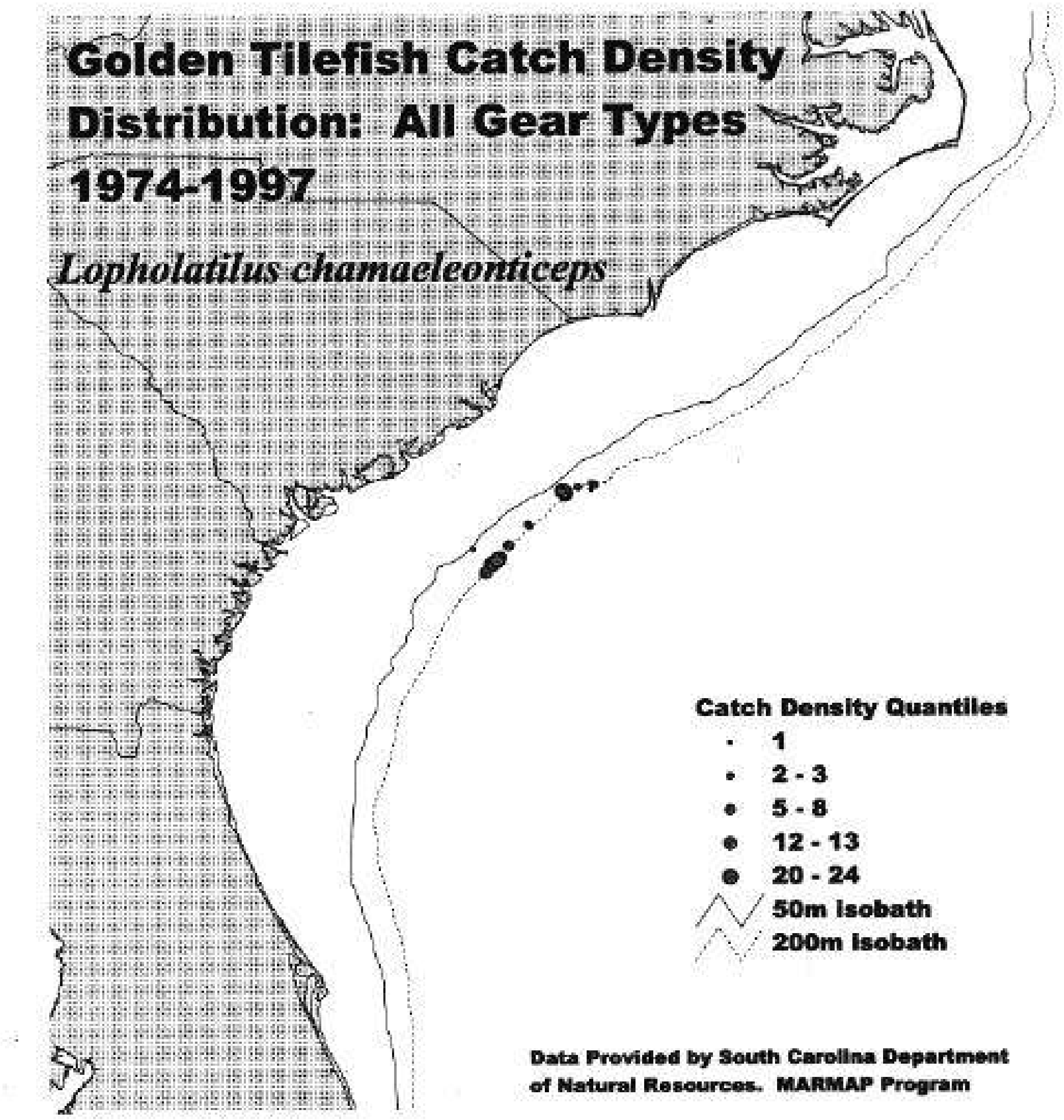


Figure 41. Golden Tilefish catch associated with hard/live bottom habitat (Data Source: MARMAP 1998).

3.3.3.3.2 Snapper Grouper Species and the Deepwater Community
(summarized from Parker and Mays, In press)

There are 19 economically important species of reef fish in the deepwater (100-300 m) fishery of the southeastern United States (Figure 42). The five species that make up over 97% of the catch by weight are tilefish, *Lopholatilus chamaeleonticep*s, snowy grouper, *Epinephelus niveatus*, blueline tilefish, *Caulolatilus microps*, warsaw grouper, *Epinephelus nigritus*, and yellowedge grouper, *E. flavolimbatus*. Less is known of the life histories of deep reef fishes than for any other group supporting a major fishery. The depth and strong currents, often to 3 knots, preclude observations by SCUBA divers and make submersible observations difficult. Distance from shore of these open ocean habitats and usually inclement weather make incidental and anecdotal observations and reports about the fish and their habitat extremely rare. Although hook and line and longline gear have been used successfully to capture some deepwater reef fishes, little is known about rare or hard to catch species.

Overall, the deep reef fish community probably contains less than 100 species. From submersible operations off NC, Parker and Ross (1986) observed 34 species of deepwater (98 to 152 m) reef fishes representing 17 families and described the behavior of species from eight families. Gutherz et al. (1995) observed 27 species of deepwater (185 to 220 m) reef fishes from submersibles off South Carolina in 1982. There were obvious differences (probably depth related) in abundance of the most common species of fish observed from the submersible from North Carolina to South Carolina. Parker and Mays (In press) present life history summaries including species composition, distribution, preferred habitat, spawning periodicity, and associated fishes and benthos for 14 species.

Observations during three submersible dives in May 1992 on the abundance and distribution of deepwater reef fishes important to fisheries were compared to the above surveys. At the Big Rock or Charleston Lumps there were apparent increases in abundance (fish/ha) over time of scamp, *Mycteroperca phenax* (5 to 45), blueline tilefish (<1 to 14), and southern hake, *Urophycis floridana* (<1 to >23). Also in the Charleston Bump area, there was an apparent decrease in snowy grouper (9 to 2). Although the recent data are sparse, they show that at least seven of nine economically important species, previously observed from submersibles, have survived intense fishing pressure at these locations.

Twenty active or retired fishermen (headboat operators and commercial fishermen who employed vertical hook and line or longline gear) from Cape Hatteras, NC to Key West, FL described the deep reef fishery in their areas. According to fishermen, coast wide stocks (usually at depths between 100 and 175 m) of yellowedge grouper, *Epinephelus flavolimbatus*, warsaw grouper, bigeye, and barrelfish were depleted before snowy grouper. Snowy grouper were most often caught between 110 and 155 m, but were sometimes taken from shallow water (<30 m) as they spawned off the Florida Keys. Tilefish usually produced monospecific catches from deeper waters, 175 to 300 m. Three areas have been unproductive for tilefish: the areas from 1) just below Cape Hatteras, NC to Cape Romain, SC, 2) Bellville, GA to St. Augustine, FL, and 3) Marathon, FL to Key West, FL. Some fishermen believe this is because they have not yet determined when tilefish migrate through these areas, although tagging studies and submersible observations of tilefish and their burrows do not give evidence of migration (Grimes et al., 1983). There is little commercial fishing by United States fishermen for deepwater species between Ft. Pierce and Homestead, FL because the area is congested with domestic recreational and Bahamian (commercial and recreational) fishermen. Florida fishermen feared revealing "secrets" and were particularly vague about descriptions of the fishery in their area.

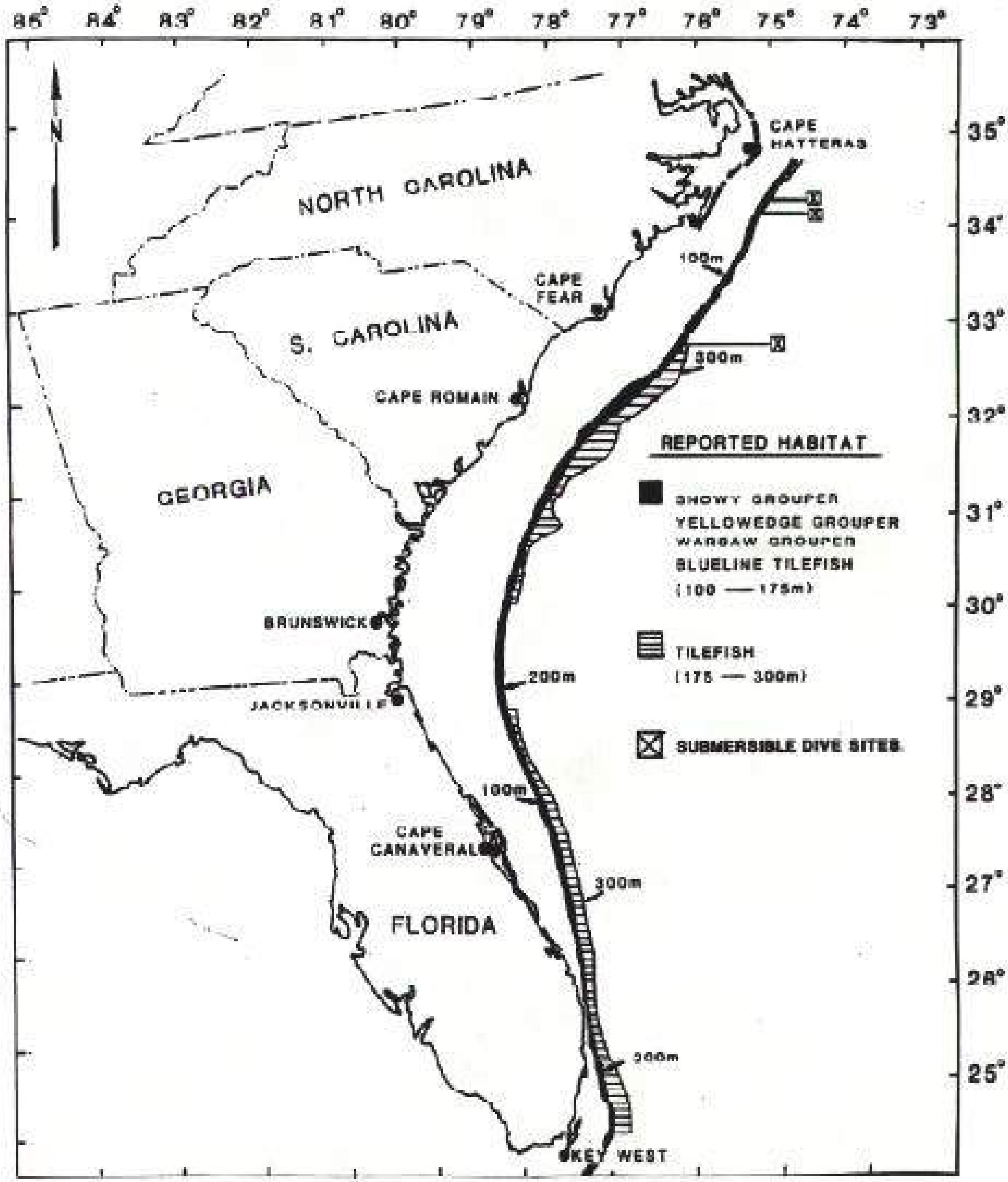


Figure 42. Deep Reef Fish Habitat (Source: Parker and Mays, In press).

3.3.3.3.3 Spawning Habitats of Snapper Grouper Species

Along with recruitment, spawning is a key demographic attribute of reef fish species. The protection of spawning habitats is an unquestionably logical component of managing essential fish habitat. Specific information on the spawning sites and component habitats for snapper grouper species is limited. Most studies of reef fish reproduction have focused on the seasonality of spawning using fishery-dependent data. *In-situ* information on the habitat characteristics of key spawning areas is uncommon. However, limited information can be obtained for individual species from reviews of spawning information by Thresher (1984), Grimes (1987), Colin and Clavijo (1988), Garcia-Cagide et al. (1994) and Domeier and Colin (1997).

Temporal patterns of spawning are more documented for snapper grouper species than spatial patterns. Several temporal patterns are present: a) spawning is concentrated over one or two winter months (as in many groupers); b) spawning occurs at low levels year-round with one or two peaks in warmer months; c) spawning occurs year-round with more than two significant peaks. In addition, spawning can occur in pairs or in various types of aggregations. Increasing amounts of evidence suggest that many species of grouper and snapper can form sizeable spawning aggregations (Domeier and Colin, 1997). However, this pattern may not be universal among all of the species within the snapper grouper management unit. In fact, some species that spawn in aggregations may also pair-spawn under certain conditions.

The site specificity of spawning aggregations may be high, on the scale of decades (Colin and Clavijo, 1988; Garcia-Cagide et al., 1994). Many explanations of the choice of spawning sites have focused on the avoidance of egg predation. This assumes that the upward rush culminating the spawning act is executed at structural features positioned in a manner favorable for immediate offshore advection of eggs away from predators on the reef (Johannes, 1978). However, this hypothesis suffers from limited (Shapiro et al., 1988) and sometimes contradictory (e.g., Appeldoorn et al., 1994) experimental evaluation.

Due to the intense constraints on studying spawning and associated habitats (e.g., gathering *in situ* behavioral data in deep waters during dusk or night), determining the combinations of key habitat attributes that favor spawning will be a protracted process for many species. However, this need not impede proactive management. Spawning sites within SAFMC jurisdiction have been identified for certain grouper and snapper species (Gilmore and Jones, 1992; Domeier and Colin, 1997). Available information for other species suggests that shelf edge environments of moderate to high structural relief are sites of spawning for many species, perhaps through the entire southeastern U. S. region. In addition, shallow areas may also be spawning sites for some snapper grouper species (see jewfish summary in Section 3.3.3.1). As new information becomes available, maps of all documented spawning areas will be created for the key species of the snapper grouper complex. In addition to pinpointing existing spawning information, this approach will allow the assessment of the spawning value of similar habitat types within SAFMC jurisdiction.

3.3.3.4 Essential Fish Habitat and Environmental Requirements

Essential fish habitat for snapper-grouper species includes coral reefs, live/hard bottom, submerged aquatic vegetation, artificial reefs and medium to high profile outcroppings on and around the shelf break zone from shore to at least 600 feet (but to at least 2000 feet for wreckfish) where the annual water temperature range is sufficiently warm to maintain adult populations of members of this largely tropical complex. EFH includes the spawning area in the water column above the adult habitat and the additional pelagic environment, including *Sargassum*, required for larval survival and growth up to and including settlement. In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse snapper grouper larvae.

For specific life stages of estuarine dependent and nearshore snapper-grouper species, essential fish habitat includes areas inshore of the 100-foot contour, such as attached macroalgae; submerged rooted vascular plants (seagrasses); estuarine emergent vegetated wetlands (saltmarshes, brackish marsh); tidal creeks; estuarine scrub/shrub (mangrove fringe); oyster reefs and shell banks; unconsolidated bottom (soft sediments); artificial reefs; and coral reefs and live/hard bottom.

3.3.3.5 Essential Fish Habitat-Habitat Areas of Particular Concern for the Snapper Grouper Species Complex

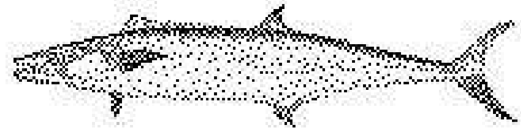
Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for species in the snapper-grouper management unit include medium to high profile offshore hard bottoms where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hard bottom areas; The Point, The Ten Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump (South Carolina); mangrove habitat; seagrass habitat; oyster/shell habitat; all coastal inlets; all state-designated nursery habitats of particular importance to snapper grouper (e.g., Primary and Secondary Nursery Areas designated in North Carolina); pelagic and benthic *Sargassum*; Hoyt Hills for wreckfish; the Oculina Bank Habitat Area of Particular Concern; all hermatypic coral habitats and reefs; manganese outcroppings on the Blake Plateau; and Council-designated Artificial Reef Special Management Zones (SMZs).

Therefore, areas which meet the criteria for designating essential fish habitat - habitat areas of particular concern include habitats required during each life stage (egg, larval, postlarval, juvenile, and adult stages.)

3.3.4 Coastal Migratory Pelagics

3.3.4.1 Description of the Species and Distribution

The habitat of adults in the coastal pelagic management unit, except dolphin, is the coastal waters out to the edge of the continental shelf in the Atlantic Ocean. Dolphin is an oceanic species that may be found on the shelf. Within the area, the occurrence of these species is governed by temperature and salinity. All species are seldom found in water temperatures less than 20° C. Salinity preference varies, but these species generally prefer high salinity. Dolphin are seldom found in waters with salinity less than 36 ppt. The scombrids prefer high salinities, but less than 36 ppt. Salinity prefence of little tunny and cobia is not well defined. The larval habitat of all species in the coastal pelagic management unit is the water column. Within the spawning area, eggs and larvae are concentrated in the surface waters.



King Mackerel, *Scomberomorus cavalla*

Estuaries are important habitats for most prey species of coastal pelagics. For this reason, estuarine habitats and factors which affect them should be considered as part of the coastal pelagic management unit. All the coastal pelagic species, except dolphin, move from one area to another and seek prey whatever local resources happen to be abundant. Many of the prey species of the coastal pelagics are estuarine-dependant in that they spend all or a portion of their lives in estuaries. Accordingly, the coastal pelagic species, by virtue of their food source, are to some degree also dependant upon estuaries and, therefore, can be expected to be detrimentally affected if the productive capabilities of estuaries are greatly degraded.

3.3.4.2 Essential Fish Habitat and Environmental Requirements

Essential fish habitat for coastal migratory pelagic species includes sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters, from the surf to the shelf break zone, but from the Gulf stream shoreward, including *Sargassum*. In addition, all coastal inlets, all state-designated nursery habitats of particular importance to coastal migratory pelagics (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas).

For Cobia essential fish habitat also includes high salinity bays, estuaries, and seagrass habitat. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse coastal migratory pelagic larvae.

For king and Spanish mackerel and cobia, essential fish habitat occurs in the South Atlantic and Mid-Atlantic Bights.

Spatial and Temporal Distribution and Relative Abundance of Spanish Mackerel in Estuarine Habitat

NOAA's Estuarine Living Marine Resource Program (ELMR), through a joint effort of National Ocean Service and NMFS, conducts regional compilations of information on the use of estuarine habitat by select marine fish and invertebrates. A report prepared through the ELMR program (NOAA 1991b) and revised information (NOAA 1998), provided the Council during the Habitat Plan development process, present known spatial and temporal distribution and relative abundance of fish and invertebrates using southeast estuarine habitats. Twenty southeast estuaries selected from the National Estuarine Inventory (NOAA 1985) are included in the analysis which resulted from a review of published and unpublished literature and personal consultations. The resultant information emphasizes the importance and essential nature of estuarine habitat to all life stages of spanish mackerel.

Regional salinity and relative abundance maps for use in determining EFH for two estuarine dependant coastal migratory pelagic species included in the data, Spanish mackerel and Cobia. These map coverages were prepared for the Council by NOAA SEA Division (Appendix F). Figures 43-46 present a representative sample of the distibution maps for juvenile Spanish mackerel. The remainder of the coverages and additional information on species and habitat distribution are available over the Internet on the Council web page under the habitat homepage (www.safmc.noaa.gov). These maps portray salinity and species relative abundances for estuaries and coastal embayments on state and/or regional maps. Depending on data availability, maps were produced at various scales: 1:24K, 1:80K, and 1:250K. For species relative abundances, these maps were developed only for juveniles of estuarine species (Nelson et al. 1991) showing the highest juvenile relative abundance in any salinity zone by season for each estuary. These maps will eventually be provided to the Council as ArcView shape files with associated data for inclusion into the Council's GIS system.

Spatial and Temporal Distribution and Relative Abundance of Cobia in Estuarine Habitat

Regional salinity and relative abundance maps were developed to aid the Council in determining EFH for Cobia. These map coverages were prepared for the Council by NOAA SEA Division (Appendix F). Figures 47- 50 present a representative sample of the distibution maps for juvenile Cobia. The remainder of the coverages and additional information on species and habitat distribution are available over the Internet on the Council web page under the habitat homepage (www.safmc.noaa.gov). Depending on data availability, maps were produced at various scales: 1:24K, 1:80K, and 1:250K. For species relative abundances, these maps were developed only for juveniles of estuarine species (Nelson et al. 1991) showing the highest juvenile relative abundance in any salinity zone by season for each estuary. These maps will eventually be provided to the Council as ArcView shape files with associated data for inclusion into the Councils GIS system.

Dolphin, *Coryphaena hippurus*

See Section 3.2.3.1.1 for a detailed description of *Sargassum* as essential fish habitat for dolphin.

Dolphin are fast aggressive predators that feed on actively swimming fish (MMS 1990). Fish are the most important items in the diet, becoming increasingly important as dolphin grow from 300 mm (12 in) to 1,500 mm (59 in). Flyingfish are important in the diet of adult common dolphin. Flyingfishes appear to be especially important in the diet of large dolphin; fish and invertebrates on *Sargassum* appers to be most important to small female dolphin. In general, many dolphin prey are associated with *Sargassum*, and most of the fishes that were found associated with *Sargassum* in the Florida Current are eaten by dolphin (MMS 1990). Dolphin probably spend a relatively large amount of time feeding on small animals associated with *Sargassum* because, although adapted for fast short-range pursuit, dolphin lack the adaptation of fishes such as tunas for long-range pursuit of prey. Dolphin in the Gulf Stream ate 32 species of fishes. Additional food included the crab *Portunis sayi* (common in *Sargassum*), shrimp, and cephalopods. Although *Sargassum* appears frequently in dolphin stomachs, it is probably ingested incidentally with assiciated small fishes and crustaceans. Off Cape Hatteras, most fish in the diet were those typically associated with *Sargassum*. The most frequently found genera wre *Hippocampus* (seahorse), *Monacanthus* (filefish), and *Aluterus* (filefish). Other prey of dolphin include balistids and fast moving fishes such as Spanish mackerel and carangids, and at night perhaps mesopelagic fishes. The presence of other smaller dolphins in the diet indicates cannibalism, and smaller dolphin may find shelter in *Sargassum* from predators, including their own species (MMS 1990).

3.3.4.3 Essential Fish Habitat - Habitat Areas of Particular Concern for Coastal Migratory Pelagics

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) include sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras from shore

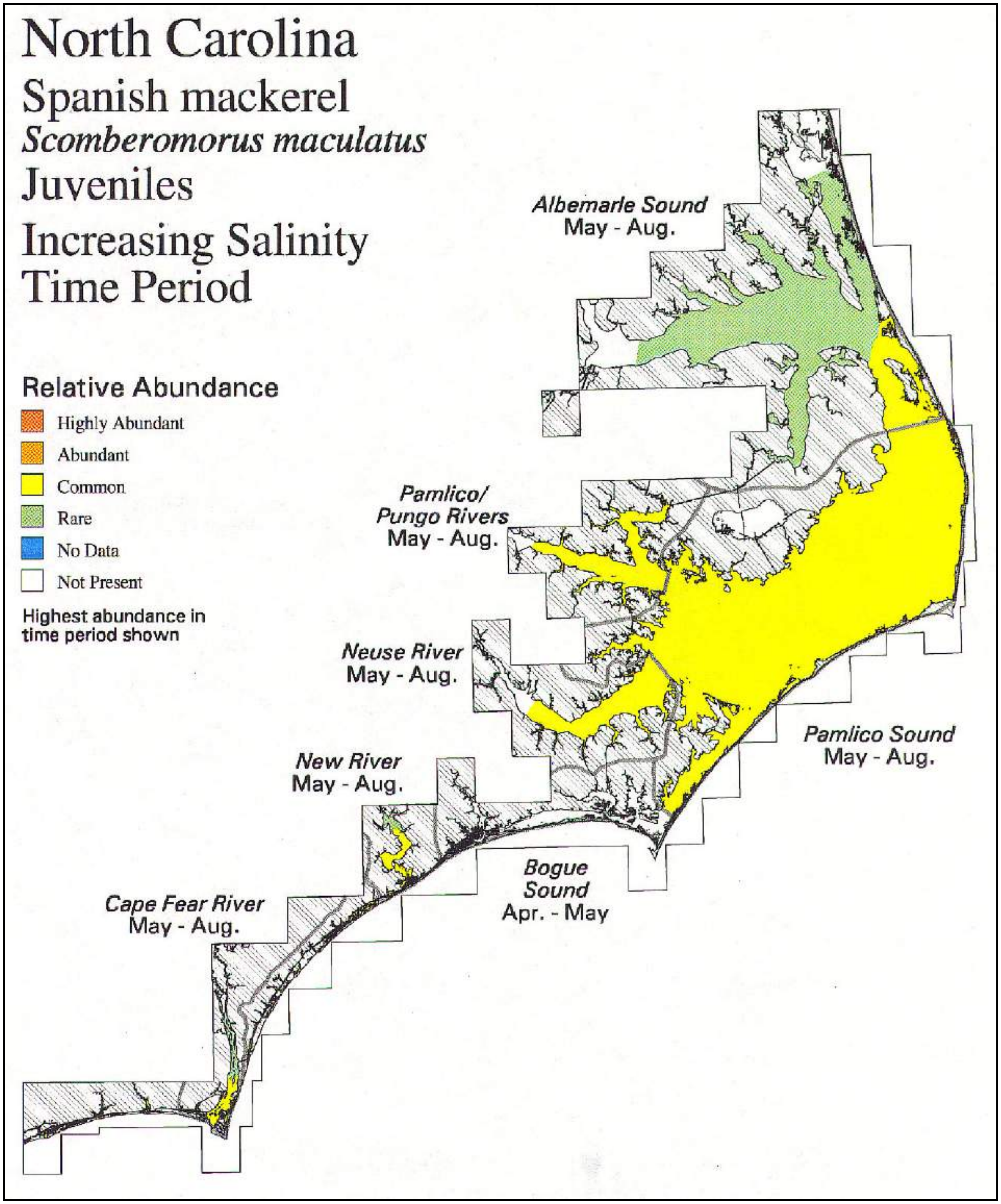


Figure 43. Spanish mackerel juvenile distribution in North Carolina estuaries in increasing salinity time period (Source: NOAA 1998).

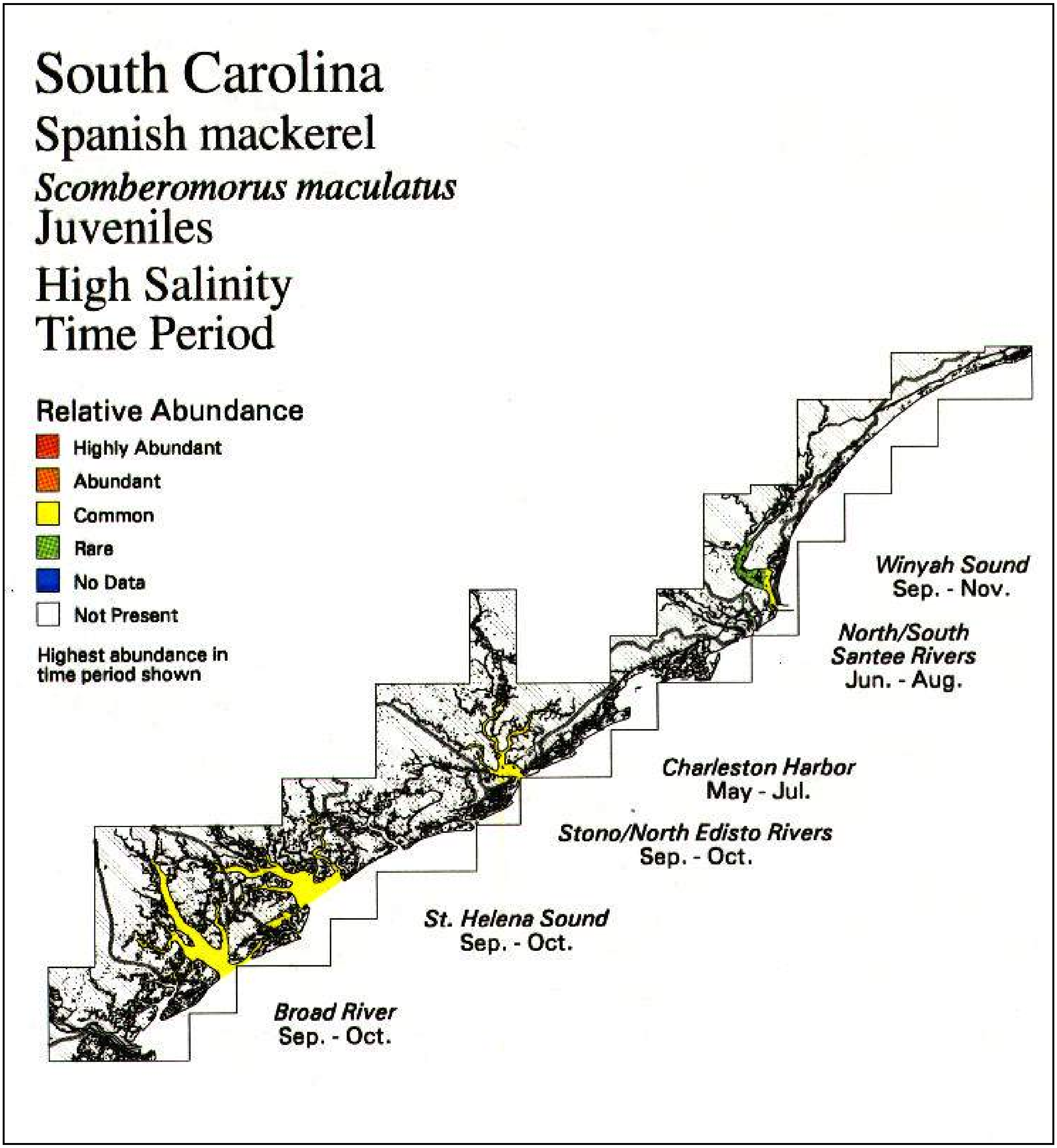


Figure 44. Spanish mackerel juvenile distribution in South Carolina estuaries in high salinity time period (Source: NOAA 1998).

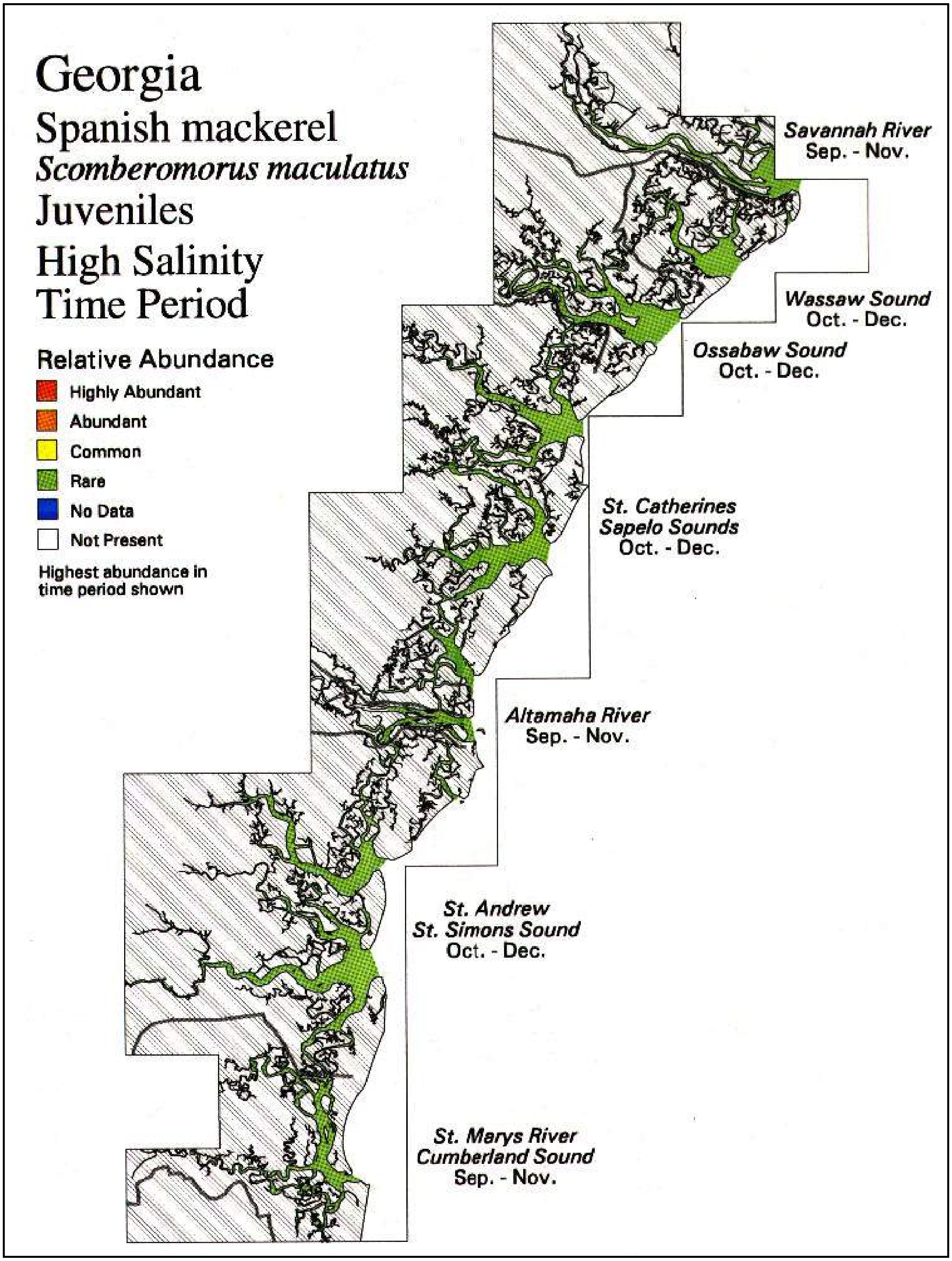


Figure 45. Spanish mackerel juvenile distribution in Georgia estuaries in high salinity time period (Source: NOAA 1998).

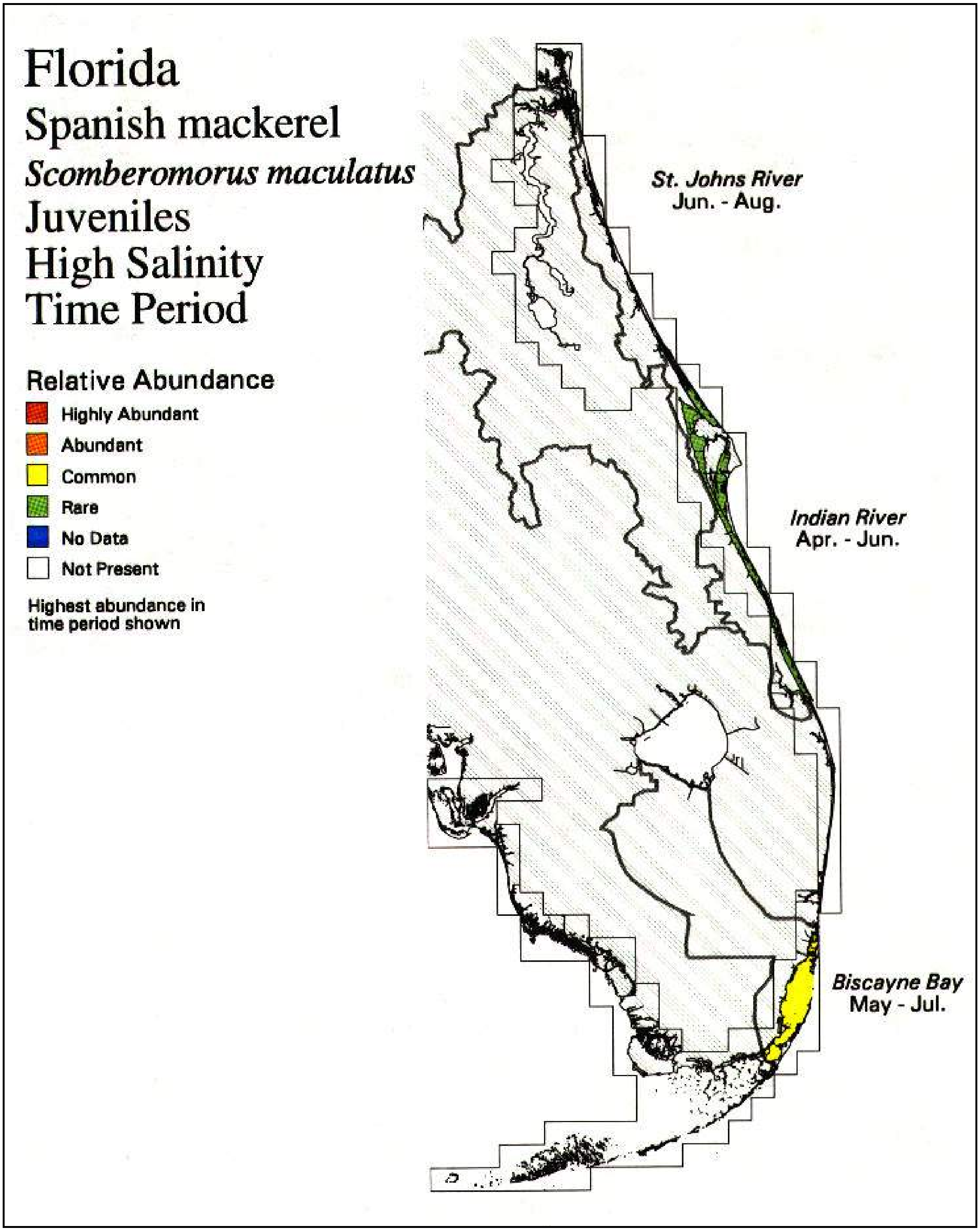


Figure 46. Spanish mackerel juvenile distribution in Florida estuaries in high salinity time period (Source: NOAA 1998).

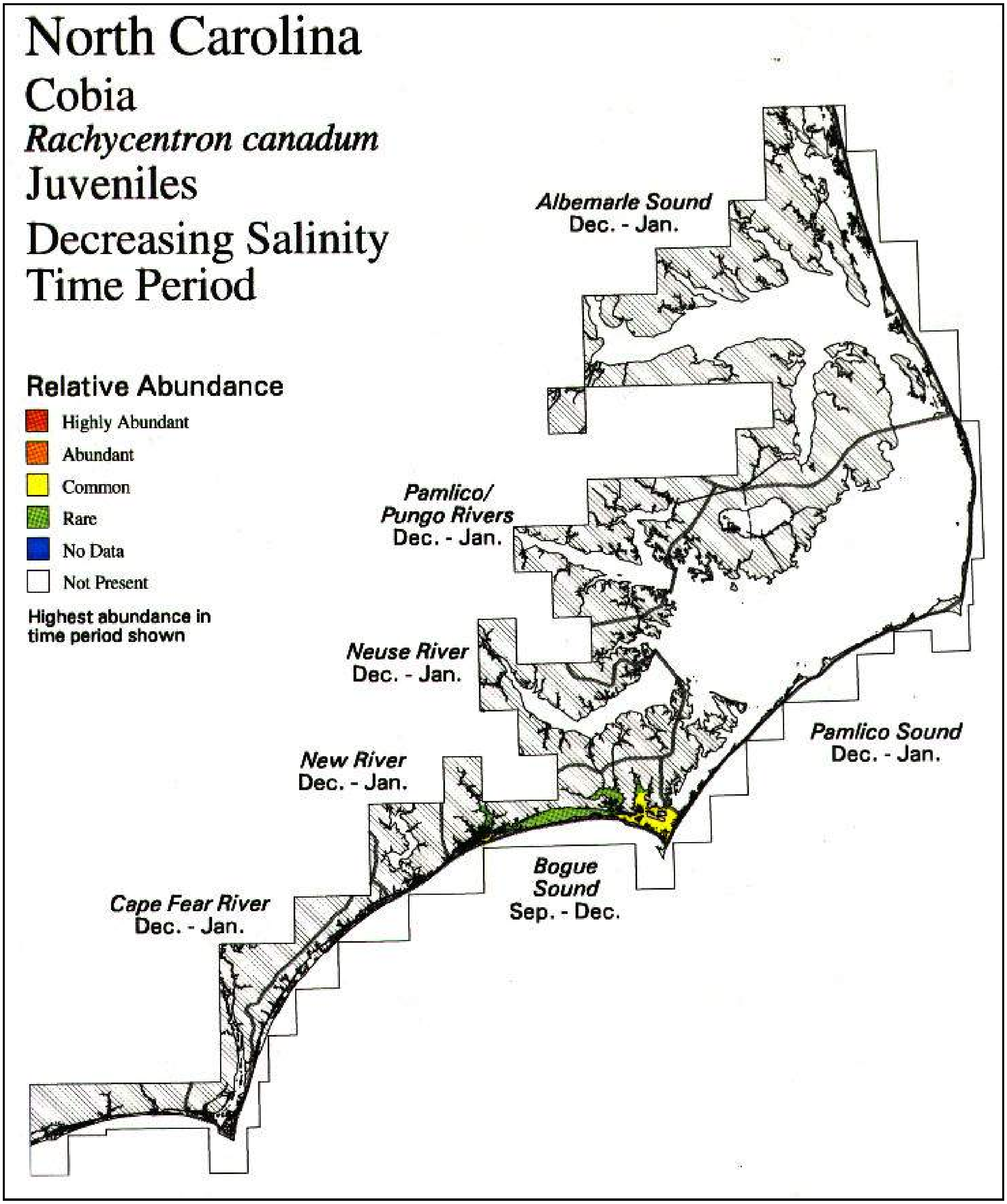


Figure 47. Cobia juvenile distribution in North Carolina estuaries in high salinity time period (Source: NOAA 1998).

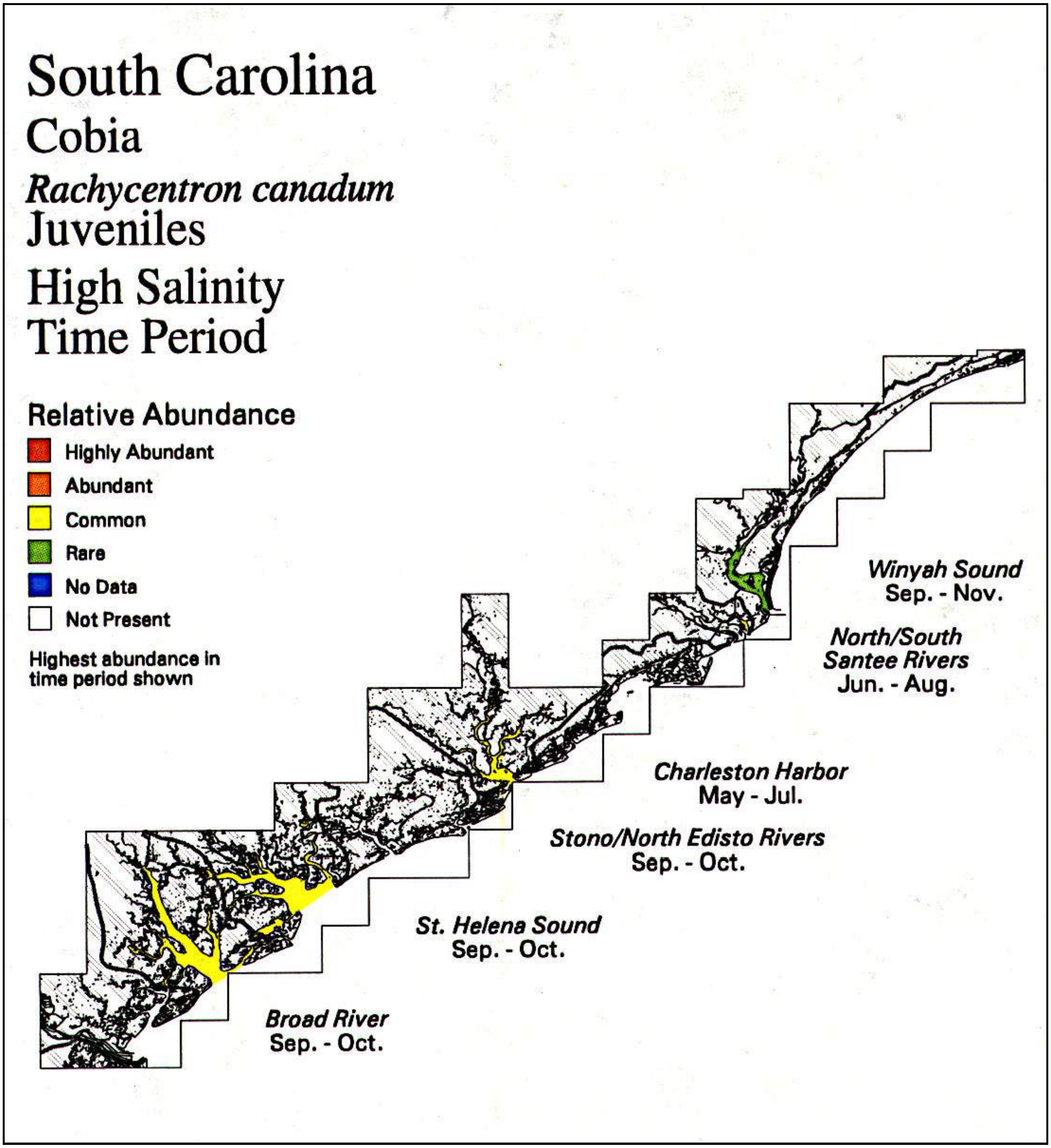


Figure 48. Cobia juvenile distribution in South Carolina estuaries in high salinity time period (Source: NOAA 1998).

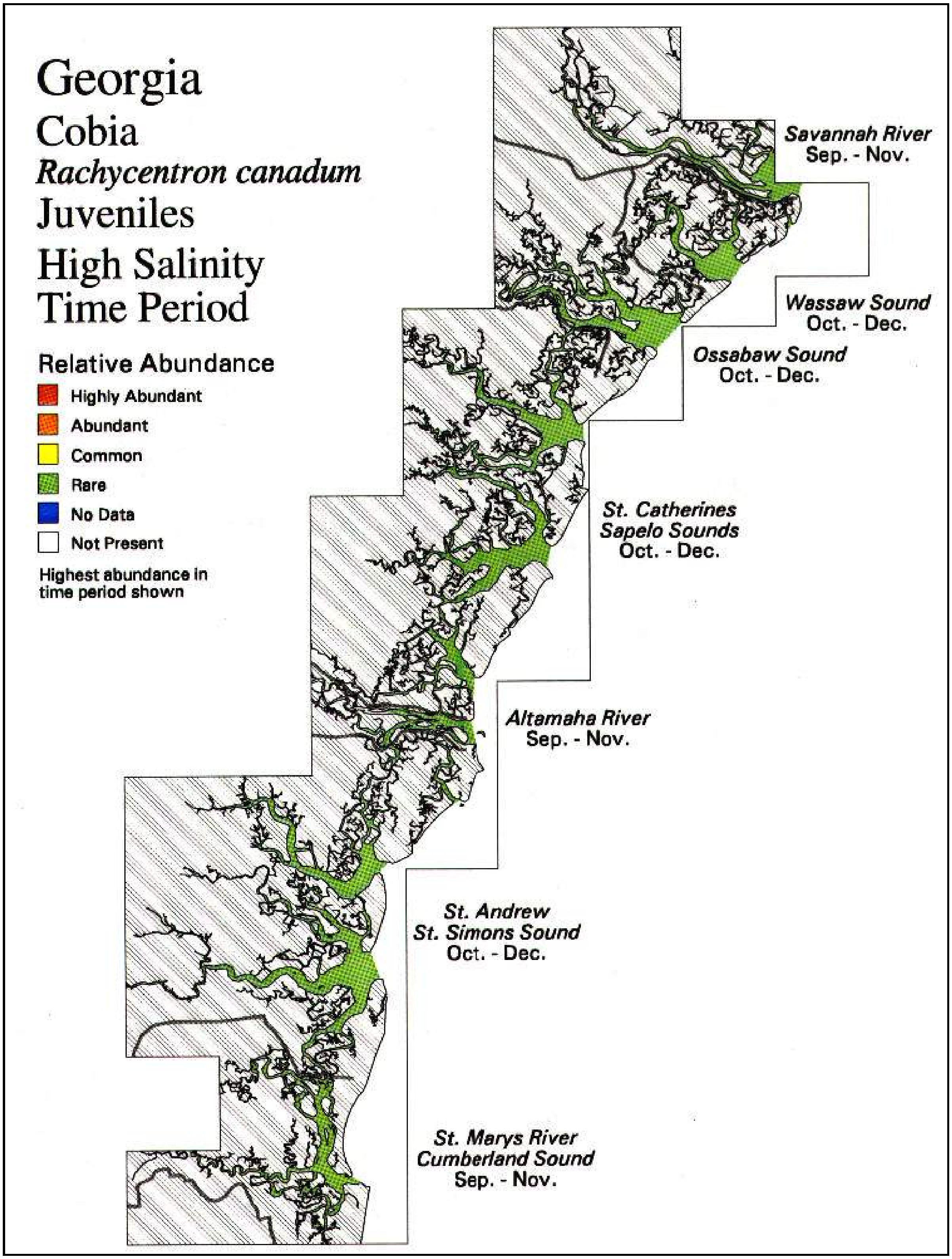


Figure 49.Cobia juvenile distribution in Georgia estuaries in high salinity time period (Source: NOAA 1998).

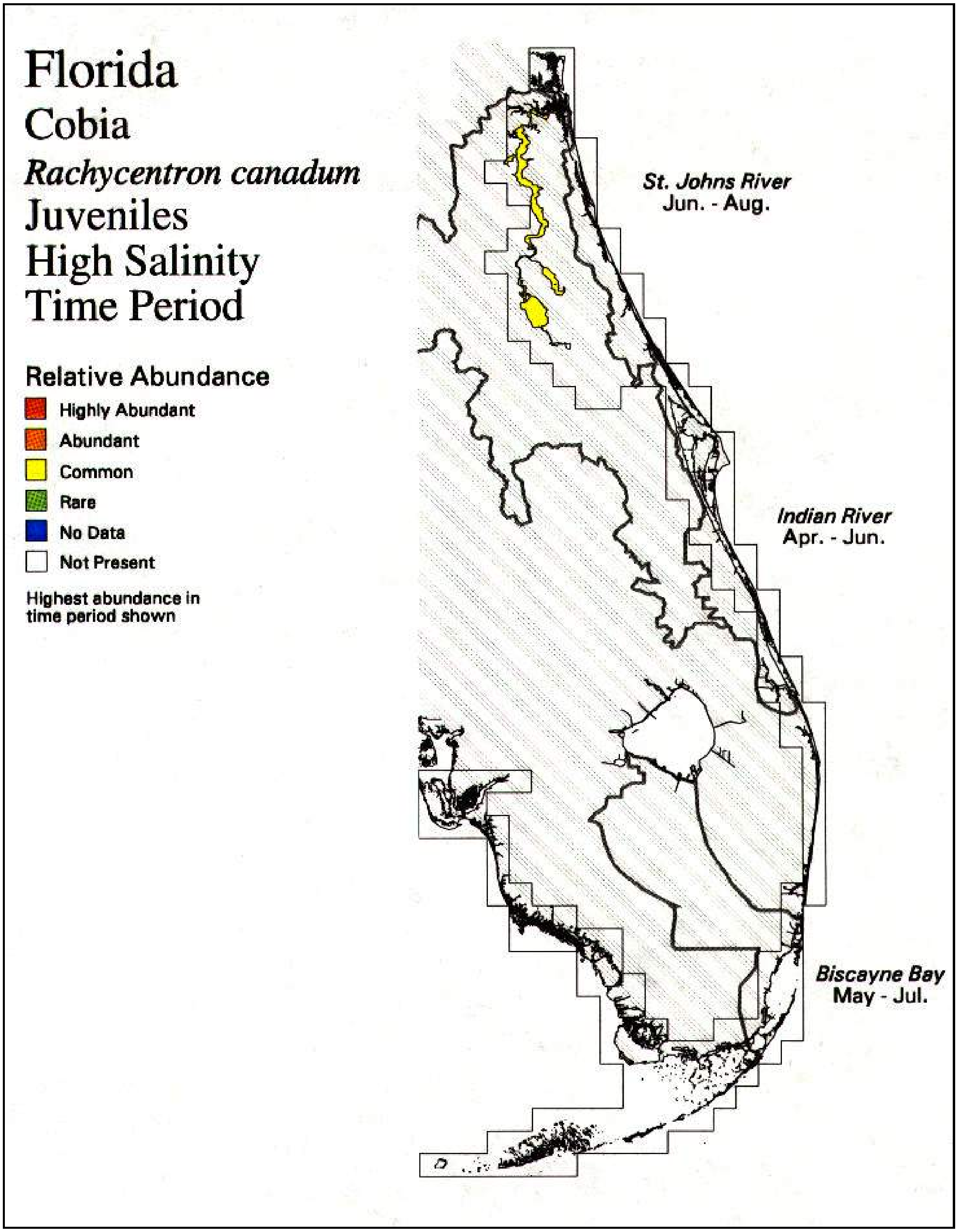


Figure 50. Cobia juvenile distribution in Florida estuaries in high salinity time period (Source: NOAA 1998).

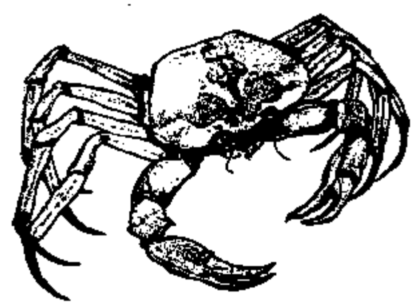
to the ends of the respective shoals, but shoreward of the Gulf stream; The Point, The Ten-Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump and Hurl Rocks (South Carolina); The Point off Jupiter Inlet (Florida); *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; nearshore hard bottom south of Cape Canaveral; The Hump off Islamorada, Florida; The Marathon Hump off Marathon, Florida; The "Wall" off of the Florida Keys; Pelagic *Sargassum*; and Atlantic coast estuaries with high numbers of Spanish mackerel and cobia based on abundance data from the ELMR Program. Estuaries meeting this criteria for Spanish mackerel include Bogue Sound and New River, North Carolina; Bogue Sound, North Carolina (Adults May-September salinity >30 ppt); and New River, North Carolina (Adults May-October salinity >30 ppt). For Cobia they include Broad River, South Carolina; and Broad River, South Carolina (Adults & juveniles May-July salinity >25ppt).

These areas include spawning grounds and habitats where eggs and larvae develop. In addition, the estuarine habitats also provide prey species along migration pathways.

3.3.5 Golden Crab

3.3.5.1 Description of the Species and Distribution

The golden crab, *Chaceon fenneri*, is a large gold or buff colored species inhabiting the continental slope of Bermuda (Luckhurst, 1986; Manning and Holthuis, 1986) and the southeastern United States from off Chesapeake Bay (Schroeder, 1959), south through the Straits of Florida and into the eastern Gulf of Mexico (Manning and Holthuis, 1984, 1986; Otwell et al., 1984; Wenner et al., 1987, Erdman 1990).



Reported depth distributions of *C. fenneri* range from 205 m off the Dry Tortugas (Manning and Holthuis, 1984) to 1007 m off Bermuda (Manning and Holthuis, 1986). Size of males examined range from 34 to 139 mm carapace length (CL) and females range from 39 to 118 mm CL. Ovigerous females have been reported during September, October and November, and range in size from 91 to 118 mm CL (Manning and Holthuis, 1984, 1986)."

Larval Distribution & Recruitment

The following text is from Lockhart et al. (1990):

"The distribution patterns of *Chaceon fenneri* and possibly *C. quinquedens* in the eastern Gulf of Mexico suggest a causal role for the Loop Current System (Maul 1977) in basic life history adaptations. Female distribution within these species' geographic ranges and the timing of larval release supports this hypothesis. Ours was the first study to discover female golden crabs in any significant numbers and was also the first to find a major population of female red crabs in the Gulf of Mexico. Both of these concentrations of females were seemingly shifted counter-current to the Loop Current circulation. We hypothesize that this counter-current shift is linked to larval release and transport, and serves to maximize recruitment into the parent population by minimizing risk of larval flushing.

Similar counter-current shifts of other female decapods have been reported or hypothesized. In the Gulf of Mexico, spawning female blue crabs (*Callinectes sapidus*) have been hypothesized to undergo a late summer spawning migration in the northeastern Gulf of Mexico that is counter to the Loop Current system (Oesterling and Adams 1979). Female western rock lobsters (*Panulirus cygnus*) are hypothesized to undergo migration to favor recruitment back into the parent population (Phillips et al. 1979). Kelly et al. (1982) proposed that only those red crab larvae (*Chaceon quinquedens*) released up-current in the species' range will recruit back into the parent population. Melville-Smith (1987a, 1987b, 1987c) in a tagging study of red crabs (*C. maritae*) off the coast of southwest Africa, showed that the only segment of the population exhibiting significant directional movement were adult females: 32% of recaptures had moved greater than 100 km and the greatest distance traveled was 380 km over 5 yr. This directional movement was later shown to be counter to the prevailing surface currents (Melville-Smith 1990). Thus, within decapods in general, and the genus in particular, adult females are capable of, and appear to undergo, long-distance directional movement in their lifetimes.

A similar migration of adult female golden crabs, counter-current to Loop Current circulation in the Gulf of Mexico, would produce the geographic population structure observed off the southeastern United States. Females would be most common farthest up-current whereas males would be most common intermediate in the species geographic range. Wenner et al. (1987) reported a 15:1 (M:F) sex ratio in the South Atlantic Bight and in this study, we had an overall sex ratio of 1:4 — both consistent with hypothesized net female movements to accommodate larval retention and offset the risk of larval flushing.

In fact, given this, two female strategies could maximize recruitment in a prevailing current. The first is for females to position themselves far enough up current so that entrainment would return larvae to the parent population (Sastry 1983). The second is to avoid larval entrainment altogether and thus avoid flushing of the larvae out of the system. Female *Chaceon fenneri*, and perhaps *C. quinquedens*, appear to use both strategies but rely mainly on the latter.

Female golden crabs release larvae offshore in depths usually shallower than 500 m. If larvae were released directly into the Loop Current-Gulf Stream System, they would be entrained for their entire developmental period. Given a developmental time of 33-40 d at 18°C (K. Stuck, Gulf Coast Research Laboratories, Ocean Springs, Mississippi, pers. comm.) and current speeds of 10-20 cm/sec (Sturges and Evans 1983), transport of the larvae would be 285 km to 690 km downstream. Thus, larvae released on the Atlantic side of Florida are in danger of being flushed out of the species' range before recruiting to the benthic stock. Likewise, larvae released directly into the current in the southeastern Gulf of Mexico would be flushed from the Gulf.

Female golden crabs release larvae from February to March (Erdman and Blake 1988; Erdman et al. 1989) and the greatest concentration of female golden crabs to date found in this study was in the northeastern Gulf of Mexico off central Florida. Only during this period and in this region (Maul 1977), can female golden crabs avoid complete entrainment and possible flushing of larvae out of the system. Partial entrainment of larvae might still occur, but its duration should be much reduced, and the risk of larval flushing minimal. This hypothesis predicts that most larvae should be found near the concentrations of females we found in the northeastern Gulf of Mexico with decreasing settlement further downstream. The abundance of juveniles should show a similar pattern.

One need not invoke similar counter-current movements for male geryonid crabs. In particular, males moving perpendicular to adult females (i.e. males moving up and down the continental slope) would have a greater encounter rate with females than males moving along the slope with females. Given low female reproductive frequency (Erdman et al. 1989), intense male-female competition (Lindberg and Lockhart 1988), and probability of multiple broods (Hinsch 1988) from a single protracted copulation (H. M. Perry, pers. obs.), the male strategy should be to intercept relatively rare receptive females all along the species' range, not to aggregate with presumably inseminated females. This hypothesis would predict a relatively uniform abundance of males along their geographic range. In addition, the incidence of inseminated females should be high farthest upstream with an ever decreasing percentage downstream. Our study supports the former hypothesis but we cannot address the latter.

The distributional patterns of geryonid crabs we observed are consistent with those reported from elsewhere. Furthermore, these patterns lead us to suggest that the Loop Current System has had a causal role in life history adaptations of *Chaceon fenneri* and perhaps *C. quinquedens*. In general, females are expected to release larvae during a time and in a region where risk of larval flushing is minimal (Sinclair 1988), whereas males are expected to compete intensely for rare, receptive mates."

The coastal physical oceanography in the Florida Keys was described by Yeung (1991) in a study of lobster recruitment:

"The strong, northward-flowing Florida Current is the part of the Gulf Stream system confined within the Straits of Florida. It continues from the Loop Current in the Gulf of Mexico, and proceeds beyond Cape Hatteras as the North Atlantic Gulf Stream.

The mean axis of the Florida Current is approximately 80 km offshore of Key West and 25 km off Miami (Lee et al. 1991). Mean annual cross-stream surface current speed in the Straits of Florida is approximately 100 cm/s (U.S. Naval Oceanographic Office 1965).

Brooks and Niller (1975) observed a persistent countercurrent near Key West extending from surface to the bottom, and from nearshore to approximately 20 km seaward. They believed that it was part of the cyclonic recalculation of the Florida Current between the Lower and Middle Keys.

The presence of a cold, cyclonic gyre was confirmed by physical oceanographic data collected in the SEFCAR cruises. It was named the Pourtales Gyre since it occurs over the Pourtales Terrace -- that area of the continental shelf off the Lower and Middle Keys (Lee et al. 1991). When the Florida Current moves offshore, the Pourtales Gyre forms over the Pourtales Terrace, and can last for a period of 1-4 weeks.

The Pourtales Gyre could entrain and retain locally spawned planktonic larvae for a short period. The combination of the cyclonic circulation and enhanced surface Ekman transport could also advect foreign arrivals into, and concentrate them at, the coastal boundary (Lee et al. 1991).

Vertical distribution of the larvae within the 3-dimensional circulation will subject them to complicated hydrographic gradients, which might influence their development time, and hence their dispersal potential (Kelly, Sulkin, and van Heukelem 1982; Sulkin and McKeen 1989). Thus, variability in the circulation features and water mass properties can lead to variability in larval transport and recruitment."

The Pourtales Gyre may provide a mechanism for entrainment of golden crab larvae spawned on the Florida east coast, and also as a mechanism to entrain and advect larvae from the Gulf and Caribbean (e.g., Cuba). This possibility is supported by the conclusion of Yeung (1991) suggesting that larvae of a foreign origin supply recruits to the Florida spiny lobster population:

"The foreign supply of pre-recruits arriving with the Florida Current might easily meet the same fate as the locally spawned larvae, that is, passing on with the Florida Current. The

Pourtales Gyre may play a significant role in recruitment by providing a physical mechanism to entrain and advect larvae into the coastal boundary.

The Pourtales Gyre, even if linked with the Dry Tortugas gyre or the Florida Bay circulation, may not be able to provide a pathway much more than 2 months in period. For locally spawned *Panulirus* larvae to be retained for their entire development would require several circuits -- not impossible, but unlikely"

The timing of the Pourtales Gyre provides a mechanism for local recruitment of *Scyllarus* larvae (Yeung, 1991) and may also provide a similar mechanism for golden crab larvae. Golden crab larvae from the Gulf of Mexico, Cuba, and possibly other areas of the Caribbean, probably provide larvae to the South Atlantic population. The proportion of local recruitment is unknown but could be significant.

Feeding

Feeding habits are very poorly known. Golden crabs are often categorized as scavengers that feed opportunistically on dead carcasses deposited on the bottom from overlying waters (Hines, 1990).

Movement

Wenner et al. (1987) found in the South Atlantic Bight that: " Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migrations such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al., 1982)."

Lindberg and Lockhart (1993) found in the Gulf of Mexico: " The golden crab *Chaceon fenneri* in the eastern Gulf of Mexico exhibits a typical bathymetric pattern of partial sex zonation and an inverse size-depth relationship, as first reported for red crabs (*C. quinquedens*: Wigley et al., 1975; *C. maritae*: Beyers and Wilke, 1980). Sex segregation, with females shallower than most males, was more evident in our results than in those of Wenner et al. (1987) from the South Atlantic Bight, primarily because our trap catch had a higher proportion of females (25.9% compared to 5.2%)."

Abundance

Golden crab abundance studies are limited. Data from the South Atlantic Bight (Wenner et al., 1987) estimated abundance from visual assessment was 1.9 crabs per hectare while traps caught between 2 and 10 kg per trap. Wenner and Barans (1990) estimated the golden crab population in small areas of 26-29 square km between 300-500 m off Charleston to be 5,000-6,000 adult crabs. In the eastern Gulf of Mexico adult standing stock was estimated to be 7.8 million golden crabs and the biomass was estimated to be 6.16 million kg (13.6 million pounds) (Lindberg et al., 1989). Experimental trapping off Georgia yielded an average catch of 7 kg per trap (Kendall, 1990).

3.3.5.2 Essential Fish Habitat and Environmental Requirements

Essential fish habitat for golden crab includes the U.S. Continental Shelf from Chesapeake Bay south through the Florida Straits (and into the Gulf of Mexico). In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse golden crab larvae. The detailed description of seven essential fish habitat types (a flat foraminferan ooze habitat; distinct mounds, primarily of dead coral; ripple habitat; dunes; black pebble habitat; low outcrop; and soft-bioturbated habitat) for golden crab is provided in Wenner et al. (1987).

Based on exploratory trapping, golden crab maximum abundance occurs between 367 and 549 meters in the South Atlantic Bight. Information on sediment composition suggest that golden crab abundance is influenced by sediment type with highest catches on substrates containing a mixture of silt-clay and foraminiferan shell. Wenner et al. (1987) further notes: "Other studies have described an association of *G. quinquedens* with soft substrates. Wigley et al. (1975) noted that bottom sediments throughout the area surveyed for red crab from offshore Maryland to Corsair Canyon (Georges Bank) consisted of a soft, olive-green, silt-clay mixture. If golden crabs preferentially inhabit soft substrates, then their zone of maximum abundance may be limited within the South Atlantic Bight. Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270-450 m between St. Augustine and Cape Canaveral, FL (30°N and 28°N). This same depth range from Savannah, GA to St. Augustine was generally characterized by Bullis and Rathjen (1959) as extremely irregular bottom with some smooth limestone or "slab" rock present. Our study indicates, however, that the bottom due east between Savannah and St. Catherines Island, GA at 270-540 m consists of mud and biogenic ooze. Further north from Cape Fear, NC to Savannah, bottom topography between 270 and 450 m is highly variable with rocky outcrops, sand and mud ooze present (Low and Ulrich, 1983)."

In a subsequent study using a submersible, Wenner and Barans (1990) found the greatest abundance in rock outcrops:

Observations on density and a characterization of essential habitat for golden crab, *Chaceon fenneri*, were made from a submersible along 85 transects in depths of 389-567 m approximately 122 km southeast of Charleston, South Carolina. Additional observations on habitat were made on 16 transects that crossed isobaths between 293-517 m.

Seven essential habitat types can be identified for golden crab from observations:

- A flat foraminiferon ooze habitat (405-567 m) was the most frequently encountered habitat. This habitat type is characterized by pteropod-foraminiferan debris mixed with larger shell fragments, a sediment surface mostly covered with a black phosphorite precipitate;

- Distinct mounds, primarily of dead coral at depths of 503 to 555 meters and constituted 20% of the bottom surveyed on dives to count crabs. Coral mounds rose approximately 15 to 23 meters in height above the surrounding sea floor and included several that were thinly veneered with a fine sediment and dead coral fragments, as well as a number that were thickly encrusted with live branching ahermatypic corals (*Lophelia prolifera* and *Enallopsammia profunda*). Fan-shaped sponges, pennatulids and crinoids were oriented into the northerly 1.4-1.9 km- h^{-1} current. The decapod crustaceans *Bathynectes longispina*, *Heterocarpus ensifer* and *Eumunida pita*, the black-bellied rosefish, *Helicolenus dactylopterus*, and the wreckfish, *Polyprion americanus*, were frequently sighted along transects in the coral mound habitat.

- Ripple habitat (320-539 m); dunes (389-472 m); black pebble habitat (446-564 m); low outcrop (466-512 m); and soft-bioturbated habitat (293-475 m). A total of 109 *C. fenneri* were sighted within the 583,480 m^2 of bottom surveyed. Density (mean no. per 1,000 m^2) was significantly different among habitats, with highest values (0.7 per 1,000 m^2) noted among low rock outcrops. Lowest densities were observed in the dune habitat (<0.1 per 1,000 m^2), while densities for other habitats were similar (0.15-0.22 per 1,000 m^2)."

A similar submersible study in the eastern Gulf of Mexico (Lindberg and Lockhart, 1993) found similar results with higher abundance on hard bottom: "Within the bathymetric range of golden crabs, crab abundance may be related more to habitat type than to depth. The greatest density (36.5 crabs/ha) occurred on or near hard-bottom canyon features."

Golden crab occupy offshore oceanic waters along the Atlantic and Gulf of Mexico coasts as adults. Offshore areas used by adults are probably the least affected by habitat alterations and water quality degradation. Currently, the primary threat comes from oil and gas development and production, offshore dumping of dredged material, disposal of chemical and other wastes, and the discharge of contaminants by river systems.

3.3.5.3 Essential Fish Habitat - Habitat Areas of Particular Concern for Golden Crab

There is insufficient knowledge of the biology of golden crabs to identify spawning and nursery areas and to identify HAPCs at this time. As information becomes available, the Council will evaluate such data and identify HAPCs as appropriate through the framework.

3.3.6 Spiny Lobster

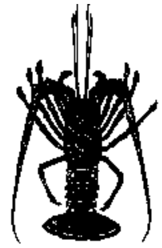
3.3.6.1 Species Distribution and Essential Fish Habitat and Environmental Requirements

Essential fish habitat for spiny lobster includes nearshore shelf/oceanic waters; shallow subtidal bottom; seagrass habitat; unconsolidated bottom (soft sediments); coral and live/hard bottom habitat; sponges; algal communities (*Laurencia*); and mangrove habitat (prop roots). In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse spiny lobster larvae.

Spiny lobster begin their existence in the Keys as larvae that arrive oceanic currents. As planktonic larvae they pass through 11 life stages in more than six months (FKNMS 1995). They then metamorphose into a transitional swimming stage (puerulus) (Little and the Milano, 1980; Lyons, 1980) that is found along Florida's southeast coast all year-long (Hunt et al., 1991). Pueruli travel through channels between the Keys and enter nursery areas in Florida Bay and the Gulf, where they preferentially settle into clumps of red alga *Laurencia* (Herrnkind and Butler, 1986). In seven to nine days a metamorphose into juveniles and take a solitary residence in the algal clumps for two to three months (Marx and Herrkind, 1985b; Hunt et al., 1991).

When juvenile spiny lobster reach a carapace length of 15 to 16 mm they leave the algal clumps and reside individually within rocky holes, crevices, coral, and sponges. They remain solitary until carapace length reaches approximately 25 to 35 mm, when they begin congregating in rocky dens. They remain in these nurseries for 15 months to two years (Hunt et al., 1991).

Adult lobsters move to deeper waters in the coral reef environment, where they occupy dens or holes during daylight hours. They are nocturnal feeders and predominantly prey upon molluscs and crustacea, including hermit crabs and conch.



Spiny lobster, *Panulirus argus*

Adults move to the offshore reef to spawn, and larvae are swept up to the East Coast by the Florida Current, where many are lost due to the length of pelagic pueruli stage (9 months) (Marx and Herrnkind, 1985a; Hunt et al., 1985 a; Hunt et al., 1991).
The following abstract of Yeung, (1996) summarizes recent research efforts on transport and retention of spiny lobster larvae: Transport and Retention of Lobster Phyllosoma in the Florida Keys. Abstract of a doctoral dissertation at University of Miami. December 1996.

"Physical transport can significantly affect recruitment variability of marine species with planktonic larvae. This especially pertinent to the phyllosoma larvae of spiny lobsters (Palinuridae), which have an estimated planktonic duration of 6-12 months. A large population of spiny lobster, *Panulirus argus*, inhabits the reef offshore of the Florida Keys in the Straits of Florida, constituting one of Florida's most valuable fisheries. The hydrography of this region is dominated by the strong Florida Current, which links the Loop Current in the Gulf of Mexico with the Gulf Stream in the North Atlantic. This dynamic oceanography favors the entrainment and dispersal of locally-hatched phyllosoma larvae, leading to contention about the origin of recruits for Florida's population. In this study, the problem of lobster recruitment is approached from the perspective of transport. The main objective is to find the linkage between spatial variables of larval distribution and transport processes. The main physical processes likely to influence larval advection are the meanders and frontal modulations of the Loop Current - Florida Current, coastal gyres and countercurrents, and wind-driven onshore surface transport. The hypothesis is that, due to those processes, intra-regional spatial variability in the distribution and abundance of phyllosomata exists along the Florida Keys. Spatial variability of transport is established with empirical observations of associated physical parameters, e.g. wind vectors, wind-driven surface onshore transport, frequency of coastal countercurrent reversals, the mode of the Loop Current, and the configuration of the Florida Current. The physical data are related to the pattern of larval distribution derived from five years of sampling. Interspecific comparison of larval recruitment strategies between palinurid and scyllarid (Scyllaridae) lobsters, who also inhabit the region and possess the phyllosoma larva, lends insight to the mechanisms of larval transport. Simulation modeling of larval trajectories in an advective model of current-modified ageostrophic transport in the Straits of Florida further aids the conceptualizing of processes, and testing and formulation of hypotheses regarding the interaction between larval behavior and oceanography. Clarification of this biological-physical coupling will advance our understanding of spiny lobster population dynamics and promote effective management of the fishery stocks."

3.3.6.2 Essential Fish Habitat-Habitat Areas of Particular Concern for Spiny Lobster

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for spiny lobster include Florida Bay, Biscayne Bay, Card Sound, and coral/hard bottom habitat from Jupiter Inlet, Florida through the Dry Tortugas, Florida.

3.3.7 Coral, Coral Reefs, and Live/Hard Bottom Habitat
3.3.7.1 Species or Groups of Species and Their Distributions
3.3.7.1.1 Shallow-water Species
3.3.7.1.1.1 Octocorallia (sea fans, sea whips, etc.)

The shelf waters of the southern and southeastern United States contain a considerable diversity of octocorals. Among those listed for the shelf regions of the western Atlantic by Bayer (1961), only 19 have not been reported from the management area (four species are reported which require confirmation). However, 36 species of primarily deeper-dwelling species have been added to Bayer's list since 1961, bringing the total shelf octocoral fauna of the present study area to 113 species. Of that total, 18 species appear to be endemic, and an additional three species find their principal distribution here (Table 22).

The temperate region from North Carolina to the southeast Florida coast contains no distinctive octocoral elements. Typical species are *Leptogorgia virgulata*, *L. setacea*, *Lophogorgia hebes*, *Muricea pendula*, and *Titanideum frauenfeldii*.

The area from Palm Beach south to the Dry Tortugas contains a tropical Atlantic fauna, which appears to be fairly homogeneous. Some faunal differences occur along the Florida reef tract in response to water temperature ranges, substrate availability, and other variables.

Cairns (1977a) published a field guide to the more common gorgonians of the Gulf of Mexico, Caribbean, and Florida. Wheaton described the octocoral fauna off southeast Florida in 20-50 meter zones (1987), off Key Largo, in 27-57 m depths (1981), at Looe Key (1988), and at Dry Tortugas (1975,1989.)

Table 22. Endemic elements of the octocoral fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southern United States.

Telestacea Pennatulacea	Alcyonacea	Gorgonacea (Scleraxonia)
Teiesto flavula	*Pseudodrifa nigra*	*Anthopodlum rubens*
Virgularia presbytes		
T. sanguinea		*Anthothela tropicalis*
Stylatula antillarum		
T. fruticulosa		**Titanideum frauenfeldii*
Acanthoptilum agassizii	*T. nelleae*	
	(Holaxonia)	*A. oligacis*
		Thesea cirtina
		T. plana
		Swiftia casta
		Trichogorgia viola
	Eunicea palmeri	
		Eunicea knighti
		Muricea pendula
		Leptogorgia medusa
		**Lophogorgia cardinalis*

* Indicates species with principal distribution within study area but also reported from Cuba.

3.3.7.1.1.2 Milleporina and Scleractinia (the fire corals, stinging corals, and stony corals)

Sixty-eight species of stony corals are known from the continental shelves of the study area, 62 of which have been noted from the Florida Keys and the Dry Tortugas alone. This is a remarkably high number, considering that the most diverse locale in the Caribbean (Jamaica) lists only 66 species (Goreau and Wells, 1967; Wells and Lang, 1973). Twelve Jamaican species are absent from Florida waters and an additional seven species are known from the Florida reef tract but not Jamaica: *Madracis asperula, Oculina tenella, O. robusta, Cladocora debilis, Caryophyllia horologium, Flabellum fragile,* and *Favia gravida*. The latter species had been considered as endemic to Brazil until their identification from Florida by Jaap (1979, personal communication) and Avent, et al. (1977), respectively. Two scleractinians are endemic to the South Atlantic and are members of the Oculinidae included in Table 23.

Table 23. Endemic elements of the scleractinian fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southeastern United States (References as listed) .

Oculina varicosa Lesueur.	Rare off Florida Keys at 72 to 90 m (236 to 295 ft) (Pourtales, 1871; Verrill, 1901). Common on the continental shelf and shelf edge north of Palm Beach (Avent, et al., 1977; Reed, 1978, personal communication). Known as far north as Cape Hatteras, North Carolina from subtidal to 152 m in depth (Reed, 1980b). Also known from Bermuda in 5 to 22 m (l6 to 72 ft.) (Verrill, 1901). Ludwick and Walton (l957).
Oculina arbuscula Verrill.	Cape Hatteras, North Carolina, to Charleston, South Carolina (McCloskey, 1970). Reportedly common off Savannah, Georgia, 3 to 25 m (10 to 82 ft). Porter (1978, personal communication) reports this species from Bermuda.

The basic pattern of stony coral distribution follows:

Corals in the 0-200 m depth that are azooxanthellate (lacking algal symbionts) are distributed throughout the tropical wetern Atlantic. Most are solitary ahermatypic corals and small colonials: *Madracis brueggemanni*, *Oculina tenella*, *Cladocora debilis.*

Corals found in deeper waters that are azooxanthellate have a temperate distribution (not found south of 30° N. Latitude). This includes solitary and some colonial species such as *Madrepora carolina* and *Madrepora oculata*.

Corals that are limited in depth to less than 70 m, are zooxanthellate, and almost exclusively colonial have a strong tropical affinity (Caribbean-Bahamas, southeast Florida, Bermuda, with extreme records in Brazil and North Carolina). This group is often referred to the shallow water reefs corals. In Florida, coral distribution is from Fowey Rocks south. Examples of this group include *Acropora palmata*, *Porites porites*, *Diplora labyrintiformis*, *Mussa angulosa*, and *Eusmilia fastigiata*.

3.3.7.1.1.3 Antipatharia (black corals)

Black corals are not well represented in the management area with the exception of *Cirripathes sp.* (probably *C. lutkeni*) which occurs rarely in the Florida Keys (Goldberg, 1979, personal communication). The species appears to be quite common below 20 m (66 ft.) on the southeast Florida coast (Goldberg, 1973a) (Table 24).

3.3.7.1.1.4 Stylasterina

Some Stylasterina have been reported in waters less than 200 m (660 ft) deep (Boschma, 1957): *Distichopora foliacea* P. from Key West at 183 m (595 ft.) and off Vaca Key (Marathon) at 152 to 244 m (500 to 720 ft.); and *Plibothrus symmetricus* P. from American Shoal at 179 m (585 ft). Each of these records probably represents unusually shallow occurrences of deeper water species.

Table 24. Shallow-water *Antipatharia* from the continental shelves of the southern United States. .

SPECIES	LOCATION/DEPTH	REFERENCE
Cirripathes desbonni (D. & M.)	Sand Key, 81 m (267 ft) Jeffs Reef	Pourtales, 1878; Reed,
	(Vero Beach, Florida), 80 to 90 m	1979, personal communication;
	(265 to 300 ft).	Goldberg, 1979, personal communication.
Antipathes pennacea (Pallas)	Crocker Reef Florida, 28 m (93 ft).	Goldberg, 1979, personal communication.
	Alligator Light, Florida, 29 to 38 m (96 to 125 ft).	Opresko, 1974.
Antipathes lenta Pourtales	Carysfort Reef - Dry Tortugas, Florida, 45 to 67 m (149 to 221 ft).	Opresko, 1974.
Parantipathes columnaris (Duch.)	Dry Tortugas, Florida, 183 m	Cairns (l979, personal communication; Smithsonian 91 m (300 ft.). Institution records).

3.3.7.1.1.5 Protected Shallow-water Species

State and Federal laws and regulations protect corals in general. Fourteen species have been identified as worthy of special protection (Table 25). Antonius, et al. (l978) noted that pillar coral (*Dendrogyra cylindrus*) was recommended for listing as an endangered species under the U.S. Endangered Species Act. A conference sponsored by the Atlantic Reef Committee, determined the species to be threatened in the management area but not endangered throughout its range (defined by the Endangered Species Act as worldwide for invertebrates). Jaap (unpublished) produced a summary document on systematics, distribution, stratigraphy, and ecology of the pillar coral for the meeting. The Florida Committee on Rare and Endangered

Plants and Animals (a private group that supplies information to state agencies) has listed as endangered throughout the Florida reef tract (in all unprotected areas, i.e., outside Biscayne National Park and other areas) an additional 13 species.

All of the corals listed as continental shelf fishery resources in the Fishery Conservation and Management Act of 1976 that may occur in the management area are found deeper than the 200 m (660 ft) contour.

3.3.7.1.2 Deepwater Corals

As a group, deepwater corals (found deeper than 200 m or 660 ft) are among the most poorly understood corals considered in this plan. Field and laboratory observations of deepwater species are sparse. Collecting expeditions have been fair to adequate; the best available sources of data are the coral specimens scattered at research institutions such as the Florida Department of Environmental Protection Marine Research Institute (formerly the Florida Department of Natural Resources Marine Lab), the Smithsonian Institution, the Museum of Comparative Zoology at Harvard, the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences, and Texas A&M University. Cairns (l979) has comprehensively reviewed the deepwater Scleractinia but the deepwater gorgonians remain relatively unstudied. The work of Cairns (1979) on deepwater scleractinian coral zoogeography revealed seven species to be endemic (i.e., limited) to the temperate region off the eastern United States. Five of those species have a primarily warm temperate distribution (*Concentrotheca laevigata, Cyathoceras squiresi, Thecopsammia socialis, Bathypsammia tintinnabulum,* and *B. fallosocialis*), two are found in cold temperate waters (*Enallopsammia profunda* and *Dasmosmilia lymani*).

Generally, Caribbean waters have more deepwater species than adjacent waters. In the warm temperate western Atlantic, 28 species occur. Of those species, 14 are tropical and do not occur north of Cape Hatteras, seven are endemic to the temperate region north of Florida and Cuba, and seven species are more cosmopolitan. North of Cape Hatteras, 12 species have been reported, six of which also occur in warm temperate waters. Distribution maps and tables of these corals are included in Cairns (1979).

In light of the inadequate data base, separate sections discussing the other major taxonomic groupings of deepwater corals are not attempted.

3.3.7.1.2.1 Distributions

Within the management area there are at least 183 species of corals collected from deeper than 200 m (660 ft.). Although information from deepwater collections is far from complete, the areas of highest coral concentration along the Atlantic coast appear to be between the 600 and 800 m (1,960 to 2,600 ft) contours of the continental slope where deepwater banks are found. Although a complete listing of coral species associated with such structures is impossible at present, at least 23 species of coral have been collected from them.

3.3.7.1.2.2 Protected Deepwater Corals

No deepwater species have been listed as endangered or threatened by the Endangered Species Act nor are any under consideration for listing (Roe 1979, personal communication).

Corallium (precious red coral) and *Keratoisis* (bamboo coral) were listed as fishery resources in the Fishery Conservation and Management Act of 1976.

3.3.7.2 Abundance and Status

3.3.7.2.1 Shallow-water Species

Prior to about 1985, information concerning relative abundance of shallow-water corals must be gleaned from a large number of papers, reports, and personal unpublished observations of specific coral habitats and communities. Since these studies/observations were almost always conducted at different times by different investigators using different methods, the composite data base was incomplete and inconsistent and did not provide a thorough assessment of the present condition of the coral stock. However, available data do allow an overview of the resource primarily from the original 1982 coral plan (GMFMC and SAFMC 1982). For purposes of discussing relative abundance of shallow-water corals, the management unit may be subdivided into seven regions based on general species compositions. Each of these regions is discussed individually below. As an overview of major shallow-water coral communities surveyed in the following. Section 3.2.1 and Appendix E presents the major hard bottom and coral reef areas of the south Atlantic. Since the late 1980's numerous surveys of shallow water corals have been undertaken.

Table 25. Corals categorized as endangered by the Florida Committee on Rare and Endangered Plants and Animals (Source: Layne, 1979 pers. comm.; Simon, 1979 pers. comm.).

Common Name	Scientific Name
Elkhorn coral	*Acropora palmata* (Lamarck)
Staghorn coral	*Acropora cervicornis* (Lamarck)
Fused staghorn coral	*Acropora prolifera* (Lamarck)
Pillar coral	*Dendrogyra cylindrus* (Ehrenberg)
Large flower coral	*Mussa angulosa* (Rallas)
Flower coral	*Eusmilia fastigiata* (Pallas)
Lettuce coral	*Agaricia agaricites* (Linnaeus)
Starlet coral	*Siderastrea siderea* (Ellis and Solander)
Brain coral	*Diploria clivosa* (Ellis and Solander)
Brain coral	*Diploria labyrinthiformis* (Linnaeus)
Brain coral	*Diploia strigosa* (Dana)
Small star coral	*Montastraea annularis* (Ellis and Solander)
Large star coral	*Montastraea cavernosa* (Linneaus)
Brain coral	*Meandrina meandrites* (Linnaeus)

* Although this Committee (FCREPA) is a private group of scientists and conservationists, the lists they prepare do contribute to efforts by the Florida Game and Fresh Water Fish Commission (GFWFC) in their own Endangered Species Program. However, since the GFWFC addresses only vertebrate animals, the FCREPA list constitutes the only state listing of marine invertebrates, including corals. These species are not necessarily rare or endangered at this time.

The most recent edition of rare and endangered biota of Florida is M. Deyrup and R. Franz (eds.), 1994. Rare and endangered biota of Florida, Vol. IV Invertebrates. University Press of Florida, Gainsville, 798pp.

3.3.7.2.1.1 North Carolina to Cape Canaveral

NOAA's Office of Coastal Zone Management (l979d) cited reports that three to 30 percent of the shelf region is covered by live bottom habitats. The coral fauna along the edge of the continental shelf from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, remains incomplete. Studies by Menzies, et al. (l966) and Macintyre and Milliman (l970) indicate that Pleistocene algal accumulations account for the ledges, small terraces, and slight rises of the continental margin off North and South Carolina, while oolitic deposits predominate in the more southerly sector. *O. varicosa* is present on the inner and mid-shelf (3 to 40 m) as small discrete colonies (<30 cm diameter, usually <15 cm), and on the outer shelf and upper slope to depths of 152 m either as individual colonies (l to 2 m diameter), thickets, or banks. While *O. varicosa* has been found in water as deep as 128 m (off Cape Lookout, North Carolina) and as far north as Cape Hatteras, North Carolina, the majority of the thickest growth occurs off the east coast of Florida, from Cape Canaveral to Ft. Pierce, in the area of the Oculina Bank Habitat Area of Particular Concern discussed in Section 3.2.1.1.3.2.

Corals on the outer continental shelf proper are characterized by patches of low relief hard bottom also referred to as live bottom (Struhsaker, 1969). Hard bottom communities throughout this shelf area have been reviewed by Continental Shelf Associates (1979).

These areas are inhabited by tropical and subtropical fishes, coralline algae, sponges, hydroids, and various species of other invertebrates and coral. They have been described at depths of 20 to 40 m (66 to 132 ft) from Onslow Bay, North Carolina, by MacIntyre and Pilkey (l969) and Huntsman and MacIntyre (1971). Four other species of scleractinians were noted: *Balanophyllia floridana Pourtales*; *Phyllangia americana* Milne-Edwards & Haime; *Astrangia danae* Agassiz (= *A. astreiformis* M.-E. & H.); and the eye coral, *Oculina arbuscula* Verrill. Additional scleractinian records for the North Carolina continental shelf include a number of small, mostly solitary species: *Rhizosmilia maculata* (reported as *Bathycyathus maculatus*), *Dasmosmilia lymani*; *Rhizatrochus fragilis* (reported as *Monomyces fragilis*); *Paracyathus defilipii*; and *Cladocora sp.* (Cerame-Vivas and Gray, 1966).

Reports from South Carolina and Georgia waters (Powles and Barans, 1979; Reed, 1978, personal communication, respectively) indicate that the coral fauna is largely the same as off North Carolina, except that coral patches are even more sparsely distributed (Barans, 1978, personal communication). Gray's Reef occurs in this region, approximately 33 km (18 nm) east of Sapelo Island, Georgia. This complex rises from a depth of 22 m (72 ft) to a crest at 18 m (59 ft). It is approximately 6 km (3.2 nm) long and 2 km (1 nm) wide. The geology of Gray's Reef has been studied by Hunt (1974). Although the area is not a true coral reef a number of corals and their associates are found there. Porter (1978, personal communication) noted that the biomass is dominated primarily by a large pink ascidian (probably *Eudistoma sp.*), secondly by the gorgonian *Leptogorqla sp.* (probably *L. virgulata*), and thirdly by scleractinians, *Oculina varicosa* identified by J. K. Reed and eye coral, *Oculina arbuscula*. If confirmed, this identification extends the range of *O. arbuscula* from Charleston to Savannah (McCloskey, 1970). Other species noted by Porter include stump coral (*Solenastrea hyades*), star coral (*Montastraea annularis*, uncommon), *Cladocora arbuscula, Astrangia poculata*, and *Phyllangia americana*.

Bayer (1961) stated that the shelf octocoral fauna from the East Coast of Florida north of Cape Canaveral is indistinguishable from the fauna from Georgia and the Carolinas. Reports from North Carolina (Menzies, et al., 1966; Cerame-Vlvas and Gray, 1966), South Carolina (Powles and Barans, 1979), and Georgia (Reed, 1978, personal communication) appear to confirm this conclusion for both octocorals and scleractinians.

3.3.7.2.1.2 Central Florida to South Florida (Cape Canaveral to Palm Beach)

This shelf region represents a transitional zone for coral fauna and deserves special consideration. The shelf edge contains a conspicuous band of pinnacles, benches, mounds, and troughs (here collectively referred to as hard bottoms) which are often capped by the Ivory Tree Coral, *Oculina varicosa* Lesueur. Although the species occurs at least as far north as Cape Hatteras, North Carolina (Reed, 1980b), its structural development is greatest in this region; thickets 1-2 m (3-6 ft) high are found on pinnacles with up to 25 m relief (Avent, et al., 1977;

Reed, 1980). A major portion of the shelf edge is littered with *Oculina* debris (MacIntyre and Milliman, 1970).

The *Oculina* community harbors a rich vertebrate and invertebrate fauna which includes other scleractinians (*Astrangia poculata* (Peters et al., 1988)*, Balanophyllia floridana, Cladocora debilis, Paracyanthus pulchellus*, and *Coenocyathus* species) and octocorals (*Telesto nelleae*, and *Tltanideum frauenfeldii*) (Avent, et al., 1977). Two hundred species of mollusks, 47 species of amphipod crustaceans, 21 species of echinoderms, and 50 species of decapod crustaceans have been found directly associated with *Oculina varicosa* (Reed, et al., 1982).

Although shelf-edge *Oculina* communities seem not to persist south of Jupiter, Florida, the species is found on coquinoid rock ledges scattered over the shallow shelf south to St. Lucie Inlet and Stuart, Florida (27° 10'N latitude) where *Oculina* is associated with decidedly Carolinian octocorals such as *Lophogorgia* and *Leptogorgia spp*. In spite of the Antillean ecological character of other groups which persist north to Cape Canaveral (Avent, et al., 1977; Briggs, 1974), the scleractinian and octocorallian fauna became Antillean only south of St. Lucie Inlet (in a similar fashion to the Mollusca studied by Work, 1969). The coquinoid ledges here possess the same species noted above, but mixed with tropical genera such as the *Diploria* (brain coral), *Isophyllia* (cactus coral), *Montastraea* (star coral), and the octocorals *Eunicea, Pseudopterogorgia*, and *Gorgonia* (Reed, 1979, personal communication).

3.3.7.2.1.3 Southeast Florida Coast (Palm Beach to Fowey Rocks)

South of 27° North latitude to near Miami, the continental shelf narrows to 3 to 5 km (1.6 to 2.7 nm) and the warm waters of the Florida current become the most dominant hydrographic feature (Lee and McGuire, 1972). Thus, in the vicinity of Palm Beach, Florida, Carolinian corals are replaced by a diverse hard-bottom community, tropical in character, zoogeographically similar to that of the Florida Keys, but less well developed than the majority of the Florida reef tract.

The hard-bottom community found in this region is dominated by gorgonian corals. The antipatharian black coral *Cirripathes lutkeni* is prominent below a depth of 22 m (72 ft.) but the scleractinians are less abundant at the northern end (Wheaton and Jaap, 1976) and in the vicinity of Miami (Courtenay, et al., 1975) than in the central Florida coastal region (Goldberg, 1973a,b). The underlying substrate is a Holocene elkhorn coral, *Acropora palmata*, and staghorn coral, *A. cervicornis*, relic reef which lies 15 to 30 m (50 to 100 ft.) below present sea level. The reef apparently has not been active for the last 7,000 years (Lighty, et al., 1977). Presently, the dominant hermatypes are the large star coral *Montastraea cavernosa*, the small star coral *M. annularis*, the lettuce coral *Agaricia lamarcki*, and the brain coral *Diploria clivosa*.

Nearshore habitats of this area (less than 4 km) are primarily sand plains. However, nearshore hardbottom reefs are also interspersed. These structures consist primarily of exposed *Anastasia*-formation limestone and Holocene caps of sabellariid worm reefs (*Phragmatopoma caudata*) with some small, domal corals represented. Nelson (1990) recorded 325 species of invertebrates and plants in association with similar nearshore hardbottom habitats at Sebastian Inlet, approximately 150 km north. Over 190 species of fishes are documented from such habitats in the Palm Beach area (Lindeman, 1997). At least 515 species total are now known from nearshore hardbottom habitats of the east coast of mainland Florida, a number expected to grow with more studies (Nelson, 1990). These habitats are discussed further in Section 3.2.1 Live/Hard Bottom Habitat.

The deeper zones of this community (20 to 30 m; 66 to 100 ft) are characterized by the presence of the scleraxonian gorgonian *Iciligorgia schrammi* as described by Goldberg (1973a).

Wheaton and Jaap (1976) and Courtenay, et al. (1975) have confirmed the existence of the same zonation oft Palm Beach and Miami Beach, respectively. Wheaton described the octocoral fauna of the outer slope and fore reef zone from Palm County, to Looe Key (Wheaton, 1987). Blair and Flynn (1989) observed hard bottom community structure off Miami.

3.3.7.2.1.4 Florida Keys (Fowey Rocks to the Dry Tortugas)

Coral reefs and hardbottom communities are common within the south Florida coastal ecosystem. With the exception of Bermuda and the northern Bahamas, the Florida Keys represent the northernmost limit of coral reefs in the western Atlantic. Coral reefs are constructed by complexes of corals and other plants and animals that build limestone skeletons or leave calcium carbonate debris as a result of their growth. The cumulative result is a three-dimensional irregular structure that is unique compared to the surrounding seascape. Well developed coral reefs similar to those found in the Bahamas and Caribbean occur from the Ragged Keys to Tortugas Banks: 25° 40' – 24° 30'N latitude, 80° 30' – 82° 40'W longitude (Jaap, 1984, Jaap and Hallock, 1990). High profile bank reefs parallel the island arc in a band four to six miles from shore. Bank reefs are characterized by spur and groove formations (Shinn, 1963), elkhorn coral (*Acropora palmata*), and *Millepora complanata* (encrusting fire coral) at the reef crest. Patch reefs are found between the coast and the offshore bank reefs and typically are characterized by an irregular ring of large corals (*Montastraea annularis, M. cavernosa* (star corals), *Colpophyllia natans, Diploria labyrinthiformis*, and *D. strigosa* (brain corals). The diversity of corals is quite variable, upwards of 60 stony coral species have been documented on an individual bank reef (Jaap et al., 1989). The diversity and abundance of octocorals tends to be greatest in patch reefs and offshore deep reefs. Coral cover is also variable and often quite low (Aronson and Murdoch, 1997). Functionally, coral reefs enhance the abundance and variety of life, provide a living breakwater that protects the coast from storm waves, provide economic benefit from fisheries and tourism, and are important education and research resources.

Many well developed patch and outer bank reefs, such as Carysfort Reef and Key Largo Dry Rocks, occur shoreward of the 18-m (60 ft) isobath and are dominated by *Acropora palmata* (elkhorn) and *Millepora complanata* (encrusting fire coral) at the crest, followed by *A. cervicornis* (staghorn), *Montastraea annularis* (small star coral), and *M. cavernosa* (large star coral), in successively deeper zones (Shinn, 1963). Prior to the 1990's, specific information on the distribution and abundance of corals on these reefs was available in individual works at localized sites (in spite of their position as the northernmost *Acropora* reefs in the western Atlantic). The outer bank reefs of Biscayne National Park to the north have been described by Voss, et al. (l969) but quantitative data on distribution and abundance of corals on a single reef were not included. Wheaton (unpublished) surveyed reefs in Biscayne National Park from 1978 to 1981.

Looe Key Reef (12.9 km, 200° off the SW tip of Big Pine Key, 24° 37'N, 81° 24'W) is a representative outer bank reef. The reef was subdivided into reef flat, spur and groove, forereef, and deep reef habitats to characterize these habitats (Wheaton and Jaap, 1988). Inshore of the reef there is a fan-like mosaic of seagrass and sediments. Progressing from the seagrass-sediments, there is a zone of consolidated rubble that is in less than one-meter deep. It is constructed by coral skeletons that have been carried into the shoal water by storm waves. This area is called reef flat or reef crest. This is a very physically controlled zone; strong waves, winds, intense solar radiation, and extreme temperatures limit the species that can survive in this habitat. Morphologically, the corals found in this area are low relief-encrusting forms and or species that can thrive in the strong wave turbulence (Geister, 1977). The reef crest at Looe Key is dominated by *Millepora complanata* (encrusting fire coral), *Porites astreoides* (mustard hill coral), and *Palythoa caribaeorum* (golden sea mat). Seaward of the reef crest, spurs and grooves (S & G.) extend from the shoal-water approximately 150 to 200 m. The S & G system at Looe Key is 5 to 9 m (16 to 30 ft) deep at the seaward spur terminus. *Acropora palmata* (elkhorn coral) skeletal material is the principal construction component of the spur formations. The spurs can be subdivided into shallow (<1 to 5 m), intermediate (2 to 7 m), and deep (7 to 9 m) habitats (Wheaton and Jaap, 1988). The numerically abundant corals in these habitats are:

Shallow: Porites astreoides, *Millepora complanata, Agaricia agaricites*
Intermediate: *Agaricia agaricites, M. complanata, P. astreoides*
Deep: *Montastraea cavernosa, Plexaura flexuosa, Acropora cervicornis*

Taxonomic richness in these S & G habitats based on Wheaton and Jaap (1988) is:

HABITAT	No. of *Octocorallia* Species	No. of *Milliporina* and *Scleractinia spp.*
Shallow S&G	4 Colony density (m2): 1.18 to 1.33	4 Colony density(m2): 7.60 to 9.59
Intermediate S&G	7 to 11 Colony density (m2): 2.16 to 6.05	16 to 18 Colony density (m2):10.11 to 10.18
Deep S&G	14 to 15 Colony density (m2): 6.15 to 8.94	20 to 22 Colony density (m2): 7.65 to 9.75

Colonies of very large, living *Montastraea annularis* (small star coral), *Diploria strigosa* (brain coral), and *Colpophyllia natans* (boulder brain coral). *Montastraea cavernosa* (large star coral) become dominant at the seaward ends of the spurs. They also can be found sitting independently off of the spur formations.

The end of the spur and groove zone at Looe Key Reef is marked by a sandy plain at 10 to 12 m (33 to 40 ft), which grades into a deeper reef zone, particularly on the west side of the reef. A series of deep spurs and grooves continues to a depth of 30 to 35 m (100 to 115 ft.). Octocorals such as the rough sea plume (*Muriceopsis flavida*; eleven percent of deep reef gorgonians) are common but are replaced by *Pseudopterogorgia bipinnata* (the bipinnate sea feather) and *Iciligorgia schrammi* with increasing depth. The scleractinians of the deep reef are similar in composition to the shallower zones but contain a relatively greater abundance of branching and star forms such as *Eusmilia fastigiata* (star or flower coral), *Porites porites*, and *Madracis spp*. (ten-rayed star coral). The larger scleractinians of the deep reef are *Agaricia spp* (lettuce coral) and *Mycetophyllia spp.* (cactus coral). To seaward the reef terminates and grades into a plain of sediments.

Patch reefs are generally located between Hawk Channel and the outer reefs. Their distribution is bimodal with major concentrations between Elliott Key and lower Key Largo and between Boca Chica Key and Key West. Fewer patch reefs are distributed between Lower Key Largo and Boca Chica Key. The distribution pattern is influenced by Florida Bay; inimical and unpredictable water quality from Florida Bay impedes reef development. The upper and lower keys block Florida Bay waters from egress into the Atlantic. In the middle keys area, there are small islands and large channels between Florida Bay and the Atlantic allowing free exchange of Florida Bay Waters. Recent studies have documented that coral growth near Florida Bay channels is retarded in contrast to corals isolated from this influence (Personal communication, Clay Cook, Harbor Branch Oceanographic Foundation). Patch reefs are also common in the Dry Tortugas, north and south of Garden Key.

Patch reefs of the Florida Keys have received the most comprehensive treatment as far as ecology and systematics of corals in the management area are concerned. Generally, patch reefs found in the lagoon between the outer reefs and the Florida Keys may include star corals *Montastraea spp.*, fire corals *Millepora spp*., regular finger coral *Porites porites* (*P. furcata* or *P. divaricata*), mustard hill coral *P. astreoides*, starlet coral *Siderastrea spp*., brain coral *Diploria clivosa*, and staghorn *Acropora cervicornis*. *Acropora palmata* (elkhorn) is almost always absent. Antonius, et al. (1978) found that five species composed 50 percent of the stony corals found on the patch reefs at Looe Key; *Millepora complanata*, the star corals *Dichocoenia stellaris, Siderastrea siderea*, and *Montastraea annularis* accounted for eight to ten percent each, while staghorn coral *Acropora cervicornis* dominated with 15 percent of the total.

Throughout the Florida Keys, hardbottom communities are distributed from near-intertidal to beyond 90 m depth. These are characterized as a low relief rocky substrate with attached algae, sponges, octocorals, and in some cases, stony corals are a conspicuous component. These habitats in the inshore waters in the immediate vicinity of the Keys are dominated by hardy corals (including brain coral *Diploria clivosa*, *Favia fragum*, *Porites porites, P. astreoides, Siderastrea radians, S. siderea, rose coral Manicina areolata*, and *Cladocora arbuscula*), which appear to have a greater tolerance to silt, thermohaline changes, and unconsolidated bottom (Vaughan, 1919; Kissling, 1965). Voss and Voss (1955) have described such an environment in the vicinity of Soldier Key, the northernmost of the Florida Keys, as have Turmel and Swanson (1976) at Rodriguez Bank, near Tavernier, Florida. The dominant scleractinian in both locations is *Porites porites* (*Porites divaricata*), found in a distinct seaward band associated with the coralline alga *Goniolithon sp*. and turtle grass *Thalassia testudinum.*

Deep reef communities (80 to 120 ft) that appear as reefs that were unable to keep pace with rising sea level are relatively common seaward of many of the individual bank reefs (Carysfort, French, Molasses, Sand Key). These formations often have low relief spur and groove formations. The area referred to as, Tortugas Banks, is a similar deep reef system with channels and characteristics of the deep reefs in the Florida Keys. Because of the low light, the coral growth is not prolific on the deep reefs.

Quantitative information dealing with distribution and abundance of gorgonians is available for several back reef areas in the Florida Keys. Opresko (1973) has analyzed gorgonian data for Boca Chita Pass, Soldier Key, and Red Reef. The first two locations lie on the seaward side of Biscayne Bay and are subject to fluctuations in salinity, temperature, and turbidity. Boca Chita Pass is the least oceanic in character and not surprisingly possesses the lowest diversity and density of gorgonians. Red Reef is a lagoonal patch reef located on Margot Fish Shoal, approximately 4 km (2 nm) east of Elliott Key and about 3 km (1.6 nm) west of the outer reef arc (Long Reef); this location displayed the greatest diversity and density of the areas studied by Opresko.

Comparative information is available for the gorgonian fauna on other lagoonal patch reefs. Bagby (1978) has studied three sites off Key Largo, Florida, chosen to provide a view of the influence of increasing oceanic conditions. The patches, hereafter referred to as Five, Seven and Nine Kilometer Reefs, are named for their respective distances from Key Largo, Florida. Nine Kilometer Reef is immediately shoreward of the outer reef arc just south of Molasses Reef. Distribution and abundance records of gorgonians from both Opresko (1973) and Bagby (1978). It is apparent that *Pseudopterogorgia americana* (slimy sea plume) and *P. acerosa* (porous *false*

Plexaura) are the most widespread species, being found at every station. In agreement with the conclusions of Opresko (1973), *P. acerosa* is most common inshore, while *P. americana* is more dominant at offshore patch reef stations. Equally widespread, but numerically less dominant, are the species *Plexaurella dichotoma* (double-forked *Plexaurella*) and *Plexaura flexuosa* (sea rod). The former is present at all stations but is abundant only at Soldier Key and Five Kilometer Reef. Two species, *Eunicea succinea* (amber Eunicea) and *Pterogorgia citrina* (yellow sea whip), are distributed in abundance at both Soldier Key and Nine Kilometer Reef, but not in intermediate areas. *Pseudoplexaura porosa* was dominant on Five Kilometer Reef and *Plexaura homomalla* (black sea rod) was of considerable importance on Red Reef, but neither was prominent elsewhere in the areas studied.

Species with patchy or widespread distributions are apparently the rule rather than the exception. Goldberg (1973a) noted that offshore patch reefs near the 9 m (30 ft) isobath off the southeast Florida coast could be dominated by either *Pseudopterogorgia americana* or *P. acerosa*. *Plexaura flexuosa* was equally abundant along with *Eunicea calyculata* (warty Eunicea) and *Muricea muricata* (spiny Muricea). Reefs at 14 to 20 m (46 to 66 ft) depths off Palm Beach are dominated by *Plexaura flexuosa* and *Pterogorgia citrina* (Wheaton, 1976). *Plexaura flexuosa* and *Pseudopterogorgia americana* dominated the shallow reefs at Long Key, Dry Tortugas (Wheaton, unpublished). Thus, any or all of these species can be found prominently on inshore or offshore reefs, in shallow water or on outer reefs at depths up to 20 m (66 ft). Their relative abundance on a given reef must therefore be interpreted with caution. Shallow patch reefs near the outer reef tract display a number of clear-water indicator species. *Gorgonia ventalina* (common sea fan), *Muriceopsis flavida* (rough sea plume), *Briareum asbestinum* (corky sea finger), and *Pseudopterogorgia bipinnata* all fall in this category, in decreasing order of consistency (Opresko, 1973; Bagby, 1978). However, only the sea fan *G. ventalina* showed any correlation between abundance and reef position. At Red Reef and Five Kilometer Reef, this species accounted for 2.7 to 4.1 percent of the total fauna. At Seven Kilometer Reef this figure increased to 6.4 percent, and at Nine Kilometer Reef it increased again to 12.8 percent.

3.3.7.2.2 Deepwater Corals

As noted in Section 5.1.2, information concerning deepwater corals is exceedingly sparse. In most instances, the information is too incomplete to make assessments as to the abundance of the stocks. With respect to the condition of the stock (i.e., mortality versus replacement rates) and overall stock stability, it is impossible, possible to make an informed assessment. In one sense of the word "condition", however, the lack of exploitation and other damaging development activities in deepwater areas (except for limited collection and damage by research dredging) infers that the stocks should be in a pristine state. Cairns (1979) documented 55 species of solitary or colonial Scleractinia referenced as "deep-water" off the east Coast of Florida including the Florida Keys. These species bathymetric ranges were from 2 to 2634 m, most were found in depths greater than 30 m.

In the Atlantic, bioherms have been reported along the margins of the Straits of Florida from Miami to the north (Squires, 1963; Neumann and Ball, 1970). One such mound observed from a submersible in 825 m (2,700 ft) depth on the Miami Escarpment was described by Neumann and Ball (1970) as "small mounds of muddy sand capped by thickets of branching, deepwater azooxanthellate-branching species of scleractinian corals." The uncollected species were possibly of the genera *Lophelia, Madrepora,* and *Dendrophyllia*. Cairns (1979, personal communication) studied collections housed at the Smithsonian Institution and suggested that deep water banks may possibly occur commonly along the Atlantic continental slope within the coral management area—particularly around the 600 to 800 m (1,980 to 2,640 ft) depth contour. If this is true, associated deepwater corals including *Enallopsammia* (which Cairns believes to be the *Dendrophyllia* reported by earlier investigators) and *Lophelia* may be relatively abundant in many localized areas.

Also identified within the Atlantic coral management area are "bump areas" (Stetson, et al., 1962; Squires, 1963) located in a broad area about 370 km (200 nm) southeast of Charleston, South Carolina, in 720 to 970 m (2,350 to 3,200 ft) of water. Here, a 5,145 km2 (1,130 nm2) area contains thousands of "humps" (hummocks of low relief) hypothesized to represent accumulations of coral material. As in the Straits of Florida, the corals were predominantly the branching azooxanthellate corals *Lophelia prolifera* and *Enallopsammia profunda*.

In the Atlantic, solitary corals may also occur along the shelf flank, slope, and plain. Although solitary deepwater corals have occasionally been collected from a single trawl in numbers exceeding several hundred individuals, such collections are rare and fit no discernable pattern.

3.3.7.3 Ecological Relationships

Most coral assemblages are so complex that holistic approaches to community metabolism are useful primarily for the purpose of comparison with similar measurements made elsewhere. Therefore, most of the attention on coral reef systems has focused on metabolism and interactions of component parts. Lewis (1977) has reviewed the components which contribute to the well known high production rates on coral reefs. Reviews of coral reef primary production and calcification rates include: Gladfelter (1985), Kinsey, (1985), Larkum and Koop (1997), Venier and Pauly (1997).

Although summarized here, supplemental information on ecological relationships is included in Appendix G.

3.3.7.3.1 Coral Ecosystems as a Special Resource

The importance of coral ecosystems and associated habitats has been well documented by numerous studies, reviews, and symposia (e.g., Jones and Endean, 1973, 1976; Bright and Pequegnat, 1974; Taylor, 1977; Bright, Jaap and Cashman, 1981, Jaap, 1984, Jaap and Hallock, 1990, Chiappone, 1996). Many of those documents emphasize the complex structure of coral ecosystems, the importance of coral for habitat, the sedentary lifestyle and its implications, the wide geographic and bathymetric distributions, and the many behavioral, physiological, ecological, and physical associations that combine to yield an exceedingly complex biological community. The Magnuson-Stevens Act recognizes these values and lists several corals as continental shelf fishery resources subject to exclusive U.S. use beyond the EEZ.

Ecosystems which include coral (solitary corals, hard bottoms or banks, bioherms, and coral reefs) often represent unique arrays of plants and animals in an integrated ecosystem system. The key to many of these systems, if there can be one most important link, is often coral itself, since the corals provide habitat and/or food for most of the other members of the ecosystem. Connell (1973) and Grassle (1973) have studied aspects of population ecology and diversity within coral reefs (see below, Section 6.2.1). Individual biotic components have also been studied -among them, microbes (DiSalvo, 1973), algae (Cribb, 1973), holothurians (Bakus, 1973), shrimps and prawns (Bruce, 1976), echinoderms (Clark, 1976), fishes (Goldman and Talbot, 1976), and others. The resultant coral community is exceedingly complex and productive. Helfrich and Townsley (1965), Odum (1971), DiSalvo (1973), Sorokin (1973c), and others have attempted to quantify and qualify the productivity of corals and their associated biota (e.g., microorganisms) compared to other marine and terrestrial communities.

Because of their vast species diversity, trophic complexity, and productivity, mature coral communities possess numerous mechanisms that enable them to resist normal disturbances, especially those biological in nature (Endean, 1976). As classified by Sanders (1968), coral reefs in deeper water (10 m) may be termed biologically accommodated communities with interspecific competition and predation major determinants of stability. Shallow reef areas (less than 10 m) may be more appropriately termed physically controlled. Numerous other factors also play major roles in coral health. It is many of those other factors that potentially threaten the continued viability of domestic corals.

The special nature of corals as a fishery is further highlighted by their sedentary attached (not mobile) existence, which separates them from the subjects of many other fishery plans. Protection via escape or camouflage is limited by the design of coral skeletons and polyps. Although some protection is afforded by polyp withdrawl, strict energy budgets restrict the use of such behavior. Hence, in the midst of persistent adversity, (e.g., water pollution, cold temperatures, sedimentation), corals appear precariously susceptible. The life history of the octocorallian and scleractinian corals is similar to the other invertebrate species. The fruits of coral sexual reproduction are planulae larvae; the larvae are free living (planktonic or benthic). The larvae select settlement sites through chemoreceptors, settle, and undergo metamorphosis to juvenile, sessile corals.

Part of the uniqueness of the reef corals covered by this FMP is their position at the northernmost limits of zooxanthellate corals in U.S. waters. Although *Solenastrea* (stump coral) and *Siderastrea* (starlet coral) occur off North Carolina where bottom temperatures drop to 10° C or 50°F (MacIntyre and Pilkey, 1969), zooxanthellate corals and coral reef development of a shallow-water and tropical nature is limited to south of Stuart Florida and dynamic coral reef accumulation is found south and west of Fowey Rocks.

Patch reef, hard bottom, and solitary corals occur north of Fowey Rocks and off west Florida, but not to the extent seen off the Florida Keys, northeast of Key Largo, or southwest of Big Pine Key. Most corals inhabiting our nation's continental EEZ, especially the hermatypic species which are less temperature tolerant, are at the very limit of their geographical range.

3.3.7.3.2 Value as Essential Fish Habitat

Coral's most valuable contribution to the marine environment is as habitat for numerous associated organisms. As described by Jones and Endean (1973, 1976), Antonius, et al. (1978), Starck (1968) Jaap (1984) Bohnsack et al. (1987) and Chiappone and Sluka (1996), and many other researchers, a coral assemblage within the management area may support rich populations of invertebrates (corals, sponges, tunicates, echinoderms, crabs, lobsters, gastropods, etc.), vertebrates (primarily fish, turtles, birds, and marine mammals), and plants (coralline algae, fleshy algae, eelgrass, turtle grass, etc.). Wells (1957) emphasized this habitat value in defining a coral reef as "... fauna and flora ... (that) ... provide the ecological niches essential to the existence of all other reef dwelling animals and plants." Undoubtedly coral is a primary provider of high quality refuge habitat for a multitude of attached and mobile organisms.

All demersal fish species under SAFMC management which can associate with coral habitats are contained within the snapper-grouper FMP. Seventy-three managed species within ten diverse families are under this plan (Section 2.2). Several of these families are among the most commercially and recreationally valuable fishes of the south Atlantic coast of the United States (e.g., snappers and groupers). All of these species can show some association with coral or hardbottom habitats during their life history. Among species, these associations differ as some coral habitat use patterns are obligate while some are facultative. In addition, temporal variations in habitat use operate at broad scales ranging from interannual to seasonal to daily (nocturnal feeding migrations). The value of coral habitats can vary accordingly. Within snapper grouper species, ontogenetic changes in habitat use lead to further variation in coral habitat use. However, the coral reef ecosystem is fundamental to the occurrence and survival of all of these species by providing direct food or shelter resources to at least some life stages of all snapper-grouper species, or providing food or shelter to their prey resources (SAFMC, 1983).

Of the ten families within the snapper-grouper plan, the three most diverse and valuable are the groupers, snappers, and grunts, with 21, 14, and 11 managed species, respectively. In groupers, the entire demersal life history of almost all *Epinephelus* species, several *Mycteroperca* species, and all *Centropristis* species, takes place in direct or peripheral association with coral or hard bottom habitats. In contrast, several species of *Mycteroperca* (gag, scamp), utilize nearshore, vegetated habitats before offshore migrations to hard structures with maturation. This latter pattern (primary use of coral/hardbottom structures during later ontogenetic stages) is also seen in many species of snappers and grunts. However, some species, particularly those preferring deeper water, utilize coral/hardbottom structures throughout their life cycle while others utilize both vegetated and hard structures opportunistically.

Similar variations in use of coral habitats are present within most of the other snapper-grouper families. For example, some managed species of triggerfish and porgy utilize coral/hardbottom during their entire demersal life history, while spadefish and hogfish typically settle in vegetated, nearshore areas and use coral/hardbottom structures only during later ontogenetic stages. Other patterns are also present. Most notably, jacks are not demersal and commonly associate with coral/hardbottom habitats as free-swimming transients, not demersal residents. Nonetheless, coral habitats are primary aggregators of prey species for many species of jacks, providing habitat of essential value for the maintenance of food resources.

The habitat diversity within a coral community is usually proportional to ecosystem diversity. Complex reef systems usually provide greater types and quantities of habitat than the more unidimensional hard bottoms. The living and nonliving components of the ecosystem are also of considerable significance in assessing value as habitat. Corals and associated benthos, e.g., sponges, tunicates, and algae, contribute most of the living habitat. Dead corals, perhaps parts of relic reefs, coral limestone, or lithified coral rock contribute refuge habitat and areas where the larvae of corals and sponges can settle. Regardless of the type of substrate or source of protection, the coral community offers space for organisms ranging from microscopic invertebrates to large fish. Those animals in turn contribute to the food webs of the entire ecosystem.

Octocorals have numerous interactions with other animals, including functioning as a refuge and food for numerous other invertebrates and fish. Octocorals are a primary substrate for encrusting fire coral (Millepora). Additionally, octocorals contribute to calcium carbonate production, adding over a ton of limestone spicules per acre/ per year to a reef habitat (Cairns, 1977).

Data from a five-year study at Biscayne National Park (BNP) support the importance of octocoral habitat. Average octocoral density was as high as 58 colonies/m^2 for eight patch reefs studied within BNP (Wheaton, unpublished). Stony coral density on the same sites averaged only 8.5 colonies/m^2 (Jaap, 1984). Tilmant, et al. (1979) reported 214 fish species from these same octocoral dominated reefs. This exceeds 134 species for Tortugas and 146 species for

Pennekamp reported by Jones and Thompson (1978). These octocoral dominated reefs are thus rich in reef fish and serve not only as refuge habitat and probably as a recruitment area.

3.3.7.3.3 Economic Values

Due to state and Federal laws prohibiting coral taking and the subsequent shift of supply to foreign sources, such as the Philippines, India, and Haiti, much of the current economic value derived from corals in the management area comes from the nonconsumptive recreational uses of living corals or collection of other reef resources.

Throughout the management area but especially in the Florida Keys, dive shops, glass bottom boats, reef fishing tours, snorkel trips, boat ramps, and/or tropical specimen collecting companies, emphasize the importance of corals to many local economies. Coastal regions depend on viable coral ecosystems therefore, extreme care must be taken to protect the long-term viability of the reef and the closely related economics of coastal counties, particularly Monroe County, Florida.

The key fact in the above discussion is the derivation of value from living corals in the natural environment rather than from any collected coral specimens. Collection of coral-associated biota constitutes another value that is related to corals. If managed appropriately, both consumptive use of associated biota and nonconsumptive uses of corals and coral reefs should not be detrimental to the environment or any user group's economic well-being. Preservation of existing fisheries that are related to corals should be of vital economic concern.

The Florida Keys are probably the mostly heavily fished area in Florida and many species are dependent on or associated with coral habitats (Bohnsack et al., 1994). Increasing fishery effort in these areas has resulted in substantial reductions in stocks of many fishery species. Sixty-three percent of the stocks (22 of 35 stocks) analyzed in Ault et al. (in press) were considered overfished with Spawning Potential Ratios below 30%.

3.3.7.3.4 Buffer Values

Coral reefs occurring along southern Florida, and indeed throughout the world, are markedly affected by patterns of water circulation. The most highly developed reefs in the management area are the Florida reefs, confined to the windward or southeastern margins of the land masses (Glynn, 1973j Shinn, 1976). Less developed coral communities and other distinguishable biotic assemblages, e.g., grass beds, frequently occur leeward of the reef barriers.

The protection offered by land from cross-platform currents (Ginsburg and Shinn, 1964) is mirrored by the buffer provided to the islands by relic and/or live coral reefs. Offshore reefs help dissipate storm energies and serve to minimize impacts of storms, wave action, and other physical stresses.

The net result of these two buffering systems is a peculiar, abiotic "symbiosis" -- islands protect corals by shielding away cold water and low salinity flows from the Florida Bay and Eastern Gulf and the corals protect land masses and nearshore communities from oceanic effects. As a result, the distribution of coral reefs parallels the distribution of islands (Shinn, et al., 1977).

Protection offered by corals may be crucial to the existence of other shallow-water, continental shelf communities. Coastal Florida, and elsewhere in the management area, is represented by a band of grasses shoreward of the coral reefs. These beds of turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) represent highly productive communities (Helfrich and Townsley, 1965), on which numerous species, e.g., spiny lobster (Herrnkind, 1979, personal communication; Davis, 1979, personal communication) and commercial finfish (Weinstein and Heck, 1979), depend for development and recruitment. Fishes and other species also use the beds as prime foraging grounds. Another coastal community protected to a lesser extent by the corals are mangroves, which along with grass beds, are crucial to nutrient flows in the coastal environment. Lastly, many less developed coral communities, categorized as solitary corals or hard bottoms, shoreward of the coral reefs are also spared from storm damage. Although not as prominent as massive coral reefs, grass beds, mangroves, and small coral assemblages are all important components of the coastal ecosystem. Without the buffer of coral reefs, those three zones would be exposed to unusually destructive forces. Also, without grass beds and mangroves to assist in filtering sediments, coastal waters would deposit particulates on corals and other bottom dwellers.

3.3.7.3.5 Sources of Energy

Stony corals and octocorals derive energy from several sources including from sunlight through their photosynthetic, symbiotic zooxanthellae (algae living in the coral tissue), from consumption of zooplankton, from bacteria (which act as biochemical recycling agents), from consumption of detritus, and perhaps even directly from dissolved organics. Antipatharian corals such as *Cirripathes* apparently rely heavily upon stinging nematocysts to feed upon animal tissues, although plant material has been noted in the gut of black corals. These energy sources are detailed in Appendix G.

3.3.7.3.6 Predators and Associations

As described in detail in Appendix G, corals are subject to the ecological pressures of predation (by fish and invertebrates), competition for space, and other interactions with associated organisms. In some instances, such as the symbiotic relationship of corals to zooxanthellae, the association is mutually beneficial. At the other end of the spectrum, however, are predatory pressures such as those applied by certain reef fishes and invertebrates that eat corals.

3.3.7.4 Biological Factors

3.3.7.4.1 Growth and Size

3.3.7.4.1.1 Octocorals (Gorgonians, Precious Corals)

The published data on gorgonian growth has been determined from work on the black sea rod (*Plexaura homomalla*). Kinzie (1974) calculated a range of growth rates of 1.0 to 40 mm (0.05 to 1.6 in) yr~1 with a mean increase in height of 20 mm (0.8 in) yr~1. In that same study, Kinzie also noted that colonial growth in terms of height need not be mirrored by growth of new branch tips. Mature *P. homomalla* colonies are 25 to 35 cm (10 to 14 in) high with multiple branches arising from a single stem; other gorgonians in the management area attain sizes averaging 18 cm (7 in) up to 2.25 m (7.4 ft.) (Cairns, 1977a). These measurements parallel data collected by Wheaton (unpublished) off Biscayne National Park.

Research on the precious black, bamboo, and pink corals has been restricted because of their occurrence in deep waters. Other than *Cirripathes lutkeni*, which lives at 20 to 174 m (66 to 535 ft), most other corals in this category occur below 200 m (660 ft).

Growth and size data for the precious corals in the management area is represented only by the work of Goldberg (1977) on *Cirripathes lutkeni*.

3.3.7.4.1.2 Stony Corals (Fire Corals, Branched Scleractinians, Brain Corals, etc.)

Growth data for stony corals is concentrated on the scleractinian species, especially the branched reef corals (*Acropora spp.*) and the head corals (*Montastraea* and others). Limited information is available on deepwater species and the hydrocorals. Growth in terms of stock size and number of colonies is not limited to new corals initiated by settling larvae; Shinn (1979, personal communication) and other have noted that many stony corals including the branched corals (*Acropora spp.*) may regenerate from small pieces remaining after damage to or destruction of a larger colony.

Much of the growth data on the branched scleractinians comes from *Acropora palmata* (elkhorn), *A. cervicornis* (staghorn), and *A. prolifera* (fused staghorn). Generally, these corals have different growth rates dependent upon temperature (*A. palmata* and *A. prolifera*), placement in the reef zone (*A. palmata*), and geographic area (*A. cervicornis*) (Gladfelter, et al., 1978). Growth rates of *Acropora* in the management area and on Caribbean reefs range from 34 to 266 mm per year for *A. cervicornis*, 47.3 to 105 mm per year for *A. palmata*, and 59.2 to 81.8 mm for *A. prolifera.* Those rates are lower if expressed solely for corals in the management area.

Gladfelter, et al. (1978) found that calcification rates (the amount of calcium carbonate deposited per unit branch perimeter) in *Acropora palmata* were independent of temperature yet dependent upon zonation; 0.85 9 per cm per year in the backreef, 1.66 in the shallow forereef, and 1.35 in the deeper forereef were typical.

The data of Shinn (1966) and Gladfelter, et al. (1978) indicate that *Acropora spp*. growth rates in terms of linear extension are higher in the warm fall months than in cooler spring months. Similarly, corals in the management area may exhibit slower growth rates than the same species in warmer climates.

Growth data for other shallow-water scleractinians (brain corals and finger corals) has been summarized by Bright, et al. (1981) and Gladfelter, et al. (1978). Generally, growth rates for these species are only ten to 20 percent that of *Acropora spp*.

Most growth rates for *Montastraea, Porites*, and *Diploria* are less than 10 mm (0.2 in) per year, excepting the work of Lewis, et al. (1968) in the Caribbean. Rates between geographic areas are more consistent than observed in *Acropora*. Also, rates recorded by Gladfelter, et al. (1978) at the backreef (2 m) and deep forereef (10 m) of Buck Island, Virgin Islands, indicated that depth did not affect growth; both portions of the reef had identical average growth rates of 7.6 mm (0.3 in per year based on colonies ranging in size from 9.63 cm2 to 138 cm2 (1.5 to 23 in2). Highest density bands of *Montastraea annularis* seem to be deposited in the warmest months of the year (Hudson, et al., 1976).

Although not quantified, several references to *Millepora* and *Manicina aereolata* growth rates have conveyed the preliminary conclusion that growth rates on suitable hard surfaces are quite high. Recently discarded bottles, rocks, and other debris may be covered by *Millepora alcicornis* or other stinging corals within several months to a year. Prior to the existing Florida coral law, several collectors have suggested rapid recolonization in the rose coral *M. aereolata* in Florida Keys waters. Limited data indicate that growth may be rapid in the first three to four years and much slower thereafter (Vaughn, 1911, 1916).

Data on growth rates of deepwater scleractinians within the management area are practically nonexistent. In general, growth rates observed in these limited reports are significantly lower than growth rates reported above for shallow-water corals in the management area.

3.3.7.4.2 Mortality Rates

Most of the information on natural or human-related mortalities of corals in the management area is in accounts of destruction related to storms, groundings, etc. These qualitative reports relay limited information on death of a coral area (e.g., "many head corals near the grounding were overturned and smashed") and occasionally certain species (e.g., "the 13°C water killed 90 percent of the staghorn corals, *Acropora cervicornis*, at Dry Tortugas," Davis, 1979, personal communication). Such conversational data represents the best available information. General aspects of coral mortality are discussed in the work of Antonius (1975, 1976, 1977, and in press).

One quantitative study was that of Antonius, et al. (1978) at Looe Key, Florida. Dive transects and inspections of the reef-building corals were transformed in to a "percent dead" number: patch reefs (ten percent); reef flat (25 percent); fore reef (ten percent); and deep reef (22 percent). The total at the Looe Key study area was 13 percent dead. These data are presented by species in the report.

Grigg (1976) calculated the annual instantaneous natural mortality rate of pink coral (*Corallium secundum*) in the Makapuu Bed off Hawaii to be 0.066 or 6.6 percent.

Natural massive mortalities of staghorn coral (*Acropora cervicornis*) at Dry Tortugas have been observed on two occasions: 1878 when nearly 100 percent of the colonies died because of unidentified "black water" (Vaughan, 1911) and in 1976 to 1977, when a winter cold front killed about 90 percent of the staghorn corals (Davis, 1979, personal communication).

The work of Jaap (1979, personal communication) at Biscayne National Park also provides some insight into coral mortalities. By measuring recruitment, Jaap quantified net changes in 4 m^2 quadrats. Negative net changes show mortality. Gain and loss in corals in fixed station quadrats must be qualified. Loss and gain in many cases is not a case of larval settlement and death. In shallow depths, storms dislodge corals and transport them to areas outside or within the sampling station. These individuals often survive the dislodgment by a process called fragmentation recruitment.

3.3.7.4.3 Abundance and Density

Calculations of the total amount of percent coverage of corals in the management area in the 1980's was estimated by extrapolating from small scattered studies. Jaap and Wheaton at Biscayne National Park, provided some percent coverage data however, their data were not representative of the entire management area. The EPA coral hardbottom monitoring project encompasses 40 sampling sites from Key Largo to Key West. This project has begun analyzing percent cover for stony corals, octocorals, sponge and macroalgae at these sites (Wheaton et al., 1996).

Qualitative statements on the distribution and abundance of corals may be made. Coral reefs are very limited in distribution, perhaps to less than one percent of the total management area; patch reefs cover slightly more area than outer bank reefs. Deepwater banks again account for less than one percent, probably less than the coral reefs. Most of the corals in the management area occur in hard bottom areas or as solitary specimens.

3.3.7.4.3.1 Octocorals

Wheaton (unpublished and 1987), Opresko (1973), and Goldberg (1973a), detailed abundance and diversity for octocorals in the southeastern Florida and Florida reef tract areas. Very limited information exists for the remainder of the management area.

At four pairs of reefs in Biscayne National Park Wheaton (unpublished) surveyed octocoral abundance and density by transect, species count, and photographic analysts. Octocoral colonies usually comprised more than half of the total coral colonies. The five most abundant species (53.9 percent of total octocorals) were *Plexaura flexuosa*, *P. homomalla*, *Gorgonia ventalina*, *Eunicea succinea*, and *Pseudopterogorgia americana*.

Mean numbers of octocoral colonies counted along a 20 m (66 ft) transect of the eight reefs were 102.81 and 155.17 (Wheaton unpublished). In 1977, as counts per quadrat, were 27.41 colonies/m^2 (range 16.00 to 46.50); in 1978, photo plot counts were 26.28 colonies/m^2 (range 9.75 to 50.00).

Opresko (1973), based on field studies at Soldier Key, Boca Chica Pass, and Red Reef, calculated mean densities of gorgonians of 11.3, 6.9, and 27.1/ m^2 respectively. Most common genera at the three areas were *Eunicea, Pterogorgia, Pseudopterogorgia, Briareum,* and *Plexaura.*

The only other density information for octocorals is from off; Palm Beach County, Florida. Goldberg (1973) reported an average density of 25.1 colonies/m2. No data were given on abundance in that area.

3.3.7.4.3.2 Stony Corals

Data on abundance and density of stony corals in the management area were presented in Jaap (unpublished). Stony corals comprised only about 21 to 22 percent of the coral biota at eight reefs in Biscayne National Park. The most common five species were *Porites astreoides*, *Millepora alcicornis*, *Porites porites*, *Montastraea annularis*, and *Siderastrea siderea*. Based on 25 m (80 ft) diver transects, stony coral abundance at the Biscayne reefs in 1977 and 1978 averaged 25.06 and 26.95 colonies, respectively.

Stony coral densities were 7.53 colonies/ m^2 in 1977 (quadrant sampling; range O to 23) and 6.16 colonies/ m^2 in 1978 (photographic analysis; range 2 to 16).

3.3.7.4.4 Diversity

3.3.7.4.4.1 Octocorals

Data on diversity was done by Wheaton (unpublished) in Biscayne National Park. Highest octocoral diversities along a single 20-m (66-ft) transect were 3.2 at Schooner Reef Control in 1977 and 3.98 at the same reef in 1978. All calculations using the H'n Shannon-Weaver species diversity index were relatively high, mostly above 3.00. Diversities of octocorals reported for Looe Key (Wheaton, 1988) ranged from 1.19 (on the reef flat) to 3.72 (back reef).

3.3.7.4.4.2 Stony Corals

Species diversity for stony corals at Biscayne National Park was comparably lower than that for octocorals (Jaap, 1979). Whereas many transects revealed octocoral diversities of over 3.00, the highest stony coral diversities (Shannon-Weaver H'n) were 2.80 at Star Reef in 1977, 3.33 at Dome Reef in 1978, and 3.06 at Schooner Reef in 1979; diversity values remained under 3.00 in all but four cases for the three years combined. Compared to other regions (see Loya, 1972; Porter, 1972; Ott, 1975), these diversities are low for stony corals. H'n ranged from 0.47 to 3.06, H'max from 1.58 to 3.46, evenness J' from 0.30 to 0.94.

3.3.7.4.5 Age

Age data on corals include scattered reports on the age of living corals and relic reefs. In the relic reefs underlying the Florida reef tract, Shinn, et al. (1977), calculated accumulation rates and ages (+ standard deviation) by Carbon-14 dating of drill cores from six reef sites identified below.

These data confirm the thickness and ages of coral rock in relic reefs. The corals present varied between sites but included *Siderastrea, Montastraea annularis, M. cavernosa, Colpophyllia*, and *Diploria*. *Acropora palmata*, long considered a major reef-builder in Florida, was absent in most reefs drilled.

Shinn (1979), in a coring survey at the Grecian Rocks off Key Largo, stated that the growth rates of *Montastraea sp.* indicate 1 m (3.3 ft) of upward growth in less than 150 years.

In Makapuu Bed, Hawaii, the Western Pacific Fishery Management Council (1979) calculated the "critical age" at which coral growth gains are overtaken by natural mortality losses. For the pink coral (*Corallium secundum*), that age was 31.4 years, which corresponds to an average colony weight of 237 g (8.2 oz.).

Site	**Accumulation Rate** (m/1,000 yrs)	**Age** (yrs)
1. Bal Harbor	0.38	6,300 + 120
2. Sewer Trench	0.74	4,930 + 70
3. Long Reef	0.65	5,630 + 120
4. Carysfort Reef		
- 4.0 m depth	0.86	4,570 +85
- 7.3 m depth	1.39	5,250 +95
5. Marker G Reefs		
- 3.1 m depth	0.49	6,170 +80
- 4.6 m depth	0.56	7,160 +85
- 8.2 m depth	-	37,480 + 1,300
6. Ft. Jefferson National Monument (Dry Tortugas)		
- 9.1 m depth	1.91	4,762 + 85
-13.7 m depth	2.28	6,017 +90

3.3.7.4.6 Reproduction and Recruitment

Reproductive and recruitment capabilities of corals in the management area have been studied at Biscayne National Park. Research quantified changes in marked plots between the summers of 1978 and 1979 (Jaap, 1979). Results were variable, ranging from an addition of 34 colonies at Elkhorn Plot 1-7 or five species at Elkhorn Plot 1-9 to a loss of ten colonies at Star Plot 3-7 or four species at Elkhorn Plot 1-4. Generally, recruitment did not appear to differ between control and experimental reefs. However, some plots (e.g., Elkhorn Controls 1-6 to 1-9) did have exceptionally high changes.

Mass spawning in corals has been observed by divers in late August, early September in Florida Keys and Dry Tortugas reefs.

Pink corals in Hawaiian waters apparently reach sexual maturity at a height of about 12 cm (4.7 in) or an age of 13 years (Grigg, 1976). The reproductive cycle is annual with spawning taking place in June and July.

Based on the assumption of steady state recruitment of the Makapuu Beds off Hawaii (Western Pacific Fishery Management Council, 1979), an estimate of recruitment was obtained by calculating the quantity of coral lost via mortality. In a system in equilibrium, the rates should be equal. The estimate of annual recruitment to Makapuu for pink coral was 5,227 colonies (Western Pacific Fishery Management Council, 1979). Fluctuations between year classes are probable. There is some indication that the assumption of an equilibrium state may not be valid in coral reefs.

3.3.7.4 Distribution

Data on the areal distributions of corals in the management area have become available through GIS. Previously isolated collection records pinpointed locations of certain species but conveyed little information on the area of stony coral beds. However paucity of abundance data in many regions prevents a realistic calculation of standing stock and biomass.

3.3.7.5 Probable Future Conditions

The information available on productivity and health (see Sections 3.3.7.4 and 3.2.1.1.1) enable several cursory statements to be made:

1) Coral growth rates are so slow in most species that recovery rates following large-magnitude harvest, human impact, or natural stresses are far slower than observed in most other living resources. In most respects many corals may be considered as a nonrenewable resource.

2) Human impacts that have been identified as possible limiting factors in coral health do not appear to be subsiding. Many chronic problems such as shipping bilge discharges, industrial and recreational pollution, and sewage have not subsided since the implementation of the original fishery management plan.

3) Natural stresses continue to act on portions of the management area where species occur at or near their geographical limits.

Despite the data gaps already mentioned, several recent efforts have generated preliminary data for use in indicating any future trends. Coring studies at Key Largo National Marine Sanctuary indicate that coral growth rates have increased in the past decade (Hudson, 1981). Whether or not that improvement is attributable to management practices is masked by the discovery by Hudson in the same study that cyclical coral growth may be normal.

Studies at Biscayne National Park have shown concentrated damage to coral immediately adjacent to several mooring buoys (Tilmant, 1979, personal communication). The variability in apparent impact was summarized as total counts of corals and diversities between buoyed and control plots which revealed no pattern in all 24 sampled plots. Perhaps the approach of directing users to particular areas may be detrimental to objectives of preserving corals. Conversely, limited damage in high use areas; may decrease damage to other areas and enhance overall coral management efforts. Quantifying these impacts is difficult.

One future determinant of coral health in the management areas is the status of stocks in nations that export corals to the United States, i.e., the Philippines and a few others. The possibility that coral exports from other countries may be curtailed or even stopped could redirect resource pressures to domestic stocks.

To allow a realistic assessment of future conditions, it appears mandatory that a multiyear survey of coral growth, stress factors, and management practices be initiated on a species- and area-specific basis. These data are a minimal base from which estimates of future conditions could be made and supported.

The fishery for snapper and grouper introduced various types of bottom fishing gear directed at those fish closely associated with hard bottoms and reefs. Roller trawls, bottom longlines, and fish traps are now prohibited for use in this fishery due to potential for bottom damage when fishing in close proximity to coral, coral reefs, or live/hard bottom. Some gear may also be lost when it becomes entangled in coral and continue to ghost fish. The competition among fishermen for a finite resource has increased fishing effort in all areas thus increasing the incidental damage to corals and coral reefs. Similarly the high recreational fishing level increasingly subjects coral bottoms to injury from anchoring by small boats and vessels.

Octocorals (other than reticulate sea fans) are being harvested for aquarium use off Florida without apparent damage to the stocks. Because they are a rich source of marine medical products, the possibility exists for harvest of substantial amounts for experimental or even commercial purposes. One American pharmaceutical company estimated its annual need to be ten tons per year of *Plexaura homomalla* for use in extraction of prostaglandin for medical research prior to the synthesis of the desired hormones. The stocks can most likely provide adequate material for experimental research purposes, but may not be able to sustain an extended commercial market should one develop. In either case, local depletion could occur as the result of localized harvest of large numbers of colonies.

3.3.7.6 Essential Fish Habitat for Coral, Coral Reefs and Live/Hard Bottom

Essential fish habitat for corals (stony corals, octocorals, and black corals) must incorporate habitat for over 200 species. EFH for corals include the following:

A. Essential fish habitat for hermatypic stony corals includes rough, hard, exposed, stable substrate from Palm Beach County south through the Florida reef tract in subtidal to 30 m depth, subtropical (15°-35° C), oligotrophic waters with high (30-35 $^{o}/_{oo}$) salinity and turbidity levels sufficiently low enough to provide algal symbionts adequate sunlight penetration for photosynthesis. Ahermatypic stony corals are not light restricted and their essential fish habitat includes defined hard substrate in subtidal to outer shelf depths throughout the management area.

B.Essential fish habitat for *Antipatharia* (black corals) includes rough, hard, exposed, stable substrate, offshore in high (30-35 $^{o}/_{oo}$) salinity waters in depths exceeding 18 meters (54 feet), not restricted by light penetration on the outer shelf throughout the management area.

C. Essential fish habitat for octocorals excepting the order Pennatulacea (sea pens and sea pansies) includes rough, hard, exposed, stable substrate in subtidal to outer shelf depths within a wide range of salinity and light penetration throughout the management area.

D.Essential fish habitat for Pennatulacea (sea pens and sea pansies) includes muddy, silty bottoms in subtidal to outer shelf depths within a wide range of salinity and light penetration.

3.3.7.7 Essential Fish Habitat - Habitat Areas of Particular Concern for Coral

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for coral, coral reefs, and live/hard bottom include The 10-Fathom Ledge, Big

Rock, and The Point (North Carolina); Hurl Rocks and The Charleston Bump (South Carolina); Gray's Reef National Marine Sanctuary (Georgia); The *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; Oculina Banks off the east coast of Florda from Ft. Pierce to Cape Canaveral; nearshore (0-4 meters; 0-12 feet) hard bottom off the east coast of Florida from Cape Canaveral to Broward County); offshore (5-30 meter; 15-90 feet) hard bottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary.

3.3.8 Calico Scallops

3.3.8.1 Description and Distribution of the Species

The calico scallop, *Argopecten gibbus*, occurs most often at moderate depths of 18-73 m (59-240 ft) and restricted generally to the continental shelf of the western North Atlantic and Gulf of Mexico between about 35˚ N and 20˚ N latitude (Broom, 1976). Identification of calico scallops can be made from shell color and morphology. The upper (left) valve has red or maroon calico markings over a white or yellow base; the lower (right valve) is more lightly pigmented. The calico markings on the shell distinguish this scallop from the solid gray or brown upper valve of the bay scallop, which resembles the calico scallop in size. Calico scallop shell morphology varies with locality, but generally the species reaches 40 to 60 mm (1.6-2.4 in) in shell height (a straight line measurement of the greatest distance between the umbo and the ventral margin), with a maximum size reported to be about 80 mm (3.2 in) in shell diameter (a straight line measurement of the greatest distance between the anterior and posterior margin) (Roe et al., 1971). The shells are almost equally convex, deeply ridged, with 17 to 23 ribs on the right valve (Allen and Costello, 1972).

Calico scallop, *Argopecten gibbus*

The calico scallop ranges from the northern side of the Greater Antilles, throughout the Gulf of Mexico, to Bermuda and slightly north of Cape Hatteras (possibly Delaware Bay) in waters varying from 2 m (6.6 ft) at Bermuda to 370 m (1,214 ft) on the northern side of the Greater Antilles (Allen and Costello, 1972). Off the Florida east coast, depth of occurrence was 9 to 74 m (30-243 ft) while off North Carolina, south of Cape Hatteras, calico scallops were reported at depths of 13 to 94 m (43-308 ft) (Allen and Costello, 1972). Roe et al. (1971) reported depth distributional differences off Florida, noting scallops south of Cape Canaveral were generally found in shallower water than north of the Cape. However, Sutherland (unpublished report) reported that scallop beds located north of Cape Canaveral were not always found in deeper water than those south of the Cape. The beds usually occur in open marine water rather than estuarine areas (Waller, 1969).

Calico scallop beds are generally distributed on the continental shelf parallel to the coastline. These beds are most abundant off Cape Lookout, North Carolina; Cape Canaveral, Florida; and Cape San Blas, Florida, in the northeastern Gulf of Mexico. On the Cape Canaveral grounds, scallops occur in long narrow bands, or beds, more than 800 m (2,625 ft) long and several hundred meters wide. A calico scallop bed near Cape Lookout, North Carolina, was elliptical and 15 km (9.3 mi) long. Off Cape San Blas, in 1957, a bed 16 km (9.9 mi) long by 8-16 km (5.0-9.9 mi) wide was located (Bullis and Ingle, 1959). The greatest concentrations of these scallops appeared to be near coastal prominences (Allen and Costello, 1972).

Populations of calico scallops were located in 1977 offshore of the South Carolina/Georgia border in 37-45 m (121-148 ft) (Anderson and Lacey, 1979). The scallop bed was elliptically shaped and oriented perpendicular to the coast.

Maturity in Atlantic calico scallops is correlated with age rather than size (Roe et al., 1971). Scallops may spawn intermittently many times during the spawning season. No data on fecundity of Atlantic calico scallops was located. Water temperatures may stimulate spawning. Atlantic calico scallops are hermaphroditic, ejecting first sperm and then eggs into the water where fertilization occurs. Part of the North Carolina Atlantic calico stock may result from larvae transported northward from the Cape Canaveral grounds by the Gulf Stream. However, oceanographic data suggest that most larvae would be retained at Cape Canaveral. Larvae settle as spat in 14 to 16 days and attach to substrates with byssal threads from the foot. Spat attach to navigation buoys, other floating objects, and dead or living mollusk shells. The spat remain attached until they reach about 2.5 cm (1 in) shell height; they then detach and can swim. Small scallops swim more readily, and adult scallops can swim 30 cm (1 ft) with one squirt (Allen and Costello, 1972). Unattached scallops have been reported from hard sand, sand with shell, and a smooth sand-gravel-shell substrate. They reach commercial shell height of 4 to 4.5 cm (1.6 to 1.8 in) in 6 to 8 months, and have a life span averaging only 18 to 20 months, with a maximum of 24 months(Allen and Costello, 1972). Monthly mortality is about 12 to 23 percent, and varies seasonally (Roe et al., 1971). Disappearance of Atlantic calico scallops from a particular area commonly occurs, and the size of the stock shows considerable annual fluctuations. Declines and mass mortalities have occurred on the grounds off North Carolina. Possible causes include migration, poor larval transport from elsewhere, and increased fishing pressure following introduction of shucking and eviscerating machines. Spawning stock is maintained because (1) not all beds are harvested each year; (2) the spawning stock includes scallops too small to market; and (3) individuals at densities too low to harvest. Atlantic calico scallops filter small particles such as unicellular algae from the water as food. Predators on juvenile and adult scallops include seastars, gastropods, squid, octopus, crabs, sharks, rays, and bony fishes.

Substrates required by calico scallops vary with scallop size. Under natural conditions, the spat usually attach to dead or living mollusk shells (Allen and Costello, 1972). However, spat has been found attached to navigation buoys (Waller, 1969) and plastic floats (Pequegnat et al., 1967). Allen (1979) reported that young calico scallops attach to a variety of materials in addition to calico scallop shells. Young scallops were found among attached hydroids, but it was not determined that spat attach to hydroids or erect bryozoans before attaching to shell. The dependence of spat on shell for setting and survival has not been studied.

Larger, unattached scallops have been reported from bottoms of hard sand (Rivers, 1962), sand and shell (Cummins et al., 1962), quartz sand (Hulings, 1961), smooth sand-shell-gravel (Struhsaker, 1969), and sand and dead shell (Drummond, 1969). Sutherland (unpublished report) described the environment of the scallop grounds off Cape Canaveral as consisting of shell fragment sands predominantly. Shelf sediments off Cape Canaveral average 60 percent calcium carbonate content; conversely, shelf sediments off Georgia average only 10 percent. High carbonate sediments off Cape Canaveral lie along the western boundary of the northerly flowing Gulf Stream and southern flowing counter currents.

Salinities of areas where calico scallops occur range between 31‰ and 37‰. However, in the laboratory at Florida State University, small scallops taken from waters off Panama City, Florida, have been grown at a salinity range of 25‰ to 30‰ (R.W. Menzel, Fla. State Univ., Tallahassee, Fla.; pers. comm.).

Depths of the heaviest concentrations of calico scallops off Cape Canaveral from 1960-1967 ranged from 26-49 m (85-161 ft), as recorded by exploratory fishing cruises (Miller and Richards, 1980). The most productive area of the shelf in the South Atlantic Bight for calico scallops occurs in the open shelf zone at 33-40 m (108-131 ft), an area with stable warm temperatures (Miller and Richards, 1980). Inshore waters (to 18 m or 59 ft) are cooled below 15˚C (59˚F), and offshore waters (55 m or 180 ft) are subjected to cold water intrusions off Cape Canaveral, Florida, leaving the intermediate shelf zone with warm temperatures (Miller and Richards, 1980). This warm shelf zone had temperatures ranging from 20˚ to 23˚C (68˚-73˚F) during February-March 1973 and was bounded on both sides by colder water (Mathews and Pashuk, 1977). Deep, cold water intrusions may have favorable impacts on calico scallops by initiating spawning and producing an abundance of phytoplankton for food, or unfavorable impacts by lowering temperatures below 15˚C (59˚F), causing mortalities of scallops (Miller et al., 1981). Off Cape Canaveral, bottom temperatures ≤ 15˚C (59˚F) occurred in depths as shallow as 40 m (131.2 ft) (Leming, 1979).

Relative abundance of the calico scallop varies with scallop size both within and between areas, seasonally and annually. They are generally most abundant off the Florida east coast near Cape Canaveral, with lesser concentrations near Cape Lookout, North Carolina and Cape San Blas, Florida. Concentrations have also been reported from the eastern Gulf of Mexico between Sanibel Island and Dry Tortugas, and 96.5 km (60 mi) offshore of the South Carolina/ Georgia border. Scallop abundance fluctuates at each area, with good years followed by years when none are available.

The Cape Canaveral scallop grounds are among the largest in the world, extending over 321.8 km (200 mi) from St. Augustine to near Stuart, Florida. Sutherland (unpublished report) made estimates of the calico stock distribution and abundance from data obtained with RUFAS (to visually capture the scallop resource) and tumbler dredges (to obtain samples). He found the bed width was highly variable and ranged from 6.7 to 2,633.5 m (22 to 8,640 feet). Juvenile calico scallop beds in 1970 surveys accounted for almost 4 percent of scallop distribution. Scallop occurrence was uniformly less than 4 percent of completed transect miles.

Figures 51a and 51b were provided by representatives of the calico scallop industry during scoping meetings and public hearings on calico scallop management and present recent calico scallop harvest areas/distribution, spawning locations, and shell distribution off southeast Florida. Additional information on calico scallop biology, harvest and distribution is presented in the Calico Scallop Fishery Management Plan (SAFMC, 1998e)

3.3.8.2 Essential Fish Habitat for Calico Scallops

The essential fish habitat for calico scallops is the unconsolidated sediments including hard sand bottoms, sand and shell hash, quartz sand, smooth sand-shell-gravel, and sand and dead shell in 43-308 ft (13 - 94 m) with concentrations occurring on the Cape Canaveral grounds (Stuart to St. Augustine, Florida) and sporadically occurring northeast and southwest of Cape Lookout, North Carolina in 62-102 ft (19 - 31 m), and offshore of the South Carolina/Georgia border in 121-148 ft (37-45m). In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse calico scallop larvae.

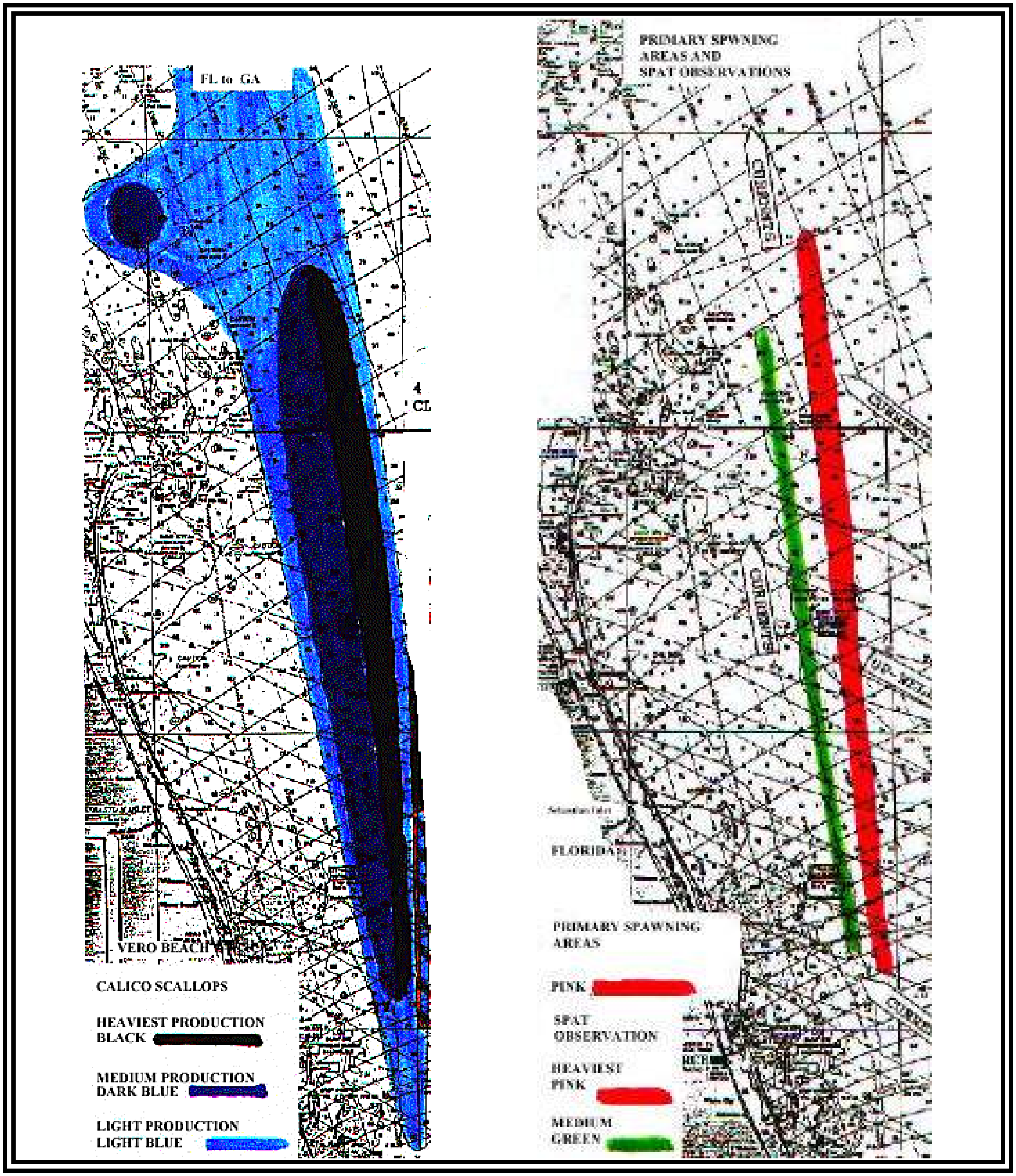


Figure 51a. Calico scallop spawning areas and fishing grounds (Source: William Burkhardt, Calico Scallop Advisory Panel.)

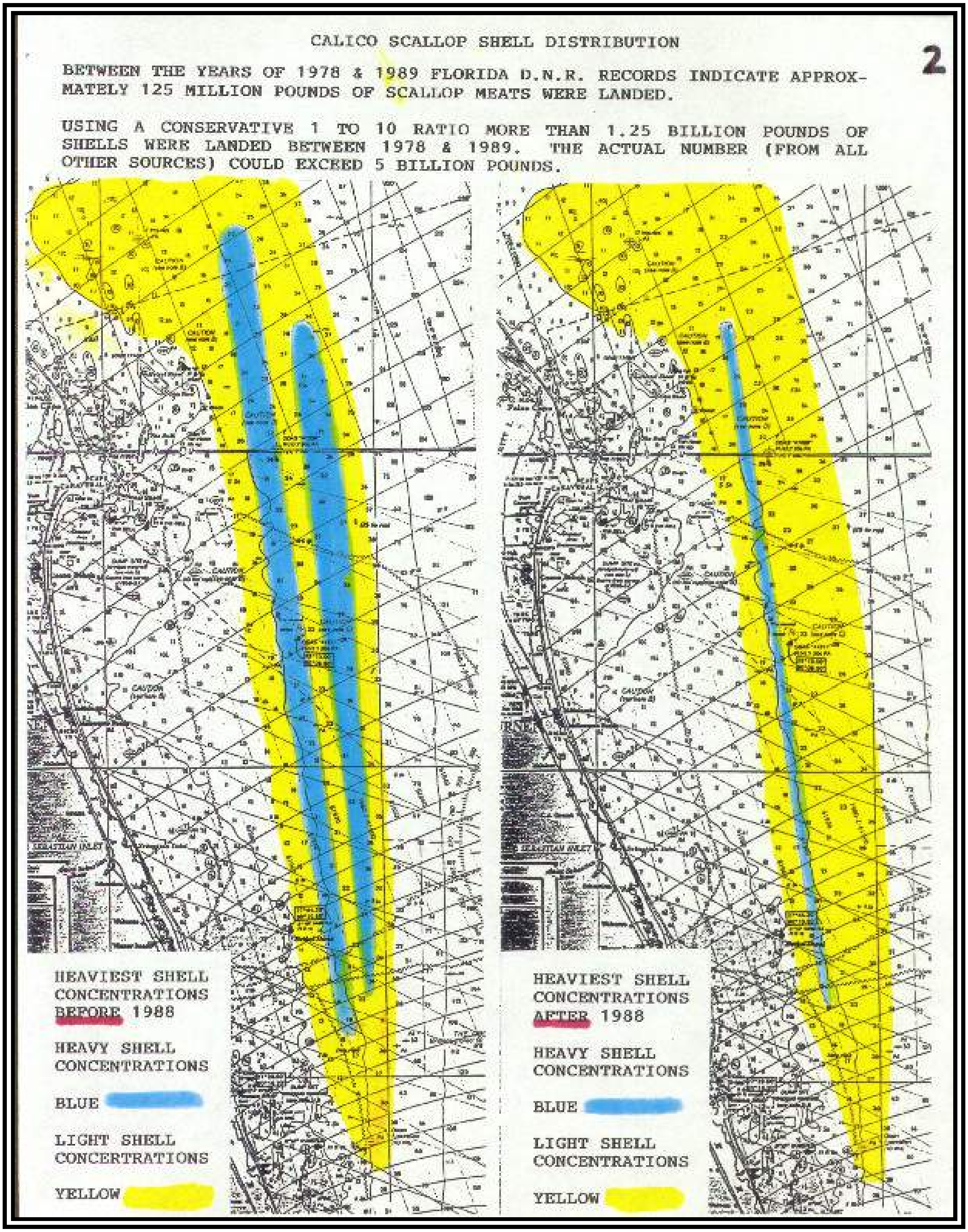


Figure 51b. Calico Scallop shell distribution (Source: William Burkhardt, Calico Scallop Advisory Panel.)

3.3.9 *Sargassum* Habitat

3.3.9.1 Description of the Species, Distribution and Environmental Requirements

See Section 3.2.3.1.1 and the Sargassum Fishery Management Plan (SAFMC 1998d) for a detailed description of Sargassum as essential fish habitat.

3.3.9.2 Essential Fish Habitat for *Sargassum*

Essential fish habitat for pelagic *Sargassum* is where it occurs in the EEZ and state waters. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse *Sargassum*.

Because of the importance of the extra-jurisdictional pelagic *Sargassum* occurring in the Sargasso Sea outside the EEZ, the United States should pursue all other options under the Magnuson-Stevens Act and other laws to protect *Sargassum* in international waters.

3.3.9.3 Essential Fish Habitat - Habitat Areas of Particular Concern for Sargassum

Establish the following areas as Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPCs) for pelagic *Sargassum*: The distribution of pelagic *Sargassum* within the South Atlantic Council's EEZ and state waters (all essential fish habitat).

3.3.10 Other Managed Species use of Essential Fish Habitat

The descriptions of the essential fish habitat types presented in Sections 3.1, estuarine habitats, and 3.2, offshore marine habitats, identify many species managed by other regional, Federal or State authoritues. For example bluefish, and summer flounder are identified in many of the habitats described in the South Atlantic region. In addition, highly migratory pelagic resources including the tunas, billfish, sharks and swordfish (list below) use pelagic habitats identified as essential fish habitat in the South Atlantic.

Highly Migratory Pelagic Species in Secretarial FMPs:

Swordfish
swordfish, *Xiaphias gladius*
Atlantic Tunas
western Atlantic bluefin, *Thunnus thynnus*
Atlantic bigeye, *T. obesus*
Atlantic yellowfin, *T. albacares*
Albacore, *T. alalunga*
Skipjack, *Katsuwonus pelamis*
sevengill shark, *Heptranchias perlo*
SMALL COASTAL SHARK SPECIES:
Angel sharks - Squatinidae
Atlantic angel sharks, *Squatina dumerili*
Hammerhead sharks - Sphyrnidae
bonnethead, *Sphyrna tiburo*
Requiem sharks - Carcharhinidae
Atlantic sharpnose shark, *Rhizoprionodon terraenovae*
blacknose shark, *Carcharhinus acronotus*
Caribbean sharpnose shark, *Rhizoprionodon porosus*
finetooth shark, *Carcharhinus isodon*
smalltail shark, *Carcharhinus porosus*

Atlantic Billfishes
sailfish, *Istiophorus platypterus*
white marlin, *Tetrapturus albidus*
blue marlin, *Makaira nigricans*
longbill spearfish, *Tetrapturus pfluegeri*
PELAGIC SHARK SPECIES:
Cow sharks - Hexanchidae
bigeye sixgill shark, *Hexanchus vitulus*
sixgill shark, *Hexanchus griseus*
Mackerel sharks - Lamnidae
longfin mako, *Isurus paucus*
porbeagle shark, *Lamna nasus*
shortfin mako, *Isurus oxyrinchus*
Requiem sharks - Carcharhinidae
blue shark, *Prionace glauca*
oceanic whitetip shark, *Carcharhinus longimanus*
Thresher sharks - Alopiidae
bigeye thresher, *Alopias superciliosus*
thresher shark, *A. vulpinus*

Highly Migratory Pelagic Species in Secretarial FMPs (cont.)

LARGE COASTAL SHARK SPECIES:

Basking sharks - Cetorhnidae
basking shark, *Cetorhinus maximus*
Hammerhead sharks - Sphyrnidae
great hammerhead, *Sphyrna mokarran*
scalloped hammerhead, *S. lewini*
smooth hammerhead, *S. zygaena*
Mackerel sharks - Lamnidae
white shark, *Carcharodon carcharias*
Nurse sharks - Ginglymostomatidae
nurse shark, *Ginglymostoma cirratum*
Requiem sharks - Carcharhinidae
bignose shark, *Carcharhinus altimus*
blacktip shark, *C. limbatus*
bull shark, *C. leucas*
Caribbean reek shark, *C. perezi*
dusky shark, *C. obscurus*
Galapagos shark, *C. galapagensis*
lemon shark, *Negaprion brevirostris*
narrowtooth shark, *Carcharhinus brachyurus*
night shark, *C. signatus*
sandbar shark, *C. plumbeus*
silky shark, *C. falciformis*
spinner shark, *C. brevipinna*
tiger shark, *Galeocerdo cuvieri*
Sand tiger sharks - Odontaspididae
bigeye sand tiger, *Odontaspis noronhai*
sand tiger shark, *Odontaspis taurus*
Whale sharks - Rhinocodontidae
whale shark, *Rhinocodon typus*

3.3.11 Anadromous and Catadromous Species use of Essential Fish Habitat

The South Atlantic Fishery Management Council decided, at its March 5, 1998 meeting, to include a description of habitats used by anadromous and catadromous species in the South Atlantic in the Habitat Plan. The Council noted, in so doing, that the Magnuson-Stevens Act requires Councils to comment on projects proposed for authorization by federal or state governments which have the potential to effect habitats, including essential fish habitats, of anadromous species. The Final Rule for Essential Fish Habitat, for the purpose of compliance with the Magnuson-Stevens Act, defined anadromous species under the authority of the Council as those which inhabit the EEZ for any portion of their life cycle. This section therefore describes the species which occur in the South Atlantic waters of the EEZ, and which are therefore deemed to be under the authority of the Council at some life stage. This text describes the species which occur, their distribution, and the habitats which they use, including those which would be defined as Essential Fish Habitat if there was a Council plan for amendment. Information in the accounts for these species is taken largely from the U.S. Fish and Wildlife Service/U.S. Army Corps of Engineers Species Profiles report series, and from the Atlantic States Marine Fisheries Commission Fishery Management Plans and stock assessment documents or National Marine Fisheries Service Recovery Plan for the shortnose sturgeon. These references are cited in the individual accounts for each species.

3.3.11.1 Alewife

The alewife (*Alosa pseudoharengus*) is a moderate-sized member of the clupeid (shads and herrings) family which is an important forage species for both Council-managed (bluefish) and Atlantic States Marine Fisheries Commission-managed (weakfish and striped bass) species. Its normal life history is that of an anadromous form, in which adults spawn in the spring in coastal rivers, and juveniles return to the ocean to grow and mature. It has also been widely stocked in inland freshwater lakes and reservoirs where it lives and reproduces entirely in freshwater and serves as a prey base for game fish such as largemouth bass, striped bass and catfish. The species is under the management of the Atlantic States Marine Fisheries Commission.

3.3.11.1.1 Description of the Species and Distribution

The alewife is a moderate-sized member of the herring family, with a grey to grey-green back and silvery sides. They range in size from about 230 mm (9 in) to over 330 mm (13 in). Alewives begin spawning at age three, have usually spawned once by age four, and have all spawned by age five. Fecundity in females ranges from 60,000 to 100,000 eggs (Fay et al. 1983). Spawning populations are younger in the south, with fish in North Carolina being primarily age three, and none older than age four. The percentage of repeat spawning is also less than 10 percent in NC (Fay et al. 1983). Spawning occurs in the spring, started earlier in the south and later in the north. Alewives generally spawn 3-4 weeks before blueback herring in areas where the two species co-occur. Alewives begin spawning at minimum water temperatures of 10.5° C (51° F) and select a wide variety of spawning sites. Eggs of alewife hatch at approximately 50 to 360 hours, depending upon temperature. The alewife yolk-sac stage lasts from 2-5 days. Larval alewives range in size from 4.3 to 19.9 mm (0.2-0.8 in). Transformation to the juvenile stage occurs at about 20 mm (0.8 in). Like juvenile blueback herring, juvenile alewives may initially exhibit upstream movement, later moving downstream as fall approaches. Emigration occurs between June and November of the first year of life. Emigration of juvenile alewives may be stimulated by heavy rainfall, high water, and sharp declines in water temperatures. Adult alewives were sampled offshore during National Marine Fisheries Service trawl surveys. The majority of catches occurred in less than 100 m (328 ft). Alewives were more abundant than blueback herring when all samples were combined. Alewives were most abundant at depths between 56 and 110 m (184 and 361 ft). Catches of the species were confined to areas north of 40 degrees north latitude in summer and fall. Winter catches were between 40 and 43 degrees north latitude. Spring catches were distributed over the entire Continental Shelf. Alewives primarily consume zooplankton, although fish eggs, crustacean eggs, insects, insect eggs and small fishes may be eaten in some areas or by larger individuals.

The alewife is reported to range from Newfoundland south to South Carolina. However, surveys conducted by Rulifson et al. (1982) in 1980 and repeated 12 years later (Rulifson 1994) indicate that the species occurs in coastal rivers only in the NC portion of the Council's area of jurisdiction, although it could occur offshore of other South Atlantic states in waters of the EEZ. In North Carolina, populations were reported in the North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent Rivers (tributaries to Pamlico Sound); New River; Cape Fear, North East Cape Fear and Brunswick Rivers; and White Oak River. Status of these populations is presented in Table 4 of Rulifson (1992). All populations were listed as either "declining" or "status unknown" as of 1992.

3.3.11.1.2 Habitat and Environmental Requirements

Spawning habitats for alewives can vary from streams only a few meters (yards) wide to larger rivers. Although some authors have reported that alewives ascend further upstream than blueback herring, others believe that upstream distribution is a function of finding appropriate spawning habitats. Alewives use standing water, oxbow lakes and mid-stream areas as spawning sites, as well as coastal ponds with an open connection to the ocean. Optimum hatching temperature was 18° C (64° F). Temperatures below 10° C resulted in the absence of a functional jaw in alewives. Alewives apparently tolerate salinity changes well. In the South Atlantic Council's area of jurisdiction, alewife occur only in the coastal rivers and estuaries of North Carolina, and in the offshore marine areas as described above.

3.3.11.2 American Shad

The American shad (*Alosa sapidissima)* has long been viewed as the premier species of the shad and herring family, and has a long tradition of supporting both commercial and recreational fisheries along the east coast since the early 1800's. It was the most valuable food fish on the east coast prior to World War II. In recent years, the sport fishery for the species has become more important economically that the commercial fishery. The species is the target of major restoration programs in the northeast and is beginning to be the focus of such programs in the South Atlantic. The Atlantic States Marine Fisheries Commission management plan for the species is currently being amended.

3.3.11.2.1 Description of the Species and Distribution

The American shad is the largest member of the herring family (Facey and Van Den Avyle 1986). Large females may reach a total length of 600 mm (23.6 in) and a weight of 5.4 kg (11.9 lb). American shad have a greenish to bluish-metallic luster on the back and are bright silver on the sides. There is usually a dark spot on the shoulder, just behind the posterior edge of the gill flap, which may be followed by 3 to 27 smaller spots. American shad are believed to enter their natal streams to spawn, entering when water temperatures are between 10 and 15° C. The peak of spawning migration generally occurs progressively later in the year from south to north, with the earliest spawning migration in the St. Johns River, FL. Peak spawning occurs in mid-January to mid-February in FL, and may occur through mid-June in the Roanoke River, NC (Kim Sparks, Department of Zoology, NC State University, personal communication). Spawning usually occurs in fresh water over substrates of sand, gravel and mud, at water temperatures of 14 to 21°C. The range of fecundity is about 100,000 to 600,000 eggs per female. Most American shad from rivers in the South Atlantic die after spawning. There are some repeat spawners in South Atlantic river systems, with the percentage generally increasing from south to north. American shad eggs generally hatch in 4-6 days at 15-18 degrees C. Larvae are about 7-10 mm (0.3-0.4 in) long upon hatching, and absorb the yolk by the fifth day. Larvae develop into juveniles after 4-5 weeks at lengths of about 25 mm (1 in). Juveniles usually form schools and move downstream at rates dictated by water temperature and current velocity. They reside in the downstream portions of coastal rivers and their associated estuaries, migrating to sea at about 90 mm (3.5 in). Emigration usually begins when temperatures drop below 15.5° C. Juveniles migrate to the Bay of Fundy and then to the Gulf of Maine where they join the adults each summer. They probably move southward and spend the winter in the mid-Atlantic area. American shad become sexually mature at age 3-5 in North Carolina for males and ages 4-6 for females. Adults which survive spawning leave the rivers and move to the Gulf of Maine where they remain through the summer and early fall. They consume a variety of invertebrate organisms and may prey on small fishes in some areas. Juvenile shad consumed amphipods, aquatic insects and terrestrial insects.

According to the recent survey by Rulifson, (1994), American shad occur in the following South Atlantic river systems and their attendant estuaries: NC--North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (Albemarle Sound tributaries); Tar-Pamlico and Neuse Rivers (Pamlico Sound tributaries); New River; and Cape Fear, North East Cape Fear and Brunswick Rivers (Cape Fear River estuary); SC--Waccamaw, Little Pee Dee, Great Pee Dee and Black Rivers (Winyah Bay); Santee River, Cooper River and Ashley River (Charleston Harbor); Edisto, Ashepoo and Combahee Rivers (ACE Basin); Sampit River; Salkehatchie River; Lynches River and Savannah River; GA--Savannah, Ogeechee, Altamaha, Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL--St. Marys, Nassau, St. Johns, Pellicer and Tomoka Rivers.

3.3.11.2.2 Habitat and Environmental Requirements

American shad require spawning habitats in inland portions of coastal rivers with water temperatures of between 14 and 21° C, with appropriate substrates and current velocities. Juvenile shad can tolerate sharp salinity changes, which allows them to use both the fresh and saline portions of estuarine nursery areas. Adults typically remain in the estuarine portion of their natal systems for 2-3 days before moving upstream. Dissolved oxygen values of at least 4.0 mg/l are required in spawning areas and values below this level can result in mortality of eggs and larvae. Proper development of American shad requires water velocities that keep the eggs suspended in the water column. Spawning commonly occurs in velocities of 30.5 to 91.4 cm/sec (1-3 ft/sec). Preferred spawning habitats seem to be shallow areas dominated by sand or gravel substrates. At sea, adults appear to prefer depths of 50-100 m, in the areas noted above.

3.3.11.3 Atlantic Sturgeon

The Atlantic sturgeon (*Acipenser oxyrinchus*) is currently the subject of a major amendment to the Atlantic States Marine Fisheries Commission's management plan for the species (Atlantic Sturgeon Plan Development Team 1998), a new stock assessment (Kahnle et al. 1998), and a Status Review conducted by the National Marine Fisheries Service and U.S. Fish and Wildlife Service (Atlantic Sturgeon Status Review Team 1998). The species is the largest fish to inhabit freshwater on the east coast(Van Den Avyle 1984), and historically formed the basis of significant subsistence and commercial fisheries. Stocks are depressed range wide, and a moratorium on possession of the species is in effect in state waters and is being recommended for federal waters.

3.3.11.3.1 Description of the Species and Distribution

Atlantic sturgeon are one of two species of anadromous sturgeon which occur on the east coast of the United States. Historically, the species was abundant in most large coastal rivers. It has a long slender body with five rows of bony plates, called scutes, which give it the appearance of being armored. Larger individuals develop relatively shorter snouts, smooth scutes from wear, and the lower lobe of the caudal fin becomes relatively longer. Atlantic sturgeon females historically grew to great sizes, with one reportedly 427 cm (14 ft) in length and weighing 368 kg (811 lbs). Sexes are indistinguishable except during the spawning season when females are swollen with eggs. Spawning migrations in the South Atlantic begin in February and occur later to the north. In the Winyah bay system, SC, adults first appear when water temperatures were 7-8 degrees C. Spawning during late May and early June occurred in downstream areas of the Pee Dee River that are bordered by palustrine forested wetlands, with substrates characterized by relatively low current velocities, turbid water, and sand and silt bottom substrates with an abundance of organic debris (Van Den Avyle 1984b). In most other systems, Atlantic sturgeon prefer spawning sites with relatively hard substrates and flowing water. Eggs are demersal and adhesive and usually attach to substrate or submerged vegetation. Hatching times vary from 94 to 168 hours depending upon temperature. Fecundity for SC females is estimated at between 871,800 and 1,616,992 eggs for fish of 48-104 kg. Newly hatched fry are approximately 11 mm (0.4 in) long. Young-of-the-year Atlantic sturgeon are found in their nursery areas, the lower portions of coastal rivers and their associated estuaries. Young Atlantics may spend several years in freshwater before migrating to sea. Juvenile Atlantics which were tagged and subsequently recaptured tended to move southward along the coast during November through January and northward during late winter and early spring. While in the estuarine nursery areas, juveniles generally occupied tidally influenced freshwater during warmer months and moved to brackish estuaries during colder periods. Tagging studies have repeatedly shown that juvenile Atlantic sturgeon wander widely, with fish tagged in SC being recaptured in NC and VA. Atlantic sturgeon are very long-lived. In SC waters, males spawned first at 5-13 years of age, and females at 7-19 years. Females also do not spawn annually, but spawn at irregular intervals. Sturgeon are benthic feeders, with protrusile mouths which resemble vacuum cleaner hoses. They are likely opportunistic feeders, feeding upon a variety of benthic macroinvertebrates in the Atlantic ocean as adults and in estuaries as juveniles. Recorded food items include polychaete worms, snails, shrimps, amphipods and isopods in marine/estuarine areas and aquatic insects, amphipods, oligochaete worms and mayfly larvae in freshwater areas.

Current distribution of the Atlantic sturgeon in the South Atlantic is reviewed in the draft of Amendment 1 to the Atlantic States Marine Fisheries Commission management plan (Atlantic Sturgeon Plan Development Team 1998) and the draft Status Review Report (Atlantic Sturgeon Status Review Team 1998). Based on the documented presence of either age 0 or 1 juveniles and/or mature males and/or females in spawning condition during the last five years (1993 to present), populations are thought to exist in the following systems: NC--Albemarle Sound and tributaries; Pamlico Sound and tributaries, including the Tar-Pamlico; Cape Fear River and tributaries; SC--Winyah Bay and tributaries (Waccamaw, Little Pee Dee, Great Pee Dee, Black Rivers); Santee River; Cooper River; ACE Basin (Ashepoo, Combahee and Edisto Rivers); and Savannah River; GA--Savannah River; Ogeechee River; Altamaha River; and Satilla River; and FL--no known spawning populations currently.

3.3.11.3.2 Habitat and Environmental Requirements

Spawning areas for Atlantic sturgeon have not been identified in all South Atlantic Rivers at this time. Identification of these habitats is a stated need in the current stock assessment (Kahnle et al. 1998). Nursery areas are the downstream portions of coastal rivers which support Atlantic sturgeon, and their associated estuaries. Nursery areas in the Waccamaw and Edisto Rivers are broad, downstream reaches which are tidally influenced and have hard sand or shale substrates. Salinities in such areas ranged from 1-5 ppt in the Edisto and 0-3 ppt in the Waccamaw. The Atlantic sturgeon’s feeding mode reflects an adaptation to gathering food from relatively soft-bottom substrates which are frequented by macroinvertebrates. The demersal, adhesive eggs suggests the need for reduced flow velocities of well-oxygenated water, low levels of suspended solids during incubation, and relatively hard-bottom substrates in spawning areas.

3.3.11.4 Blueback Herring

The blueback herring (*Alosa aestivalis*) is a small species of the herring family which is also an important forage species for other species managed by the Council and Commission. It is preyed upon by the same species that prey on alewife and other clupeid species. It is a schooling species which spawns in the lower portions of the tributary rivers of estuaries along the east coast from Nova Scotia to the St. Johns River in Florida (Fay et al. 1983). It, along with alewife, historically has formed the basis of an important commercial fishery, as well as being an important link in estuarine and marine food webs, forming a linkage between zooplankton and top predators.

3.3.11.4.1 Description of the Species and Distribution

Blueback herring have a blue to blue-green back and silver sides with a prominent dark spot on the shoulder. In contrast to the alewife, bluebacks have a black peritoneum lining the body cavity. They range in size from around 230 mm (9 in) at age three to around 313 mm (12.3 in) at age eight or nine. Bluebacks vary more than alewives in age of first spawning, though in general their maturation rates are similar (Fay et al. 1983). Fecundity of blueback herring females ranged from 45,800 eggs in a 238 mm (9.4 in) individual to 349,700 from a 310 mm (12.2 in) fish. Blueback begin spawning at warmer temperatures than alewives, around 14 degrees C (57 F). Both species cease spawning when water temperatures rise above 27 degrees C. Both species scatter their eggs and spawn in groups. Blueback herring eggs hatch in approximately 55 to 94 hours, depending upon the temperature. Yolk-sac larvae average 5.1 mm (0.2 in) at absorption and remain in the stage for 2-3 days. Larval blueback herring range from 4-15.9 mm (0.2-0.6 in) in length. Larvae appear to prefer areas with less than 12 ppt salinity. Transformation to the juvenile stage is completed at about 20 mm (0.8 in) in length. Juveniles may exhibit an initial upstream movement during the summer, followed by downstream movement beginning in October. Juveniles exhibit diel movement, moving toward the bottom during the day and toward the surface at night. Emigration from estuarine nursery areas occurs between June and November of their first year. Little information is available on the species once emigration to sea has occurred. Catch data from National Marine Fisheries Service trawl surveys indicate that bluebacks spend most of their time offshore in water depths of less than 100 m (328 ft). Bluebacks were most abundant, north of Cape Hatteras, at depth between 27 and 55 m (89 and 180 ft). Catches of bluebacks in summer and fall were confined to the areas north of 40 degrees north latitude. Winter catches were between 40 and 43 degrees north latitude. Spring catches were distributed over the entire Continental Shelf portion of the study area (Fay et al. 1983). Blueback herring, like alewives, are primarily zooplankton feeders. Young-of-the year bluebacks consumed various species of copepods.

Bluebacks have a broader range in the South Atlantic, occurring in coastal rivers of all four states. Rulifson's (1994) recent survey indicates that the species occurs in the following river systems: NC--North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent Rivers (tributaries to Pamlico Sound); New River; Cape Fear, North East Cape Fear and Brunswick Rivers; and White Oak River; SC--Waccamaw, Little Pee Dee, Great Pee Dee, Lynches and Black Rivers (tributaries of Winyah Bay); Santee River; Cooper River; Ashley River; the Edisto, Ashepoo and Combahee Rivers (ACE Basin); Sampit River, Salkehatchie River; and Savannah River; GA--the Savannah, Ogeechee, Altamaha, Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL-- the St. Marys, Nassau, St. Johns, Pellicer, Moultrie and Tomoka Rivers.

3.3.11.4.2 Habitat and Environmental Requirements

Blueback herring are reported to prefer spawning sites with fast currents and associated hard substrates; however, in South Atlantic coastal rivers, they frequently use flooded back swamps and spawn in and among the vegetation of aquatic bed habitats. Preferred temperatures of juveniles ranged from 20 to 22 degrees C, but they were encountered in the field at temperatures ranging between 11.5 to 32 degrees C (53-89 F). Bluebacks are apparently highly tolerant of salinity changes, since direct transfers of adults from fresh water to salt water and the reciprocal produced no mortality. The species requires coastal rivers, associated palustrine forested and aquatic bed wetland habitats, and downstream estuaries as well as the offshore marine environment for completion of its life cycle.

3.3.11.5 Hickory Shad

The hickory shad (*Alosa mediocris*), is a medium-sized member of the shad family which has a center of abundance in the mid-Atlantic region of the east coast (Klauda et al. 1991). Its biology and life history are not as well known as other shad and herring species. In contrast to American shad, it was not important to historical commercial fisheries, but in more recent years has provided the basis for an important recreational fishery in some South Atlantic rivers such as the Roanoke in NC.

3.3.11.5.1 Description of the Species and Distribution

Hickory shad are grey-green along the back, with iridescent silvery or sometimes bronzy sides. They are distinguished from other anadromous clupeid fish by the presence of a strongly projecting lower jaw, among other features. Hickory shad reach a maximum length of about 600 mm (23.6 in). They are usually the first of the anadromous clupeid to ascend spawning rivers in the spring, when water temperatures are 12 or 13 degrees C. Spawning can occur as early as March in southern rivers. Little information is available about hickory shad spawning activity, but it is thought that they spawn largely at night. Fecundity ranged from 61,000 eggs in two-year old females to over 500,000 eggs in older females. Eggs hatch in 48-72 hours at temperatures between 18 and 21 degrees C. Larvae are 5.2-6.5 mm (0.2-0.3 in) in length. The yolk sac is fully absorbed at four to five days of age. Postlarvae transform to juveniles at 10-35 mm in length (0.4-1.4 in). Young hickory shad leave the freshwater and brackish portions of rivers in the early summer and migrate to estuarine nursery areas at an earlier age than the other clupeid species. Studies in the Neuse River estuary of NC suggest that young hickory shad may migrate directly to saline areas and not use the fresher portions of estuaries. The distribution and migration of hickory shad once they depart to oceanic waters is essentially unknown, although they are occasionally harvested along the coast of southern New England during summer and fall. This suggests that they may migrate in a pattern similar to that of American shad. The age of hickory shad populations in the South Atlantic ranged from two to eight years. Repeat spawning occurs, but percentages are variable. Food habits of juvenile hickory shad have not been studied. Adults are primarily fish eaters, but also consume squid, fish eggs, small crabs and pelagic crustaceans. Adults apparently do not feed during the spawning migration.

In the South Atlantic region, hickory shad are documented as occurring in the following river/estuary systems (Lee et al. 1980 et seq., Rulifson 1994): NC--Chowan, Roanoke and Scuppernong Rivers (Albemarle Sound tributaries); Tar-Pamlico, Neuse, Trent Rivers (Pamlico Sound tributaries); New River; Cape Fear and North East Cape Fear Rivers; SC--Waccamaw, Little Pee Dee, Great Pee Dee, Black, Santee, Cooper, Ashley, Edisto, Ashepoo, Combahee, Sampit, Salkehatchie, Savannah and Lynches Rivers; GA--Savannah, Ogeechee, Altamaha, Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL--St. Marys, Nassau, St. Johns and Tomoka. The most recent comprehensive survey (Rulifson 1994) indicated that status of the species was unknown in about half of the SC rivers and all FL rivers.

3.3.11.5.2 Habitat and Environmental Requirements

Information on the habitat requirements of hickory shad is sparse. Major spawning sites for hickory shad are in the freshwater reaches of coastal rivers, including tributary streams and flooded back swamps. Studies of conducted in the Roanoke and Neuse Rivers, NC and the Altamaha River, GA, suggest that the species may prefer tributary streams and flooded back swamps as spawning habitat, rather than the main river channel. Hickory shad eggs have been collected in water temperatures ranging from 9.5 to 22 degrees C. Dissolved oxygen levels at egg collection sites ranged from 5-10 mg/l. Juveniles were collected in salinities ranging from 10-20 ppt. No additional information is available on the habitat requirements of this species.

3.3.11.6 Shortnose Sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) is a federally-listed endangered species, for which a Recovery Plan is currently being prepared (NMFS 1997). The species occurs in South Atlantic rivers, and on occasion in marine waters. There are apparently no documented records from the EEZ in the South Atlantic (Mark Collins, SC Department of Natural Resources, personal communication to R.W. Laney);however, the species is included here since the Council also must consider the impacts of its plans on federally listed protected species. It is an anadromous species which historically, with the Atlantic sturgeon, formed the basis for a valuable commercial fishery. Information in this account is taken largely from the August, 1997 version of the draft Recovery Plan for the species (National Marine Fisheries Services 1997), with supplementation from other sources as cited.

3.3.11.6.1 Description of the Species and Distribution

The shortnose sturgeon occurs in large coastal rivers of eastern North America, historically from the St. John River in New Brunswick, Canada to the Indian River, Florida (NMFS 1997). The shortnose is a small species for sturgeon, reaching maturity at fork lengths of 45-50 cm (18-20 in) and maximum size of approximately 120 cm (47 in)(Dadswell et al. 1984). It differs from juvenile Atlantic sturgeon in having a shorter nose, wider mouth, and no enlarged bony plates between the base of the anal fin and the lateral row of scutes (see Figure 6 in Gilbert 1989).

Shortnose sturgeon are found in rivers, estuaries and the sea, but populations spend most of their time in their natal rivers and estuaries (NMFS 1997). In the southeast, the species is estuarine anadromous (i.e., spends most of the year in estuaries and ascends the freshwater portions of rivers to spawn in the spring). Adults in rivers in the south Atlantic forage at the interface of fresh tidal water and saline estuaries. Spawning occurs in the early spring. At hatching, shortnose sturgeon larvae are blackish-colored, 7-11 mm (0.3-0.4 in) long and resemble tadpoles (Dadswell et al. 1984). Larvae have a large yolk-sac, poorly developed eyes and fins, and are capable of only limited swimming. It is likely that they hide under available cover at spawning sites. The yolk-sac is absorbed in 9-12 days, and larvae resemble miniature adults by about 20 mm (0.8 in) in length. They likely begin swimming downstream at this size. Larvae collected in the wild were in the deepest waters of the channel. Laboratory studies suggest that their is a two-stage downstream migration: a 2-day migration by larvae, followed by a residency period of young-of-the-year fish, then a resumption of migration by yearlings the second summer of life. Juveniles occur in or at the saltwater/freshwater interface in most rivers

(Savannah-see Hall et al. 1991; Altamaha-see Flournoy et al. 1992). Juveniles in the Savannah River use sand/mud substrate in depths of 10-14 m (33-46 ft) (Hall et al. 1991). Warm summer temperatures above 28 degrees F may severely limit available juvenile nursery habitat in some southern rivers. Summering habitat in the Altamaha River was limited mainly to one cool, deep water refuge (Flournoy et al. 1992). Adults which occur in freshwater or tidal fresh reaches of rivers in summer and winter often occupy only a few short reaches of the total river length. As with juveniles, adult summer habitat may be limited to cool, deep refugia.

Shortnose sturgeon historically occurred in most rivers of the four South Atlantic states from the Albemarle Sound system in NC through the Indian River system in FL. There have been no recent documented captures in the Albemarle Sound or any of its tributaries (Chowan and Roanoke Rivers being the major ones), or in the Pamlico Sound and its tributaries (Tar, Neuse Rivers). There are several recent reports of sturgeon from the Albemarle Sound which were allegedly shortnose, but there has been no confirmation by professional fishery biologists. There is currently a population of shortnose in the Cape Fear River and the NC portion of the Waccamaw River. In South Carolina, populations presently exist in the Winyah Bay system (Waccamaw, Pee Dee and Black Rivers), the Santee River, the Cooper River, the ACE Basin (Ashepoo, Combahee and Edisto Rivers) and the Savannah River. Georgia populations occur in the Savannah, Ogeechee, Altamaha, St. Marys and Satilla Rivers. Florida has shortnose presently only in the St. Johns River.

3.3.11.6.2 Habitat and Environmental Requirements

Shortnose sturgeon in the south Atlantic portion of the range require the use of large coastal rivers from the estuarine portions to upstream spawning areas. At present in the South Atlantic, populations exist in the Cape Fear River (NC); Waccamaw River (NC/SC), Pee Dee River (NC/SC) and Black River tributaries of Winyah Bay (SC); Santee River (SC); Cooper River (SC); the ACE Basin tributaries, Ashepoo, Combahee and Edisto Rivers (SC); Savannah River (SC/GA); Ogeechee River (GA); Altamaha River (GA); Satilla River (GA); St. Marys River (GA/SC); and St. Johns River (FL). Historic populations occurred in the Chowan River (NC) and likely Roanoke River and Albemarle Sound (NC); likely the Pamlico Sound and tributaries the Tar and Neuse Rivers (NC); possibly the North and New Rivers (NC); and Indian River (FL). These latter systems should be considered potential areas for restoration of shortnose sturgeon populations.

Habitat and environmental requirements of shortnose sturgeon are reviewed in Gilbert (1989). Shortnose require large rivers unobstructed by dams, or in which the dams are above their preferred spawning areas, or at which fish passage has been provided. Shortnose are apparently able to maintain completely freshwater populations (Connecticut River; Santee River). Preferred temperature ranges and upper and lower lethal temperatures for shortnose are not currently known. Shortnose sturgeon is seldom found in shallow water where water temperatures exceed 22 degrees C; however, in the Altamaha they were found at temperatures as high as 34 C. Temperatures at wintering sites ranged from 5-10 C in Winyah Bay. Shortnose spawning generally occurs earlier and at lower temperatures than Atlantic sturgeon. Dadswell et al. (1984) report that most shortnose spawn at between 9-12 C. Spawning habitat for shortnose in SC was reported to be flooded hardwood swamps along the inland portions of rivers . Shortnose sturgeon prefer waters of lower salinity than Atlantic sturgeon. The maximum salinity at which shortnose were found is 30-31 ppt, slightly less than sea water. In areas where shortnose sturgeon and Atlantic sturgeon co-occur, shortnose are typically found in waters less than 3 ppt. Adult sturgeon are typically found in areas with little or no current throughout their lives, especially when they are present in the lower portions of rivers and in the estuaries. Shortnose have been reported from shallower waters in the summer (2-10 m; 6.5-33 ft) and deeper water in the winter (10-30 m; 33-99 ft). They have been observed feeding in heavily vegetated, muddy backwater areas; however, in general submerged aquatic vegetation does not appear to be an important factor in their life history.

3.3.11.7 Striped Bass

The striped bass (*Morone saxatilis*) is a wide-ranging species of considerable commercial and recreational importance. While all stocks of striped bass which occur in South Atlantic rivers are anadromous, it appears that only the Albemarle Sound stock is migratory to any degree. Riverine striped bass stocks in rivers to the south of Albemarle Sound apparently do not undertake oceanic migrations. All North Carolina riverine striped bass stocks are managed under the Atlantic States Marine Fisheries Commission's management plan. Remaining South Atlantic stocks are managed by individual state jurisdictions, or cooperatively in cases where states share a watershed. Striped bass have also been widely stocked in inland reservoirs as a game fish.

3.3.11.7.1 Description of the Species and Distribution

The striped bass is a larger-sized member of the perch family. It has an elongate, moderately compressed body. Dorsal coloration ranges from shades of green, to steel blue and almost black. Laterally, striped bass are silver with seven or eight horizontal black stripes, one of which always follows the lateral line. In contrast to the clupeids, striped bass have an anterior spiny dorsal fin, and also have sharp spines on the posterior edge of the gill flap. Striped bass spawn in the spring in fresh water or nearly fresh portions of coastal rivers in the South Atlantic beginning mid-February in FL to as late as mid-June in North Carolina. Most spawning occurs at temperatures of 18-21 degrees C. Peak spawning in the Savannah River occurred at 17 C, and in the Roanoke at 19 C. Eggs are semi-buoyant and require suspension by currents of at least 30 cm/sec. Buoyancy of the eggs may vary from river to river. Fecundity ranges from 15,000 to 40.5 million eggs, depending on the size of the female. Hatching time varies from about 30 to 80 hours, depending upon temperature. Striped bass have three larval stages: yolk-sac, fin-fold and post fin-fold. Yolk-sac larvae are 5-8 mm (0.2-0.3 in) in length and absorb the yolk at 7-14 days of age. Fin-fold larvae are 8-12 mm and remain in this stage for 10-13 days. Juvenile body form is attained at about 30 mm and 20-30 days. Little is known about the distribution and movements of juveniles in South Atlantic rivers. They do school and apparently prefer clean sandy substrates, but have been found over gravel beaches, rock bottoms and soft mud.

Juveniles move downstream to nursery areas which may include tidally-influenced fresh waters and estuaries. Maturation rates of striped bass in southern coastal rivers is not generally available. Striped bass are fairly long-lived, with migratory races living as long as 30 or more years. Aged fish in southern rivers were generally age 11 or less (see Hill et al. 1989, Table 3). Striped bass initially feed on mobile planktonic invertebrates, shifting to larger aquatic invertebrates and fish as they grow. In FL, juvenile striped bass feed predominantly on mosquito fish, mollies and freshwater shrimp, larger juveniles feed on threadfin shad, and adults feed primarily on schooling prey fishes, especially clupeids.

3.3.11.7.2 Habitat and Environmental Requirements

Preferred spawning sites vary. In the Roanoke River, NC, preferred spawning sites near Roanoke Rapids and Weldon are rocky and relatively deep, with relatively fast currents. Spawning habitat on the Roanoke is approximately 208 km (130 mi) upstream from the river mouth and even further from the ocean. In other South Atlantic rivers, spawning sites are typically within 60 km (37.5 mi) of the coast, with some sites in tidally-influenced fresh areas. Actual spawning habitats for most South Atlantic rivers are specified in Table 2 of Hill et al. (1989). Sites identified include: NC--Tar-Pamlico River, km 90-238; Neuse River, NC Highway 55 to SR 1915 bridge; North East Cape Fear River, downstream of Lands Ferry; SC--Waccamaw-Pee Dee system, either the Pee Dee River or Intercoastal Waterway; Pee Dee River, upstream from US 301 bridge; Black River, upstream from US 701 bridge; Wateree River, downstream of km 51; Congaree River, km 8-85, but most near km 60; Lynches River, upstream of Highway 41 bridge; Cooper River, lower end of tailrace canal; Ashley River, near km 55; Combahee River, between US 17 and 17-A bridges; GA--Savannah River, km 30-40; Ogeechee River, km 47-55; Altamaha River, km 16; and FL--St. Johns River, Oklawaha River, Wekiva River, Black Creek and Dunn's Creek.

Juvenile striped bass prefer shallow areas with substrates ranging from sand to rock, in the lower portions of coastal rivers and estuaries. Normal development and hatching of striped bass eggs requires dissolved oxygen levels of at least 3-5 mg/l. Adequate current velocity is also a key factor influencing the survival of striped bass eggs, as noted above. Larvae require oxygen levels of 5-6 mg/l, and the optimal range for juveniles is probably 6-12 mg/l. Adult striped bass do not tolerate oxygen levels below 3 mg/l. Larval striped bass tolerate temperatures of 12-23 degrees C, with an optimal range of 16-19 C. Optimal temperature for juveniles is between 24-26 C. As striped bass grow, temperature preference shifts toward cooler waters. In southern rivers, the presence of thermal refugia in the form of springs, spring-fed streams, artesian upwellings may be essential to survival of adults during hot summers. Tolerance of salinity varies with age. Low salinities of 0-3 ppt enhance the survival of eggs and larvae. The range of salinity tolerances and optima generally expand with age. Combinations of high salinity and low temperature cause the highest mortality in young striped bass.

3.3.11.8 American eel

The American eel is the only catadromous species which occurs in the South Atlantic region. Catadromous species are those which live in freshwater as adults, but return to the Atlantic Ocean where they were spawned to complete their life cycle. The American eel supports valuable commercial and limited recreational fisheries throughout its range. Harvested adults are often shipped alive to markets in Europe. The juvenile eels, called glass eels or elvers, are highly valuable because they are used in aquaculture operations for growing out for market. The American eel is also an important prey species for larger marine and freshwater fishes.

3.3.11.8.1 Description of the Species and Distribution

The American eel has an elongate and snakelike body, with dorsal and anal fins which are confluent with the caudal fin, producing an apparent single fin which encompasses much of the body. The body is covered by minute embedded scales. Eels range in color from gray, through yellow to green on the dorsal surface and are usually lighter in color on the ventral side. Color changes with the change in life stage. Large females can reach 1270 mm (50 in) in length. The life cycle of the American eel includes oceanic, estuarine and riverine phases. Adult eels migrate from freshwater portions of inland rivers to the spawning area in the Atlantic Ocean, generally south of Bermuda and north of the Bahamas, centered about 25 degrees N and 69 degrees W. Maturity occurs beyond age 3 for males and age 4-7 for females in northern populations, but may occur earlier in the south. Fecundity is 10-20 million eggs per female. Hatching occurs in February through August, with the larval stage lasting a year or longer.

Larvae are 7-8 mm at hatching. The larval stage is called a leptocephalus, and the leptocephali drift with and are transported by ocean currents. The Gulf Stream is the principal means of transportation for larvae along the eastern seaboard of North America. Larvae are abundant in the Florida Straights and in the area between Bermuda and the Bahamas from April through August. The leptocephali metamorphose into a glass eel stage. Glass eels actively migrate toward land and fresh water, and as they approach coastal areas, external pigmentation develops and the body becomes uniformly dark brown or black. This stage is called an elver. Most elvers move into coastal estuaries and up coastal rivers in the late winter or spring of the year. They generally arrive earlier in southern rivers. Migrating elvers have been collected in January in FL and SC, and in January through May, with peaks in March and April, in NC. Elvers are typically 46-60 mm (1.8-2.4 in) in length in south Atlantic estuaries. Elvers occupy portions of estuaries near the salt-fresh water interface before ascending rivers. Once elvers cease their migration, they begin metamorphosis to the next phase called yellow eels. Some authors believe that yellow eels which remain in the estuarine portion of systems are predominantly male, while those moving further inland become female; however, such a pattern has not been consistently observed. Yellow eels remain in estuaries or rivers for up to 14 years before undertaking the spawning migration back to the Atlantic Ocean. Yellow eels begin metamorphosis into the final stage, called silver eels, in the fall prior to seaward migration. Eels are primarily nocturnal and have a diverse diet. Eels in freshwater feed on insects, worms, crayfish and other crustaceans, frogs and fish. Elvers in saltwater are planktivorous. Blue crabs and clams may be significant prey items in some estuaries. Eels serve as prey for both largemouth bass and striped bass.

The American eel historically occurred throughout the entire South Atlantic, in all coastal rivers and inland freshwater streams, lakes and ponds. In some watersheds, however, construction of dams has prevented juvenile recruitment and has effectively eliminated the American eel from that portion of the watershed above the dams (e.g. Roanoke River Basin in NC and VA). Investigations should be conducted in all South Atlantic rivers with dams to assess whether American eels have been eliminated from the upper portions of other southeastern watersheds.

3.3.11.8.2 Habitat and Environmental Requirements

Spawning occurs in the Atlantic Ocean at the general locality noted above. Depths at which spawning occurs are not known; however, larvae collected near Bermuda occurred only at depths between 550 and 2200 m (1800-7205 ft). Postlarval eels tend to be bottom dwellers and hide in burrows, tubes, snags, plant masses, other types of shelter, or the substrate itself. Presence of soft, undisturbed bottom sediments is important to migrating elvers as shelter.

American eels have broad tolerances for varying temperature and dissolved oxygen. Preferred temperature was 16.7 degrees C. Salinity may provide a key factor in American eel migration movements during the larval, glass eel, and elver stages, along with currents. Alterations in the pattern or magnitude of freshwater inflows into coastal rivers and estuaries could alter salinity and current regimes and thereby affect the number, timing and spatial patterns of upstream migrations by elvers. Since elvers can absorb 60 percent of their oxygen requirements through their skin, they are able to tolerate low DO conditions, as can adult eels, which can use both branchial and cutaneous respiration.

3.4 Essential Fish Habitat Degradation: Marine Biodiversity Implications

The protection of fish habitat is an essential component of marine biodiversity conservation (Norse, 1993). The conservation of biodiversity is fundamental to maintenance of the characteristic structures and functions of ecosystems. The objectives of conservation and enhancement of Essential Fish Habitat under the Magnuson-Steven Act parallel objectives of the United Nations Convention on Biological Diversity, a binding international agreement adopted in 1993. To accomplish the objectives of conservation and sustainable use under the Convention, specific Articles address the requirement for identification and monitoring, sustainable use of components of biological diversity, research and training, and public education and awareness. In addition, one Article explicitly addresses the importance of marine protected areas, the need to restore degraded ecosystems, and the recovery of threatened species.

The National Research Council panel on marine biodiversity (NRC, 1995) concluded that to describe, understand, and predict changes in marine biodiversity, information is needed on: (1) patterns of biodiversity (mapping), (2) anthropogenic and natural processes that generate or alter these patterns, and natural processes that generated a given pattern (linkages and processes), and (3) consequences to ecosystem function of biodiversity change. Those changes are often due to environmental stressors resulting from human activities. These include effects of fishing, alteration of habitats by nearshore construction projects, and chemical pollution (summarized elsewhere in Section 4.0 of this document).

In requiring the FMCs, along with NMFS, to describe EFH (mapping), identify EFH (linkages and processes), identify stressors, and make recommendations on how best to restore degraded habitats, the Magnuson Act closely parallels the recommendations of other national and international forums. The major threats to biodiversity include overexploitation, introduction of alien species, unsustainable mariculture, land-based activities, and habitat alteration and destruction. Managing threats to biodiversity will require integrated marine and coastal area management, marine protected areas, and socio-economic alternatives. The encompassing goal is to maintain ecosystem structure and function. Research gaps that currently retard that goal are information on: (1) patterns of biodiversity (genetic, species, ecosystem), (2) effects of biodiversity changes on ecosystem function, (3) the effects of changes in habitat (quality and quantity) on biodiversity, and (4) alternative management models (socio-economic and biological). Successful implementation of measures to conserve and enhance EFH will be consistent with the now internationally agreed need for habitat and biodiversity conservation.

Several non-fishing effects on EFH may influence marine biodiversity in coastal areas of the southeast U.S. Of particular relevance to nearshore areas is the potential for faunal shifts in response to coastal urbanization, an infrequently considered issue of potentially high significance to biodiversity. For example, the majority of artificial habitats in nearshore waters of southeast Florida result from construction activities for waterfront access and shoreline stabilization, not fishery enhancement. Rip-rap , seawalls, and dock piles are replacing mangrove and grass shoreline habitat in large areas of southeast and east-central Florida via mitigation or restoration activities.

Extensive structural modifications of estuaries may result in species abundance shifts that are not attributable only to water quality and salinity changes induced by upland modifications. Increased channelization by dredging and the addition of rocky structures to the water column may favor shifts from "estuarine" assemblages to "reef" assemblages because of comparatively higher abundances and diversities of incoming ichthyoplankton and the replacement of vegetation with hard structure favoring reef species (Lindeman, 1997). Such shifts may not only involve relative species abundances but also longer nearshore residence times for the maturing life stages of certain reef species. For example, the artificial, 12 m deep reefs adjacent to the side of the leeward barrier island (the Government Cut jetties) of South Miami Beach may lengthen the time interval before maturing reef fishes undergo substantial offshore migrations. Adults of many grunts and snappers (bluestriped grunts, sailors choice, gray snappers, porkfishes, etc.) are commonly found on these structures. In areas lacking artificially maintained inlets and the massive rip-rap jetties they require, these adult reef fish faunas would only be found on the deep reefs at the outer shelf edge, several kilometers offshore.

Reef species that remain in or near modified estuaries through reproductive maturity may ultimately reinforce faunal shifts. Inshore-spawned eggs and larvae are more likely retained within estuaries or coastal lagoons than eggs and larvae that would normally be spawned offshore. For example, reproductively active porkfishes, angelfishes, and other reef species occur on bridges within southeast Florida lagoons, presumably because of the steep vertical relief created by bridge construction and channelization. Pile structures supporting large bridges connecting barrier islands and keys generate eddies and other turbulence that can allow settlement of certain fishes. Perhaps more importantly, these structures often support large concentrations of planktivorous juvenile and adult fishes. Therefore, narrow gauntlets of predators may be present across bridged inlets and channels of southeast Florida. These could decrease numbers of larvae ingressing through channels while, paradoxically, providing significant habitat for juveniles and adult reef fishes (Lindeman, 1997).

Recognition of the importance of tidal channel and leeward barrier island areas as conduits of larval ingress into estuaries and as concentrated settlement sites and juvenile nurseries is needed. Gilmore (1988) found that seagrass beds associated with inlets possessed the richest faunas within the Indian River Lagoon, east-central Florida. Management agencies should place considerable emphasis on limiting negative habitat impacts in these areas. This goal is difficult in application because it may conflict with existing coastal management policies. For example, channels are often considered optimal areas for the siting of large marinas because of better flushing characteristics. However, construction of marinas and docks at previously vegetated channel shorelines increases depth and structural relief, and can ultimately favor greater colonization and inshore residence of reef species.

Inshore faunal shifts from estuarine to reef species operate at population through ecosystem levels and deserve recognition by management agencies and long-term evaluation by researchers (Lindeman, 1997). Superimposed on these factors is the role of anthropogenic modifications of freshwater runoff into estuaries; a factor which may also change existing faunal measures of biodiversity due to differential responses to salinity stress (Serafy et al., 1997).

4.0 THREATS TO ESSENTIAL FISH HABITAT

4.1 Adverse Impacts of Non-Fishing Activities on Essential Fish Habitat

The waters and substrate that comprise essential fish habitat (EFH) as defined by the Magnuson- Stevens Fishery Conservation and Management Act (MSFCMA), and under jurisdiction of the South Atlantic Fishery Management Council (SAFMC), are diverse, widely distributed, and closely affiliated with other aquatic and terrestrial environments. These characteristics make them readily susceptible to a large number of human activities.

The Essential Fish Habitat (EFH) Interim Final Rule (Federal Register 62 FR 244) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The following definitions apply for interpreting the definition of the EFH rule:

- Waters include aquatic areas and their physical, chemical, and biological properties that are used by fish and invertebrates, and where appropriate may include areas historically used by fish and invertebrates;

- Substrate includes sediment, hard bottom, structures underlying the waters, and biological communities;

- Necessary means the habitat required to support a sustainable fishery and a healthy ecosystem; and

- Spawning, breeding, feeding, or growth to maturity covers species' full life cycle.

Fish habitat is the geographic area where the species occurs at any time during its life. This area can be described by ecological characteristics, location, and time. EFH includes waters and substrate that focus distribution; e.g., coral reefs, marshes, or submerged aquatic vegetation (SAV), and other characteristics that are less distinct such as turbidity zones, water quality, and salinity gradients. Habitat use may change or shift over time due to climatic change, human activities and impacts, and/or other factors such as change with life history stage, species abundance, competition from other species, and environmental variability in time and space. The type of habitat available, its attributes, and its functions are important to species productivity, diversity, health, and survival.

Convention for Threats Identification

The ecological requirements for managed species and biotic communities, including identification of EFH, are addressed in this document. Threats to those habitats are described in terms of those that generally occur landward of the shoreline (Threats to Estuarine Processes) and those that occur oceanward of the shoreline (Threats to Offshore Processes). Threats to Estuarine Processes include agriculture, aquaculture, silviculture, urban/suburban development, commercial and industrial activities, navigation, recreational boating, mining, hydrologic modifications, and natural events and global change. Threats to Offshore Processes include navigation; dumping; offshore sand and mineral mining; oil and gas exploration, development, and transportation; commercial and industrial activities; and natural events and global change. A more comprehensive list of individual activities that may be considered as threats is provided in Section 6.3.17.

Every reasonable effort was made to identify the principal non-fishing and fishing-related threats to EFH and to provide examples and information concerning the relationship between threat-related activities and EFH. Other information sources and examples undoubtedly exist and related studies are underway or are in various stages of publication. Accordingly, the following discussion is a starting point for the identification of threats to EFH. While it meets the strict time limitations imposed by the MSFMA, regular updating is required to ensure comprehensive and current coverage of the topic addressed.

4.1.1 Estuarine Processes

Many species of the south Atlantic region are dependent during at least some life history stages on near-shore waters vulnerable to impacts from land-based sources. Especially vulnerable are species or species groups that require estuaries or freshwater tributaries as primary larval or post-larval habitat. In the Southeast, these species include anadromous fish such as striped bass, blueback herring, alewife, American shad, hickory shad, and sturgeons; and brackish species including Atlantic menhaden, summer and southern flounder, red drum, spot, croaker, weakfish, penaeid shrimp, blue crab and others (Epperly and Ross 1986).

Near-shore EFHs at risk from land-based impacts include submerged shellfish beds; subtidal and intertidal mudflats and shell hash; SAV beds, including eelgrass (*Zostera marina*), Cuban shoal grass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*); and emergent tidal marshes including both saltmarshes dominated by smooth cordgrass (Spartina alterniflora) and brackish marshes dominated by black needlerush (*Juncus roemerianus*). These habitats may be affected both by direct destruction and by degradation of water quality or other factors such as hydrologic modification. Elimination or degradation of wetlands not immediately adjacent to EFH also may diminish the quality and productiveness of downstream estuaries.

The precise relationship between fishery production and habitats in undetermined. Accordingly, the exact degree to which habitat alteration has affected fishery production is also unknown, but is thought to be substantial. Turner and Boesch (1987) assembled and examined evidence of the relationship between the extent of wetland habitats and the yield of fishery species that depend on coastal bays and estuaries. The evidence examined show that fishery stock losses follow wetland losses and fishery stock gains follow wetland gains. While most of the studies were related to shrimp production, other fisheries are likely follow this trend.

In the southeastern U.S., the dominant sources of land-based impacts include major land-disturbing activities such as agriculture, silviculture, and residential and commercial development. The following discussions characterize major threats in the coastal zone of the Southeast, summarize ways that EFH is impacted, and characterize the current extent of such impacts. Impacts can occur at three scales: immediate watersheds of EFH; broader watersheds of important estuarine nurseries; and distant or indirect impacts mediated through more widespread movement of water and its chemical and physical make-up.

4.1.1.1 Agriculture

Agriculture in the Southeast has undergone dramatic changes over time. Most operations were at one time individual and small-scale enterprises, but in recent years have transformed into highly integrated, large-scale industries. Besides the extensive conversion of wetlands to crop and animal production, the most dramatic change in southern agriculture is the large scale expansion in animal production that has occurred during the last decade. The most dramatic increases have occurred in corporate hog operations in North Carolina. According to North Carolina Agricultural Statistics, the 1996/1997 hog numbers (8,969,200) for the 44 coastal counties are more than quadruple the 1986 numbers (2,117,800) for the same area. At the same time, the number of hog farms has declined precipitously, by a factor of three.

Other southeastern states have not yet experienced the same increase in swine herds. South Carolina's coastal counties, in fact, experienced a net reduction in swine herds from 374,000 head in 1986 to 194,900 head in 1996 (South Carolina Agricultural Statistics). Georgia had a similar decrease in the coastal plain counties, decreasing from 400,911 head in 1987 to 317,795 head in 1992 (Georgia Agricultural Statistics). Florida numbers experienced a decline in Atlantic watersheds from about 23,541 head in 1987 to 12,482 head in 1992 (Florida Agricultural Statistics). Part of the reason for the differences in hog production among the states is the development of industrial hog-growing technologies in North Carolina, plus differences in state regulatory programs. South Carolina, for instance, recently adopted very stringent and restrictive new laws governing hog-growing operations.

Poultry production, a second major agricultural animal product, has also increased substantially in the Southeast. Again, North Carolina leads the nation in several poultry categories. In 1996, 313,735,000 birds were produced in coastal North Carolina; up from 45,588 966 birds in 1986. South Carolina coastal counties also showed a significant increase in production over this decade: 57,834,000 birds were produced in 1986 and 140,038,000 in 1996. The increases in the Georgia and Florida Atlantic coastal counties were much more moderate from 1987 to 1992, with production rates of 12,907,265 to 15,438,031 birds, and 2,780,706 to 2,886,335 birds, respectively (all data from state agricultural statistics).

Patterns in cropland use also have been in flux. In the North Carolina coastal plain, harvested cropland has remained almost static during the past decade, at about three million acres. However, fertilizer use has increased from 848,927 tons in 1986 to 2,006,251 tons in 1996 (not including swine and other animal waste land application). During the same period, South Carolina has experienced a net decrease in harvested acreage in the coastal plain, from 1,759,162 acres to 1,589,420 acres, but a net increase in fertilizer usage of about 38 percent to 331,597 tons. Harvested cropland along the Georgia coast is up slightly, to about 900,000 acres in 1992. Comparable data on fertilizer usage are not yet available. Harvested cropland in the Florida Atlantic coastal plain is down from about 1.1 million acres in 1992 to 675,081 acres in 1996. (All data from state agricultural statistics).

The overall pattern in crop production is one of great intensification of use on a fairly stable land base. Large increases in fertilizer usage and manure-based nitrogen fluxes (from surface and groundwater and from airborne sources) have occurred during the last decade in at least some southeastern states, including watersheds that were already artificially enriched.

4.1.1.1.1 Potential Threats to EFH from Agriculture

Potential threats include: conversion of wetlands to agricultural lands, or for farm related purposes such as roads and irrigation ponds; direct and non-point source discharge of fill, nutrients, chemicals, and surface and ground waters into streams, rivers, and estuaries; hydrologic modification of ditches, dikes, farm ponds and other similar structures and water control devices; damage to wetlands and submerged bottoms by livestock grazing and/or movement; and cumulative and synergistic effects caused by association of these and other related activities.

Certain agricultural activities present a threat to EFH in the Southeast. The major components of this threat include wetland conversion, nutrient over enrichment with subsequent deoxygenation of surface waters, shading by excessive algae and plant growth, and stimulation of toxic dinoflagellates; sedimentation; and delivery of toxicants into sensitive waters.

Agriculture (including silviculture) accounted for 87 percent of all wetland losses observed nationally between the mid 1950's and mid 1970's (Tiner 1984). This loss has been estimated at more than 458,000 acres per year between the mid 1950's and mid 1970's in the coterminous U.S. (Tiner 1984). The most extensive loses observed in the Southeast were in Florida and North Carolina where agricultural drainage continues to destroy large tracts of wetlands (Tiner 1984). Current agriculture conversion statistics for the Southeast show that:

- During the mid-1970's to the mid-1980's "Florida showed a net wetland loss of 260,000 acres, mainly from the destruction of palustrine wetlands. Two-thirds of the loss of palustrine wetlands was attributalbe to agricultural development..." (Hefner *et al* 1994)

- "Between the mid-1970's and mid 1980's, more than 100,000 acres of freshwater forested wetlands in Georgia were destroyed, mostly because of conversion to land uses such as agriculture." (Dahl *et al* 1991)

- Between 1982 and 1989, South Carolina lost 155,500 acres, of this amount agriculture was responsible for 28 percent. (Dahl 1997)

- In North Carolina about one-third of the wetland alteration in the coastal plain has occurred since the 1950's. Of this amount, agriculture was responsible for about 42 percent. (Cashin *et al* 1992)

Excessively enriched waters often do not support desirable species or populations of fish and invertebrates. They also may not support food chain and other ecological assemblages needed to sustain desirable species and populations. When overly abundant, nutrients such as nitrogen (ammonia) and phosphorus may degrade or eliminate EFH and its flora and fauna through several processes. Most problematic of these is the process whereby dissolved oxygen in the water is reduced by decaying plant life that prospered under nutrient rich conditions. In severe oxygen depletion situations fish and invertebrates may suffocate from oxygen deprivation.

Nutrient enrichment may also lead to direct toxicity when toxic organism populations "bloom" or become excessively large -- situations that are becoming more prevalent and which are discussed in detail in subsequent sections. Although affected by acidity, water temperature, and other factors, total ammonia concentrations in excess of about 2 mg/L normally exceed the chronic exposure level for fish (Mueller and Helsel 1996). In alkaline water at high temperature, the criteria may be exceeded by total ammonia concentrations of less than 0.1 mg/L. The natural conversion of ammonia to nitrate in streams removes oxygen from water and, therefore, may also harm fish (Mueller and Helsel 1996). While less problematic in estuarine and marine environments, phosphorus is a major factor in nutrient enrichment and eutrophication of freshwater systems. There are no minimum discharge standards for phosphorus; however, the U.S. EPA recommends that phosphates should not exceed 0.05 mg/L when discharged into streams entering lakes and reservoirs (Muller and Helsel 1996). Since freshwater systems may be used directly by anadromous fish, and they may also discharge into coastal waters, the quality of these waters has considerable bearing on many commercially and recreationally important aquatic resources and their habitats, including EFH.

In extreme situations living resources may be temporally or permanently displaced due to shifts in the aquatic food web, or by the physical presence of certain plant life. Excessive plant growth may also impede requisite functions (e.g., photosynthesis) of desirable plant life, hence

EFH, as in the case of SAV where leaves may become covered with dense growths of algae, diatoms, and other biota such as bacteria and fungi.

Agriculture is believed to be the single largest contributor of nutrients into southeastern watersheds. In the Tar-Pamlico Estuary Basin in North Carolina, agriculture is responsible for approximately 45 percent of total nitrogen loading to the estuary, and 55 percent of phosphorus loading (NCDEHNR 1997a). An additional 33 percent of nitrogen and 17 percent of phosphorus comes from atmospheric sources that include, but is not limited to agriculture (NCDEHNR 1994, 1997a). In the adjacent Neuse River Basin, 54 percent of nitrogen is estimated to arise from agricultural sources (NCDEHNR 1993, 1997b). These two tributaries discharge into Pamlico Sound, the nation's second largest estuary, and the largest in the Southeast.

Animal production is a threat to southeastern estuarine nutrient balances. The current usual management practice for manure from swine and other confined domestic mammals is storage and treatment in anaerobic lagoons followed by land application. This process relies on volatilization of nitrogen to account for roughly 80 percent of the total produced nitrogen, with concomitant downwind delivery in a zone of influence of roughly 100 kilometers (Rudek 1997). Airborne deposition of nitrogen into coastal waters in the region has been verified from field data to be a major source of enrichment in a number of southeastern estuaries. The most complete work at this time is focused on the Neuse River Estuary in North Carolina, where primary production was boosted two to three times by atmospheric deposition at ambient levels (Paerl *et al* 1995a, 1995b). Actual plant uptake by crops on land-application fields accounts for no more than 10 percent of nitrogen use. Surplus nitrogen is delivered to shallow groundwater systems which, in turn, feed warm-season surface flows into adjacent streams and rivers. Thus, the vast majority of this material is redeposited on land and in surface waters.

Studies by Barker 1997 and Barker and Zublena 1995 also show that many North Carolina coastal counties are receiving swine-based nitrogen and/or phosphorus at levels in excess of total crop-plant growth needs. This analysis actually underestimates the problem, because it considers only direct land-applied nutrients and ignores swine-based atmospheric deposition in these counties. A report compiled for Senator Tom Harkin (D-IA) analyzed manure production patterns nationally by county and found zones of very high production in coastal North Carolina and in individual counties in the other three southeastern states. That document also reports excessive production above crop growth needs in many areas (Minority Staff 1997).

A recent estimate of agricultural emissions of ammonia from the North Carolina coastal plain is about 200.3 million pounds of nitrogen from animal waste, and 15 million pounds of nitrogen from fertilizers. Hogs alone contribute about 135 million pounds of nitrogen emissions in coastal North Carolina; larger than the entire National Atmospheric Deposition Program estimate of airborne deposition from all sources in the North Carolina coastal plain (Rudek 1997).

In response to nutrient enrichment problems and public concern, the North Carolina General Assembly has moved to impose a two-year moratorium on the development of new or enhanced hog farms, pending the replacement of current anaerobic lagoon technology with a more acceptable alternative.

High nutrient loadings also have been documented in other southeastern river basins and estuaries. Among seven river basins in Florida and Georgia examined recently by the U.S. Geological Survey, two in Georgia (the Altamaha and the Satilla) were found to be very high in nitrogen inputs at 5,470 (kg/yr)/km^2 and 5,430 (kg/yr)/km^2, respectively. Animal waste was the dominant source of nitrogen loading in both basins. Fertilizer was the biggest source in the St.

Johns River Basin in Florida, and the Ogeechee Basin in Georgia. The most dominant sources of nutrient loading are non-point-source in origin, and predominantly agricultural (USGS 1997).

The National Water Quality Assessment Program is also examining the Santee Basin and nearby coastal drainages in South Carolina. Data from 1994 covering 24,868 square miles in South and North Carolina are being considered for this analysis. Although definitive information is not yet available, nutrient pollution of lakes and the rivers themselves has been identified as a major water quality issue for the program (USGS 1994). The first reports from this program are now available and include an annotated bibliography of water quality databases and recent publications on the water quality of the region (Abrahamsen *et al* 1997).

Impacts of sediment from non-point-sources including agriculture and silviculture remain at the top of the water pollution list nationally (USEPA 1990) and in the southeastern states (NCDEHNR 1996b). While sediment-based impacts are typically considered to be most acute in freshwater systems, sediment pollution can also threaten EFH. Because sedimentation is a natural process in most aquatic systems it is generally not problematic except where deposition rates vastly exceed ambient conditions. In these situations, benthic animals and plants and demersal fishes that are unable to adjust or relocate may be buried or undergo disruption in growth and reproduction. Lethal and non-lethal effects of turbidity include ingestion of non-food particles by shellfish and polychaete worms, clogging of pores and gills, erosion of gills and other apparatuses such as fins, tentacles, and cilia that may be used for locomotion and feeding, burial of eggs and juveniles, and burial of substrates that may be needed for cover, attachment, and reproduction. In areas that support SAV, primary production levels may be reduced where light penetration is limited by increased turbidity.

While generally less important as a potential threat to EFH in the south Atlantic region, sediment deprivation may be locally troublesome since subsidence and erosion of wetlands and other habitats may result. Impounded coastal wetlands used for rice culture and other agricultural crop production in North Carolina, South Carolina, and Georgia are notable since large areas have been permanently altered even though tidal flow has been restored in many cases. In the Altamaha River Estuary in Georgia vast areas of freshwater and brackish tidal forested wetlands have been converted to emergent wetlands following construction of dikes and ditches that interrupted both deposition of alluvial materials and other processes.

Sediment pollution from agriculture is widespread in the coastal zone of the southeastern states. For example, North Carolina's "303d list," the listing of degraded water bodies required to be compiled by the Clean Water Act, contains an array of coastal streams degraded at least in part by agricultural sediment pollution. These include tributaries of the Northeast Cape Fear River and Black River; Potecasi Creek (Chowan River); Trent River (Neuse Basin); Little River (Pasquotank Basin); Tranter's, Grindle, Conetoe and Town creeks (Tar-Pamlico Basin); and Newport River (NCDEHNR 1996a).

Pathogens from agricultural sources also threaten EFH, especially shellfish waters. The biggest single threat is probably poorly managed animal waste. A secondary source is land-disturbing activity related to putting new land into agricultural production. This may result in additional delivery of fecal-coliform bacteria in quantities of potential concern.

The most dramatic cases of contamination of EFH from agricultural sources include spills of animal waste into coastal watersheds. North Carolina has suffered a number of recent spills, including many in the summer of 1995. A large swine lagoon rupture in 1995 spilled about 25 million gallons of waste into the New River Estuary causing severe anoxia, stimulating toxic algal blooms, and elevating fecal bacteria concentrations in both the receiving waters and sediments. Effects of this event persisted for over 61 days (Burkholder *et al* 1997). Similar ,but smaller, events were documented into tributaries of the Cape Fear River Estuary, North Carolina, from both swine and poultry sources. Impacts included large nutrient delivery, algal blooms, and contamination with huge loads of fecal bacteria; including pathogenic *Clostridium perfringens* (Mallin *et al* 1997). This study documented 30 animal waste spills in North Carolina in 1995 and 1996.

Bacteria from other agricultural sources also may contribute to contamination of shellfish waters. As wetland landscapes are developed for agriculture, offsite water delivery is enhanced (Skaggs *et al* 1980). Many scientists believe that this hydrologic effect may contribute to elevated fecal coliform counts in receiving waters. This is suggested by preliminary studies in Otter Creek, Broad Creek, and the South River, North Carolina (J. Sauber personal communication).

The variation in the scope and composition of agricultural non-point-source discharges and in the receiving waters creates an almost endless range of possible effects on aquatic resources, including EFH. Exposure of estuarine finfish and shellfish to toxic levels of insecticides, herbicides, and fungicides may occur, resulting in significant declines in populations Scott (1997). Sublethal effects also are evident. For example, many compounds released by agricultural operations may adversely affect hormones such as estrogen and androgen that are linked to immune suppression (Scott 1997). These compounds usually do not kill the animal immediately, but reduce its life span and often its ability to reproduce.

Agricultural compounds that have been identified as having properties damaging to aquatic organisms include the commonly used herbicides aldicarb and atrazine and others such as, endosulfan, chlorpyrifos, and trace metals such as copper and mercury.

The enormous variation in the scope and composition of agricultural nonpoint source discharges and in the environmental nature of the receiving waters creates an almost endless range of possible effects on aquatic resources, including EFH. As noted in Scott (1997):

> *"Agricultural nonpoint source (NPS) runoff may result in significant discharges of pesticides, suspended sediments and fertilizers into estuarine habitats adjacent to agricultural areas or downstream from agricultural watersheds. Exposure of estuarine finfish and shellfish to toxic levels of insecticides, herbicides, and fungicides may occur, resulting in significant declines in field populations. Development of new management techniques such as Integrated Pest Management (IPMs), Best Management Practices (BMPs), and Retention Ponds (RP) are risk management tools which have been used to reduce contaminant risk from agricultural NPS runoff."*

In association with Scott's (1997) observations, the National Ocean Service (NOS), Charleston Laboratory examined effects of NPS agricultural runoff on living marine resources in an attempt to define impacts on fishery resources and to develop risk reduction strategies to minimize/mitigate impacts. Investigations involving coastal estuarine ecosystems in South Carolina examined several sites used for vegetable farming (e.g. tomatoes, cucumbers and snap beans), where varied levels of risk reduction strategies were employed. The studies used grass shrimp (*Palaemonetes pugio*) and the mummichog (*Fundulus heteroclitus*) as well as other macropelagic populations. These two species represent more than 85% of the total macrofaunal (>15mm) densities in small tidal creek nursery grounds in South Carolina and they are important due to their role in estuarine food webs. The studies demonstrated that pesticide exposure caused fish and invertebrate abundance reductions and mortality. Comparison of field results with laboratory toxicity tests clearly established that implementation of an integrated risk reduction strategy can significantly reduce NPS agricultural pesticide runoff. At intensively managed (IPM, BMPs, and RP) agricultural sites where strict NPS control techniques were administered, instream pesticide (azinphosmethyl, endosulfan, and fenvalerate) levels were reduced by 89-90%. (Preceding from: Scott 1997.)

According to Scott (1997) the commonly used herbicides aldicarb and atrazine are potential endocrine disrupting chemicals (e.g. compounds that adversely affect hormones such as estrogen and androgen) and are linked to immune suppression. A 1992, Texas investigation found atrazine at concentrations > 60 ug/L in 98% of surface water samples that were taken on an annual basis. Laboratory toxicity tests of atrazine effects on estuarine phytoplankton revealed that chronic, low level atrazine exposure over multiple generations lead to enhanced sensitivity of phytoplankton and combined alachlor and atrazine exposure caused greater than simple additive toxicity in phytoplankton. (Scott 1997.)

The chronic effects of agriculture derived non-point source discharge have been extensively studied in Florida where impacts are occurring on a large scale basis. Essentially all of Florida Bay has undergone significant and undesirable biological, chemical, and physical change due to large scale agricultural practices, including hydrologic modification, in the Everglades. While these changes are occurring primarily in waters that lie outside of SAFMC jurisdiction, they are notable because of their size, magnitude, and complexity. Two basic lessons from the Everglades/Florida Bay situation also have application in watersheds found along the south Atlantic. They are: (1) the chronic environmental and ecological effects of regional agricultural practices may be extremely large and devastating and (2) the financial costs associated with analyzing and remedying these effects are likely to be enormous and possibly ineffective.

The factors associated with EFH degradation by agricultural related hypoxia are only poorly understood, but are of concern. Thus far, the extensive hypoxic zones and conditions observed in the Gulf of Mexico have not occurred the south Atlantic region. Exceptions include relatively small, yet harmful, localized events in portions of North Carolina and South Carolina. In this region, North Carolina's estuarine waters are particularly vulnerable due to their shallow depths, poor flushing characteristics, and the abundance of hog farms found in the coastal zone. Although the most conspicuous effect of hypoxia is the mortality of larger fish and possibly invertebrates, even greater harm may be occurring with sensitive larval and juvenile forms since they are most vulnerable to oxygen depletion and other forms of environmental perturbation.

4.1.1.2 Aquaculture

The U.S. is not a major competitor in the global aquaculture marketplace and ranks ninth worldwide (1993 figures) in the value of its aquaculture products (1996 DNAP). About $1.5 billion in farm-raised seafood is imported annually, including virtually all Atlantic salmon and more than half of the shrimp. Estimates indicate that the U.S. supplies only 5.9 percent of its actual seafood needs (1996 Draft National Aquaculture Development Plan. Unpublished document prepared by the National Science and Technology Council). Considering the substantial economic incentive to increase U.S. aquaculture production and gradual elimination of technological barriers involving production and disease control, expanded aquaculture efforts can be expected in the southeast and the nation.

4.1.1.2.1 Potential Threats to EFH from Aquaculture

Potential threats include: dredging and filling of wetlands and other coastal habitats and other modification of wetlands, submerged bottoms, and waters through introduction of pens, *nets, and other containment and production devices; introduction of waste products and toxic chemicals; and introduction of exotic organisms.*

Existing aquaculture activities along the south Atlantic seaboard are limited almost exclusively to rearing subadult fish and invertebrates in enclosures such as pens or impoundments that are located either on high ground or in aquatic systems. Other techniques such as rearing in floating pens in open waters have been proposed in other regions of the country, however, we are currently unaware of any large scale proposals of this type within the south Atlantic coastal zone.

Mechanical enclosures can cause localized disturbance of benthic environments. This includes burial or occupation of the area used by epifauna and infauna, and disturbance of this zone by production and harvest related activities. In South Carolina, where grow out of juvenile clams is conducted on a moderately large scale, the pens that are used (essentially crab exclusion devices) occupy a substantial area of intertidal bottom. Although the extent of this activity is such that large-scale elimination or damage to estuarine bottoms has not occurred, the situation may eventually need closer inspection and adjustment. Presently, most related complaints are minor and deal with the loss of natural aesthetics and interference with recreational boating. No EFH related concerns have been documented as of this writing. In its review of permit applications involving placement of structures and nets, the NMFS routinely recommends that these structures be removed immediately following resource harvest or use.

Coastal impoundments are used for production of shrimp, crayfish, red drum, and talapia in several southeastern states. In most instances, this involves use of existing impoundments, however, some of these have been modified to attain better enclosure and to better accommodate water control. From a physical or structural perspective the use of existing impoundments is not problematic in terms of filling or directly eliminating aquatic habitat, except where repairs or modifications are needed. Modifications usually involve excavation and/or filling of wetlands and submerged bottoms. Impoundments are most detrimental when they physically isolate productive habitats and preclude use by native species, or when they interfere with natural processes needed for water quality maintenance. According to Dr. Charles Wenner of the South Carolina Department of Natural Resources (personal communication), extremely low dissolved oxygen levels and fish kills frequently occur in impounded wetlands where tidal and wind circulation are severely limited and the enclosed waters are subjected to solar heating.

Aquaculture related impacts that adversely affect the chemical and biological nature of coastal systems may include the introduction of excessive waste products, exotic organisms, and toxic substances. (As previously noted, significant and adverse chemical and biological change is also possible with the construction and operation of coastal impoundments.)

Problems resulting from the introduction of food and fecal wastes from aquaculture operations may be similar to certain agricultural activities (see Section 4.1.1.1). Important distinctions exist, however, principally with regard to the level of magnitude between discharges associated with each entity. While agricultural operations have been shown to have large regional effects, those associated with aquaculture operations are, for the time being, likely to be less of a problem and most prevalent when pond or other enclosures are drained or flushed. In these situations Engle (personal communication) reports that entire tidal creek systems may turn bright green for a period of time depending upon the flushing rate. Except as noted below, greater nutrient input and localized eutrophic conditions are currently the most probable environmental effect of aquaculture activities in the southeast. In association with this, it is important to note that shellfish harvest closure may occur where coliform bacteria levels exceed state standards.

The introduction of exotic organisms through aquaculture activities is an extremely serious matter. Many of Florida's aquatic systems are undergoing ecological change as a result of numerous introductions, in connection with the aquarium and other trades, of freshwater fish and aquatic plants. Although similar results are possible in connection with the marine environment, such changes have been less common. South Carolina officials and shrimpers have been concerned over occurrence of a highly contagious and lethal virus that has been found in imported shrimp that were being grown in coastal impoundments. Concern also has been raised over the open-water capture of blue shrimp (*Penaeus stylorostris*) which is a Pacific species grown in coastal impoundments. Fortunately, there is no evidence to suggest that the blue shrimp is reproducing in South Carolina coastal waters.

4.1.1.3 Silviculture

Forested wetlands are the most abundant wetland type along the eastern seaboard. They include such diverse types as black spruce bogs, cedar swamps, red maple swamps, and bottomland hardwood forests (Tiner 1984). Scrub/shrub and forested wetlands account for over 59.4 million acres within coastal counties from North Carolina to Florida (Field *et al* 1991). These wetlands also have been the most affected by forestry practices and, to a lesser degree, development. At a national level, from the mid 1950's to the mid 1970's, about 440,000 acres/year of palustrine wetlands (including forested wetlands) were lost (Tiner 1984). About 87 percent of this loss is accounted for by agricultural development; including silviculture (Tiner 1984). Trends in the Southeast follow the national trend with North Carolina and Florida registering the most extensive wetland losses (Tiner 1984).

4.1.1.3.1 Potential Threats to EFH from Silvaculture

Potential threats include: conversion of wetlands to silviculture production sties or for tree removal and other silviculture related purposes such as roads and irrigation ponds; direct and/or non-point-source discharge of fill, nutrients, chemicals, and surface and ground waters into streams, rivers and estuaries; hydrological modification to include ditches, dikes, irrigation ponds and other similar structures and water control devices; damage to wetlands and submerged bottoms by timber harvest activities; and cumulative and synergistic effects caused by association of these and other silviculture and non-silviculture related activities.

Silviculture presents a significant threat to EFH largely due to the concentration of this activity in landscape positions near certain EFH, especially anadromous fish spawning and nursery areas and brackish primary and secondary nursery areas. Although silviculture typically is a less intensive land use activity than agriculture or urban development (Hughes 1996), the periodic intense disturbances associated with harvest, the installation and maintenance of dense drainage systems in wetlands and former wetlands, changes in vegetation, and the use of nutrient supplements and toxicants can significantly and adversely affect surface waters, EFH, and their associated biota.

The most important fundamental change with installation of intensive silviculture, pertains to the water management system. Dense drainage systems allow the removal of significant amounts of water from hydric soil sites, intercept rain, and dewater stored groundwater. The effect on the wetlands can be serious if water tables are lowered such that hydric soils loose their water content. Organic constituents of hydric soils can then be oxidized, causing soil subsidence and liberation of previously bonded metals and nutrients. Clearing vegetation from wetland soils may also divert surface water into runoff pathways to the extent that both annual average runoff and event-related peak flows are exacerbated (Daniel 1981, McCarthy and Skaggs 1992). This runoff is a threat because it can change salinity regimes in receiving brackish water systems and it carries excess nutrients and other potential pollutants into sensitive waters and EFH (Pate and Jones 1980).

The sensitivity of EFH to water balance perturbations is variable and poorly understood. Although some important species are highly sensitive to excessive salinity changes at young age classes (e.g., brown shrimp; Hunt *et al* 1980), relatively little is known about the overall implications of flow modification from drained silvicultural areas. Limited studies on pumped drainage water in North Carolina showed minor impact to juvenile and adult spot and Atlantic croaker in response to pumping (Broad Creek Study Report). Effects on spring post-larval settlement periods for brown shrimp remain speculative since the effects of rainfall during pumping have not been determined.

In the Altamaha drainage in Georgia, water balance disturbance is thought to be a key factor in declining catch per unit effort of blue crab and shrimp (J. Holland personal communication) and an in-depth hydrological investigation of that area has been proposed. Livingston *et al* (1997) showed that reductions in freshwater inflow to the Appalachicola River Estuary in Florida led to initial turbidity reductions and increased primary productivity. Over time productivity reductions and major food web shifts were observed, probably in response to decreased nutrient delivery. As reported by Livingston *et al* (1997) food web shifts remained minor so long as river flow did not greatly exceed natural limits. There is a concern that southeastern watersheds would respond in a similar manner.

Silviculture also has the potential to significantly affect nutrient delivery patterns into EFH, both through soil amendments with nitrogen and phosphorus and through changes in nutrient processing and delivery systems. Modification of these delivery patterns can be a threat to EFH. Typical forestry operations in the Southeast add limited nitrogen and phosphorus during the growing cycle (Amatya *et al* 1996). In addition, typical wetland soils are effective at removing incident nitrogen through nitrification and denitrification pathways. Wetlands are important sinks for atmospherically derived nitrogen. As such, riparian and isolated wetlands may buffer EFH from vehicle and animal waste-derived nitrogen enrichment. Drainage networks effectively short-circuit this buffering capacity by reducing retention periods and denitrification opportunities (Whigham *et al* 1988, EDF and WWF 1992).

The huge areas involved and their proximity to sensitive estuaries makes forestry a major player in nutrient enrichment. For instance, in North Carolina's Neuse River Estuary, forests account for 17 percent of total nitrogen delivery (NCDEHNR 1993). The adjacent Pamlico Basin reflects a forestry contribution for nitrogen of about 10 percent (NCDEHNR 1994).

Sediment yields from silviculture in the coastal zone are not considered a substantial threat to EFH. Sedimentation is typically lower than Piedmont or mountain sites as a result of lower terrestrial slopes and enhanced opportunity for deposition in the slower moving receiving waters, including canal systems.

Information is poor on forestry contributions to fecal coliform contamination in the Southeast. Initial studies have found relationships between elevated runoff rates after clear cutting and fecal coliform delivery, but other factors were also at work (J. Sauber personal communication).

Non-nutrient pollution from silviculture is also of concern, though poorly documented. A number of studies have shown release of mercury and other metals from peat soils subjected to intensive drainage (Evans *et al* 1984, Gregory *et al* 1984). Elevated mercury concentrations also have been found in organic sediments in riparian coastal watersheds (Otte *et al* 1987). In North Carolina, fish from the Waccamaw Basin show elevated mercury levels (NCDEHNR 1996b) and metal levels in sediments are elevated throughout the Albemarle-Pamlico Region due to a variety of sources (Riggs *et al* 1991). Although not directly related to silviculture, real estate ventures by timber companies have converted large areas of forest land to residential property. This has resulted in much faster rates of surface water runoff and discharge of waters that contain higher concentrations of pesticides and fertilizers. In coastal areas and in inland locations bordering rivers and streams, property values may be greatly increased and the conversion of forest land to residential and commercial property is proceeding at a rapid rate.

4.1.1.4 Urban/Suburban Development

The coastal region of the southeast is a highly sought after place to live. With its extensive and accessible coastline and mild winter climate the southeast coastal zone is one of the nation's fastest growing regions. The regional growth rate here is more than four times the national average (Chambers 1992) and between 1980 and 2010 the south Atlantic coastal population is expected to increase by as much as 73 percent (Chambers 1992).

As the population increases so does urbanization. People require homes and related infrastructure such as roads, schools, water and sewer facilities, power transmission lines, etc. These needs often are met at the expense of EFH since residential growth has led to large scale modification of wetlands and other irreplaceable environments. Tiner (1984) estimates that about 8 percent of the national rate of wetland losses that occurred from the mid 1950's to the mid 1970's resulted from urban development.

Chemicals produced and used by people also find their way into the waters as point-source and non-point-source runoff. Examples include oil from roads and parking lots, and pesticides, herbicides, and fertilizers from golf courses and residential lawns etc. This has lowered water quality in waters and wetlands adjacent to urban developments. As a result, the quality of EFH is often much reduced and thousands of acres of shellfish waters are closed. The South Carolina Department of Natural Resources' (SCDNR) Tidal Creek Project (TCP) provides insight into the effects of urbanization and suburban development on South Carolina tidal creeks (Holland *et al* 1996). This study has implications for other states as well. The study is examining developmental effects on salinity, dissolved oxygen (DO), and pollution in tidal creeks having trophic, shelter, and nursery functions required by commercially, recreationally, and ecologically important fish and invertebrates. The study reveals the complexity of the environmental and ecological factors involved and shows correlations between development; changes in tidal creek chemical, physical, and biological characteristics; and alteration of species distribution, composition, and abundance.

The TCP identifies salinity as a major factor in controlling the distribution and abundance of living marine resources (Holland *et al* 1996). In watersheds having the greatest areas of roofs, roads, and parking lots it was found that recruitment and colonization by benthic fauna in these areas was less predictable than in more stable environments. TCP confirms that suitable DO concentrations are essential for maintaining balanced indigenous populations of fish, shellfish, and other aquatic biota in tidal creeks and that pollution- related decreases in DO may pose the greatest threat to the environmental quality of estuaries (Holland *et al* 1996). With respect to contaminants, bioassays of sediments taken in connection with the TCP study indicate that potentially toxic conditions for living marine resources may occur in the upper reaches of tidal creeks in developed watersheds. Polyaromatic hydrocarbons in sediments were highest where surface runoff from roads was discharged into tidal creeks and sediment bound pesticides were more prevalent in the marsh and near houses (Holland *et al* 1996).

As the linkage between urban and suburban development and declining fish abundance and health or quality is reenforced, the implications of anticipated population growth in coastal areas become even greater. This situation is especially critical in the Southeast where recreationally and commercially important species are almost totally dependent on estuaries for their survival and for about $5.5 billion in annual commercial fishery benefits (Chambers 1990).

4.1.1.4.1 Potential Threats to EFH from Urban/Suburban Development

Potential threats: conversion of wetlands to sites for residential and related purposes such as roads, bridges, parking lots, commercial facilities, reservoirs, hydropower generation facilities, and utility corridors; direct and/or non-point-source discharge of fill, nutrients, chemicals, cooling water, and surface waters into ground water, streams, rivers and estuaries; hydrological modification to include ditches, dikes, flood control and other similar structures; damage to wetlands and submerged bottoms; and cumulative and synergistic effects caused by association of these and other developmental and non-developmental related activities.

Wetlands and other important coastal habitats continue to be adversely and irreversibly altered for urban and suburban development. (*Note*: certain related activities such as navigation are discussed in later sections). Of major concern is the piecemeal elimination of wetlands by filling for houses, roads, septic tank systems, etc. Wetland filling can directly eliminate or diminish the functional value of EFH and associated areas and resources. While the total area of wetlands affected by development is unknown, the rate of conversion was once estimated at 8 percent of the national average loss of 458,000 acres or 36,640 acres per year (Tiner 1984). Requests to alter coastal areas remain high and between 1981 and 1996, in the southeast the NMFS reviewed more than 23,871 proposals requesting to alter wetlands for housing, shoreline structures, docks, roadways, and other related activities. A survey of 5,622 of these proposals involved 19,729 acres of wetlands (see Tables 26, 27, 28, & 29).

Another major threat posed by urban and suburban development is that of non-point-source discharges of the chemicals used in day to day activities, in operating and maintaining homes, roads, vehicles, etc. In addition to chemical input, changes that affect the volume, rate, location, frequency, and duration of surface water runoff into coastal rivers and tidal waters are likely to be determinants in the distribution, species composition, abundance, and health of southeastern fishery resources and their habitat.

Results of various studies in the South Atlantic Bight indicate that chemical contaminants from industrial, urban/suburban, and agricultural sources may cause impacts in estuarine ecosystems. Highest contaminant concentrations and greatest impacts were observed in the headwaters of small tidal creeks which are the true nursery grounds for fish, crustacean and mollusc. Protection and management of non-point-source runoff loading into these watersheds is essential in protecting habitat quality (Scott *et al* 1997). In the long-term, impacts of chemical pollution (e.g., petroleum hydrocarbons, halogenated hydrocarbons, metals, etc.) are likely to adversely impact fish (Schaaf *et al* 1987). Despite current pollution control measures and stricter environmental laws, toxic organic and inorganic chemicals continue to be introduced into marine and estuarine environments.

Results of the previously mentioned TCP investigation confirm that suitable DO concentrations are essential for maintaining balanced indigenous populations of fish, shellfish, and other aquatic biota in tidal creeks and that pollution related decreases in DO may pose the greatest threat to the environmental quality of estuaries." The study found that:

- DO in tidal creeks fluctuated with phases of the moon, time of day, and tidal stage.

- DO in tidal creeks in developed and undeveloped watersheds often did not meet the state water quality standard of 4mg/L.
- The most stressful DO levels occurred during early morning and at night-time low tides.
- The DO levels in tidal creeks in developed watersheds were less predictable and had greater unexplained variance than those of undeveloped watersheds.
- Point in time DO measurements in tidal creeks do not adequately represent exposure of living resources stressful low DO levels.
- Living resources in tidal creeks in developed watersheds were more frequently exposed to stressful low DO levels than those inhabiting tidal creeks with undeveloped watersheds.
- The factors that contribute to low DO in South Carolina tidal creeks need further study and a DO budget for tidal creeks and associated saltmarshes is needed so that the major factors controlling low DO conditions can be identified and addressed from a management perspective.

With respect to contaminants, bioassays of sediments taken in connection with the TCP study indicate that potentially toxic conditions for living marine resources may occur in the upper reaches of tidal creeks in developed watersheds. Polyaromatic hydrocarbons in sediments were highest where surface runoff from roads was discharged into tidal creeks and sediment bound pesticides were more prevalent in the marsh and near houses.

(Preceding is a summary taken from Holland et al 1996)

Finally with regard to urban/suburban development, and in particular regard to non-point source discharges, the South Carolina Statewide Water Quality Assessment for FY 1992-1993 (SCDHEC 1994) provides an indication of the role of non-point source discharges in one southeastern state. According to the Assessment:

- Non-point source (NPS) pollution is the most responsible factor for nonsupport of classified water uses in rivers, lakes, and estuaries in the state.
- Of the 26,313 river miles assessed via water quality monitoring stations, 10,534 miles, or 40%, were determined to be partially supporting or not supporting overall use. NPS sources of pollution were identified as the contributing factor 33% of the time. These NPS sources included agriculture, pasture land, silviculture, construction, urban runoff/storm sewers, resource extraction, and hydromodification.
- South Carolina has approximately 945 square miles of estuaries, including marshes. The assessment analyzed data collected from 342 square miles of estuaries. About 30% of the estuarine areas do not fully support overall use. NPS pollution sources were identified as the contributing factor 38% of the time .
- Of the 135 shellfish areas assessed, 63% were impacted by NPS, including marinas, 22% were impacted by point sources, and 27% were unconditionally approved. (The percentages totaled exceed 100% due to multiple source impacts.)
- The South Carolina NPS Task Force listed the 32 highest priority water bodies/watersheds that are targeted for implementation action. Of these water bodies/watersheds, 15 are located in the coastal zone.
- Sixty-two watershed units are located in the coastal zone. Based on information from the Statewide Assessment and from more recent Watershed Water Quality Management Strategies, 44% of these units have been impaired by NPS pollution; 39% have been impaired by unknown sources of pollution; 24% have been impaired by point sources; 16% have been impaired by natural or other sources; and 30% have no known impairment. [The percentages totaled exceed 100% due to multiple source impacts. Also, based on the Statewide Assessment, 38 of the 62 watershed units (or 61%) have not been fully assessed.]

Point source discharges related to urbanization derive mainly from municipal sewage treatment facilities or storm water discharges that are controlled through Environmental Protection Agency (EPA)-mandated regulations under the Clean Water Act and by state water quality regulations. Threats related to these discharges are probably less important than the other factors previously discussed because efforts are underway to improve treatment. The primary concerns with municipal point-source discharges involve treatment levels needed to attain acceptable nutrient inputs and overloading of treatment systems due to rapid development of the coastal zone. It is also important to consider that the portion of water entering estuaries from sewage treatment plants is increasing. In locations where treatment is poor, or water conditions are unsuitable for adequate dilution of discharges, EFH may be adversely affected. Of primary concern is excessive nutrification of receiving waters, but other factors such as those associated with non-point-source discharges also apply.

The EPA withdrew the storm water Phase II direct final rule published on April 7,1995 (60 FR 17950) and promulgated a new final rule in its place (60 FR 17958). This action by the EPA instituted changes to the National Pollutant Discharge Elimination System (NPDES) stormwater permit application regulations under the Clean Water Act for Phase II dischargers. Phase II dischargers generally include all point-source discharges of storm water from commercial, retail, light industrial and institutional facilities and from municipal separate storm sewer systems serving populations of less than 100,000. This rule establishes a sequential application process in two tiers for all Phase II stormwater discharges. The first tier provides the NPDES permitting authority flexibility to require permits for those Phase II dischargers that are determined to be contributing to a water quality impairment or are a significant contributor of pollutants to waters of the U.S. "Permitting authority" refers to the EPA or States and Indian Tribes with approved NPDES programs. The EPA expects this group to be small because most of these types of dischargers have already been included under Phase I of the storm water program.

The second tier includes all other Phase II dischargers. This larger group will be required to apply for permits by the end of six years, but only if the Phase II regulatory program in place at that time requires permits. The EPA has stated that it is open to, and committed to, exploring a number of non-permit control strategies for the Phase II program that will allow efficient and effective targeting of real environmental problems. As part of this commitment, the EPA has initiated a process to include stakeholders in the development of a supplemental Phase II rule under the Federal Advisory Committee Act. This rule will be finalized by March 1, 1999 and will determine the nature and extent of requirements, if any, that will apply to the various types of Phase II facilities prior to the end of the six-year application period defined by the rule.

4.1.1.5 Industrial/Commercial Activities

The southeastern U.S. is a prime location for industrial siting. The climate is favorable, economic incentives exist, land is readily available and relatively inexpensive, an adequate labor base exists, and the infrastructure for shipping of supplies and products is well developed. Further, the region's many rivers and streams provide an abundance of water needed for textile mills, paper mills, and heavy manufacturing (e.g., steel fabricating) and other similar facilities.

In addition to a favorable setting for industrial development, commercial growth is ever expanding. Although less conspicious in many areas, the tourist industry also is a vital part of the coastal economy and many of the South's most popular vacation spots are located on or near the coast. With expansion of this industry, new hotels, related businesses, marinas, roads, and other facilities are being built. The increase in visitors and resource users is expected to continually grow and may diminish only when, as a result of over use and development, the environmental quality of the area is reduced.

4.1.1.5.1 Potential Threats to EFH from Industrial/Commercial Activities

Potential threats include: conversion of wetlands to industrial and appurtenant sites such as roads, parking, and administrative and distribution centers; point and non-point-source discharge of fill, nutrients, chemicals, cooling water, air emissions, and surface and ground waters into streams, rivers, estuaries and ocean waters; hydrological modification to include ditches, dikes, water and waste lagoons; intake and discharge systems; hydropower facilities; and cumulative and synergistic effects caused by association of these and other industrial and non-industrial related activities. In addition to ongoing activities, previous industrial and commercial activities have, in many locations, led to deposition of harmful materials that are subject to resuspension and reincorporation into aquatic food chains.

Industrial and commercial development can affect EFH in a number of ways. Most apparent is the conversion of wetlands and upland buffers to sites for buildings, plants, parking, storage and shipping or materials and products, and treatment or storage of wastes or by-products. Because of an abundance of hard impervious surfaces associated with industrial and commercial operations they are often major contributors of non-point-source contaminants into aquatic environments, including those that support EFH. Many industries; e.g., paper mills, consume and pollute large volumes of water including that which is needed to sustain a healthy coastal environment. Industries may also produce airborne emissions that contain contaminants. These contaminants have been shown to reappear in coastal waters and EFH. A readily observable example is acidification of waters from atmospheric deposition of industrial emissions and coal fired power plants.

Commercial development along the south Atlantic coast also has been extensive and relatively few coastal areas are free of commercial development. Past development practices were especially detrimental and before adequate regulation it was not uncommon excavate and fill marshes and shallow water environments for residential, commercial and industrial uses. Such practices have been largely eliminated because most of the coast is either developed or protected from such practices. However, uplands are a decreasing commodity in the coastal zone and the demand for filling wetlands and other aquatic sites is likely to persist. Consequently, proposals aimed at altering wetlands for commercial and other purposes will continue to require local, state, and federal involvement if significant adverse impacts to EFH are to be effectively controlled.

The total amount of EFH that has been eliminated or degraded by commercial and industrial development is unknown, but it is extensive. NMFS data show that between 1981 and 1996, 1,466 proposals were received for industrial and commercial development in wetlands that are subject to regulatory provisions the River and Harbor Act and Section 404 of the Clean Water Act. In association with this, 430 proposals sought approval to alter about 3,202 acres of EFH (see Tables 26, 27, 28, & 29).

Point-source-discharges from commercial activities may be similar to those associated with urban and suburban development. Accordingly, the information and discussions contained in Section 4.1.1.3 should apply. Pollution and water use may alter the flow, pH, hardness, dissolved oxygen, and chemical composition other parameters that affect individuals, populations, and communities (Carins 1980). Within aquatic systems industrial point-source discharges also may alter species and population diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, and species richness and evenness both at the point of discharge and downstream locations (Carins 1980). Growth, visual acuity, swimming speed, equilibrium, feeding rate, response stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites of finfish, shellfish, and related organisms may be altered by chemical and thermal changes. Some industries, such as paper mills, are major water users and associated effluent can dominate and control conditions in substantial portions of rivers and other water bodies where they are located. Usually parameters such as substrate, currents, dissolved oxygen, pH, nutrients, temperature, and suspended materials are key factors affecting the distribution and abundance of EFH. The direct and synergistic effects of other discharge components such as heavy metals and various chemical compounds are not well understood, but current research shows that these constituents may be of greater importance than previously thought. For example, more subtle factors such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food are being uncovered (Scott *et al* 1997).

The cumulative effect of many types of discharges on various aquatic systems also is not well understood, but attempts to mediate their effects are reflected in various water quality standards and programs in each state and within the various water systems. Industrial wastewater effluent is regulated by the EPA through the NPDES permitting program. This program provides for issuance of waste discharge permits as a means of identifying, defining, and controlling virtually all point-source-discharges. The complexity and the magnitude of effort required to administer the NPDES permit program limit overview of the program and federal agencies. Consequently, the NMFS and the FWS generally do not provide comments on NPDES application notices. For these same reasons, it is not presently possible to estimate the singular, combined, and synergistic effects of industrial (and domestic) discharges on aquatic ecosystems.

Where chronic non-point-source discharges and accidental releases of harmful or toxic substances mix, especially harmful effects on aquatic life and habitat, including EFH, is likely. An added concern with industrial operations is the release of contaminants into the atmosphere. Such materials may be transported various distances and directly and indirectly deposited into aquatic ecosystems (Baker *et al* 1993). In the southeast, surface water acidification and mercury accumulation in sediments are of particular concern since sources of these material lie in other regions and are not subject to local and regional (southeastern) controls. In view of this, the regulation of surface water contamination from atmospheric pollution should be addressed from a local, regional, and international perspective.

4.1.1.6 Navigation

Support for navigation in the southeast Atlantic region has resulted in widespread modification of subtidal and intertidal areas used by commercial and recreational vessels. This includes the construction and maintenance of thousands of miles of waterways such as the Atlantic Intracoastal Waterway and the myriad of other channels that lead to ports, turning basins, and harbors of refuge. Construction and maintenance of existing ports and recreationally-based marinas and basins have altered substantial areas of EFH. Dredged material disposal and disposal of contaminated sediments is a dominant issue. Filling of wetlands and conversion of EFH from shallow to deep water habitats are persistent threats associated with new facilities and the maintenance and expansion of existing facilities. Where coastal inlets are stabilized and maintained for navigation purposes effects on nearshore environments and fish and invertebrate populations may be substantial.

A second major concern related to navigation is the host of environmental problems associated with vessel operations. These range from contamination of water by oil, grease, anti-fouling paints, and discharges of sewage, garbage, and debris to the direct destruction of EFH by grounding, anchor damage, propwashing, scarring, etc. Most physical damage is accidental; however, activities such as propwashing may be intentional.

4.1.1.6.1 Threats to EFH from Navigation

Potential threats: Navigation related threats to EFH located within estuarine waters can be separated into two categories: Navigation support activities and vessel operations. Navigation support activities include, but are not limited to, excavation and maintenance of channels (includes disposal of excavated materials); construction and operation of ports, mooring and cargo handling facilities; construction and operation of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. Potentially harmful vessel operations activities include, but are not limited to: discharge or spillage of fuel, oil, grease, paints, solvents, trash, and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; and transfer and introduction of exotic and harmful organisms through ballast water discharge.

4.1.1.6.1.1 Navigation Support Activities

The most conspicuous navigation-related activity in many estuarine waters is the construction and maintenance of navigation channels and the related disposal of dredged materials. The amount of subtidal and intertidal area affected by new and maintenance dredging is unknown, but undoubtedly great. Orlando *et al* (1988) analyzed 18 major east coast estuaries from North Carolina to Florida east coast and found over 703 miles of navigation channels and 9,844 miles of shoreline modifications related to navigation works. Between 1981 and 1986 the NMFS received over 4,877 proposals for new navigation projects in the south Atlantic region. A detailed analysis showed that 1,692 of these proposals involved plans to alter 24,825 acres of EFH through dredging and filling (Tables 26, 27, 28, & 29).

While channel excavation itself is usually visible only while the dredge or other equipment are in the area, the need to dispose of excavated materials has left its mark in the form of confined and unconfined disposal sites, including those that have undergone human occupation and development. Chronic and individually small discharges and disturbances routinely affect water and substrate and may be significant from a cumulative or synergistic perspective. EFH impacts include, direct removal/burial of organisms as a result of dredging and placement of dredged material; turbidity/siltation effects, including increased light attenuation from turbidity; contaminant release and uptake of nutrients, metals, and organics; release of oxygen consuming substances; noise disturbance to aquatic and terrestrial organisms; and alteration of hydrodynamic regimes and physical habitat.

The maintenance and stabilization of coastal inlets also is a prominent navigation activity. Studies and reports by the COE, the NMFS, and others link jetty construction to possible changes in plankton movement (USACE 1980, USDC 1991, Miller 1988, Miller *et al* 1984). This is a major concern since significant modification of inlet hydrodynamics may diminish the ability of sub-adult fish and invertebrates to reach estuarine nursery grounds. Where significant reductions in recruitment (into estuarine waters) of desirable species is realized, production declines in ecologically, recreationally, and commercially important species may result. The use of jetties to stabilize navigation channels at coastal inlets also has been linked to changes in coastal geomorphology that affects nearshore environments. For example, coastal geologists have expressed concern that construction of jetties at Oregon Inlet on the North Carolina Outer Banks could cause catastrophic beach erosion and accelerate barrier island migration (Pilkey and Dixon 1996). Such change could adversely affect the extensive and highly productive submerged vegetation beds which are located behind the coastal barriers.

The relocation of freshwater/saltwater transition zones due to channel deepening may, in some cases, be responsible for significant environmental and ecological change. As an example, salinity shifts after channel deepening and water diversion in the lower Savannah River caused vegetation shifts from freshwater to brackish species in surrounding wetlands. In the lower Savannah River, increased mortality of sub-adult striped bass also has been linked to salinity increases caused by navigation-related modifications such as channel deepening and flow diversion. Modifications that increase estuarine salinities may also create more hospitable conditions for shellfish predators such as boring sponge, oyster drill, and keyhole limpet. In south Florida, increased channelization by dredging and the addition of rocky structures may have favored shifts from estuarine assemblages to reef assemblages because of comparatively higher abundances and diversities of incoming ichthyoplankton, higher inshore salinities, and replacement of vegetation with hard structure that favors reef species (Lindeman 1997). Similar situations are possible in other watersheds where dredging and dredged material disposal are prominent features; however, little documentation of these changes is available.

The expansion ports and marinas has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel numbers and vessel size. Elimination or degradation of aquatic and upland habitats are commonplace since port and marina expansion almost always require the use of open water, submerged bottoms, and riparian zones. Ancillary related activities and development often utilize even larger areas, many of which provide water quality and other functions needed to sustain living marine resources. Vessel repair facilities use highly toxic cleaners, paints, and lubricants that can contaminate waters and sediments. Modern pollution containment and abatement systems and procedures can prevent or minimize toxic substance releases; however, constant and diligent pollution control efforts must be implemented. The operation of these facilities also poses an inherent threat to EFH by adversely affecting water quality in and around these facilities. The extent of the impact usually depends on factors such flushing characteristics, facility size, location, depth, and configuration. When facilities such as marinas are constructed it is common to restrict shellfish harvest in a set or established zone that may be affected by sewage and other hazardous materials. It is now common practice to consider safe zones with respect to public health and aquatic resources when siting marina and port facilities.

Major ports in the south Atlantic region include Morehead City and Wilmington in North Carolina; Georgetown, Charleston, and Port Royal in South Carolina; Savannah and Brunswick in Georgia; and Fernandina Beach, Jacksonville, Port Canaveral, Port Everglades, Port St. Joe, Fort Pierce, Palm Beach, and Miami in Florida. Cargo arriving and departing through these ports is diverse and ranges from highly toxic and hazardous chemicals and petroleum products to relatively benign materials such as wood chips. Major spills and other discharges of hazardous materials are uncommon, but are of constant concern since large and significant areas of estuarine habitat and fishery resources are at risk. Expansion of these facilities and certain operation and maintenance activities are likely to occur at the expense of EFH.

There have been recent positive trends in the development of beneficial uses for clean dredged materials. For example, the deepening of the Wilmington Harbor navigation channel in North Carolina generated rock that is being used for creation of an offshore reef. Similar activities are being investigated in connection with planned deepening of Charleston Harbor in South Carolina. These activities will require monitoring to evaluate their success, but if beneficial other uses of dredged material could be developed. On a cautionary note, conversion of one habitat type to another may not be desirable since associated ecological trade-offs could be harmful to desirable or managed species. The classic example of this is the Winyah Bay, South Carolina dredged material disposal site, where submerged and intertidal bottoms have been converted to emergent marsh without any assessment of the ecological role of the disposal site.

Dredging and disposal of excavated materials is a major component of all southeastern ports and many marinas. Dredged materials are often contaminated and extensive testing for heavy metals and other contaminants is required. At many locations finding suitable disposal sites for dredged materials is also difficult and costly. Whenever contaminated dredged materials are placed in offshore waters, or in locations where decant is discharged into surrounding waters there is high probability that these contaminants will reenter aquatic food webs. As existing upland disposal sites are filled this problem is likely to be exacerbated. Already, direct overboard dispersal of dredged material occurs at some location such as in reaches of the Atlantic Intracoastal Waterway in North Carolina. In other locations such as the Savannah River, Georgia, a technique referred to as "agitation dredging" is used. In this case, about 200,000 cubic yards of materials are resuspended from ship berths each year by bottom dragging or by hydraulic excavation with direct disposal into the adjacent navigation channel. In addition, hydraulic bottom scour systems are presently in place in Wilmington, North Carolina, and experimental use of these devices is planned at one facility in Savannah and at the U.S. Navy's Kings Bay, Georgia, Submarine Base. The environmental impact associated with the use of this technique is unclear, but significant use of bottom scouring devices could be problematic since planktonic and weak swimming fish and invertebrates could be impinged or entrained in intakes and plumbing, and turbidity and sedimentation could be exacerbated. Of particular concern is those aquatic environments that contain anadromous fish since planktonic and weak swimming fish could be heavily impacted.

An additional, but more limited dredging practice is the prop dredging of bottoms, mostly by recreational vessels, to obtain navigable depths. This practice is generally performed without benefit of state or federal permits and is almost always destructive.

The SAFMC is opposed to open water disposal of dredged material into aquatic systems when adverse impacts to habitat used by fisheries under their jurisdiction is likely to be adversely impacted. The SAFMC urges state and federal agencies, when reviewing permits considering open water disposal, to identify the direct and indirect impacts such projects could have on fisheries habitat. It is also their view that the conversion of one naturally functioning aquatic system at the expense of creating another (marsh creation through open water disposal) must be justified using the best available information. Construction of piers and docks also affects EFH, but the degree of the impact is often disputed. Impacts are dependent on the size, location, and number of similar structures in a given area. Pier and dock construction involves often involves jetting of pilings and this causes temporary and localized affects on EFH due to increased sedimentation and habitat displacement. Sedimentation may be a problem in systems such as SAV that are already stressed and are declining or marginal value due to low water clarity. The pilings are treated and toxic chemicals are released into the waters and sediments, but this is not perceived to be a major problem since the pilings are eventually covered with encrusting and fouling organisms. Perhaps the greatest threats from piers and docks are those associated with marsh and SAV shading and the erosion, due to wave action, of substrates in the vicinity of support piles. Substantial harm to SAV and benthic communities may also result from secondary effects associated with boat use, including constant grounding due to wave and tidal action.

The overall biological effects of piers and docks has not been well quantified. However, between 1981 and 1996, the NMFS reviewed requests for almost 6,000 piers and docks along the southeast coast between North Carolina and Florida. In areas having marginal depths and especially where SAV is present, habitat damage in the vicinity of piers and docks may be substantial and disproportionately large in cases where such structures are abundant (Ludwig *et al* 1997). These structures represent a substantial feature in southeastern watersheds and they warrant continued monitoring and regulatory review.

4.1.1.6.1.2 Vessel Operations

In connection with watercraft operation and support the USEPA (1993) has identified several principal concerns. These include pollutants discharged from boats; pollutants generated from boat maintenance activities; exacerbation of existing poor water quality conditions; pollutants transported in storm water runoff from parking lots, roofs, and other impervious surfaces; and the physical alteration or destruction of wetlands and of shellfish and other bottom communities during the construction of marinas, ramps, and related facilities.

Marinas and other sites where vessels are moored or operate often are plagued by accumulation of anti-fouling paints in bottom sediments, by fuel spillage, and overboard disposal of trash and wastewater. In areas where vessels are dispersed and dilution factors are adequate, the water quality impacts of vessel operations is likely to be offset to some degree. In a study of marinas in North Carolina it was found that marinas may contribute to increases in fecal coliforms, sediment oxygen demand, and chlorophyll a, and decreases in dissolved oxygen (NCDEHNR 1990). In addition, boating and other activities (e.g., fish waste disposal) may contribute to increased water temperature, bioaccumulation of pollutants by organisms, water contamination, sediment contamination, resuspension of sediments, loss of SAV and estuarine vegetation, changes in sediment composition loss of benthic organisms, changes in circulation patterns, shoaling, and shoreline erosion. Pollutants associated with marinas include nutrients, metals, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls (USEPA 1993).

Marina personnel and boat owners use a variety of boat cleaners, such as teak cleaners, fiberglass polish, and detergents and cleaning boats over the water, or on adjacent upland, creates a high probability that some cleaners and other chemicals will enter the water (USEPA 1993). Copper-based antifouling paint is released into marina waters when boat bottoms are cleaned in the water (USEPA 1993). Tributyl-tin, which is a major environmental hazard, has been largely banned except for use on military vessels. Fuel and oil are often released into waters during fueling operations and through bilge pumping. Oil and grease are commonly found in bilge water, especially in vessels with inboard engines, and these products may be discharged during vessel pump out (USEPA 1993).

One of the more conspicuous byproducts of commercial and recreational boating activities in coastal environments is the discharge of marine debris, trash, and organic wastes into coastal waters, beaches, intertidal flats, and vegetated wetlands. The debris ranges in size from microscopic plastic particles (Carpenter *et al* 1972), to mile-long pieces of drift net, discarded plastic bottles, bags, aluminum cans, etc. In laboratory studies, Hoss and Settle (1990) demonstrated that larvae of estuarine-dependent fishes including Atlantic menhaden, spot, mullet, pinfish, and flounder consume polystyrene microspheres. Investigations have also found plastic debris in the guts of adult tuna, striped bass, and dolphin (Manooch 1973, Manooch and

Mason 1983). Based on the review of scientific literature on the ingestion of plastics by marine fish, Hoss and Settle (1990) conclude that the problem is pervasive. Most media attention given to marine debris and sea life has focused on threatened and endangered marine mammals and turtles, and on birds. In these cases, the animals become entangled in netting or fishing line, or ingest plastic bags or other materials. Recently, a 35-foot- long sperm whale stranded and died in North Carolina due to ingestion of a plastic float, plastic jugs, a large piece of rubber, 50 feet of nylon rope, and a large plastic bag (D. Engel personal communication).

The production of plastic resin in the U.S. increased from 6.3 billion pounds in 1960 to 47.9 billion pounds in 1985. The increased production, utilization, and subsequent disposal of petro-chemical compounds known as plastics has created a serious problem of persistent marine debris. Marine ecosystems have, over the years, become the final resting place for a variety of plastics originating from many ocean and land-based sources including the petroleum industry, plastic manufacturing and processing activities, sewage disposal, and littering by the general public and government entities (commercial fishing industry, merchant shipping vessels, the U.S. Navy, passenger ships, and recreational vessels) (Department of Commerce, 1988c).

Effective January 1, 1989, the disposal of plastic into the ocean is regulated under the Plastic Pollution Research and Control Act of 1987, implementing MARPOL Annex V (Appendix L). Recognizing worldwide concern for preservation of our oceanic ecosystems, the Act prohibits all vessels, including commercial and recreational fishing vessels, from discharging plastics in U.S. waters and severely limits the discharge of other types of refuse at sea. This legislation also requires ports and terminals receiving these vessels to provide adequate facilities for in-port disposal of non-degradable refuse, as defined in the Act.

The utilization of plastics to replace many items previously made of natural materials in commercial fishing operations has increased dramatically. The unanticipated secondary impact of this widespread use of plastics is the creation of persistent marine debris. Commercial fishing vessels have historically contributed plastics to the marine environment through the common practice of dumping garbage at sea before returning to port and the discarding of spent gear such as lines, traps, nets, buoys, floats, and ropes. Two types of nets are routinely lost or discarded drift gill nets and trawl nets (Department of Commerce 1988c). These nets are durable and may entangle marine mammals and endangered species as they continue to fish or when lost or discarded.

An estimated 16 million recreational boaters utilize the coastal waters of the United States (Department of Commerce, 1988c). Disposal of spent fishing gear (e.g. monofilament fishing line), plastic bags, tampon applicators, six pack yokes, styrofoam coolers, cups and beverage containers, etc. is a significant source of plastic entering the marine environment.

In the mid 1970s, the National Academy of Science (NAS) estimated that approximately 14 billion pounds of garbage was disposed of annually into the world's oceans. Approximately 85% of total trash is produced from merchant vessels, with 0.7% of that total, or eight million pounds annually being plastic. The use of plastics has risen dramatically since the NAS study. At present, 20% of all food packaging is plastic and by the year 2000 this figure may rise to 40% (CEE, 1987).

The main contribution of plastic to the marine environment from cruise ships is the disposal of domestic garbage at sea. Ships operating today carry between 200 and 1,000 passengers and dispose of approximately 62 million pounds of garbage annually, of which a portion is plastics (CEE, 1987).

The U.S. Navy operates approximately 600 vessels worldwide, carrying about 285,000 personnel and discharging nearly four tons of plastic refuse into the ocean daily (Department of

Commerce, 1988a). The U.S. Coast Guard and NOAA operate 226 vessels which carry nearly 9,000 personnel annually and have internal operating orders prohibiting the disposal of plastic at sea. MARPOL Annex V does not apply to public vessels although the Plastic Pollution Research Control Act of 1987 requires all Federal agencies to come into compliance by 1994 (CEE, 1987).

Sewage and other wastes discharged from recreational boats may be most problematic in marinas and anchorage sites where vessels are concentrated. Despite existing federal and state regulations involving discharges of sewage and other materials, detection and control of these activities are difficult and discharges still occur. According to the 1989 American Red Cross Boating Survey, there were about 19 million recreational boats in the U.S. (USEPA 1993). About 95 percent of these boats were less than 26 feet in length and a large number of these boats used a portable toilet, rather than a larger holding tank. Given the large percentage of smaller boats, facilities for the dumping of portable toilet waste should be provided at marinas that service significant numbers of boats under 26 feet in length (USEPA 1993).

Increased recreational boating activity may contribute significantly to pollution of southeastern coastal waters by petroleum products. All two-cycle outboard engines require that oil be mixed with gasoline, either directly in the tank or by injection. That portion of the oil that does not burn is then ejected, along with other exhaust products, into the water. In 1990, 52,030 boats were registered in coastal North Carolina (North Carolina Wildlife Resources Commission, personal communication). Based on this number, conservative estimates indicate that about 84,549 gallons per year of oil (in fuel) is discharged annually into North Carolina's coastal waters (Hoss and Engel 1996). For comparison purposes, hydrocarbon discharges for coastal North Carolina in 1982, from boating and urban runoff are about 470 and 2,270 tons, respectively. Increased use of personal water craft such as jet skis has added to the volume of hydrocarbon being introduced into southeastern waters since the engine exhaust from these vessels is discharged directly into the propellant water jet. Similar problems are inferred for other states and areas having high concentrations of boats.

The chronic effects of vessel grounding, prop and jet ski scarring, and anchor damage are generally more problematic in conjunction with recreational vessels. While grounding of ships and barges is less frequent, individual incidents can have significant localized effects. Propeller damage to submerged bottoms occur in all areas where vessels ply shallow waters. In addition, direct damage to multiple life stages of associated organisms, including egg, larvae, juveniles, and through water column de-stratification (temperature and density), resuspending sediments, and increasing turbidity (Stolpe 1997, Goldsborough 1997) have been observed in connection with vessel operation. This damage is particularly troublesome in North Carolina and Florida, the two South Atlantic states with submerged rooted vegetation in their coastal waters. In North Carolina, no official quantitative estimate of SAV damage has been performed; however, preliminary observations indicate that damage to the state's 135,000 acres of SAV is localized around marinas or other boat access points (R.L. Ferguson personal communication). Scarring estimates for Florida indicate that about 173,000 of the state's 2.7 million acres of SAV are scarred (Sargent *et al* 1995). On the Atlantic coast of Florida there are about 69,360 acres of SAV and 3,770 acres (18 percent) have been scarred by prop and other water craft action.

The ever increasing number of registered power boats along the south Atlantic coastal zone, and those temporarily entering coastal areas through tourism ensure that this threat is likely increase over time. Power boat registrations on Florida's east coast, not including sailboats, totaled 108,048 vessels in 1992-93. Of these, 95 percent were pleasure craft (Sargent et al. 1995).

The rapid increase in popularity of jet skis or "personal water craft" is also problematic. While these vessels are not propeller driven, the water jet removes sediment from seagrass roots and rhizomes and can cause damage. Further, these craft can operate in shallower waters and can access seagrass areas with relative ease. In addition to direct impacts to grassbeds. These machines are exceedingly loud and can create large wakes. It is reasonable to hypothesize that the audio and physical environment of shallow nursery areas may be disrupted in manners which stress postlarval life stages. The degree of stress is currently uninvestigated.

Incidences of commercial groundings are few, but where they occur on hard bottom habitats damage may be extensive and long-term. For example, groundings in the Florida Keys National Marine Sanctuary have caused extensive damage to coral reefs and signs of recovery are slow to appear.

The cumulative effect of anchor scarring in seagrass beds is not as damaging as that caused by propeller and jet powered vessels. On coral reefs, however, damage caused by anchoring of recreational boats is significant (Davis, 1977). Dragging or pulling anchors through coral beds breaks and crushes the coral, destroying the coral formation. Most reef damage of this type occurs in the Florida Keys and in nearshore waters.

The effects of vessel induced wave damage have not been quantified, but may be extensive. The most damaging aspect relates to the erosion of intertidal and SAV wetlands located adjacent to marinas, navigation channels, and boating access points such as docks, piers, and boat ramps. Wake related erosion in places along the Atlantic Intracoastal Waterway and elsewhere is readily observable and has undoubtedly converted substantial area of emergent wetlands to less important habitat such as submerged bottom. In heavily trafficked areas bottoms may become unstable and colonization by bottom dwelling organisms may not be possible. Indirect effects may include the resuspension of sediments and contaminants that can affect EFH. Where sediments flow back into existing channels, the need for maintenance dredging, with its attendant impacts, may increase.

The introduction of exotic species by vessel operations is linked largely to the world wide movement of commercial vessels. Exotic species may be brought into the U.S. by several methods, but capture and release in ballast waters is of most concern. With the introduction of the zebra mussel into the Great Lakes and its rapid dispersal into other waters, considerable attention is being directed at this problem. According to one estimate, two million gallons of foreign ballast water are released every hour into U.S. waters (Carlton 1985). This possibly represents the largest volume of foreign organisms released on a daily basis into North American ecosystems. The introduction of exotic organisms threatens native biodiversity and could lead to changes in relative abundances of species and individuals that are of ecological and economic importance. This has already been observed in other parts of the world. While EFH has not been directly affected, recent introduction of a brown mussel into the Gulf of Mexico is of concern and is being investigated. It is anticipated that technology such as use of filters or open ocean exchange of bilge waters can be used to reduce the spread of non-native species. Considering the extent of port development and shipping along the south Atlantic, addressing this issue is of paramount importance.

4.1.1.7 Inshore Mining

Inshore mining, as a category of EFH threats, is generally confined to a few specific locations where associated effects may be substantial. Between 1981 and 1996 the NMFS received only 434 of these proposals for review. Of these, 307 were from Florida and involved phosphate mining. While these activities undoubtedly have a dramatic effect on local landscapes and wetlands, the majority are well inland of most EFH locations. Where these activities occur along the coast, phosphate rock, sand, gravel, stone, and marl are generally mined. Phosphate rock is sought mostly for fertilizer production and the other materials are used mostly for fill, roadbed construction, and concrete production. The products of mining operations may eventually be transported to other locations and construction and operation of shipping facilities and navigation channels could involve EFH.

4.1.1.7.1 Threats to EFH from Inshore Mining Activities

Potential threats include: conversion of wetlands to mine pits and uplands, or to reclaimed aquatic sites and uplands that lack pre-mine habitat and fishery production values; direct and/or non-point-source discharge of fill, tailings, chemicals, cooling and processing water, and surface and ground waters into streams, rivers and estuaries; hydrological modifications including those associated with ditches, dikes, water and waste lagoons, intake and discharge systems; and cumulative and synergistic effects associated with other mining and non-mining activities. Related shipping, storage, and processing facilities also can threaten EFH.

Where mining activities occur in areas identified as EFH, the local effect is often dramatic and extremely damaging. In eastern North Carolina phosphate mining has essentially eliminated an entire estuarine creek ecosystem in Beaufort County. In Dade and Monroe Counties, Florida, limestone removal operations have converted large areas of wetlands to open pits. While most state and federal regulations require restoration of mine sites, such action is costly and often fails to produce environments that are similar in ecological character and productivity to those that were destroyed.

EFH designation could further fishery management opportunities in certain locations and in the case of certain mining activities. In locations where suitable mitigation cannot be provided, the creation of new mines and expansion of existing operations may be curtailed or prohibited. Other less intrusive mining operations, such as minor removal of sand and gravel, are likely to continue, but needed environmental protection measures (e.g., seasonal work restrictions) could be specified to minimize impacts to fishery resources and prevent significant harm to EFH.

The construction and operation of mining-related facilities such as storage, processing, and shipping facilities and other related infrastructure such as roads, also presents a threat to EFH. Discussions found in Sections 4.1.1.6 and 4.1.1.7 address these factors.

4.1.1.8 Hydrologic Modifications

Alteration of freshwater flows into coastal marine waters, typically via the construction of canals, has changed temperature, salinity, and nutrient regimes, reduced the extent of wetlands, and degraded estuarine and nearshore marine habitats (Reddering 1988, Whitfield and Bruton 1989). The following summary is largely taken from Serafy *et al* (1997). Profound changes to the South Florida ecosystem have occurred with the construction of an extensive inland and coastal canal system by the COE which began as early as 1917 (Hoffmeister 1974, Teas *et al* 1976). Today, the system constitutes a 1400-mile network of canals, levees, locks and other flood control structures which modulates fresh water flow from Lake Okeechobee, the Everglades, and coastal areas. These areas, which serve as nursery areas for a wide diversity of organisms, have experienced drastic changes in both the amount of freshwater they receive, and in the fashion in which it is delivered. For example, in southern Biscayne Bay, Florida, canal locks are all that separate this occasionally hypersaline lagoon from the entirely freshwater canal systems. When the locks open, the salinity of marine waters downstream often drops 20 ppt within 60 minutes before recovering as rapidly (Wang and Cofer-Shabica 1988). This may occur several times a day and over several months, particularly during the rainy season (i.e., May to October) when water temperatures are also at maximum levels.

4.1.1.8.1 Threats to EFH from Hydrologic Modifications

Potential threats: Most hydrologic modifications are performed with other activities that are identified as having potential to adversely impact EFH. As such, the activities involved are similar or identical to those identified in other sections. Other threats are possible with mosquito control, aquaculture, wildlife management, and flood control projects and activities. Hydrologic modification can involve entire watersheds and drainage basins for large scale water diversion projects, where silviculture and/or agriculture activities are large in scale and/or intensity, and where runoff from urban and suburban development is substantial. Threats related to hydrologic modification can involve any activity that alters water quality or the rate, duration, frequency, or volume at which water enters or moves through an aquatic system. Consequently, activities associated with industrial, urban, and suburban development (including those occurring on uplands), ditching, draining, diking, and impounding may all qualify as hydrologic modification related threats.

Rapid salinity fluctuations can represent a significant stress for a marine organism, depending on its osmoregulatory ability and/or its behavioral response (Serafy *et al.* 1997). In fishes, abrupt salinity changes can cause mineral imbalances in the blood which tends to become diluted as salinity drops, and concentrated as it rises -- either of which can be lethal (Mazeaud *et al* 1977). Rectification of proper osmotic balance in response to salinity stress requires energy expenditure, often at the cost of growth, reproduction and/or resistance to other stressors, including high temperature (Moore 1972, Schreck 1990). The combination of high temperatures and low salinity pulses on marine organisms has received only limited attention (Moore 1972, Albertson 1980).

Only one study has examined the combined effects of high temperature and freshwater pulses on subtropical marine fishes of the Western Atlantic. Serafy *et al.* (1997) combined a field survey of nearshore fishes in Biscayne Bay, Florida, with a series of laboratory-based freshwater pulse experiments. A 13-month trawl project was supplemented with high temperature - low salinity challenge experiments on eight fishes: five species that dominated canal-influenced habitats (*Eucinostomus gula, Lagodon rhomboides, Haemulon sciurus, Opsanus beta,* and *Lucania parva*) and three species that were less common in these areas (*Cynoscion nebulosus, Haemulon favolineatum,* and *Cyprinodon variegatus*). Of the five fishes that dominated the nearshore habitats, three exhibited no mortality when subjected to freshwater pulses, while *L. rhomboides* and *L. parva* exhibited 12.5 percent and 50.0 percent mortality rates, respectively. Mortality was 100 percent for the three species that were less common in habitats influenced by canals. These laboratory and field results support the hypothesis that anthropogenic changes to fresh water delivery regimes can play a partial role in determining the species compositions of nearshore fish assemblages within Biscayne Bay, Florida.

Holland *et al* (1996) found that salinity was a major factor in controlling the distribution and abundance of living marine resources in South Carolina estuaries. In watersheds having the greatest areas of roofs, roads, and parking lots it was found that surface water discharges tended to be "flashier" and that recruitment and colonization by benthic fauna in these areas was less predictable than in more stable environments.

4.1.1.9 Dams, Impoundments, and Other Barriers to Fish Passage

Thousands of wetland acres have been impounded each year in the Southeast for purposes such as waterfowl habitat creation, aquaculture, agriculture, flood control, and mosquito control. Historically, large areas of wetlands were impounded in South Carolina for rice production. Projects range in size from minor, such as repair of existing embankments, to large-scale projects where constructing dikes and water- control structures may affect relatively large wetland tracts.

Numerous dams and other structures have been built on major rivers for industrial water uses, hydropower facilities, reservoirs, and as part of flood control projects. Those facilities near the coast can have an adverse effect by blocking fish passage, and modifying hydrology and sediment and nutrient flows to coastal waters.

4.1.1.9.1 Threats to EFH from Dams, Impoundments, and Other Barriers to Fish Passage

Potential threats: Direct effects of impoundments and other barriers are removal of habitat, conversion of habitat away from historic usage, alteration of hydrology, and modification of water quality by modification of temperature, salinity, and nutrient and sediment fluxes. Flow regimes often are controlled and differ substantially from pre-impoundment flows. This can adversely affect anadromous fish migration and spawning as well as food production for prey species needed by larvae and juveniles.

Large acreages of coastal wetlands have been impounded along the Southeast Atlantic. Reasons vary, but include aquaculture, waterfowl production, mosquito control, and in the Old South prior to 1912, rice production. The overall amount of impounded coastal wetlands is not known, but probably exceeds 200,000 acres. Between 1981 and 1996, the NMFS reviewed 721 proposal of varying sizes that blocked or impounded EFH (Tables 26-29). A review of 190 of these projects revealed that about 7,131 acres of EFH would be adversely altered through these projects.

A primary biological concern for barriers and impoundments is the impact on estuarine-dependent marine fisheries production. Most impoundments are managed for resources other than fish (e.g., waterfowl). The management regimes, based largely on seasonal consideration, may exclude or severely restrict access by fish and invertebrates. This decreases habitat area and proportionately, the production of fishery resources. Even if fisheries gain access, conditions within impoundments may not be hospitable and organisms may not be able to escape and enter harvestable and reproductively active populations found in surrounding waters. Other management regimes, such as marsh burning, may adversely affect fishery resources. Water quality and nutrient outflow also may be compromised.

New impoundments pose a potential risk to EFH and fish production and must be carefully evaluated. However, within the south Atlantic, some positive aspects are evident related to existing impoundments. Because wetlands have been extensively damaged, these areas (especially old rice fields) provide a wealth of available habitat. Further, production of fisheries organisms within these areas is often excellent. Crab production, for example, has been shown to be high in some areas and the production of many estuarine-dependent species has been observed. Strides have been made in revising existing management regimes to better accommodate fishery production and these early efforts are producing positive results. In Florida, the Subcommittee on Managed Marshes, an interagency ad hoc group is making impressive strides in reestablishing fisheries access to impounded wetlands. These types of efforts provide a positive solution for better integrating the uses associated with these areas.

Dams and other barriers have been constructed on almost every major southeastern river. They serve multiple purposes including hydropower production, water supply, and flood attenuation. Dams located on the Roanoke and Neuse Rivers in North Carolina, the Cooper and Santee Rivers in South Carolina, and on the Savannah River on the South Carolina - Georgia border are major impediments to anadromous fish migrations. Most of these structures are old and were built either before their effects on fish and other wildlife were known, or at a time when environmental concerns were of lesser importance than economic and political factors. Considering the present level of knowledge of their effect on fish migration and production, water quality, and flow alteration, it is unlikely that major new structures will be built. The present challenge is to revisit older structures to determine their usefulness and where their negative impacts outweigh their benefits, they should be removed or modified. An example is removal of the Quaker Neck Dam on the Neuse River in North Carolina. Where removal is not feasible then consideration must be given to providing for, or improving fish passage and for modifying flow regimes to mimic pre-impoundment flows. These considerations will rely on new research and improvements in fish passage technologies.

4.1.1.10 Natural Events

Coastal processes may be dramatically altered by natural events. These include short term events such as severe storms, hurricanes, floods, etc., and longer-term events such as global warming and sea level rise. Effects vary from potentially positive to catastrophic. For example, a moderate storm may provide needed freshwater, flush and recharge stagnant water bodies, and transfer nutrients from uplands and high marsh surfaces to tidal waters. On the other hand, shoreline erosion, wetlands destruction and subsidence and substantial changes in the structure of coral communities (e.g., Bythyell et al., 1993) are possible. The eventual result of global climate change is even less predictable. However, it is evident that coastlines and related ecosystems are changing and human activities may be involved and could largely frame the outcome. Considering the extensive level of coastal development in the coastal zone, even a minor increase in sea level rise can have serious consequences for humans, EFH, and the fishery resources that rely on coastal habitats.

4.1.1.10.1 Threats from Natural Events

Potential threats: Coastal and inland storms can cause severe acute and chronic perturbations including habitat erosion, burial of habitat and organisms by sediment deposition; creation of strong currents that alter habitats and remove biota; damage by wind and waves; creation of turbidity levels that can cause physiological damage and disrupt feeding, spawning migration, and other vital processes; and abrupt changes in salinity and other water quality characteristics such as fecal coliform levels. Long-tern climatological changes can bring about similar changes by altering weather patters. Large scale ecological changes may also occur where temperature changes favor or harm a particular species or group. Changes that cause relocation of frontal boundaries, weed lines, and stratification and temperature boundaries may also cause substantial and undesirable environmental change.

Hurricanes and other severe climatological events and change can drastically alter shorelines and associated environments including wetlands. Some changes may be positive such as the flushing of stagnant systems. However, wind induced erosion and overwash can remove and fill large areas of SAV and emergent wetlands. In overwash areas, newly created "uplands" are often quickly developed and stabilized and geomorphological processes that lead to rebuilding of wetlands and shallow water areas may be precluded.

Although the issue of global warming is controversial, all models predict some temperature increases, especially in the higher latitudes of the Northern Hemisphere (USDC 1997). According to the U.S. Department of Commerce, significant Arctic warming, particularly after 1920, may be related to increased solar radiation, increased volcanic activity, and other naturally occurring factors (USDC 1997). Human induced increases in greenhouse gas concentrations combined with natural conditions to cause unprecedented warming in the Arctic in the 20th century, and between 1840 and the mid-20th century the Arctic warmed to the highest level in the past four centuries.

Global temperature increases of a degree or two can cause sea level rise if melting of the Arctic tundra and ice cap follow. Possible effects include: significant loss of coral reefs, salt marshes, and mangrove swamps that are unable to keep up with sea level rise; loss of species whose temperature tolerance ranges are exceeded (this could be especially problematic for corals); elevated nutrient and sediment loading; saltwater intrusion into freshwater ecosystems such as freshwater marshes and forested wetlands; invasion of warmer water species into areas occupied by cooler habitat species; and physical changes that could have much broader implications by altering flows, food chains, and climate (USDC 1997). The severity of impact on natural resources, including certain EFH will be determined by natural and human obstruction to inland habitat shifts, resilience of species and populations to withstand changes in environmental conditions, and the rate of environmental change (USDC 1997).

Other relevant information on this topic is contained in Section 4.1.2.6.

4.1.2 Offshore Processes

4.1.2.1 Navigation

Offshore dredging for navigation is mainly limited to inlet bar channels and other port entrances; e.g., Port Canaveral, Florida. The sediments are typically coarse and the bottom communities are low diversity reflecting the dynamic nature of these areas. Bottom organisms occupying this zone are generally sparse and adapted to the dynamic nature of the habitat they occupy. As such, dredging in these locations generally does not pose the same magnitude or type of impact incurred when working in nearshore environments. The same is true for vessel operations, although to some degree the problems discussed in Section 4.1.1.6 also apply. Vessel operation impacts are mainly linked to sinking, grounding, routine disposal trash and wastes, and the accidental release or spillage of cargo and fuel.

4.1.2.1.1 Threats to EFH from Navigation

Potential threats include: excavation and burial of EFH in connection with creation and maintenance of navigation channels; elevation of turbidity and resuspension of toxic and harmful components of dredged materials (includes material that cause elevated sediment and dissolved oxygen demands); interruption of coastal sand movement and sub-adult fish migration through construction of channel stabilization structures such as jetties; potentially harmful vessel operations such as discharge or spillage of fuel, oil, grease, paints, solvents, trash, and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; and transfer and introduction of exotic and harmful organisms through ballast water discharge.

With a few exceptions, offshore dredging is performed using hopper dredges. Hopper dredges generally dump accumulated material through a split hull; however, the use of these dredges in connection with pipelines and vessel pump out is becoming more commonplace, especially where sand is needed for beach replenishment. Closer inshore, sidecast dredges may be used where wave amplitude is slight and dredging volumes are relatively minor. In protected waters pipeline dredges are almost always used since they provide the most effective and efficient means for removing and redepositing bottom sediments. On rare occasion, as in the case of the Cape Canaveral Ship Channel, pipeline dredges may be used in open waters but their vulnerability to wave damage generally precludes this. Bucket dredges and scows are employed in some locations, but such use is usually limited to situations where other dredges cannot operate due to water depth and pumping distances (for pipeline dredges).

In connection with offshore waters, threats to EFH are most significant in terms of possible burial of benthic communities in the vicinity of dump sites and in connection with turbidity from dumped materials. Contamination of the water column and bottoms is also possible if the dredged material is contaminated. Sediments may also be re-dispersed after being dumped in offshore sites and burial of productive bottoms is possible. On occassion, designated dump sites are not adequately studied or they change and high quality benthic habitat may be damaged or destroyed.

Considering that most ports are located in estuarine waters, other navigation related threats may be less severe in offshore waters. Notable exceptions may include the overboard disposal of trash, cargo, and wastewater from ocean going vessels (see Section 4.1.1.2.), and disposal of dredged material (see Section 4.1.2.2). Although comparisons are unavailable, it is likely that most vessel related disposal occurs on the open ocean, rather than in estuarine and nearshore waters where such activities are likely to be observed.

Within Florida waters, particularly in the Florida Keys, vessel groundings represent a chronic threat to live coral habitat. Anchoring is also a problem, however, it has become less of a threat through wide spread use of single point mooring buoy systems. Vessel groundings can be broken into two broad categories: large vessel and ship groundings that often result in severe injury to live coral colonies and non-living reef framework; and small recreational boat groundings that result in numerous strikes to individual coral colonies in both inshore and offshore areas. Large vessel and ship groundings occur infrequently, but result in far more significant injury to coral reefs and other habitat types. Recreational boat groundings are much more frequent. Between 1993 and 1997, 2089 groundings were reported in the Florida Keys National Marine Sanctuary. Many more are likely unreported.

Reported Vessel Groundings* in
Florida Keys National Marine Sanctuary (FKNMS)
1993 to 1997

Year	Total Reported Vessel Groundings
1993	280
1994	550
1995**	400
1996**	399
1997**	460
Total	2089

*Data from FKNMS & Florida Marine Patrol Computer Assisted Dispatch Report

** Grounding data for 1995 through 1997 are incomplete and require further data anaylsis.

Note: The above numbers do not represent coral reef groundings alone. Reported groundings occur in all types of habitats found in the FKNMS.

Accurate baseline data for live coral coverage does not exist for the vast majority of Florida coral reefs. In some cases though, sufficient data are available to allow calculation of the actual extent of a grounding incident. For example, on August 10, 1994, the R/V Columbus Iselin, a 154-foot research vessel, was conducting survey work for the University of Miami when it struck Looe Key, a spur and groove reef. Approximately 345 square meters of living coral and 338 square meters of non-living coral reef framework were destroyed.

Injuries to coral from groundings take several forms and include crushing, splitting and fragmentation, dislodging colonies, and depending on the severity of the incident, sedimentation and/or burial. In general, groundings occur on or near the reef crest where coral formations are closest to the water surface. Species commonly injured in the reef crest include elkhorn coral *(Acropora palmata),* staghorn coral (*Acropora cervicornis*), fire coral *(Millepora complanata)*, starlet coral (*Siderastrea siderea*), mustard hill coral (*Porities astreoides*), and knobby zoanthidean (*Palythoa mammillosa*). Species that inhabit deeper areas such as brain coral (*Diploria strigosa*), star coral (*Montastrea annularis*), and large star coral (*Montastrea cavernosa*) are at risk from deep draft vessels. Small individual groundings may recover over time, but the loss of live coral coverage is likely to take decades. Catastrophic groundings involving large ships or freighters may never fully recover.

4.1.2.2 Dumping

Dredged material disposal in ocean waters generally involves disposal of sediments dredged from inshore areas such as port facilities. Where navigation approaches from offshore and inlets are involved these materials may also be placed in offshore sites. Most of the sediments taken from inshore areas are fine, contain some degree of contamination, and produce at least short-term impacts such as turbidity plumes when removed or deposited. The overall effects of dumping on or near EFH may be serious, but are not well studied. The SAFMC policy on dumping (see Section 5.3.1) provides additional detail on the subject. The principal authority for designating ocean disposal sites for placement of dredged material is the Regional Administrator of the EPA. The EPA develops and publishes Environmental Impact Statements (EIS) and the rule making paperwork for ocean disposal site designations. Corps of Engineer Districts provide the EPA with the necessary information to prepare the EIS and to identify significant issues to be addressed in the site designation process. Information required from the Districts includes: zone or siting feasibility data, justification for the need for ocean disposal, and alternatives to ocean disposal. The purpose of the EPA site designation process (see Appendix K) is to establish sites that minimize impacts to the environment, economize disposal site management and monitoring activities, and support multiple users (C. McArthur personal communication).

Under provisions of the Marine Protection Research and Sanctuaries Act (MPRSA), ocean disposal of hazardous and toxic materials, other than dredged materials, is prohibited by U.S. flag vessels and by all vessels operating in the U.S. territorial sea and contiguous zone. The EPA may issue emergency permits for industrial waste dumping into ocean waters if an unacceptable human health risk exists and no other alternative is feasible. The MPRSA assigns responsibility the ocean disposal of dredged material to the EPA and the COE. This involves designating ocean sites for disposal of dredged material; issuing permits for the transportation and disposal of the dredged material; regulating times, rates, and methods of disposal and the quantity and type of dredged material that may be dumped; developing and implementing effective monitoring programs for the sites; and evaluating the effect of dredged material disposed at the sites (C. McArthur personal communication).

To date, offshore ocean dumping sites have been approved for ports at Wilmington, North Carolina; Brunswick, Georgia; Charleston, South Carolina; and Miami, Fort Pierce, Jacksonville, and Fernandina Beach, Florida (C. McArthur personal communication). The COE has identified Port Everglades and Palm Beach, Florida; Port Royal, South Carolina; and Wilmington, North Carolina as locations in need of new or additional designated ocean dumping sites.

Region IV of the U.S. Environmental Protection Agency identifies the following concerns in connection with existing South Atlantic Ocean Dredged Material Disposal Sites (ODMDS):

Ocean Dredged Material Disposal Site	Site Specific Concerns
Charleston, SC ODMDS	Live bottom areas proximal to the site subject to possible impact.
Miami, FL ODMDS	Effect of disposal plumes on nearshore coral reefs are under investigation.
Fort Pierce, FL ODMDS	Offsite transport of disposed dredged material and subsequent burial of nearby hard bottom communities is of concern to local community.
Jacksonville, FL ODMDS	Lies within Northern Right Whale Critical Habitat and site may be undersized.
Fernandina, FL ODMDS	Lies within Northern Right Whale Critical Habitat.
Brunswick, GA ODMDS	Lies within Northern Right Whale Critical Habitat.
Wilmington, NC ODMDS	Wood debris in dredged material suspected of migrating off site into shrimping grounds.

Dumping of trash, wastewater, and unwanted cargo is more likely to occur on the open seas since it is less observable here than in inshore waters. Prior to passage of the Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 (PL 100-220) an estimated 14 billion pounds of garbage was being dumped into the ocean each year. More than 85 percent was believed to have come from the world's shipping fleet in the form of cargo-related wastes.

4.1.2.2.1 Threats to EFH from Dumping

Potential threats include: burial of habitats and their flora and fauna, introduction of contaminants and toxic substances into waters and substrates, increased and harmful turbidity levels, and creation of hazards to fishing and navigation.

Threats associated with ocean dumping sites include covering of live bottom areas in or near a dump site; impacts to nearshore coral reefs and live bottoms by disposal plumes; offsite transport of disposed dredged material and subsequent burial of nearby hard bottom communities; designated sites that are too small to handle the load; migration of debris (e.g., wood) to fishing grounds; and the location of dumping sites within critical habitat of endangered species such as the northern right whale.

Because monitoring of disposal activities is sometimes inadequate, there are reports of dredged material dumping outside of designated dump sites (short dumping). One recent example of a possible short dumping event involves the excavation associated with the Fort Pierce Harbor, Florida, expansion project. In this case, over 400,000 cubic yards of fill from this project was dumped at a mid-shelf site. Numerous complaints arose thereafter from fisherman and divers that the fill was short-dumped and large areas of reef habitat had been covered. These sites had previously served as productive snapper/grouper fishing locations. Only limited monitoring information is available to examine the specifics of this incident; however, Reed (1996) summarizes much of the available information regarding the mud deposits potentially derived from this event.

Even with the use of approved practices and disposal sites, ocean disposal of dredged materials is expected to cause environmental harm since contaminants will continue to be released, productive bottoms will still be filled, and localized turbidity plumes and reduced oxygen zones will persist. Further, analyses are needed for use in dump site designation. For example, there have already been observed cases (e.g., at Charleston) where dump sites were designated and then, after dumping had been initiated, it was determined that valuable hard bottom habitats were located in or near the dump site. The effects of new disposal techniques such as creation of nearshore berms and "beneficial uses" of dredged material such as creation of shallow water habitats and emergent wetlands are, in many cases, unclear and may cause long-term geomorphological and ecological change that is harmful to certain species and environments. The SAFMC recognizes offshore berm construction as a disposal activity. As such, its policies regarding disposal of dredged materials apply. The SAFMC also recommends that research should be conducted to quantify larval fish and crustacean transport and use of inlets prior to any consideration of placement of underwater berms. Until the impacts of berm creation in inlet areas on larval fish and crustacean transport is determined, the SAFMC recommends that disposal activities should be confined to approved ODMDS. The SAFMC further believes that new offshore and near shore underwater berm creation activities should be reviewed under the most rigorous criteria and on a case-by-case basis.

In the absence of MPRSA and MPPRCA repeal or weakening, major dumping threats to EFH within federal waters should be limited mostly to illegal dumping and accidental disposal of material in unapproved locations. However, many agencies lack sufficient staff and funds to carry out mandated responsibilities and the opportunity for illegal and accidental dumping may be substantial. The effect of insuffìcent monitoring and enforcement is evident by the tons of debris, sometimes including hazardous materials such as syringes and medical wastes, that are deposited along the nation's beaches every year.

As noted in Section 4.1.2.2 (above) the SAFMC has developed Policies for disposal of dredged material in waters under its jurisdiction. With regard to use of Ocean Dredged Material Disposal Sites (ODMDS) the policy provides that:

- ODMDS should be designated or redesignated so as to avoid the loss of live or hard bottom habitat and minimize impacts to all living marine resources.
- Notwithstanding the fluid nature of the marine environment, all impacts from the disposal activities should be contained within the designated perimeter of the ODMDS.
- The final designation of ODMDS should be contingent upon the development of suitable management plans and a demonstrated ability to implement and enforce that plan.
- The Council encourages EPA to press for the implementation of such management plans for all designated ODMDS.
- All activities within the ODMDS are required to be consistent with the approved management plan for the site. The Council's Habitat and Environmental Protection Advisory Panel when requested by the Council will review such management plans and forward comment

to the Council. The Council may review the plans and recommendations received from the advisory sub-panel and comment to the appropriate agency.

- ODMDS management plans should specify those entities/ agencies which may use the ODMDS, such as port authorities, the U.S. Navy, the Corps of Engineers, etc. Other potential users of the ODMDS should be acknowledged and the feasibility of their using the ODMDS site should be assessed in the management plan.
- Feasibility studies of dredge disposal options should acknowledge and incorporate ODMDS in the larger analysis of dredge disposal sites within an entire basin or project. For example, Corps of Engineers' analyses of existing and potential dredge disposal sites for harbor maintenance projects should incorporate the ODMDS as part of the overall analysis of dredge disposal sites.

4.1.2.3 Offshore Sand and Mineral Mining

Offshore mining for minerals has not been a significant issue in the south Atlantic region (oil and gas mining is discussed separately). Earlier consideration of mining for manganese nodules and removal of useable materials and metals from seawater have not materialized, probably due to market conditions. Recent discovery of large phosphate deposits in waters off North Carolina could eventually lead to requests to mine these deposits. As readily available upland sources of minerals and other materials are depleted, the extraction of marine deposits will become more feasible and likely to occur.

The mining of sand for beach nourishment presents a large, complex, and politically charged threat to EFH in the southeast. Between 1981 and 1996, the NMFS reviewed more than 200 dredge proposals to nourish beaches. Most of these projects are large in scope and affect miles of coastline and nearshore habitats. Where sand is removed from nearshore environments, channels, and inlets , additional EFH alteration is possible due to a number of factors such as down drift erosion and removal of materials that eventually nourish shallow waters located behind barrier islands. A survey of 120 of the more than 200 beach nourishment projects received by the NMFS showed that about 5,735 acres of aquatic sites were subject to excavation and filling.

4.1.2.3.1 Threats to EFH from Offshore Sand and Mineral Mining

Potential threats include: removal of substrates that provide habitat for fish and invertebrates; creation (or conversion) of habitats to less productive or uninhabitable sites such as anoxic holes or silt bottom; burial of productive habitats in the vicinity of the mine site or in nearshore disposal sites (as in beach nourishment); release of harmful or toxic materials either with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and modification of hydrologic conditions that cause erosion of desirable habitats.

Offshore mining of sand for beach nourishment has steadily increased along the south Atlantic coast. Presently, sand mining and beach nourishment activities are performed along the entire south Atlantic coast from North Carolina to Florida. Major projects include those at Wrightsville Beach, North Carolina; Myrtle Beach and Folly Beach in South Carolina; and many of Florida's beaches such as Palm Beach, Boca Raton, and Miami Beach. Large-scale beach nourishment has also been performed at Tybee Island in Georgia, however, the material for that project was obtained from the Savannah Harbor deepening project. In addition to the larger projects that can involve millions of cubic yards of material, a substantial number of smaller projects involving beach scraping and removal of nearshore and inlet sand deposits are performed annually. While most of the larger projects are publicly funded and performed by the COE, many of these smaller projects are paid for with local revenues and/or private funds.

Although some of the environmental effects of sand mining and beach nourishment are documented there is much that is not known or studied (National Research Council 1995). NMFS and the FWS began raising questions over related effects as long as twenty years ago. In North Carolina and South Carolina concern over nearshore populations of mole crab (*Emerita talpoida*) and donax (*Donax* spp.) was raised with several projects. Although frequently requested, no long term studies on impacts to these and other beach fauna were ever performed. The fate of these species, from a population perspective, is of concern since they are important food items for transitory and resident fishes (e.g., Florida pompano, kingfishes, and spot) that are of economic and recreational importance (Hackney et al., 1996). Limited studies performed by Reilly and Bellis (1978) showed significant reductions in occurrence and biomass of mole crabs and donax at nourished beaches. Considering that many miles of southeastern beach front are now filled and/or subjected to scraping and sand relocation each year the cumulative effect of this activity could be substantial.

In Florida, beach nourishment projects require the dredging and filling of millions of cubic yards of fine sediments among shallow cross-shelf habitats, repetition or these activities at 3-10 year intervals, and tens of millions of dollars in annual expenditures (ACOE, 1996). Among mid-shelf sand plains, often having nearby reef habitats, dredges create large craters and increased turbidity. At both dredge and fill sites, acres of shallow water hard bottom, seagrass, or other habitats can be directly buried or subjected to elevated turbidity. Nearshore reefs buried or indirectly affected by dredging in south and central Florida can be utilized by over 325 invertebrate species (Nelson, 1989), 190 fish species, and serve as nursery habitats for many managed species (Lindeman, et al., In press). The timing of burial and anthropogenic turbidity spikes may have important effects upon the recruitment of settlement-stage fishes and invertebrates. Early spring through early fall dredge related burial of hard bottom may eliminate habitat required by larvae of many marine organisms during peak recruitment periods (Hackney et al., 1996, Lindeman and Snyder, MS).

Based primarily on summary tabulations of data for southeast Florida within ACOE (1996), Lindeman (1997) estimates that:

- At least 47 large-scale offshore dredge and inshore fill projects have occurred since 1960.
- Approximately 97 additional large-scale dredge projects are conservatively planned to occur between 1997 and 2046.
- Over 48,000,000 cubic yards of offshore sediments have been dumped within an intertidal/subtidal corridor of approximately 500 feet x 110 miles in the last 36 years.
- Over 80,000,000 additional cubic yards of excavated offshore material may be dumped within the same corridor of subtropical southeast Florida in the next 50 years.

Long-term estimates of mean turbidity values under natural conditions are not available for most areas. Therefore, the percentages of affected animals and algae that can tolerate repetitious (e.g. 2 to 4 hours to 4 to 6 times a day for three months) sedimentation and elevated turbidity events (that may approximate continuous three-month storms), are unknown. With exception of hurricanes, highly turbid nearshore conditions in southeast Florida are typically the product of winter storms and heavy runoff during the rainy season. Near Miami, Florida turbidity in the nearshore hard bottom habitat is highly variable, and affected by winds, longshore currents, swell condition and upland runoff. Summer-fall months normally show lower turbidity level (1-4 NTUs [Nepphlometric Turbity Units] and winter-spring months show higher average levels (3-7 NTUs) (Miami-Dade DERM unpublished). Direct effects of dredging activities on corals have been discussed by Marszalek (1981), Goldberg (1988) and Blair et al. (1990). Although sublethal effects of elevated turbidity are poorly known in tropical marine environments, some information is available. Bak (1978) showed that a relatively short period of dredge-induced turbidity stress created an abrupt decrease in growth in two species of hard corals (*Agaricia* and *Madracis*). From both the magnitude and duration of suppressed calcification, he concluded that such metabolic shock may have long-term consequences on reproduction. Long-term resuspension of bottom sediments has been shown to adversely affect an important hard coral, *Montastrea annularis* (Dodge et al., 1974). Teleniski and Goldberg (1995a; 1995b) have recently demonstrated negative effects of sediment loads on hard corals at turbidity levels of approximately 18 NTUs. This is noteworthy, as the Florida state administrative threshold for temporary shut-downs of dredge operations is substantially higher (29 NTUs). Such work is needed for other taxa and would provide a scientific basis for maximum turbidity thresholds (Goldberg, 1988; Teleniski and Goldberg, 1995b). Herrnkind et al. (1988) demonstrated that increased siltation can cause direct loss of critical habitat for spiny lobster recruitment. Enhanced resuspension of sediments over time and chronic turbidity may lower key growth and reproduction rates of some algal and invertebrate populations which are a basis for primary and secondary production on an ecosystem scale (Lindeman, 1997b). The potential for management decisions to multiply over time and impact unintentionally large spatial scales is of concern (Odum, 1982; Rothschild et al., 1994) and is particularly relevant when affected species are also over harvested (Ault et al., in press).

Mineral and other mining presently does not occur along the south Atlantic coast. Extensive phosphate deposits have been located in Onslow Bay in North Carolina and large quantities of mineral nodules containing manganese and other metals are abundant along the continental shelf floor. It is reasonable to conclude that mining of these and other materials could become economically feasible. If initiated, mining of marine bottoms would cause substantial bottom disturbance that could impact productive hard bottom communities, shellfish beds, and wintering grounds for demersal fish. Since related port and processing facilities do not presently exist, new mooring and dockside facilities would be needed and related secondary impacts would be expected. These impacts are discussed in detail in Section 4.1.1.6 of this document.

4.1.2.4 Oil and Gas Exploration, Development, and Transportation

Extensive areas of the south Atlantic have been designated and blocked off for oil and gas development. This activity, however, has been relatively dormant, unlike the activities that proliferate in the Gulf of Mexico. Initial exploration in the vicinity of Cape Hatteras several years ago did not advance due to environmental and other concerns including consistency issues associated with North Carolina's Coastal Zone Management Program. As of this writing, interest in the potential for renewed oil and gas exploration off North Carolina is again being considered. Environmental Impact Statements have been prepared for Mid-Atlantic Sale 121 and South Atlantic Sale for the exploration of oil and gas offshore of Cape Hatteras, North Carolina. Should gas or oil be found, the laying of pipe to North Carolina's shoreline facilities would likely have to traverse barrier islands and associated wetlands. As oil and gas levels decline, exploration will undoubtedly resume and if economically viable reserves are located, this activity could expand and inshore and offshore EFH could be at risk.

4.1.2.4.1 Threats to EFH from Oil and Gas Exploration, Development, and Transportation

Potential threats include: elimination or damage to bottom habitat due to drill holes and positioning of structures such as drilling platforms, pipelines, anchors, etc., release of harmful and toxic substances form extracted muds, oil, and, gas and from materials used in oil and gas recovery; damage to organisms and habitats due to accidental spills; damage to fishing gear due to entanglement with structures and debris; and damage to fishery resources and habitats due to effects of blasting (used in platform support removal); and indirect and secondary impacts to nearshore aquatic environments affected by product receiving, processing, and distribution facilities.

Although the continental shelf of the South Atlantic Bight has been the focus of moderate interest for exploration of oil and gas resources, there are presently no ongoing related activities in the region with exception of that mentioned in Section 4.1.2.4 (above). Considering the current status of the industry, a brief overview of the facilities that might be emplaced on the Outer Continental Shelf (OCS) to facilitate oil and gas exploration, development, and production is presented. This includes drilling vessels (jack-ups, semi-submersibles, and drill ships), production platforms, offshore moored terminals, and pipelines.

Oil and gas related activities are inherently intrusive and pose a considerable level of threat to marine and estuarine ecosystems, including EFH. As discussed below, exploration and recovery operations may cause substantial localized bottom disturbance. Where large scale development is undertaken the area of impact may be greatly expanded and become regional in scale. The toxic nature of hydrocarbon products and certain drilling materials (e.g., drilling muds), spill clean up chemicals, and the large volume of unrefined and refined products that must be moved within the coastal zone places large areas and resource bases as risk.

Structure emplacement can be expected to disturb some bottom area and, if anchors are deployed, the area of disturbance could be expanded. Jack-up rigs and semi-submersibles are generally used in water depths not exceeding 400 meters and disturb about 1.5 ha (3.7 ac) of bottom each. Conventional fixed platforms are also employed where water depths are less than 400 meters and they disturb about 2 ha (4.9 ac). Where water depths exceed 400 meters, dynamically-positioned drill ships may be used and sea floor disturbance is usually limited to the well site. Tension leg platforms may also be employed at these depths and the potential bottom disturbance area associated with these structures is about 5 ha (10.25 ac).

Each exploration rig, platform, terminal, and pipeline emplacement on the OCS can be expected to disturb surrounding areas. Exploration rigs, platforms, and pipe laying barges use an array of eight 9,000 kg anchors to position a rig and barge, and to move the barge along the pipeline route. These anchors are continually moved as the pipe laying operation proceeds and the total area actually affected by the anchors will depend on water depth, wind, currents, anchor chain length, and the size of the anchors and chain (MMS 1996). With conventional, fixed multi-leg platforms, which are anchored to the sea floor by steel pilings, explosives are generally used to sever conductors and pilings. These support structures are substantial in size since they must withstand hurricane conditions and have an average lifespan of about 20 years. The Minerals Management Service requires severing support structures at five meters below the sea floor surface so as to preclude interference with commercial fishing operations.

Possible injury to biota from use of explosives extends horizontally to 900 meters from the detonation site, and vertically to the surface. Based on MMS data, it is assumed that approximately 80 percent of removals of conventional fixed platforms in the Gulf of Mexico, in water less than 400 meters in depth, will be performed with explosives (MMS 1996). Alternative methodologies such as mechanical cutting and inside burning are often ineffective and are hazardous to workers.

Associated bottom debris commonly associated with over water oil and gas operations includes cable, tools, pipe, drums, assorted trash, and structural parts of platforms. The amount of bottom debris deposited around a site may vary and may be measured in tons. Extensive analysis of remotely-sensed data within developed lease blocks indicates that the majority of ferromagnetic bottom debris falls within a 450 meter radius of the site. The Fisherman's Contingency Fund, which was established by the oil and gas industry, provides recourse to commercial fishing interests for recovery of equipment losses due to shrimp net entanglement (MMS 1996).

Blowouts occur when improperly balanced well pressures result in sudden, uncontrolled releases of petroleum hydrocarbons. Blowouts can occur during any phase of development: exploratory drilling, development drilling, production, or workover operations. About 23 percent of all blowouts will have associated oil spills, of which eight percent will result in oil spills greater than 50 barrels, and four percent will result in spills greater than 1000 barrels. In subsurface blowouts, sediment will be resuspended and bottom disturbance will generally occur within a 300 meter radius. Whereas larger grain sediment will settle first, fined grained material may remain in suspension for periods of up to thirty days or longer. Fine grained material may be redistributed over a significantly large area depending on the volume of sediment disturbed, bottom morphology, and currents (MMS 1996).

The major operational wastes associated with offshore oil and gas exploration and development include drilling fluids and cuttings, and produced waters. Other important wastes include: from drilling--waste chemicals, fracturing and acidifying fluids, and well completion and workover fluids; from production--produced sand, deck drainage, and miscellaneous well fluids; and from other sources--sanitary and domestic wastes, gas and oil processing wastes, ballast water, storage displacement water, and miscellaneous minor discharges (MMS 1996). Major contaminants or chemical properties of materials used in oil and gas operations may include those that are highly saline; have a low ph.; contain suspended solids, heavy metals, crude oil compounds, organic acids, priority pollutants, and radionuclides; and those which generate high biological and chemical oxygen demands. Pierce *et al.* (1980) documented that wild fish have been injured by petroleum pollutants. Grizzle (1983) suggested that larger liver weights in fish collected in the vicinity of production platforms versus control reefs could have been caused by increased toxicant levels near the platforms. He also suspected that severe gill lamella epithelium hyperplasia and edema in red snapper, vermilion snapper, wenchman, sash flounder, and creole fish were caused by toxicants near the platforms. These types of lesions are consistent with toxicosis.

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in near shore base areas. Oil spills may result from many possible causes including equipment malfunction, ship collisions, pipeline breaks, human error, or severe storms. Oil spills may also be attributed to support activities associated with product recovery and transportation. In addition to crude oil spills, chemical, diesel, and other oil-product spills can occur with OCS activities. Of the various potential OCS-related spill sources, the great majority are associated with product transportation activities (MMS 1996).

As of this writing, only test wells have been drilled in the South Atlantic Bight area and these have been confined to inshore areas. All of these wells were capped immediately after drilling. No production or transportation facilities such as offshore terminals and pipelines have been built, nor are any such facilities currently planned in South Atlantic Bight waters. Despite this, millions of barrels of crude oil and refined product transit South Atlantic Bight waters by tank vessel every year and the potential exists for the discharge of thousands of barrels of oil due to vessel collision or sinking. Discharge of untreated ballast water from transiting vessels is also a chronic low level source of petroleum-based pollution.

4.1.2.5 Commercial and Industrial Activities

Direct physical encroachment into offshore environments by industrial activities is relatively limited along the south Atlantic seaboard. Notable exceptions include thermal intake and outfall structures associated with power plants in North Carolina and Florida, and sea walls that are used to protect commercial and industrial development. Several municipal sewage outfalls which discharge commercial and possibly light industrial wastes also exist. Because these facilities are relatively uncommon, direct physical impacts may be minor on a regional scale. Indirect effects, such as those associated with point and non-point-source discharges are thought to be substantially greater since it has been shown that discharges, including trash and debris, from land based activities may reach coastal waters and food webs.

Commercial development for hotels, motels, and related infrastructure along the south Atlantic shoreline has been extensive. Because many of these developments are located on unstable and shifting coastlines, maintaining associated buildings, revetments, bridges, causeways, beaches etc. has, and will continue to have an adverse effect on nearshore and offshore processes and environments.

4.1.2.5.1 Threats to EFH from Commercial and Industrial Activities

Potential threats include: direct and/or non-point-source discharge of chemicals, placement of intake structures, and protective sea walls (often used in connection with commercial establishments), and cumulative and synergistic effects caused by these and other industrial and non-industrial related activities.

Future exploration and recovery of marine resources and placement of offshore mooring and unloading facilities could substantially threaten offshore EFHs. Although none of these activities or facilities are presently being planned. it is likely that continued economic growth, depletion of limited natural resources, and use of limited coastal lands will eventually lead to greater exploitation of offshore resources.

Electric power generation is needed for commercial and industrial development, and for residential purposes (See Section 4.1.1.4). When located in coastal waters, power generation facilities may adversely affect EFH and associated biota. Potential threats include direct displacement of wetlands, submerged bottoms, and vegetated upland buffer areas for generation facilities and ancillary uses such as fossil fuel storage, cooling towers, and water intake and outfall structures; construction of navigation channels and docks for unloading coal, oil, and other materials needed for operation of generators and equipment; discharge of toxic substances from air emissions; cooling waters (e.g., chlorine); and from point and non-point-source discharges emanating from impervious surfaces and coal and slag piles; discharge of thermal discharges that may be lethal to flora and fauna, or that serve as attractants that subject fish, invertebrates, and marine mammals to thermal stress when changes in plant operation or weather occur; and entrainment and impingement of living marine resources in which organisms succumb to or are damaged as a result of entrapment in intake structures or capture on screens.

Although relatively minor in its present scale, the commercial harvest of *Sargassum* from coastal waters off North Carolina is of concern. *Sargassum* weed lines and associated frontal zones provide cover, trophic, and other attributes needed to sustain endemic fish and invertebrates of the pelagic *Sargassum* community and associated fauna. The weed lines may be especially important during early life stages of sea turtles and certain fish and they are important sites for the North Carolina and South Carolina offshore recreational fishery.

The occurrence of methyl mercury in the flesh of the large piscivorous fish such as king and Spanish mackerel and other large pelagic and demersal species such as amberjack, wahoo, snapper, and grouper has been documented and is of concern largely with respect to human consumption of these species (D. Engel personal communication). The probable source of these contaminants is atmospheric input from worldwide inventories associated with emissions from incinerators, fossil fueled power plants, automobiles, and industry. As such, the regulation of surface water contamination from atmospheric pollution may require local, regional, and international efforts.

Effects related to commercial development are similar to those from urban and suburban development and the discussions in Section 4.1.1.4 apply. Further, effects of shoreline modifications such as beach nourishment are found in Section 4.1.2.3.

4.1.2.6 Natural Events/Global Change

Coastal processes may be dramatically altered by natural events. These include shorter term forces such as storms, hurricanes, floods, etc., and longer-term events such as global warming and sea level rise. Minor events can be beneficial, but severe events are almost always substantial or catastrophic in terms of their environmental effect (see Section 4.1.1.10). With extensive development of the coastal zone, sea level rise can have serious consequences for humans, EFH, and the fishery resources that rely on coastal habitats. The eventual result of global change is even less predictable. However, it is evident that coastlines and related ecosystems are changing and human activities may be involved and could largely frame the outcome. Considering the extensive level of coastal development in the coastal zone, even a minor increase in sea level rise can have serious consequences for humans, EFH, and the fishery resources that rely on coastal habitats.

4.1.2.6.1 Threats to EFH from Natural Events/Global Change

Potential threats: Coastal and inland storms can cause severe acute and chronic perturbations including habitat erosion, burial by deposition of sediment onto submerged bottoms; creation of strong currents that alter habitats and remove biota; damage by wind and waves, elevation of turbidity that can cause physiological damage and disrupt feeding, spawning, migration, and other vital processes; and abrupt changes in salinity and other water quality characteristics such as fecal coliform levels. Long-tern climatological changes can bring about similar changes by altering weather patters and through sea level rise which can inundate habitats and cause depths that do not support existing habitats and biota (e.g., corals). Large scale ecological changes may also occur where temperature changes favor or harm a particular species or group. Changes that cause relocation of frontal boundaries, weed lines, and stratification and temperature boundaries may also cause substantial and undesirable environmental change.

Catastrophic storms can substantially alter nearshore and inner shelf environments. Some of these changes may be brief and insignificant while others may persist and affect the long-term geological and ecological evolution of coastal environments. How well coastal wetlands survive climate change and resultant sea level rise depends upon the rate of relative sea level rise and marsh accretion. Relative sea level rise is a function of both land submergence and real water level rise. Since both processes lower land surface relative to water levels, it is often difficult to separate the relative magnitudes of each. Global estimates on sea level rise conceal a significant variation in relative sea level change found in various regions of the U.S., ranging from over 10 mm per year decline in the sea surface along the coast of southeastern Alaska to a 10 mm per year rise along the northeastern Main and Louisiana coasts (Stevenson *et al* 1986).

In the face of rising relative sea level, coastal marshes may keep pace if vertical marsh accretion increases sufficiently. At the current rate of sea level rise, most coastal wetlands of the East and Gulf Coast of the U.S. have kept pace with sea level rise (Stevenson *et al* 1986). Out of 18 U.S. wetlands for which sufficient data on accretion rates and relative sea level rise are available, only four sites (encompassing the Mississippi River Delta and Blackwater Marsh in the Chesapeake Bay) have not accrued sediment fast enough to keep pace with relative sea level rise. Wetland response to sea level rise is determined largely by tidal range magnitude and, in general, wetlands in regions with relatively small tidal ranges have lower rates of vertical accretion because less sediment is transported by tidal action (Stevenson *et al* 1986). By the same token, coastal areas with higher tidal ranges are less vulnerable to sea level rise (Reid and Trexler 1991).

Hurricanes play a critical role in the structure of both coral reef habitats and the organism assemblage that use these habitats. See Lirman and Fong (1997) for a recent summary of much of this litterature relevant to the Florida Reef Tract.

Both sea level rise and changing water temperatures will influence U.S. coral reefs located in southern Florida, on small isolated banks in the Gulf of Mexico off Louisiana and Texas, and off Puerto Rico and Hawaii. At current rates, sea level rise (1 to 2 mm/yr) does not inhibit coral reef vertical growth, estimated to be roughly 10 mm/yr (Grigg and Epp 1989); sea level rise under scenarios of global warming is likely to equal or exceed these limits (Reid and Trexler 1991).

Coral bleaching, which involves the loss of the mutualistic algae living with the coral is believed to stem from such stresses as sedimentation, pollution, or unusually cold or warm water temperatures. With bleaching, energy needed for growth is insufficient and if bleaching is frequent protracted death may result (Goreau 1990a). Coral bleaching has been observed sporadically around the world for decades and was almost always linked to localized conditions such as muddy river water plumes, or elevated water temperature. In the past decade; however, coral bleaching has taken place on an unprecedented and worldwide scale with bleaching episodes occurring in 1980, 1983, 1987-88, and 1990 (Goreau 1990a, William and Williams 1990, Williams 1990). In the Caribbean, all of the major bleaching episodes in the 1980's have been associated with above-normal water temperatures (Goreau 1990b).

Water temperature increases of 2 to 3 degrees above normal can cause bleaching at any latitude. Corals may be able to adapt physiologically to gradual temperature increases, but rapid increases, as presently predicted with global warming could cause coral die-offs.

4.2 Adverse Impacts of Fishing Activities on Essential Fish Habitat

4.2.1 Introduction

The Sustainable Fisheries Act requirement for identification of threats to EFH posed by fishing activities will be addressed in a report by Peter Auster and Richard Langton that is being prepared, under contract, for the NMFS. A copy of the draft report (Auster and Langton 1998) is is available and is included as Appendix M to this document. Information relavant to the south Atlantic contained in the final report will summarized and included in a later version of this document.

The effects of fishing are the subject of numerous, mostly site specific and fishery specific, investigations that focus largely on economic and social factors. Most early fisheries management efforts deal with increased yields, gear, and identifying and locating new target species and markets. With the world wide decline of many fish stocks emphasis has shifted, in recent years, to stock management and recovery. This change in management emphasis has gradually led to realization that reductions in the size and quality of fishery habitats have reached critical levels. It has also furthered the view that, in certain situations, fishing itself may be profoundly changing the physical and biological character of fish harvest and life requisite areas.

Trawling and other fishing activities that involve direct contact between fishing gear and the aquatic environment can alter the structural character of fish habitats. When the change is sufficient enough to preclude or limit use by fishery directed or target species, declines in catch abundance and individual fish size may occur. Although a clear cause and effect relationship is evident, determination of the level of effect inducted by physical change may be complex. Relevant factors, in addition to the magnitude of the direct physical change, may include disturbance frequency and duration, seasonality, and other environmental, ecological, and physiological processes that control recovery and recruitment of requisite species of the community. As noted by Auster and Langton (1998) "... mobile fishing gear reduced habitat complexity by (1) directly removing epifauna or damaging epifauna leading to mortality, (2) smoothing sedimentary bedforms and reducing bottom roughness, and (3) removing taxa which produce structure (i.e., taxa which produce burrows and pits)."

As difficult and complex as restoring habitats and controlling fish harvest has proven to be, success in these efforts still may not yield satisfactory results. Environmental changes brought about by physical alteration of substrates and changes in species composition may create conditions that cannot sustain preexisting plant and animal assemblages or abundances. As noted by Auster and Langton (1998), population response (and successful fishery management) may be linked to parameters that are closely correlated to...ecological relationships (and) population response may be the result of "(1) independent single-species (intraspecific) responses to fishing and natural variation, (2) interspecific interactions such that as specific populations are reduced by fishing, non-harvested populations experienced a competitive release, (3) interspecific interactions such that as non-harvested species increase from some external process, their population inhibits the population growth rate of the harvested species, and (4) habitat mediation of the carrying capacity for each species, such that gear induced habitat changes alter the carrying capacity of the area." As further implied by Auster and Langton (1998), the magnitude of environmental or ecological change needed to affect a fishery may not need to be monumental from a physical perspective. After all, significant reductions in benthic diatoms and microalgae can affect higher trophic levels.

In their conclusion Auster and Langton (1998) state, "...primary information is lacking for us to strategically manage fishing impacts on EFH without invoking precautionary measures. A number of areas where primary data are lacking, which allow better monitoring and improved experimentation, ultimately leading to improved predictive capabilities, are:

1. The spatial extent of fishing induced disturbance . While many observer programs collect data at the scale of single tows or sets, the fisheries reporting systems often lack this level of spatial resolution. The available data makes it difficult to make observations, along a gradient of fishing effort, in order to assess the effects of fishing effort on habitat, community, and ecosystem processes.

2. The effects of specific gear types, along with a gradient of effort on specific habitat types. These data are the first order needs to allow an assessment of how much effort produces a

measurable level of change in structural habitat components and the associated communities. Second order data should assess the effects of fishing disturbance in a gradient of type 1 and type 2 disturbance treatments.

3. The role of sea floor habitats on the population dynamics of harvested demersal species. While there is often good time series data on late juvenile and adult populations, and larval abundance, there is a general lack of empirical information (except in coral reef, kelp bed, and for SAV fishes) on linkages between EFH and survival, which would allow modeling and experimentation to predict outcomes of various levels of disturbance."

Auster and Langton (1998) further state that, "Recovery of benthic communities, especially for sessile invertebrates, is dependent upon recruitment at the larval stages. Two aspects of this process that are necessary for success are 1) proximity of reproductively mature adults, and 2) an undisturbed site for settlement and growth to maturity. If the intensity of fishing is too great then the possibility of a type 2 disturbance, where a small patch of reproductive animals is isolated by large expanses of sea floor, exists. The frequency of disturbance is equally important because newly settled juveniles may be damaged or destroyed if their settlement surface is perturbed at a critical time in their life cycle. Fishing should therefore be conducted with an intensity that does not create isolated benthic communities that are then expected to recolonize an area if the objective is a sustainable level of harvest. Similarly the habitat requirements of the harvested species have to be taken into account, as suggested in terms of 1 and 3 above, to insure that the habitat itself is not disturbed anymore frequently than is required to maintain the integrity of the benthic community that supports the fishery."

4.2.2 Gear Impacts and Council Action

4.2.2.1 Gear Used in Fisheries Under South Atlantic Council Fishery Management Plans

The following is a list of gear currently in use (or regulated) in fisheries managed under the South Atlantic Council fishery management plans. In general if gear is not listed it is prohibited or not commonly used in the fishery:

Snapper Grouper Fishery Management Plan

1. Vertical hook-and-line gear, including hand-held rod and manual or electric reel or "bandit gear" with manual, electric or hydraulic reel (recreational and commercial).

2. Spear fishing gear including powerheads (recreational and commercial).

3. Bottom longlines (commercial).
   - Prohibited south of a line running east of St. Lucie Inlet, Florida and in depths less than 50 fathoms north of that line.
   -May not be used to fish for wreckfish.

4. Sea bass pots (commercial).
   -May not be used or possessed in multiple configurations.
   -Pot size, wire mesh size and construction restrictions.
   -May not be used in the EEZ south of a line running due east of the NASA Vehicle Assembly Building, Cape Canaveral, Florida.

5. Special Management Zones (created under the Snapper Grouper FMP).
   -Sea bass pots are prohibited in all Special Management Zones.
   -Fishing may only be conducted with hand-held hook-and-line gear (including manual, electric, or hydraulic rod and reel) and spearfishing gear in specified Special Management Zones, however, in other specified Special Management Zones a hydraulic or electric real that is permanently affixed to a vessel ("bandit gear") and/or spear fishing gear (or only powerheads) are prohibited.

Shrimp Fishery Management Plan

1. Shrimp trawls -- wide-ranging types including otter trawls, mongoose trawls, rock shrimp trawls, etc. (commercial).
   -Specified areas are closed to trawling for rock shrimp.

Red Drum Fishery Management Plan

1. No harvest or possession is allowed in or from the EEZ (no gear specified).

Golden Crab Fishery Management Plan

1. Crab traps (commercial).
   -May not be fished in water depths less than 900 feet in the northern zone and 700 feet in the middle and southern zones.
   -Trap size, wire mesh size and construction restrictions.

Coral, Coral Reefs, and Live/Hard Bottom Habitat.

1. Hand harvest only for allowable species (recreational and commercial).
2. Oculina Bank Habitat Area of Particular Concern
   -Fishing with bottom longlines, bottom trawls, dredges, pots or traps is prohibited.
   -Fishing vessels may not anchor, use an anchor and chain, or use a grapple and chain.

Coastal Migratory Pelagic Resource Fishery Management Plan

1. Hook and line gear, usually rod and reel or bandit gear, hand lines, flat lines etc. (recreational and commercial).
2. Run-around gillnets or sink nets (commercial).
   -A gillnet must have a float line less than 1,000 yards in length to fish for coastal migratory pelagic species.
   -Gillnets must be at least 4-3/4 inch stretch mesh.
3. Purse seines for other coastal migratory species (commercial) with an incedental catch allowance for Spanish mackerel (10%) and king mackerel (1%).
4. Surface longlines primarily for dolphin.

Spiny Lobster Fishery Management Plan

1. Traps, hand harvest, dip nets and bully nets (recreational and commercial).
   -Trap size and construction restrictions.

4.2.2.2 Physical Alterations

Commercial and recreational fishing can potentially stress the health of the coral or coral reefs. These fishing operations are directed at a multitude of finfish and shellfish that live near or in coral habitats. Among the most important such species near outer bank reefs are snappers

(*Lutjanus spp.* and *Rhomboplites spp.*), grouper (*Mycteroperca spp.*), and tilefish (*Lopholatilus spp.*) (Bright and Pequegnat, 1974; Antonius, et al., 1978). Patch reefs and hard bottoms supply habitat to comparably diverse fisheries stocks, including the fish listed above, plus stone crabs (*Menippe mercenaria*), spiny lobsters (*Panulirus argus*), shrimp (*Penaeus spp.*), and many others (Smith, 1976; Hopkins, et al., 1977; Davis, 1979, personal communication). Nearly all areas in which corals live support some type of fishing venture. Tropical specimen collectors harvest fish from areas with or without corals. Extensive tropical fish collecting may alter ecological relationships. Fish collectors harvest mostly juveniles from waters less than 15 m (50 ft) deep (Feddern, 1979, personal communication). Fish populations in deeper waters and in difficult collecting areas (e.g. coral reefs) may remain as recruitment reserves.

In addition to specific fishing-related stresses, fish gear impacts may also be an important source of coral destruction both inside and outside state waters. Based on observations of the industry and conversations with scientists in the field, these potential gear damages could include shrimp trawling in hard bottom areas, calico scallop dredging, snapper-grouper trawling, shrimpers trawling for lobsters, lobster pot fishing, and reef fish traps. In each case, the gear is equipped with weights or chains that may physically damage corals and associated biota. Geographically, these activities occur in the northeastern and eastern Gulf of Mexico (shrimp trawling, scallop dredging), the shelf off western Florida between St. Marks and Tarpon Springs (trawling), Florida Middle Grounds near parts of Tarpon Springs and Madeira Beach (snapper and grouper), the Florida Keys (lobster potting, lobster trawling, fish traps), off northeastern Florida and Georgia (rock shrimp, brown shrimp), and off Georgia and South Carolina (shrimp trawling, snapper-grouper trawling). The potential impacts include disruption of the hard bottom communities inhabited by the silt-tolerant corals (*Solenastrea, Oculina, and Siderastrea*), sponges, shellfish, and finfish in the Gulf and off the southeastern states; physical harm to coral reefs that have fish or shellfish traps dropped on, dragged through, or swept into them; and possible biological harm to the reef associated biota (e.g., lobster pot removal of adult tropical fish and fish trap removal of resident reef species). The opinion that lobster traps are harmful to hard bottom areas when they are fished with excessively long buoy lines has been expressed. These practices in shallow waters entail dragging the traps across the bottom during retrieval.

Bottom longline fishing for snapper and grouper had expanded in the management area as a result of economic stress in other fisheries. Lines were frequently set adjacent to coral reefs where reef fishes congregate. They are not normally set across the reefs because of potential loss of the gear. An increased use of stronger wire cable for longline allows use of the gear over hard bottom with less risk of gear loss, but with more potential for habitat damage. Jaap (1981, personal communication) has identified two species of corals brought in by bottom longline fishermen.

Significant user conflict developed between traditional reef fish fishermen and roller trawl fishing vessels off Daytona Beach. The former claims that roller trawls are destroying the habitat, including *Oculina varicosa* coral banks.

Tunnicliffe (1980) reported coral damage in Jamaica where large fish traps thrown on the reefs caused much breakage and death of corals. Similarly, a Florida fish trap study (Taylor and McMichaels, 1981, personal communication) reported coral pieces, some identified as staghorn in traps, indicating that wire traps will break some fragile corals.

The impact of fishing activities on coral via incidental catch has been studied by the St. Petersburg laboratory of the Florida Department of Natural Resources. The study, sponsored by the National Marine Fisheries Service during 1978, consisted of onboard sampling of collections from 196 shrimp trawls on the shelf off western Florida, between Apalachicola and Dry

Tortugas. Results showed soft corals (Renilla) in 25 of the 196 trawls, with most of those trawls in the northern Gulf region near Apalachicola. The quantity of corals per trawl ranged from only a few pieces to about 25.

Impacts from fishing may be categorized as physical or chemical. Physical impacts may result from gear damage or simply gear use. Nets and pots may be lost on reef outcroppings as seen near Dry Tortugas and at the Sambo Reefs In the Keys (Bright and Jaap, in press). Hand fishing by spear or lobster loop may result in overturned coral heads or damaged corals from diver contact. Hook and line fishing may affect corals to a limited extent, but not nearly so much as towed or emplaced gear. Lobstering with traps directly on corals is a rare, accidental occurrence that can damage fragile species (*Acropora cervicornis* or staghorn coral) or large brain corals like *Diploria* (Bright and Jaap, in press). Lobsters and other reef residents may also be collected by stunning with poisons or explosions. Jaap and Wheaton (1975) conducted field studies on acetone, quinaldine in an acetone solution, and Chem-Flsh-Collector (a commercial rotenone preparation) and also reviewed the literature on anesthetics and poisons. Their field studies on gorgonians and scleractinians at Eastern and Western Sambo Reefs off Boca Chica Key, Florida, revealed that rotenone and quinaldine often induced coral polyp retraction and occasionally caused tissue discoloration. The scleractinians *Acropora cervicornis*, *A. palmata*, *Siderastrea siderea*, *Diploria strigosa*, and *Dichocoenia stokesii* were damaged by the rotenone (Jaap and Wheaton, 1974). Several gorgonians and other test corals were not affected by the chemicals at the test levels. Associated reef species such as the urchin, *Diadema antillarum* and some crabs and shrimps, vacated the treatment area or died. Quinaldine and bleach are used to stun or drive out mobile animals to ease live capture; rotenone is a toxicant when used in sufficient doses (Jaap, 1979, personal communication). In the Bahamas, chlorine bleach fishing among corals was a common practice of fishermen. Often, a characteristic pattern of infection ensues whereby zones of the blue-green algae, *Oscillatoria submembranacea*, the bacteria, *Desulfovibrio* and *Beggiatoa* invade the stressed coral tissues (Campbell, 1977). Explosives may be used in some areas to collect fish (Ronquillo, 1950; Christian, 1973) or move coral rock, but its damage to living corals has never been adequately quantified (Johannes, 1975). Explosives do not appear to be in use at this time, but were used at Carysfort Reef near Key Largo from about 1900 to the early 1950s (Shinn, 1979, personal communication). Damage throughout that period was severe but recovery since the 1950s has resulted in no visible effects of the blasting.

Lastly are the possible impacts of artificial fishing reefs. Throughout the management area, fishing associations, state resource agencies, and private groups have built artificial reefs on the inner continental shelf. In many instances tires have been the primary reef building blocks. Problems arise, however, when the bundles of tires weighted with concrete break loose from their mooring and roll about unanchored. In Monroe County, Florida, near Coffins Patch Reef off Marathon, the damage to coral has been so severe that the tires were removed (Richard Heibling, personal communication). A similar problem occurred off Fort Myers, Florida (Casey, 1979, personal communication). The problem appears to be proper placement of the reef and not the construction, Although the untethered tires are doing much damage, artificial reefs firmly attached do provide valuable habitat for many fishes.

4.2.2.3 Fish Traps

4.2.2.3.1 Trap Loss and Ghost Fishing

TRAP LOSSES (from Kelly, 1990 as summarized in SAFMC 1991a)

There are many reasons why fish traps are lost both inshore and offshore. A common reason is gear failure, which includes pot warp (line) parting, the buoy separating from the pot warp or the buoy breaking up. This gear failure can be caused by normal wear and tear, powerboat propellers, and sea turtles or sea gulls biting the buoys or pot warp. Theft is also a major cause of lost traps in many areas. Losses occur because of setting the traps too deep or on too steep a slope. Storm surge and wave action can cause loss of traps, particularly in shallow inshore waters. Traps without buoys are less susceptible to storm damage, but may be moved from a site by currents or wave action and become unretrievable. In coralline areas, the buoy lines may become entangled on coral, chafe, and break. Offshore, losses are primarily caused by large vessels cutting or dragging gear, gear failure, and storms. Strong currents submerging buoys or sweeping traps away from the locations where they were set and traps becoming entangled with other fishing gear and anchors have also been cited as causes of trap loss.

The percentage of traps lost varied considerably among studies by both area and depth fished. Wolf and Chislett (1974) reported pot losses of 10-20% per trip in exploratory efforts in deep water shelf edges in the Virgin Islands. They attributed these losses to pots tumbling down steep slopes. While trap fishing off Boca Raton, Florida, Craig (1976) had a trap loss approaching 20% for a period of six months, with at least some loss due to theft. In Broward County, Florida trap fishermen, had an average of 20.3% annual loss due mainly to strong currents, entanglement and theft. Dade County, Florida trap fishermen reported losing 1-5 traps per trip, with an annual loss of 100%. Losses were due to theft or loss of buoys. Traps (sic) theft was such a problem that traps were brought back to port at the end of each fishing day in Dade (Sutherland and Harper, 1983). Munro (sic) County, Florida trap fishermen had estimated average annual trap losses of 63%. The losses were mainly from currents and severance of buoys by large ships in deep water and from vandalism inshore. Trap loss was not a problem in Collier County, Florida with an annual loss of only 5%. This was possibly due to the fact that fishermen brought back traps to the dock after each trip (Taylor and McMichael, 1983). About 85% of traps used off Key Biscayne, Florida in a study on mesh selectivity by Sutherland et al. (1987) were lost with most losses attributed to theft. Trap loss due to theft and vessels cutting of fouling lines was reported as a major problem in the Virgin Islands (Swingle et al., 1970; Olsen et al., 1974; Sylvester, 1972).

In Jamaica, Munro and Thompson (1973) had such a theft problem in their study that the use of buoyed traps had to be abandoned. While losses due to theft, storms, and vessels can not easily be controlled, the trap fishermen can inspect gear frequently for wear and tear and use more durable materials.

GHOST TRAPS AND DERELICT TRAPS (from Kelly, 1990 as summarized in SAFMC 1991a)

Fish traps that fishermen cannot locate and retrieve or that are abandoned, but still capable of catching fish, are referred to as ghost traps. Ghost traps have long been a subject of concern, but opinions have changed considerably since Olsen et al. (1978) made their observations. They noted that if traps were lost, mortality of juvenile and forage species could decimate a fishing ground. They suggested that considerable mortality could take place over the 1-2 years before the mesh corroded away, and indicated corrosion time would be longer and mortality would be greater for small sizes of mesh. A more recent study made by Harper and McClelland (1983) estimated the average fishing life of eight traps observed off Key Biscayne to be from 5.5 to 157 days before becoming unable to capture fish. While the decay and catch rates of ghost traps are not well documented, at least some evidence indicates that lost traps quickly become damaged and ineffective (Sutherland et al., 1978). Most of the reports of injury and mortality of ghost traps appear to be anecdotal. However, an underwater video was presented to the South Atlantic Fisheries Management Council on June 11, 1990 that documented dead and injured fish in ghost traps in the Florida Keys. The video was presented by Fernand Braun in an effort to persuade the council to ban fish traps. Also, in the Harper and McClelland (1983) study, 19.2% of the 130 fish known to enter their traps were reported to die.

Derelict traps are lost or abandoned traps that are incapable of catching fish due to structural damage or deterioration. Derelict traps have small holes or breaks in the wire mesh, gaps between ceiling and floor panels and walls, or entire panels deteriorated or missing (Smolowitz, 1978).

Traps become derelict in a number of ways. Predator damage, wire mesh corrosion, escape windows opening, and materials fastened to escape devices decomposing have all been documented.

Munro et al. (1971) speculated that lost traps that have accumulated large numbers of fish may be attacked and rendered ineffective by large predators such as nurse sharks (*Ginglymostoma cirratum*). Harper and McClelland (1983) found the funnel openings enlarged with the prongs bent back and speculated that the damage was by large predators attempting to escape. Seams were also split by predators such as cubera snapper (*Lutjanus cyanopterus*), great barracuda (*Sphyraena barracuda*), yellow jacks (*Caranx bartholomae*), and lemon sharks (*Negaprion brevirostris*) in Harper and McClelland's study. He found mortality of these large predators to be high. In Craig's study (1976) escapement through trap holes caused by predators became a problem if traps were not hauled after 5 or 6 days. Fish are rarely caught in traps with holes or breaks in the mesh (Craig, 1976; Sutherland and Harper, 1983; Ward, 1983). Even small holes or breaks in the wire mesh apparently render them ineffective as fish traps.

Using a submersible for observation, Sutherland et al. (1983) found juvenile fish numerous in and around derelict traps. The derelict traps and other man made objects appeared to serve as artificial reefs on "barren" sand sea floor areas (Sutherland et al. 1983; Harper and McClelland, 1983). Sutherland et al. (1983) observed that fish were absent or rare near traps on or adjacent to reefs.

TRAP DESIGN AND GHOST FISHING (from Kelly, 1990 as summarized in SAFMC 1991a)

Various methods have been proposed to alleviate the concerns of ghost traps. Since trap design is one of the keys as to whether a ghost fishing situation will be created (Smolowitz, 1978), many of these methods deal with trap design. Designs to prevent ghost fishing were primarily developed for northern or temperate invertebrate (lobster) fisheries.

Degradable sections of hinges that rot in a specified time period are one such design requirement that has been adopted by both the Gulf of Mexico and South Atlantic Fishery Councils. When the degradable link fails, the trap no longer fishes. The self destruct devices are designed to prevent or reduce ghost fishing without reducing efficiency of the trap or significantly increasing the costs.

Kumpf (1980) conducted a limited experiment to determine the durability and suitability of 4 types of materials for self-destruct devices that were inexpensive, available locally, and simple to replace. He tested unoiled jute, sisal, 16 gauge, and 18 gauge galvanized wire in his experiments. The unoiled jute and sisal lasted 42 days while the galvanized wire was still intact at the end of the 120 days of the testing. He noted the galvanic couplings with a short life spans (sic) are available or could be manufactured if there was a sufficient demand.

Several problems are encountered in the use of self-destruct panels and hinges. They are not readily accepted by fishermen because of possible catch losses and the time lost in repair or replacement. The trap may land with the degradable panel facing down. And, time for degradable panels or hinges to deteriorate may be longer than predicted. Corrosion of metal hinging materials occurs more slowly in colder, slower moving water and biodegradable materials take longer to break down in deeper water where there are fewer organisms to attack the materials.

Gordon Sharp, a Florida Marine Patrol officer in Key West, stated that he found 95% of the traps he has seized in areas closed to trap fishing to be constructed illegally. The primary construction violations he found were uses of non-degradable hinge materials such as rubber, nylon or stainless steel, or the use of illegal thicknesses of jute.

Escape vents for sublegal fish are another design element demonstrated to reduce the catch of and damage to sublegals (Smolowitz, 1978). Smolowitz also noted other advantages to the use of sublegal vents such as improving the quality of the catch and increasing trap efficiency. Fewer fish in the traps should result in fewer injuries, and in areas with large populations, sublegal escape vents should allow more legal sized fish to be caught.

One design feature that has received little attention is the trap funnel. The funnel size, shape, mesh size, and type of funnel (straight or horseneck) all have effects on retention of trapped fish and would therefore have an effect on the ability of a ghost trap to retain fish (see trap design and structure).

4.2.2.3.2 Prohibition of Fish Traps

The Council prohibited the use of fish traps in the South Atlantic EEZ; however, black sea bass traps may be used north of Cape Canaveral (Vehicle Assembly Building, 28° 35.1' N Latitude).

Traps are inexpensive, easily constructed, easy to use and require little skill (although the most successful fishing depends on skill in locating productive fishing grounds), fish unattended, catch a wide range of species not caught by other gear, allow economic exploitation of low density fish stocks, allow fishing where other methods are uneconomical or have become uneconomical because of overfishing and are able to be fished over a wide range of depth, bottom types and conditions. On the other hand, traps are bulky, result in trap loss and ghost fishing, catch species that were not traditional food fish, are fished near live bottom causing habitat damage, result in a bycatch of which a portion dies upon release, result in gear and user group conflict, and existing regulations are extremely difficult or impossible to enforce.

The Council concluded that the issue of traps is a critical issue to the State of Florida and in the long term to the entire South Atlantic as well. Florida deliberated the issue of traps for many years and the Florida State Legislature prohibited the use of fish traps in 1980. There have been many problems since then due to the inconsistency between state and federal regulations. The snapper grouper resource off the Florida Atlantic coast has continued to decline. The snapper grouper stocks are more overfished off Florida than they are anywhere else in the South Atlantic.

The Council concluded that if they cannot prohibit fish traps, they will never be able to stop overfishing of the snapper grouper resource. The Council concluded that traps are non-selective by size and by species (e.g., red grouper recruit to the hook and line fishery at around 19" and to the trap fishery at around 11"). Bohnsack et al. (1989) do note that modifications to mesh size will alter the size of fish caught. They noted that total value, species caught, number of individuals and mean total weight per haul declined with meshes larger or smaller than 1.5" hexagonal mesh. The mesh sizes required to correlate with the 20" minimum sizes would be so large as to result in de facto prohibition on use of fish traps.

Traps unnecessarily kill an abundance of tropical fish because they harvest angel fish, tangs, parrot fish, etc. The Council has based this conclusion on input from commercial and recreational fishermen and from processors and dealers. In addition, information contained in Bohnsack et al. (1989) document the catch of these species. Unfortunately, these species were not recorded separately in the commercial landings data until recently, thus the commercial landings data are not available to quantify the extent to which catches of these species have increased.

Since March 1, 1991 the State of Florida has prohibited the harvest of tropical fish: "The purpose and intent of this Chapter is to protect and conserve Florida's tropical marine life resources and to ensure the continued health and abundance of these species. The further intent of this Chapter is to ensure that the harvesters in this fishery use non-lethal methods of harvest and that the fish, invertebrates and plants so harvested be maintained alive for the maximum possible conservation and economic benefits." Allowing fish traps in federal waters would make Florida's regulations difficult, if not impossible, to enforce and would not address Problem #5 which is, that "the existence of inconsistent state and federal regulation makes it difficult to coordinate, implement and enforce management measures and may lead to overfishing. Inconsistent management measures create public confusion and hinder voluntary compliance."

The way in which fish traps were used made enforcement extremely difficult. All other kinds of fishing gear are eventually brought back to the dock where they can be examined by state marine patrol officers or other law enforcement personnel. Once traps are placed in the water, they were seldom are brought back to the dock. Testimony documents the various kinds of violations recorded in the Key West area (e.g., biodegradable panel requirement violations). The loss of traps was high ranging from 20% to 63% and in certain sectors trap loss may be as high as 100%.

The SAFMC Law Enforcement Committee and Advisory Panel were established to advise the Council on enforceability of various management approaches. They noted that the existing system is difficult to enforce and is incompatible with Florida state law, that the 100 foot contour limitation is difficult to enforce and that poaching is a big law enforcement problem in the fish trap fishery. These two bodies recommended to the Council that a total prohibition on use of fish traps in the South Atlantic EEZ was the most enforceable of all alternatives considered.

The enforcement issue was summarized by Kelley (1990): "Enforcement is the largest problem of all. There are widespread abuses of the regulations governing the use of fish traps. There seems to be no effective way to enforce regulations in a fishery, such as trap fishing, where gear can't be observed readily by enforcement officials. The largest present day problems in the Florida Keys and South Florida are the extensive trap poaching and the use of illegally constructed or deployed traps." In addition, Officer Gordon Sharp (a Florida Marine Patrol officer in Key West) presented information at public hearings and Council meetings indicating the great difficulty in enforcing existing regulations and noted a large number of violations of existing regulations.

The Council recognized that gear that is not brought back to shore at the end of a fishing trip makes enforcement extremely difficult. The Council considered other, less drastic measures that would allow traps to be used but concluded that the at-sea enforcement required to effectively monitor and ensure compliance with existing regulations does not and will not exist. Therefore, the Council was persuaded that nothing short of a total ban would be enforceable.

Continued use of such highly efficient gear in a stressed fishery is no longer biologically tolerable. Thirteen of 27 snapper grouper species identified in Amendment 4 are documented as overfished with SSRs of less than 30%. Although insufficient data are available to determine SSRs for the remaining 15 species, they are also thought to be overfished. From a socioeconomic perspective, continued use of fish traps will result in a small group of fishermen removing a disproportionate share of the available fish, thus precluding their use by all other user groups at best and at worst leading to overfishing.

There is evidence that fish trapping causes habitat damage where fish traps are set in trawls on live bottom and where grappling hooks are dragged across live bottom to retrieve them. Testimony and video records of damaged *Oculina* reefs off Palm Beach County, provided to the Council at the February 1991 meeting, depicted significant and measurable damage to coral reef and live bottom communities. These activities leave an imprint of the trap upon the bottom communities and trenches caused by grappling hooks dragged over the bottom for the purpose of locating and recovering traps. Lost traps not only continue to fish, as it has been pointed out in the ghost trap discussion, but may contribute considerable secondary habitat damage by becoming mobilized at times of storm activity and impacting delicate bottom communities. These problems cannot be alleviated by trap design modifications even if such modifications could be enforced.

The affect of selective removal of herbivores on the health of coral reefs was discussed LaPointe (1989). These species were harvested by fish traps more frequently than by hook and line gear. Again, due to the fact that commercial statistics did not record these fish by species, data was unavailable to document the level of harvest by fish traps or by hook and line.

Prohibiting fish traps was determined to be consistent with Florida's Coastal Zone Management Plan. Also, internationally, a number of countries (e.g., Bermuda) have tried to manage fish trap gear only to end up prohibiting their use. Bermuda has managed their snapper grouper fishery for a number of years and imposed a limited entry system with trap limitation. In addition, modifications to mesh size were also attempted. The Bermudian Government concluded that regulation the fish trap fishery was not effective and recently imposed a total ban on use of fish traps. The Council concluded that a total prohibition on the use of fish traps was the most effective alternative to address the stated problems and to achieve the plan's stated objectives.

4.2.2.4 Entanglement Nets (summarized from SAFMC, 1991a)

Catch by entanglement nets during 1988 was 1,398 pounds from North Carolina through Georgia (less than 1% of the combined state catch) and 253,739 pounds from the Florida East Coast (6% Florida East Coast catches). Much of the Florida landings are from a directed stab net fishery for gray snapper that operates in the EEZ. The Gulf Council and the State of Florida have prohibited entanglement nets. Florida regulations read as follows: "No person shall harvest in or from state waters any snapper of the family of Lutjanidae or any member of the genera *Epinephelus* or *Mycteroperca* by or with the use of any gear other than those types of gears specified in SubSection 1, provided however that snapper and grouper harvested as an incidental bycatch of other species lawfully harvested with other types of gears shall not be deemed to be unlawfully harvested in violation of this section, if the quantity of snapper/grouper so harvested does not exceed the bag and possession limits as specified elsewhere." The South Atlantic Council's actions track the Florida regulations in intent with respect to limiting possession to the bag limit and for species without a bag limit, no possession is allowed. Florida prohibited entanglement nets because it is an inappropriate gear to use on live bottom. Some of the reef fish are not necessarily found on the live bottom, however, many are and fishermen use stab nets to catch gray snapper on the live bottom areas.

The Council has concluded that entanglement nets are not an appropriate gear for the snapper grouper fishery and the prohibition will prevent use and/or expansion from North Carolina through Florida's East Coast.

Entanglement nets targeting species other than those included in the management unit are limited to the bag limit if the species is under a bag limit, and if no bag limit is applicable, then no retention is allowed.

4.2.2.4.1 Prohibition on the Use of Entanglement Nets

The Council prohibited the use of entanglement nets (including, but not limited to, gill nets and trammel nets) for the harvest of species in the snapper grouper management unit in Snapper Grouper Amendment 4 (SAFMC 1991a). The simultaneous possession of entanglement nets and species in the management unit is prohibited.

4.2.2.5 Bottom Longlines (summarized from SAFMC 1991a)

4.2.2.5.1 Prohibition on the Use of Bottom Longlines in the Wreckfish Fishery

The Council prohibited bottom longlining in the wreckfish fishery in the entire South Atlantic EEZ (SAFMC 1991a). Bottom longline is defined as a stationary, buoyed, and anchored groundline with hooks attached. Regulations are written to prohibit simultaneous possession of wreckfish and all the necessary components for bottom longlining.

In February 1991 the South Atlantic Council requested an emergency prohibition of longlining for wreckfish (i.e., prohibit the simultaneous possession of wreckfish and operable bottom longline gear and prohibit use of bottom longlines). The 1991/92 fishing year was to begin on April 16 and the Council requested that the prohibition be in place by April 16. This same action was included in Amendment 4 which would not be implemented prior to the April 16 start of the fishing year.

The Council was concerned about wastage of fish, gear loss, gear conflict, habitat damage and negative economic effects (both short and long run) attributable to the use of bottom longline gear in the wreckfish fishery. The bottom habitat on the wreckfish fishing grounds, which comprise an area of the Blake Plateau of approximately 50-75 square nautical miles, is characterized by a rocky ridge system having a vertical relief greater than 50 meters and a slope greater than 15° (SAFMC 1993). The depth range in this area is 450-600 meters; the substrates in areas of the Blake Plateau exhibiting significant relief are generally characterized as composed of manganese phosphate pavements, phosphorite slabs and coral banks (Pratt and McFarlin, 1966; Stetson et al, 1969). This high relief, in conjunction with the strong tidal effects, makes gear loss probable (as reported by fishermen who have already tried longlines in the wreckfish fishery) which results in the loss of all fish on the gear as well as those which get hooked subsequently. Testimony from fishermen indicated gear loss on wreckfish longline sets was as great as 100% of the gear taken out on a single trip. According to accounts from fishermen, extensive lengths of lost longline gear have been observed on their fathometers. Fishermen can apparently see fish hooked on parted longline gear but are unable to recover the parted gear and its catch. Wreckfish fishermen use circle hooks that virtually prevent fish from working the hook free. The Council recognized that there was also some ghost fishing potential from lost vertical gear but believes that the extent of potential loss with vertical gear is much smaller by virtue of the fewer number of hooks used and the greater control over the gear.

Although the area is 50-75 square nautical miles, virtually all wreckfish fishing takes place along limited, high relief ledge areas within this area because wreckfish are found along the ledges and are not evenly distributed over the wider area. The sub-areas that produce wreckfish are typically 300 yards wide and 1 - 4 nautical miles long. Thus far, fishermen fishing vertical drop gear have been able to work in relatively close proximity without any major conflicts. If bottom longlines had been allowed to be used in this area, vessels would have not only lost gear due to the rough bottom, but this lost gear would create a hazard for those using vertical lines which would result in loss of that gear. This problem would have become progressively worse over time as more gear was lost, the more hangs were created for both longline and vertical gear, creating even more gear loss. This condition could have continued until much of the ground is unfishable. The wire cable that is used will remain a hazard for many years as the rate of decay is slow. While extensive hangs may ultimately provide protection for the resource due to much of the fishing grounds being unfishable, it may well result in the loss of the fishery. The use of longlines will result in gear losses to vertical hook and line fishermen that far exceed their losses prior to the introduction of longlines. This will serve to reduce benefits to those fishing with the traditional vertical gear.

The potential for gear entanglement and gear conflict also raised the issue of vessel safety. It was the Council's opinion that this situation would have lead to conflicts that jeopardize the safety of the vessels and fishermen participating in the wreckfish fishery.

Longline cable on the bottom has the potential to break some of the ledges, overhangs and associated organisms, and otherwise damage the habitat on which the wreckfish depend. Habitat damage caused by the longlines would violate the SAFMC habitat policy and should be avoided.

The wreckfish fishery has employed efficient vertical gear since its inception, and the addition of longlines would have eroded benefits to the majority of fishermen and adversely impact the resource and habitat. If longlines had been allowed, then all or at least many wreckfish fishermen may have been forced to adopt the gear in order to compete resulting in more gear loss from parted longlines.

The Council determined that bottom longlines were not in the best interest of the wreckfish resource, habitat, fishermen or society at large. Further, the problems outlined justified prohibiting this gear/fishing method in the wreckfish fishery.

4.2.2.5.2 Use of Bottom Longlines in the Snapper Grouper Fishery (summarized from SAFMC 1994)

The Council prohibited the use of bottom longline gear for snapper grouper in the South Atlantic EEZ within 50 fathoms (SAFMC 1994).

Catch by bottom longlines during 1988 was 470,306 pounds from North Carolina through Georgia (6% of the combined state catches) and 576,310 pounds from the Florida East Coast (13% Florida East Coast catch). The Council was concerned about the use of bottom longline gear targeting species in the snapper grouper management unit in live bottom areas. Habitat damage and intense competition among users are problems that arise when this gear is used within 50 fathoms where significant live bottom occurs and where competition with hook and line vessels occurs. The Council concluded that this gear is appropriate for use in the deep-water snowy grouper/tilefish fishery where much of the bottom is mud with sparse live bottom areas. Allowing use of this gear deeper than 50 fathoms would preserve the traditional fishery which takes place in deeper water out to 50 fathoms. Based on information from South Carolina, up until 1983 the snapper grouper fishery was limited to vertical hook and line or bandit reels. Bottom longlines were introduced in the Gulf of Mexico after hook and line gear became less effective due to decreases in resource abundance; use of the gear grew rapidly. Up until this point there has been no gear prohibition on bottom longlines. After the golden tilefish and snowy grouper fisheries were developed, bottom longlines became the predominant gear, again as resource abundance declined. For species like snowy grouper and tilefish, it was not very efficient to use vertical hook and lines as the resource abundance declined from unfished levels. As the tilefish and snowy grouper stocks off South Carolina declined, the number of people using longlines decreased. Off South Carolina virtually all of the golden tilefish occurred well outside the 50 fathom mark and there was more than enough gear to adequately harvest these resources in the mid-depth zone. Vertical lines are much more environmentally acceptable and less damaging than bottom longlines.

This regulation essentially segments the mid-shelf and the deep-water complex to the bottom longlines. This measure was supported during the public hearing process and the Council concluded that prohibiting use of longline gear within 50 fathoms will prevent the problems of habitat damage and intense competition while at the same time allow fishermen using this gear to continue fishing in deeper water. This action effectively limits longlines to targeting the deep water component of the snapper grouper fishery and keeps the use of longlines outside of the rough bottom habitat.

The Council very briefly considered moving the line in to the 40 fathom contour but was concerned that there are substantial *Oculina* coral banks along this depth zone. It was further noted that the 50 fathoms was a compromise from the 100 fathom contour (which was mentioned) and that the 50 fathom contour effectively separates the inshore and deep water snapper grouper complexes.

4.2.2.6 Bottom Trawls

4.2.2.6.1 Prohibition on the Use of Bottom Trawls (from SAFMC 1987)

The use of trawl gear to harvest fish in the directed snapper grouper fishery south of Cape Hatteras, North Carolina (35°15' N. Latitude) and north of Cape Canaveral, Florida (Vehicle Assembly Building, 28°35.1' N. Latitude) is prohibited (SAFMC 1987). A vessel with trawl gear and more than 200 pounds of fish in the snapper grouper fishery on board will be defined as a directed fishery. The amendment also establishes a rebuttable presumption that a vessel with fish in the snapper grouper fishery on board harvested its catch of such fish in the Exclusive Economic Zone.

The Council based the trawl prohibition on habitat destruction and the desire to prevent overfishing of vermilion snapper. Fishes present in live bottom areas are described by Grimes et al. (1982) and include 113 species representing 43 families of predominantly tropical and subtropical fishes. Vermilion snapper were more abundant on the shelf edge than on the open shelf (Grimes et al., 1982). Miller and Richards (1980) described the distribution of live bottom habitat in the South Atlantic Bight and reported the most productive area of the shelf for commercial reef fish as being in the open shelf zone between 33 and 40 meters. Parker et al. (1983) reported on a survey of the areas from Cape Canaveral, Florida to Cape Fear, North Carolina and from Cape Fear to Cape Hatteras, North Carolina. From Cape Hatteras to Cape Fear 14,486 square km between 27 and 101 m were surveyed and contained 2,040 square km (14%) of reef habitat of which only 204 square km (10%) had one meter or more relief (distance from the highest point of the live bottom to the ocean floor). In the area from Cape Fear to Cape Canaveral, 24,826 square km between 27 and 101 m were surveyed and contained 7,403 square km (30%) of reef habitat of which 1,743 square km (7%) had one meter or more relief. The Oregon II cruise report (Anon, 1978) supports the scattered nature of live bottom in the South Atlantic from Cape Canaveral, Florida to Cape Hatteras, North Carolina. The Fishery

Management Plan reported that in terms of the entire shelf area, current data suggest that from three to 30 percent of the shelf is suitable bottom for snapper grouper species (SAFMC, 1983a).

The report on effects of a research trawl on live bottom (Van Dolah et al., 1987) documents that habitat damage does occur from the use of trawl gear even in the case of one pass through an area in a controlled study. The abstract is as follows:

"The effects of a research trawl on several sponge and coral species was assessed in a shallow-water, hard-bottom area located southeast of Savannah, Georgia. The study entailed a census of the numerically dominant species in replicate 25-m^2 quadrants located along five transects established across a trawling alley. The density of undamaged sponges and corals was assessed in trawled and non-trawled (control) portions of each transect immediately before, immediately after, and 12 months after a 40/54 roller-rigged trawl was dragged through the alley once. Some damage to individuals of all target species was observed immediately after trawling, but only the density of barrel sponges (*Cliona* spp.) was significantly reduced. The extent of damage to the other sponges (*Ircinia campana, Haliclona oculata*), octocorals (*Leptogorgia virgulata, Lophogorgia hebes, Titanideum frauenfeldii*) and hard corals (*Oculina varicosa*) varied depending on the species, but changes in density were not statistically significant. Twelve months after trawling, the abundance of specimens counted in the trawled quadrants had increased to pre-trawl densities or greater, and damage to the sponges and corals could no longer be detected due to healing and growth. Trawl damage observed in this study was less severe than the damage reported for a similar habitat in a previous study. Differences between the two studies are attributed to (1) differences in the roller-rig design of the trawls used, and (2) differences in the number of times the same bottom was trawled."

The authors point out that in a study by Tilmant (1979) looking at the effects of commercial bait shrimping with roller-frame trawls in a shallow-water area of Biscayne Bay, Florida damage was much more severe: "Tilmant observed severe damage (specimens crushed or torn loose) to more than 80% of the stony corals, 50% of the sponges and 38% of the soft corals along the trawl path." It should be noted however, that this frame trawl consists of a solid, rectangular frame to which a net is attached and is used to fish grass bed areas; it was not designed to "roll over" live bottom and would be expected to cause significant damage to corals, etc.

Importantly, habitat damage described by Van Dolah et al. (1987) resulted from one tow of trawl gear through the study area. That study was designed to evaluate the effects of a research trawl that does not typically cross the same bottom area more than once. Commercial trawling does not operate in this manner. Under commercial fishing conditions, a live bottom area would be fished over and over until the catches from such an area become unprofitable. Under such conditions, habitat damage would be expected to be much greater than is indicated from the above study.

The Oregon II cruise report (Anon, 1978) indicated that drags with a trawl yielded a total catch of 476 pounds which included 424 pounds of finfish and 46 pounds of sponges and corals (10 percent of the total catch). This area was reported to have been on a mud bottom but turned out to be a low profile live bottom of sand ridges, clumps of sponges and scattered corals. Further indication of habitat damage is reported by Wenner (1983):

"The 3/4 Yankee trawl net effectively covers a much wider area of the bottom than the measured sweep (8.7 m) due to the configuration of the otter doors, ground cables, and bottom leg lines.

Although this arrangement cannot increase the actual spread of the net beyond the headrope length, the passage of these cables over the substrate creates a disturbance that serves to herd fish in the path of the net (Baranov 1969). This net does, however, damage the sponge-coral habitat by shearing off sponges, soft corals, bryozoans, and other attached invertebrates. The 56 trawl tows made in the sponge-coral habitat for this study collected 2,351 kg of attached invertebrates (including sponges, soft corals, tunicates, bryozoans, and hydroids) yielding an average 42 kg/tow. This is only the amount of bottom material actually removed from the habitat. An estimate of the total amount of bottom destroyed by the doors, ground cables, and leg lines cannot be ascertained from the current study.

Personal observations and interviews with commercial fishermen attest to the productivity of the sponge-coral habitat. Most studies indicate the importance of habitat availability and space in determining the abundance and diversity of reef fishes (Emery 1978). With this in mind, and given the knowledge that 1) the use of the 3/4 Yankee trawl net reduces the amount of attached invertebrate growth (the amount damaged by doors and ground cables is presently not quantifiable); 2) the places where the invertebrates had been attached may be sanded over and rendered unsuitable for recolonization; and 3) the removal of these attached invertebrates reduces refugees for decapods, polychaetes, etc., that are food items for *Centropristis striata* and other benthic feeders, one must conclude that the continued use of this trawl net reduces the amount of productive fish habitat. For these reasons, in addition to the ineffectiveness of the gear in sampling commercially important species, alternate nondestructive methods, such as direct observations or the use of mark-recapture techniques with trap catches, should be employed in assessment surveys of the commercially important species of this habitat."

Results of trawl survey work in Australia provide some insight into what can happen to catches in an area after the continued use of commercial trawl gear. Young and Sainsbury (1985) report that "At moderate to low levels of fishing effort, the main effect of fishing on the relative abundance of bottom shelf fishes is by alteration of the relative frequency and spatial distribution of habitat types. In particular this refers to the conversion of areas with dense epibenthos (sponge, corals, hydroids, gorgonians) to areas with sparse epibenthos. (It may be noted that even at the relatively low intensity of trawling of the past few years the fishing effort exerted on the main trawl grounds is sufficient to sweep 50 to 100 per cent of the area of those grounds per year.)." These results are from trawling conducted in 1982 as compared to trawl catches in 1966 from the same locations and at the same time of year. The catch composition shifted from species associated with sponges, soft corals etc. (during 1966) to those associated with open sandy bottom (during 1982).

A similar type of scenario for the South Atlantic was suggested by Bob Low (pers. comm.):

Parker et al. (1983) estimated that, in the area they surveyed between Cape Fear and Cape Canaveral, there were 7,403 square km of reef habitat. Of this, 1,743 square km had an average profile exceeding 1 m. Assuming that such ground could not be trawled, this leaves about 5,660 square km (1,398,000 acres) of trawlable reef habitat. The average boat might pull a net with a footrope of 120 feet, giving an effective sweep of the roller gear of about 72 feet maximum. A typical tow over open bottom is perhaps 3 hours at 2 knots. The area swept by the roller gear per tow is then about 20 acres/hour or 60 acres/tow. Assume that 20 boats participate for 4 months (January-April) each year. [Note: The actual number of vessels during 1987 was seven.] The average vessel makes 3 trips/month, with 3 days of fishing each trip. The average (24 hr) fishing

(24 hr) fishing day includes perhaps 4 tows. A typical trip therefore consists of 12 tows or 36 hr of fishing. The 20 boats make an aggregate of 240 trips. This equates to 2,880 tows, covering around 172,800 total acres. If each tow was over a previously unswept area, the total area covered by the roller gear would then amount to about 12% of the trawlable reef habitat estimated by Parker et al. (1983). Under one set of assumptions, the area affected by the doors, bridles, and warps would add to this. Under a second set, repetitive trawling over identical areas would reduce the total area impacted. Van Dolah et al. (1987) noted a substantial renewability within a year. There are likely to be 8 months of recovery time between trawling seasons. Doesn't that allow for significant restoration in many of the trawled areas?"

The above scenario indicated that about 12 percent of available habitat between Cape Fear and Cape Canaveral would be impacted annually by trawling, whereas in the Australian work the area impacted was between 50 and 100 percent. The Council has concluded that the level of damage to the live-bottom habitat in the South Atlantic is significant and that our available knowledge is not sufficient to risk impacting the long-term abundance of snapper and groupers by reducing their habitat. The results shown by Van Dolah et al. (1987) indicated that regeneration of tissue sufficient to have rounded off the tops of partially severed sponges and to have closed wounds on other sponges occurs within a year but that additional growth is limited as indicated by some of the sponges being obviously shorter than before the trawling damage. This supports the Council's concern because in a four month trawling season there would be a net loss of habitat (i.e. more damage than regrowth) with the effects being cumulative over time. By destroying habitat we destroy the productivity of the resource being harvested and we are in essence drawing on the principal, not just taking the interest so that next year the same amount of trawling will represent more than 12 percent of the habitat and the year after even more. Given this information, the South Atlantic Fishery Management Council concluded that over the long-term there would be a net loss of existing habitat, which is counter to the Council's habitat policy and the Magnuson Act.

Indirect evidence of habitat damage is provided in Christian et al. (1985) where they report on attempts to use crab nets rigged with light chain and plastic mud rollers. These nets proved to be inadequate for offshore fish trawling on broken bottom because the light molded plastic mud rollers were not durable and did not prevent net damage. They further reported that captains who tried crab nets soon switched to nets with heavy netting, properly rigged sweep systems and steel vee-doors for trawling over rough bottom. Further indication of habitat damage was presented in Section II of Snapper Grouper Amendment 1 with the numerous references to gear damage, gear loss and the need to use rollers and modified doors to be able to trawl in rough and broken areas.

An additional reference concerning potential habitat damage is provided by Moore and Bullis (1960) when they reported on the discovery of a deep water reef in the Gulf of Mexico. The MV Oregon was cruising over the continental slope about 40 nautical miles due east of the Mississippi Delta and observed an unusual tracing on the depth recorder. They sampled this bottom area using a shrimp trawl and reported the following: "A drag, made over the area with a shrimp trawl, contained a large mass of coral, other invertebrates, and fish. The netting of the trawl was torn and most of its contents were lost, but about three hundred pounds of coral remained in the bag. A sample was brought back to the laboratory where is was identified by Moore as *Lophelia prolifera.*"

Invertebrates associated with sponges and corals occur in disproportionately high densities which suggests that they may use sponges and corals as a food source or a refuge from predation (Wendt et al., 1985). These invertebrates in turn serve as a food source for various snapper and grouper species. In addition, corals are very slow growing with some such as *Oculina* sp. only growing between 11 and 16 mm per year (Reed, 1981). Damage to these areas can negatively affect the food and shelter available to snappers and groupers. Further, Grimes et al. (1982) note the importance of the live bottom and shelf edge habitats in serving as reservoirs for recruits in shallow areas (less than 30 m).

The best estimate of the number of boats operating in the fishery during the winter of 1986/87 was four boats (one South Carolina boat fishing in South Carolina and three North Carolina boats fishing in South Carolina, Georgia and Florida). The number of vessels increased to seven during the winter of 1987/88. These vessels fished during the slow period for shrimp which is normally January to March/April. Even though the actual number of boats is small, the amount of habitat damage is significant when one realizes that these boats fish directly on the limited live bottom habitat in these areas. Productive snapper grouper habitat on the continental shelf is limited and trawl gear is fished repeatedly in these areas over this three to four month period. Most, if not all, fishermen use Loran which allow them to return to the exact spot and trawl a particular rock out-cropping repeatedly. The data previously described from Australia points out the changes to bottom habitat and catches resulting from such a fishery.

Vermilion snapper in the early 1980s were experiencing growth overfishing (see SAFMC 1983a p. 44-58 for a more detailed discussion). Yield per recruit (or yield per individual) analysis indicated that a 12 inch minimum size will increase yield per recruit from 132 g to 177 g which is equivalent to a 34 percent increase in yield if recruitment is constant. Confidential data available to the South Atlantic Council indicated that the minimum mesh size of 4 inches is not being adhered to and as a result the Council's prior action establishing the mesh restriction has not been effective in releasing small vermilion (less than 12 inches). The trawl prohibition will result in an increase in yield for vermilion snapper. Catch data from South Carolina (Bob Low, pers. comm.) show a slight negative correlation between trawl landings and hook & line landings ($r = -0.13$). A good fishery independent index of abundance would allow us to examine the affect of trawl catches on abundance of vermilion snapper. Given the available information, the South Atlantic Fishery Management Council concluded that the trawl prohibition would increase yield; however, our ability to measure this increase is lacking.

The potential existed for more vessels to enter the fishery particularly if the calico scallop, shrimp and sea scallop fisheries have not been productive or are not active during this time period. The actual number of vessels during 1987/88 was seven, greater than the number expected. This further supported the Council's concern that effort could have increased rapidly.

Impacts on affected vessels from prohibiting use of trawl gear in the snapper grouper fishery were not significant. Input from public hearings, committee and Council meetings indicated that income from fish trawling made up a small portion of total income. No trawl fishermen came forward with information during the public hearing process indicating that impacts would be significant. Fishermen used this fishing method primarily as a fill-in activity and had the ability to utilize other gear (e.g. electric & hydraulic reels, black sea bass traps, longlines, etc.) to fish snappers and groupers. These general conclusions are supported by the following in Christian et al. (1985):

"The major seafood industry in the South Atlantic Bight is based on shrimp, and this dependence on one crop has made the industry financially precarious. ... Therefore, fishermen have looked to other activities such as bottom trawling for finfishes to supplement their income. This is not the single salvation for the whole industry. Although fish trawling can offer an alternative which may aid some shrimpers in maintaining year-round income, suitable trawling bottom in this area is limited, and target species of such a fishery (snapper, grouper, and porgies) are relatively long-lived, slow-growing, and can sustain only limited fishing pressure."

4.2.2.7 Gear in State Waters

Appendix H presents a compilation of gear types used in North Carolina, and the Habitat Subcommittee recommendations to the North Carolina Marine Fisheries Commission concerning the habitat impacts of specific commercial and recreational gears used in North Carolina.

In Biscayne National Park, Florida, spiny lobster, stone crab, and blue crab are targeted with heavy, medium and light traps respectively. These traps can inflict damage in a number of ways including contact with the bottom habitat during deployment, retrieval and when lost. The fishery is prosecuted by using heavy traps that are frequently set near structural complex and fragile offshore reefs and may be loss or abandoned by the end of the season (Ault et al., 1997). Spiny lobster and stone crab traps area used over *Thalassia* while blue crab traps

The conclusions and recommendations of the study documenting the "Impacts of Commercial Fishing on Key Habitats within Biscayne National Park" (Ault et al., 1997) are as follows:

"The bait shrimp fishery regularly comes in contact with a largest contiguous area of BNP's submerged habitat resources. Depending on season, from 25% to 52% of BNP's entire area is swept by the fishery. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research. While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (sponges and corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas supporting high densities of sponges and corals. The feasibility of accurately making the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated. Further trawl damage experiments in conjunction with closure area essential for obtaining accurate estimates of rates of recovery for trawl-damaged sponges and corals.

The primary resource that the three major trap fisheries affect is seagrass with damage to underlying plants dependent on trap type and soak time. Loss of underlying *Thalassia* averages about 13% of trap area per week for lobster traps and 28% per week for stone crab traps. For blue crab traps, loss of underlying *Halodule* averages about 30% of trap area per week. Further measurements of size and spatio-temporal extent of each of the trap fisheries is required before reliable estimates of trap-induced damage can be made. Additional field experiments which focus on the rate at which *Thalassia* and *Halodule* recolonize areas trap-damaged are strongly recommended."

4.3 Cumulative Impacts

This section analyzes cumulative impacts, which are defined as "impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of who undertakes such actions." The overall cumulative impact of human-induced activities and natural events remains poorly documented, understood and in dire need of more study. Even so, it is evident that the effect of human activity on aquatic systems has been substantial in locations where access and economically profitable modification could be readily accommodated. Dahl (1990) reports that in the 1780's there were about 20.3 million acres of wetlands in Florida, about 6.8 million acres in Georgia, about 6.4 million acres in South Carolina, and about million acres in North Carolina. By the 1980's Florida's wetlands had been reduced to 11.0 million acres, Georgia's to 5.3 million acres, South Carolina's to 4.7 million acres, and North Carolina's to 5.7 million acres. Overall about 36.3 percent of all wetlands in states under SAFMC purview have been eliminated. On a state-by-state basis this includes 46 percent of Florida's wetlands, 23 percent of Georgia's wetlands, 27 percent of South Carolina's wetlands, and 49 percent of North Carolina's wetlands.

As an indication of the scope of developmental pressure, hence one aspect cumulative effect on EFH (coastal and tributary wetlands), NMFS data show receipt of more than 20,778 individual development proposals (COE permit applications, federal projects , etc.) in North Carolina, South Carolina, Georgia, and Florida between 1981 and 1996 (See Tables 26, 27, 28, & 29). A subsample of 4,000 of these development proposals involved over 13,856 acres of various wetland habitats.

While it is believed that most regulated activities are implemented as planned, Mager and Thayer (1986) report that limited monitoring indicate that about 20 percent of the projects they examined did not comply with provisions of the associated permits. Notably, most of the differences observed related more to design of structures and not the area of habitat affected. As shown in the following tables, individually and cumulatively significant impacts to EFH can be moderated through the COE regulatory program; however, significant wetland perturbations persist. This situation is largely perpetuated by (1) regulatory provisions that exempt regulation of certain wetland types and activities and (2) by severe staffing limitations within regulatory and environmental review agencies. In the absence of substantial correction in these two areas, significant wetland areas will continue to be adversely altered or eliminated, and regulatory and review agency effectiveness will be limited.

In addition to the direct cumulative effect incurred by developmental type activities, EFH is also jeopardized by persistent increases in certain chemical discharges. In that case incremental change in habitats, hydrology, and chemical inputs produced, over time, an enormous and extremely harmful result whose negative economic and social implications may far exceed any benefits related to the causative factors. Unfortunately, the effect of adding ever greater volumes and varieties of chemicals to surface waters is often insidious and resulting declines in the abundance and quality of affected and harvested resources may be slow and difficult to identify. As illustrated by Scott *et al* (1997), the effects may be realized at rudimentary trophic and ecological association levels in key portions (including EFH) of estuarine environments.

The rate and magnitude of anthropomorphic change on EFH, whether cumulative, synergistic, or individually large, is influenced by natural parameters such as temperature, wind, currents, rainfall, salinity, etc.. Consequently, the level of threat posed by a particular activity or group of activities may vary considerably from location to location. This situation may be most acute in locations that are subject to extreme weather and oceanic conditions such as hurricanes and large waves, or where the effects of periodic or global change is most prevalent.

Nutrient over enrichment has become a large cumulative problem for southeastern EFH. Excessive nutrients may be directly toxic. Even relatively low nitrate-nitrogen levels (as low as 3.5 uM NO_3-N) have been found to cause impacts on both growth and survival in eelgrass (*Z. marina*) during spring and fall growing seasons (Burkholder *et al* 1992). In contrast, Cuban shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*) were stimulated by nutrient enrichment (Burkholder *et al* 1994). Eelgrass provides important brackish water habitat element for finfish, crustaceans and molluscs in North Carolina (Thayer *et al* 1984). Nitrate toxicity to eelgrass in the field has yet to be documented, although nitrate concentrations in the range found to have an impact in mesocosm experiments certainly occurs in many estuarine settings.

The effects of nutrient enrichment and stimulation of toxic dinoflagellates and other algae, especially *Pfiesteria piscidida*, has been widely reported by the news media. The high abundance of small heterotrophic algae in southeastern estuaries was well known among plankton researchers during the 1980's and earlier; however, the toxic nature of *Pfiesteria* was not reported until the late 1980's (Burkholder *et al* 1992, 1993, 1995; Noga *et al* 1993). The most recent analyses suggest that a large suite of *Pfiesteria*-like small heterotrophic dinoflagellates exist in most southeastern estuaries (P. Tester personal communication.). These organisms include toxic forms, like *Pfiesteria*, and may be responsible for a significant number of fish kills associated with eutrophic estuaries (Burkholder *et al* 1992). Recent fish kills in North Carolina and Maryland have been attributed, at least in part, to these organisms (Burkholder *et al* 1995), and recent analyses suggest that toxic dinoflagellates (and related organisms) are on the rise at a global scale (Paerl 1988, Smayda 1989, Paerl *et al* 1995a).

The stimulation of toxic organism population growth by nutrient enrichment may be related to factors outside the south Atlantic region. The most notable recent case was the transport of the toxic dinoflagellate *Ptychodiscus brevis* in 1989 by the Gulf Stream and associated eddies into Onslow Bay, North Carolina. Among other impacts offshore and inshore, this seriously impacted scallop production in Bogue Sound, North Carolina (Tester *et al* 1989).

Enrichment of estuarine algal and bacterioplanktonic communities by excessive nutrients is probably the most often cited example of estuarine degradation globally (Nixon 1995, NRC 1994, Ryther and Dunstan 1971). In general, the ecological pathway involves enhanced algal or bacterial production and metabolism followed by excessive oxygen uptake and subsequent deoxygenation. Anoxia and hypoxia have been identified as the fundamental problems facing Chesapeake Bay, the Gulf of Mexico, the Tar-Pamlico and Neuse River Estuaries, and other locations throughout the world (Paerl 1988). Associated processes may be complex. For example, nutrient uptake and excessive autotroph production may result in deposition of organic material into benthic sediments, where increased sediment oxygen demand may occur at some later time. In stratified estuaries, the process may even be exacerbated by the re-release of nutrients as sediment oxygen demand is exerted in bottom, anoxic waters. The ecological effects of modification of production patterns also includes hypercapnia (elevated levels of carbon dioxide), which exerts powerful effects on some organisms (Burnett 1997).

Algal blooms in Southeastern waters represent a major threat to EFH. Important algal blooms have been documented in Albemarle Sound, the Chowan River, the Tar-Pamlico River, the Neuse River Estuary, the New River Estuary, Bogue Sound, the St. Johns River and Indian River (NOAA 1996). Algal levels can be extremely high in grossly enriched waters. A one-day survey of the Pamlico Estuary in 1988 found chlorophyll a (an algal pigment) in excess of 200 ug/l, compared to a North Carolina Water Quality Standard of 40 ug/l (15A NCAC 2B.0200). Another type of algal community stimulation occurs when airborne nitrogen from all sources, including agriculture, is deposited through wet and dry deposition into distant oceanic waters. This phenomenon was largely unrecognized until recently (Paerl, 1985, 1993). Consequences of this type of deposition, where the majority of "new" primary production comes from this source, can be quite significant, both on patterns in primary and secondary production and in the taxonomic makeup of that production, including the toxic forms cited above.

Among the most serious problems caused by algal blooms and other effects of over enrichment is the removal of oxygen from the water. The extent of deoxygenation in southeastern estuaries has been well documented (Rader *et al* 1987; Stanley, 1985). A more recent survey of the south Atlantic region found periodic hypoxic conditions in 13 of the 21 estuaries surveyed, with bottom-water anoxia in 11 locations. Only once instance of anoxia was found along the Sea Island Coast of South Carolina and Georgia, and this was linked to stratified conditions in the Savannah River. Major anoxic events were documented in the Neuse River, the Tar-Pamlico River Estuary, the Indian River and St. Helena Sound (NOAA 1996). Although seasonal low-oxygen events may be natural in Southeastern stratified estuaries, expansion in the size or persistence of deoxygenated areas has been identified for some of the above listed waters (Breitburg 1990, Rabalais et al 1996).

Effects of deoxygenation on resident and post-larval fish, crustacean, and mollusc communities can be significant. The enormous fish kills that have plagued the Tar-Pamlico and Neuse River Estuaries have received abundant popular press since the late 1980's, and have recently been systematically analyzed (Pietrafesa and Miller 1997). This study identified 246 kills in the Pamlico during the period 1985-1995, and 73 in the Neuse, including many over 1,000,000 fish. Fish kills have also been documented in the St. John River, Florida and Charleston Harbor, South Carolina (Burkholder et al 1995).

Another possible manifestation of nutrient over enrichment is the occurrence of chitonoclastic shell disease in blue crabs. This is believed by some to be related to water pollution (either stress incurred after exposure to anoxic conditions or cadmium). Little is known absolutely (Noga *et al* 1990). In addition, fish diseases have been implicated throughout polluted estuaries, but the link to pollution remains uncertain (Noga *et al* 1989).

The impact of fish kills from nutrient over enrichment is difficult to assess in terms of their effect on stocks of commercially important fish. Many of the fish killed are juveniles and Atlantic menhaden appear especially vulnerable. If these stocks are density independent, then kills translate directly into reduced adult population sizes. Vaughan (1986) found that in Atlantic menhaden, catastrophic kills, where 10 percent mortality events occur periodically, coupled to the accumulating 1 percent annual losses from permanent habitat loss, could cause a loss of 60 percent of the fishery within 30 years.

Impacts of atmospheric deposition of nutrients on inshore EFH is well documented, as cited above (and in Fisher and Oppenheimer, 1991). Some studies suggest that nutrient enrichment from atmospheric and more traditional surface water sources can also modify planktonic and epibenthic algal communities to the detriment of fish. Changes in the phytoplankton community lead to changes in the grazer community, including the reduction or elimination of preferred prey items for planktivorous fish and fish larvae. One example is the plankton community of Western Albemarle Sound, North Carolina, where nanoplankton (the small-celled algae that are the principal food source for crustacean zooplankters) are replaced in part in some years by blue-green algae of low food value, with a concomitant elimination of the zooplankters preferred by some anadromous fish larvae and juveniles (Rulifson *et al* 1986).

Besides fish, plankton, and algae, vascular marine plants also are adversely affected by excessive nutrients and their consequences. Eutrophication may cause the reduction in coverage of SAV due to shading associated with water column turbidity and the growth of epiphytic filamentous algae. Although significant dieoffs of SAV have occurred in some locations in the Southeast, including the Pamlico River Estuary, the direct causes of algal growth stimulation has not been established (Davis *et al* 1985). NOAA's recent survey of impacts on SAV found declines in 5 of 21 estuaries of the Southeast, including Albemarle/Pamlico Sounds, but increases in Biscayne Bay and Charleston Harbor (NOAA 1996).

New analytical approaches may advance management evaluations of cumulative environmental effects. Ecological risk assessment procedures provide a useful frame for comprehensively structured analyses of anthropogenic effects (EPA, 1992). These procedures involve the systematic evaluation of stressors and effects using flexible methods that foster detailed evaluations of effects (Harwell et al., 1995). The application of risk assessment principles to environmental assessments could result in more comprehensive scientific products that also carry more administrative weight. In addition, systematic applications of decision support systems can offer logically consistent methods to evaluate multiple policy alternatives. Decision support systems aid the objective identification of appropriate decision combinations according to multiple priorities and they support group-based policy evaluations (Saaty, 1990; Keyes and Palmer, 1993; Schmoldt et al., 1994)). Combined utilization of these approaches may identify previously underemphasized factors and objective policy alternatives (Lindeman, 1997b). Ultimately, they may foster more logical and explicit decision-making regarding cumulative effects issues.

Table 26. Acres of habitat alterations requested by type of projects reviewed in North Carolina between 1981 and 1996 (Source: Andy Mager, NMFS SERO pers. comm.).

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	183	60	3,256	144	3,112	124
BE	48	31	1,463	1,218	245	1
BR	395	188	1,076	814	262	1,291
DO	415	6	1	0	1	0
EL	13	1	4	0	4	0
HO	204	1383	920	337	583	757
IN	192	91	190	122	68	119
IR	59	30	204	104	100	6
MD	343	314	11,116	11,103	13	49
MI	62	7	3,195	1,234	1,961	2,745
MM	2	1	8	0	8	0
NA	610	349	2,058	1,768	290	48
OI	10	0	-	-	-	-
OT	187	72	819	698	121	556
PI	51	26	7	7	0	2
SH	1,518	1,016	691	246	445	111
TR	13	2	1	1	0	1
WR	3	2	3	3	0	25
Total	**4,308**	**2,331**	**25,012**	**17,799**	**7,213**	**5,835**

(BA) barriers and impoundments; (BE) beach nourishment projects; (BR) bridges, roads, and causeways; (DO) docks and other minor structures; (EL) electric generating facilities; (HO) housing developments; (IN) commercial and industrial developments; etc.; (IR) irrigation and drainage works;(MD) maintenance dredging; (MI) mining and mineral exploration; (MM) marsh management areas; (NA) navigation projects, marinas, etc.; (OI) oil and gas construction;(OT) unclassified; (PI) oil, gas, and chemical pipelines; (SH) bulkheads, small fills, groins, etc.; (TR) transmission lines; (WR) wetland restoration projects.

N1 = Total number of projects reviewed.
N2 = Number of projects where acreage was determined.

Table 27. Acres of habitat alterations requested by type of projects reviewed in South Carolina between 1981 and 1996 (Source: Andy Mager, NMFS SERO pers. comm.).

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	236	99	3,252	460	2,792	54
BE	32	16	1,889	861	1,028	0
BR	331	174	772	226	546	456
DO	1,647	6	2	0	2	0
EL	15	1	1	0	1	0
HO	101	43	163	37	126	23
IN	142	54	185	120	65	142
IR	76	47	2,218	25	2,193	2
MD	200	117	2,503	1,391	1,112	0
MI	32	7	791	65	726	86
MM	13	1	1	0	1	0
NA	405	201	809	244	565	180
OI	3	0	0	0	0	0
OT	185	61	660	574	86	388
PI	177	85	44	38	6	22
SH	1,330	595	580	302	278	112
TR	109	9	13	13	0	0
WR	2	0	-	-	-	-
Total	**5,037**	**1,516**	**13,883**	**4,356**	**9,527**	**1,467**

Table 28. Acres of habitat alterations requested by type of projects reviewed in Georgia between 1981 and 1996 (Source: Andy Mager, NMFS SERO pers. comm.).

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	133	15	551	12	539	33
BE	8	4	305	305	0	0
BR	215	62	719	509	210	999
DO	604	13	4	0	4	0
EL	14	0	0	0	0	0
HO	57	20	159	15	144	881
IN	144	38	1,520	485	1,035	980
IR	32	14	82	14	68	4
MD	112	67	2,936	2,348	588	36
MI	33	1	200	200	0	363
MM	4	1	0	0	0	23
NA	200	68	2,478	558	1,920	175
OI	3	3	1	1	0	0
OT	96	16	287	26	261	48
PI	70	20	8	8	0	63
SH	704	204	169	66	103	71
TR	90	19	3	3	0	2
Total	**2,519**	**565**	**9,422**	**4,550**	**4,872**	**3,678**

(BA) barriers and impoundments; (BE) beach nourishment projects; (BR) bridges, roads, and causeways; (DO) docks and other minor structures; (EL) electric generating facilities; (HO) housing developments; (IN) commercial and industrial developments; etc.; (IR) irrigation and drainage works;(MD) maintenance dredging; (MI) mining and mineral exploration; (MM) marsh management areas; (NA) navigation projects, marinas, etc.; (OI) oil and gas construction;(OT) unclassified; (PI) oil, gas, and chemical pipelines; (SH) bulkheads, small fills, groins, etc.; (TR) transmission lines; (WR) wetland restoration projects.

N1 = Total number of projects reviewed.

N2 = Number of projects where acreage was determined.

Table 29. Acres of habitat alterations requested by type of projects reviewed in Florida between 1981 and 1996 (Source: Andy Mager, NMFS SERO pers. comm.).

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	169	16	72	21	51	4
BE	120	24	2,078	1,440	638	1
BR	1,309	199	833	253	580	483
DO	3,307	14	8	7	1	0
EL	7	0	-	-	-	-
HO	4,029	1,265	4,271	1,486	2,785	1,313
IN	988	247	1,307	630	677	475
IR	166	51	99	39	60	11
MD	1,486	125	428	373	55	11
MI	307	9	322	310	12	170
NA	1,521	451	2,497	1,907	590	197
OI	11	2	1	0	1	1
OT	815	102	509	206	303	99
PI	95	8	22	14	8	39
SH	6,214	1,471	1,351	394	957	432
TR	119	10	15	10	5	9
WR	115	6	43	3	40	4
Total	**20,778**	**4,000**	**13,856**	**7,093**	**6,763**	**3,249**

(BA) barriers and impoundments; (BE) beach nourishment projects; (BR) bridges, roads, and causeways; (DO) docks and other minor structures; (EL) electric generating facilities; (HO) housing developments; (IN) commercial and industrial developments; etc.; (IR) irrigation and drainage works;(MD) maintenance dredging; (MI) mining and mineral exploration; (MM) marsh management areas; (NA) navigation projects, marinas, etc.; (OI) oil and gas construction;(OT) unclassified; (PI) oil, gas, and chemical pipelines; (SH) bulkheads, small fills, groins, etc.; (TR) transmission lines; (WR) wetland restoration projects.

N1 = Total number of projects reviewed.
N2 = Number of projects where acreage was determined.

A cumulative assessment of population-scale fishing effects in the Florida Keys documents that 13 of 16 grouper species, 7 of 13 snappers, and 2 of 5 grunts are recruitment overfished (Ault et al., in press). The cumulative result of technologically enhanced fishing effort has been the accelerated removal of those top predators with most economic value. Therefore, intensive effort is now being expended to obtain species that are lower on the food chain (Pauley et al., 1998). This has serious implications; as the lower levels of the food chain decline, the chances of revival at the top of the food chain are diminished even further (Williams, 1998). Top-down ecosystem degradation can result in a variety of unfavorable species abundance shifts (Goeden, 1982) and, potentially, outright ecosystem collapse (Pauley et al, 1998). Further cumulative assessments of managed species in the South Atlantic may reveal long-term declines similar to those now identified in the Keys. Under such circumstances, traditional management measures (e.g., size and harvest limits), may not be adequate to rebuild sustainable fisheries for the most desirable species.

5.0 ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

Established policies and procedures of the SAFMC and the NMFS (Appendix N) provide the framework for conserving and enhancing essential fish habitat. Integral components of this framework include adverse impact avoidance and minimization; provision of compensatory mitigation whenever the impact is significant and unavoidable; and incorporation of enhancement as a fundamental component of fishery resource recovery. New and expanded responsibilities contained in the MSFCMA will be met through appropriate application of these policies and principles. In assessing the potential impacts of proposed projects, the SAFMC, the NMFS, and USFWS are guided by the following general considerations:

- The extent to which the activity would directly and indirectly affect the occurrence, abundance, health, and continued existence of fishery resources;

- The extent to which the goal of "no net-loss of wetlands" would be attained;

- The extent to which an unacceptable precedent may be established or potential for a significant cumulative impact exists;

- The extent to which adverse impacts can be avoided through project modification or other safeguards;

- The availability of alternative sites and actions that would reduce project impacts;

- The extent to which the activity is water dependent if loss or degradation of EFH is involved; and

- The extent to which mitigation may be used to offset unavoidable loss of aquatic habitat functions and values.

5.1 SAFMC Essential Fish Habitat and Environmental Protection Policy

In recognizing that managed species are dependent on the quantity and quality of their essential habitats, it is the policy of the SAFMC to protect, restore, and develop habitats upon which species fisheries depend; to increase the extent of their distribution and abundance; and to improve their productive capacity for the benefit of present and future generations. For purposes of this policy, "habitat" is defined as the physical, chemical, and biological parameters that are necessary for continued productivity of the species that is being managed. The objectives of the SAFMC policy will be accomplished through the recommendation of no net loss or significant environmental degradation of existing habitat. A long-term objective is to support and promote a net-gain of fisheries habitat through the restoration and rehabilitation of the productive capacity of habitats that have been degraded, and the creation and development of productive habitats where increased fishery production is probable. The SAFMC will pursue these goals at state, Federal, and local levels. The Council shall assume an aggressive role in the protection and enhancement of habitats important to species, and shall actively enter Federal, decision-making processes where proposed actions may otherwise compromise the productivity of fishery resources of concern to the Council.

5.2 SAFMC Essential Fish Habitat Policy Statements

5.2.1 SAFMC Policy Statements on Essential Fish Habitat Types

5.2.1.1 SAFMC Policy for Protection and Enhancement of Marine Submerged Aquatic Vegetation (SAV) Habitat.

The South Atlantic Fishery Management Council (SAFMC) and the Habitat and Environmental Protection Advisory Panel has considered the issue of the decline of Marine Submerged Aquatic Vegetation SAV (or seagrass) habitat in Florida and North Carolina as it relates to Council habitat policy. Subsequently, the Council's Habitat Committee requested that the Habitat Advisory Panel develop the following policy statement to support Council efforts to protect and enhance habitat for managed species.

Description and Function:

In the South Atlantic region, SAV is found primarily in the states of Florida and North Carolina where environmental conditions are ideal for the propagation of seagrasses. The distribution of SAV habitat is indicative of its importance to economically important fisheries: in North Carolina, total SAV coverage is estimated to be 200,000 acres; in Florida, the total SAV coverage is estimated to be 2.9 million acres. SAV serves several valuable ecological functions in the marine systems where it occurs. Food and shelter afforded by SAV result in a complex and dynamic system that provides a primary nursery habitat for various organisms that is important both to the overall system ecology as well as to commercial and recreationally important fisheries. SAV habitat is valuable both ecologically as well as economically; as feeding, breeding, and nursery ground for numerous estuarine species, SAV provides for rich ecosystem diversity. Further, a number of fish and shellfish species, around which is built several vigorous commercial and recreational fisheries, rely on SAV habitat for a least a portion of their life cycles.

Status:

SAV habitat is currently threatened by the cumulative effects of overpopulation and consequent commercial development and recreation in the coastal zone. The major anthropogenic threats to SAV habitat include:

(1) mechanical damage due to:
- (a) propeller damage from boats,
- (b) bottom-disturbing fish harvesting techniques,
- (c) dredging and filling;

(2) biological degradation due to:
- (a) water quality deterioration by modification of temperature, salinity, and light attenuation regimes;
- (b) addition of organic and inorganic chemicals.

SAV habitat in both Florida and North Carolina has experienced declines from both natural and anthropogenic causes. However, conservation measures taken by state and federal agencies have produced positive results. The National Marine Fisheries Service has produced maps of SAV habitat in the Albemarle-Pamlico Sound region of North Carolina to help stem the loss of this critical habitat. The threats to this habitat and the potential for successful conservation measures highlight the need to address the decline of SAV. Therefore, the South Atlantic Council recommends immediate and direct action be taken to stem the loss of this essential habitat. For more detailed discussion, please see Appendix 2.

Management:

Conservation of existing SAV habitat is critical to the maintenance of the living resources that depend on these systems. A number of federal and state laws and regulations apply to modifications, either direct or indirect, to SAV habitat. However, to date the state and federal regulatory process has accomplished little to slow the decline of SAV habitat. Furthermore, mitigative measures to restore or enhance impacted SAV have met with little success. These habitats cannot be readily restored; the South Atlantic Council is not aware of any seagrass restoration project that has ever prevented a net loss of SAV habitat. It has been difficult to implement effective resource management initiatives to preserve existing seagrass habitat resources due to the lack of adequate documentation and specific cause/effect relationships. (for more detailed discussion, please see Appendix 3)

Because restoration/enhancement efforts have not met with success, the South Atlantic Council considers it imperative to take a directed and purposeful action to protect remaining SAV habitat. The South Atlantic Council strongly recommends that a comprehensive strategy to address the disturbing decline in SAV habitat in the South Atlantic region be developed. Furthermore, as a stepping stone to such a long-term protection strategy, the South Atlantic Council recommends that a reliable status and trend survey be adopted to verify the scale of local declines of SAV.

The South Atlantic Council will address the decline of SAV, and consider establishing specific plans for revitalizing the SAV resources of the South Atlantic region. This may be achieved by the following integrated triad of efforts:

Planning:

- The Council promotes regional planning which treats SAV as a integral part of an ecological system.
- The Council supports comprehensive planning initiatives as well as interagency coordination and planning on SAV matters.
- The Council recommends that the Habitat Advisory Panel members actively seek to involve the Council in the review of projects which will impact, either directly or indirectly, SAV habitat resources.

Monitoring and Research:

- Periodic surveys of SAV in the region are required to determine the progress toward the goal of a net resource gain.
- The Council supports efforts to
  (1) standardize mapping protocols,
  (2) develop a Geographic Information System databases for essential habitat including seagrass, and
  (3) research and document causes and effects of SAV decline including the cumulative impacts of shoreline development.

Education and Enforcement:

The Council supports education programs designed to heighten the public's awareness of the importance of SAV. An informed public will provide a firm foundation of support for protection and restoration efforts.

Existing regulations and enforcement need to be reviewed for their effectiveness.

Coordination with state resource and regulatory agencies should be supported to assure that existing regulations are being enforced.

SAFMC SAV Policy Statement- Appendix 1

DESCRIPTION AND FUNCTION

Worldwide, Submerged Aquatic Vegetation (SAV) constitutes one of the most conspicuous and common shallow-water habitat types. These angiosperms have successfully colonized standing and flowing fresh, brackish, and marine waters in all climatic zones, and most are rooted in the sediment. Marine SAV beds occur in the low intertidal and subtidal zones and may exhibit a wide range of habitat forms, from extensive collections of isolated patches to unbroken continuous beds. The bed is defined by the presence of either aboveground vegetation, its associated root and rhizome system (with living meristem), or the presence of a seed bank in the sediments, as well as the sediment upon which the plant grows or in which the seed back resides. In the case of patch beds, the unvegetated sediment among the patches is considered seagrass habitat as well.

There are seven species of seagrass in Florida's shallow coastal areas: turtle grass (*Thalassia testudium*); manatee grass (*Syringodium filiforme*); shoal grass (*Halodule wrightii*); star grass (*Halophila engelmanni*); paddle grass (*Halophila decipiens*); and Johnson's seagrass (*Halophila johnsonii*) (See distribution maps in Appendix 4). Recently, *H. johnsonii* has been proposed for listing by the National Marine Fisheries Service as an endangered plant species. Areas of seagrass concentration along Florida's east coast are Mosquito Lagoon, Banana River, Indian River Lagoon, Lake Worth and Biscayne Bay. Florida Bay, located between the Florida Keys and the mainland, also has an abundance of seagrasses, but is currently experiencing an unprecedented decline in SAV distribution.

The three dominant species found in North Carolina are shoalgrass (*Halodule wrightii*), eelgrass (*Zostera marina*), and widgeongrass (*Ruppia maritima*). Shoalgrass, a subtropical species has its northernmost distribution at Oregon Inlet, North Carolina. Eelgrass, a temperate species, has its southernmost distribution in North Carolina. Areas of seagrass concentration in North Carolina are southern and eastern Pamlico Sound, Core Sound, Back Sound, Bogue Sound and the numerous small southern sounds located behind the beaches in Onslow, Pender, Brunswick, and New Hanover Counties (See distribution maps in Appendix 4).

Seagrasses serve several valuable ecological functions in the marine estuarine systems where they occur. Food and shelter afforded by the SAV result in a complex and dynamic system that provides a primary nursery habitat for various organisms that are important both ecologically and to commercial and recreational fisheries. Organic matter produced by these seagrasses is transferred to secondary consumers through three pathways: herbivores that consume living plant matter; detritivores that exploit dead matter; and microorganisms that use seagrass-derived particulate and dissolved organic compounds. The living leaves of these submerged plants also provide a substrate for the attachment of detritus and epiphytic organisms, including bacteria, fungi, meiofauna, micro- and marcroalgae, macroinvertebrates. Within the seagrass system, phytoplankton also are present in the water column, and macroalgae and microalgae are associated with the sediment. No less important is the protection afforded by the variety of living spaces in the tangled leaf canopy of the grass bed itself. In addition to biological benefits, the SAVs also cycle nutrients and heavy metals in the water and sediments, and dissipate wave energy (which reduces shoreline erosion and sediment resuspension).

There are several types of association fish may have with the SAVs. Resident species typically breed and carry out much of their life history within the meadow (e.g., gobiids and syngnathids). Seasonal residents typically breed elsewhere, but predictably utilize the SAV during a portion of their life cycle, most often as a juvenile nursery ground (e.g., sparids and lutjanids). Transient species can be categorized as those that feed or otherwise utilize the SAV only for a portion of their daily activity, but in a systematic or predictable manner (e.g., haemulids).

In Florida many economically important species utilize SAV beds as nursery and/or spawning habitat. Among these are spotted seatrout (*Cynoscion nebulosus*), grunts (Haemulids), snook (*Centropomus sp.*), bonefish (*Albulu vulpes*), tarpon (*Megalops atlanticus*) and several species of snapper (Lutianids) and grouper (Serranids). Densities of invertebrate organisms are many times greater in seagrass beds than in bare sand habitat. Penaeid shrimp, spiny lobster (*Panulirus argus*), and bay scallops (*Argopecten irradians*) are also dependent on seagrass beds.

In North Carolina 40 species of fish and invertebrates have been captured on seagrass beds. Larval and juvenile fish and shellfish including gray trout (*Cynoscion regalis*), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), mullet (*Mugil cephalus*), spot (Leiostomus xanthurus), pinfish (*Orthopristis chrysoptera*), gag (*Mycteroperca microlepis*), white grunt (*Haemulon plumieri*), silver perch (*Bairdiella chrysoura*), summer flounder (*Paralichthys dentatus*), southern flounder (*P. lethostigma*), blue crabs (*Callinectes sapidus*), hard shell clams (*Mercenaria mercenaria*), and bay scallops (*Argopecten irradains*) utilize the SAV beds as nursery areas. They are the sole nursery grounds for bay scallops in North Carolina. SAV meadows are also frequented by adult spot, spotted seatrout, bluefish (*Pomatomus saltatrix*), menhaden (*Brevortia tyrannus*), summer and southern flounder, pink and brown shrimp, hard shell clams, and blue crabs and offshore reef fishes including black sea bass (*Centropristis striata*), gag (*Mycteroperca microlepis*), gray snapper (*Lutianus griseus*), lane snapper (*Lutjanus synagris*), mutton snapper (*Lutianus analis*), and spottail pinfish (*Diplodus holbrooki*). Ospreys, egrets, herons, gulls and terns feed on fauna in SAV beds, while swans, geese, and ducks feed directly on the grass itself. Green sea turtles (*Chelonia mydas*) also utilize seagrass beds, and juveniles may feed directly on the seagrasses.

SAFMC SAV Policy Statement- Appendix 2

STATUS

The SAV habitat represents a valuable natural resource which is now threatened by overpopulation in coastal areas. The major anthropogenic activities that impact seagrass habitats are: 1) dredging and filling, 2) certain fish harvesting techniques and recreational vehicles, 3) degradation of water quality by modification of normal temperature, salinity, and light regimes, and 4) addition of organic and inorganic chemicals. Although not caused by man, disease ("wasting disease" of eelgrass) has historically been a factor. Direct causes such as dredging and filling, impacts of bottom disturbing fishing gear, and impacts of propellers and boat wakes are easily observed, and can be controlled by wise management of our seagrass resources (See Appendix 3). Indirect losses are more subtle and difficult to assess. These losses center around changes in light availability to the plants by changes in turbidity and water color. Other indirect causes of seagrass loss may be ascribed to changing hydrology which may in turn affect salinity levels and circulation. Reduction in flushing can cause an increase in salinity and the ambient temperature of a water body, stressing the plants. Increase in flushing can mean decreased salinity and increased turbidity and near-bottom mechanical stresses which damage or uproot plants.

Increased turbidity and decreasing water transparency are most often recognized as the cause of decreased seagrass growth and altered distribution of the habitats. Turbidity may result from upland runoff, either as suspended sediment or dissolved nutrients. Reduced transparency due to color is affected by freshwater discharge. The introduction of additional nutrients from terrigenous sources often leads to plankton blooms and increased epiphytization of the plants, further reducing light to the plants. Groundwater enriched by septic systems also may infiltrate the sediments, water column, and near-shore seagrass beds with the same effect. Lowered dissolved oxygen is detrimental to invertebrate and vertebrate grazers. Loss of these grazers results in overgrowth by epiphytes.

Large areas of Florida where seagrasses were abundant have now lost these beds from both natural and man-induced causes. (This is not well documented on a large scale except in the case of Tampa Bay). One of these depleted areas is Lake Worth in Palm Beach County. Here, dredge and fill activities, sewage disposal and stormwater runoff have almost eliminated this resource. North Biscayne Bay lost most of its seagrasses from urbanization. The Indian River Lagoon has lost many seagrass beds from stormwater runoff has caused a decrease in water transparency and reduced light penetration. Many seagrass beds in Florida have been scarred from boat propellers disrupting the physical integrity of the beds. Vessel registrations, both commercial and recreational, have tripled from 1970-71 (235, 293) to 1992-93 (715,516). More people engaged in marine activities having an effect on the limited resources of fisheries and benthic communities, Florida's assessment of dredging/propeller scar damage indicates that Dade, Lee, Monroe, and Pinellas Counties have the most heavily damaged seagrass beds. Now Florida Bay, which is rather remote from human population concentrations, is experiencing a die-off of seagrasses, the cause of which has not yet been isolated. Cascading effects of die-offs cause a release of nutrients resulting in algal blooms which, in turn, adversely affect other seagrass areas, and appear to be preventing recolonization and natural succession in the bay. It appears that Monroe County's commercial fish and shellfish resources, with a dockside landing value of $50 million per year, is in serious jeopardy.

In North Carolina total SAV coverage is estimated a 200,000 acres. Compared to the state's brackish water SAV community, the marine SAVs appear relatively stable. The drought and increased water clarity during the summer of 1986 apparently caused an increase in SAV abundance in southeastern Pamlico Sound and a concomitant increase in bay scallop densities. Evidence is emerging, however, that characteristics of "wasting disease" are showing up in some of the eelgrass populations in southern Core Sound, Back Sound, and Bogue Sound. The number of permits requested for development activities that potentially impact SAV populations is increasing. The combined impacts of a number of small, seemingly isolated activities are cumulative and can lead to the collapse of large seagrass biosystems. Also increasing is evidence of the secondary removal of seagrasses. Clam-kicking (the harvest of hard clams utilizing powerful propeller wash to dislodge the clams from the sediment) is contentious issue within the state of North Carolina. The scientific community is convinced that mechanical harvesting of clams damages SAV communities. The scallop fishery also could be harmed by harvest-related damage to eelgrass meadows.

SAFMC SAV Policy Statement- Appendix 3

MANAGEMENT

Conservation of existing SAV habitat is critical to the maintenance of the living resources that depend on these systems. A number of federal and state laws require permits for modification and/or development in SAV. These include Section 10 of the Rivers and Harbors Act (1899), Section 404 of the Clean Water Act (1977), and the states' coastal area management programs. Section 404 prohibits deposition of dredged or fill material in waters of the United States without a permit from the U.S. Army Corps of Engineers. The Fish and Wildlife Coordination Act gives federal and state resource agencies the authority to review and comment on permits, while the National Environmental Policy Act requires the development and review of Environmental Impact Statements. The Magnuson Fisheries Conservation and Management Act has been amended to require that each fishery management plan include a habitat section. The Council's habitat subcommittee may comment on permit requests submitted to the Corps of Engineers when the proposed activity relates to habitat essential to managed species.

State and federal regulatory processes have accomplished little to slow the decline of SAV habitat. Many of the impacts cannot be easily controlled by the regulations as enforced. For example, water quality standards are written so as to allow a specified deviation from background concentration, in this manner standards allow a certain amount of degradation. An example of this is Florida's class III water transparency standard, which defines the compensation depth to be where 1% of the incident light remains. The compensation depth for seagrass is in excess of 10% and for some species is between 15 and 20%. The standard allows a deviation of 10% in the compensation depth which translates into 0.9% incident light or an order of magnitude less than what the plants require.

Mitigative measures to restore or enhance impacted areas have met with little success. SAV habitats cannot be readily restored; in fact, the South Atlantic Council is not aware of any seagrass restoration project that has ever avoided a net loss of seagrass habitat. It has been difficult to implement effective resource management initiatives to preserve seagrass habitat due to the lack of documentation on specific cause/effect relationships. Even though studies have identified certain cause/effect relationships in the destruction of these areas, lack of long-term, ecosystem-scale studies precludes an accurate scientific evaluation of the long-term deterioration of seagrasses. Some of the approaches to controlling propeller scar damage to seagrass beds include: education, improved channel marking restricted access zones, (complete closure to combustion engines, pole or troll areas), and improved enforcement. The South Atlantic Council sees the need for monitoring of seagrass restoration and mitigation not only to determine success from plant standpoint but also for recovery of faunal populations and functional attributes of the essential habitat type. The South Atlantic Council also encourages long-term trend analysis monitoring of distribution and abundance using appropriate protocols and Geographic Information System approaches.

SAFMC SAV Policy Statement- Appendix 4

(SAV Distribution Maps in SAFMC 1995 and Revised in Appendix C)

5.2.2 SAFMC Policy Statements on Activities Affecting Habitat

5.2.2.1 SAFMC Policy Statement Concerning Dredging and Dredge Material Disposal Activities

5.2.2.1.1 Ocean Dredged Material Disposal Sites (ODMDS) and SAFMC Policies

The shortage of adequate upland disposal sites for dredged materials has forced dredging operations to look offshore for sites where dredged materials may be disposed. These Ocean Dredged Material Disposal Sites (ODMDSs) have been designated by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) as suitable sites for disposal of dredged materials associated with berthing and navigation channel maintenance activities. The South Atlantic Fishery Management Council (SAFMC; the Council) is moving to establish its presence in regulating disposal activities at these ODMDSs. Pursuant to the Magnuson Fishery Conservation and Management Act of 1976 (the Magnuson Act), the regional fishery management Councils are charged with management of living marine resources and their habitat within the 200 mile Exclusive Economic Zone (EEZ) of the United States. Insofar as dredging and disposal activities at the various ODMDSs can impact fishery resources or essential habitat under Council jurisdiction, the following policies address the Council's role in the designation, operation, maintenance, and enforcement of activities in the ODMDSs:

The Council acknowledges that living marine resources under its jurisdiction and their essential habitat may be impacted by the designation, operation, and maintenance of ODMDSs in the South Atlantic. The Council may review the activities of EPA, COE, the state Ports Authorities, private dredging contractors, and any other entity engaged in activities which impact, directly or indirectly, living marine resources within the EEZ.

The Council may review plans and offer comments on the designation, maintenance, and enforcement of disposal activities at the ODMDSs.

ODMDSs should be designated or redesignated so as to avoid the loss of live or hard bottom habitat and minimize impacts to all living marine resources.

Notwithstanding the fluid nature of the marine environment, all impacts from the disposal activities should be contained within the designated perimeter of the ODMDSs.

The final designation of ODMDSs should be contingent upon the development of suitable management plans and a demonstrated ability to implement and enforce that plan. The Council encourages EPA to press for the implementation of such management plans for all designated ODMDSs.

All activities within the ODMDSs are required to be consistent with the approved management plan for the site.

The Council's Habitat and Environmental Protection Advisory Panel when requested by the Council will review such management plans and forward comment to the Council. The Council may review the plans and recommendations received from the advisory sub-panel and comment to the appropriate agency. All federal agencies and entities receiving a comment or recommendation from the Council will provide a detailed written response to the Council regarding the matter pursuant to 16 U.S.C. 1852 (i). All other agencies and entities receiving a comment or recommendation from the Council should provide a detailed written response to the Council regarding the matter, such as is required for federal agencies pursuant to 16 U.S.C. 1852 (i).

ODMDSs management plans should indicate appropriate users of the site. These plans should specify those entities/ agencies which may use the ODMDSs, such as port authorities, the U.S. Navy, the Corps of Engineers, etc. Other potential users of the ODMDSs should be acknowledged and the feasibility of their using the ODMDSs site should be assessed in the management plan.

Feasibility studies of dredge disposal options should acknowledge and incorporate ODMDSs in the larger analysis of dredge disposal sites within an entire basin or project. For example, Corps of Engineers analyses of existing and potential dredge disposal sites for harbor maintenance projects should incorporate the ODMDSs. as part of the overall analysis of dredge disposal sites.

The Council recognizes that EPA and other relevant agencies are involved in managing and/or regulating the disposal of all dredged material. The Council recognizes that disposal activities regulated under the Ocean Dumping Act and dredging/filling carried out under the Clean Water Act have similar impacts to living marine resources and their habitats. Therefore, the Council urges these agencies apply the same strict policies to disposal activities at the ODMDSs. These policies apply to activities including, but not limited to, the disposal of contaminated sediments and the disposal of large volumes of fine-grained sediments. The Council will encourage strict enforcement of these policies for disposal activities in the EEZ. Insofar as these activities are relevant to disposal activities in the EEZ, the Council will offer comments on the further development of policies regarding the disposal/ deposition of dredged materials.

The Ocean Dumping Act requires that contaminated materials not be placed in an approved ODMDS. Therefore, the Council encourages relevant agencies to address the problem of disposal of contaminated materials. Although the Ocean Dumping Act does not specifically address inshore disposal activities, the Council encourages EPA and other relevant agencies to evaluate sites for the suitability of disposal and containment of contaminated dredged material. The Council further encourages those agencies to draft management plans for the disposal of contaminated dredge materials. A consideration for total removal from the basin should also be considered should the material be contaminated to a level that it would have to be relocated away from the coastal zone.

5.2.2.1.2 Offshore and Nearshore Underwater Berm Creation

The use of underwater berms in the South Atlantic region has recently been proposed as a disposal technique that may aid in managing sand budgets on inlet and beachfront areas. Two types of berms have been proposed to date, one involving the creation of a long offshore berm, the second involving the placement of underwater berms along beachfronts bordering an inlet. These berms would theoretically reduce wave energy reaching the beaches and/or resupply sand to the system.

The Council recognizes offshore berm construction as a disposal activity. As such, all policies regarding disposal of dredged materials shall apply to offshore berm construction. Research should be conducted to quantify larval fish and crustacean transport and use of the inlets prior to any consideration of placement of underwater berms. Until the impacts of berm creation in inlet areas on larval fish and crustacean transport are determined, the Council recommends that disposal activities should be confined to approved ODMDSs. Further, new offshore and near shore underwater berm creation activities should be reviewed under the most rigorous criteria, on a case-by-case basis.

5.2.2.1.3 Maintenance Dredging and Sand Mining for Beach Renourishment

The Council recognizes that construction and maintenance dredging of the seaward portions of entrance channels and dredging borrow areas for beach re-nourishment occur in the

EEZ. These activities should be done in an appropriate manner in accordance with the policies adopted by the Council.

The Council acknowledges that endangered and threatened species mortalities have occurred as a result of dredging operations. Considering the stringent regulations placed on commercial fisherman, dredging or disposal activities should not be designed or conducted so as to adversely impact rare, threatened or endangered species. NMFS Protected Species Division should work with state and federal agencies to modify proposals to minimize potential impacts on threatened and endangered sea turtles and marine mammals.

The Council has and will continue to coordinate with Minerals Management Service (MMS) in their activities involving exploration, identification and dredging/mining of sand resources for beach renourishment. This will be accomplished through membership on state task forces or directly with MMS. The Council recommends that live bottom/hard bottom habitat and historic fishing grounds be identified for areas in the South Atlantic region to provide for the location and protection of these areas while facilitating the identification of sand sources for beach renourishment projects.

5.2.2.1.4 Open Water Disposal

The SAFMC is opposed to the open water disposal of dredged material into aquatic systems which may adversely impact habitat that fisheries under Council jurisdiction are dependent upon. The Council urges state and federal agencies, when reviewing permits considering open water disposal, to identify the direct and indirect impacts such projects could have on fisheries habitat.

The SAFMC concludes that the conversion of one naturally functioning aquatic system at the expense of creating another (marsh creation through open water disposal) must be justified given best available information.

5.2.2.2 SAFMC Policy on Oil & Gas Exploration, Development and Transportation

The SAFMC urged the Secretary of Commerce to uphold the 1988 coastal zone inconsistency determination of the State of Florida for the respective plans of exploration filed with Minerals Management Service (MMS) by Mobil Exploration and Producing North America, Inc. for Lease OCS-G6520 (Pulley Ridge Block 799) and by Union Oil Company of California for Lease OCS-G6491/6492 (Pulley Ridge Blocks 629 & 630). Both plans of exploration involve lease blocks lying within the lease area comprising the offshore area encompassed by Part 2 of Lease Sale 116, and south of 26° North latitude. The Council's objection to the proposed exploration activities is based on the potential degradation or loss of extensive live bottom and other habitat essential to fisheries under Council jurisdiction.

The SAFMC also supported North Carolina's determination that the plans of exploration filed with MMS by Mobil Exploration and Producing North America, Inc. for Lease OCS Manteo Unit are not consistent with North Carolina's Coastal Zone Management program.

The Council has expressed concern to the Outer Continental Shelf Leasing and Development Task Force about the proposed area and recommends that no further exploration or production activity be allowed in the areas subject to Presidential Task Force Review (the section of Sale 116 south of 26° N latitude).

The SAFMC recommends the following to the MMS when considering proposals for oil and gas activities for previously leased areas under Council jurisdiction:

1) That oil or gas drilling for exploration or development on or closely associated with live bottom habitat, or other special biological resources essential to commercial and recreational fisheries under Council jurisdiction, be prohibited.
2) That all facilities associated with oil and gas exploration, development, and transportation be designed to avoid impacts on coastal wetlands and sand sharing systems.
3) That adequate spill containment and cleanup equipment be maintained for all development and transportation facilities and, that the equipment be available on site within the trajectory time to land, and have industry post a bond to assure labor or other needed reserves.
4) That exploration and development activities should be scheduled to avoid northern right whales in coastal waters off Georgia and Florida as well as migrations of that species and other marine mammals off South Atlantic states.
5) That the EIS for Lease Sale 56 be updated to address impacts from activities related to specifically natural gas production, safety precautions which must be developed in the event of a discovery of a "sour gas" or hydrogen sulfide reserve, the potential for southerly transport of hydrocarbons to near shore and inshore estuarine habitats resulting from the cross-shelf transport by Gulf Stream spin-off eddies, the development of contingency plans to be implemented if problems arise due to the very dynamic oceanographic conditions and the extremely rugged bottom, and the need for and availability of onshore support facilities in coastal North and South Carolina, and an analysis of existing facilities and community services in light of existing major coastal developments.

The SAFMC recommends the following concerns and issues be addressed by the MMS prior to approval of any application for a permit to drill any exploratory wells in Lease Sale 56 and that these concerns and issues also be included in the Environmental Impact Statement for the Outer Continental Shelf (OCS) Leasing Plan for 1992-1997:

1) Identification of the on-site fisheries resources, including both pelagic and benthic communities, that inhabit, spawn, or migrate through the lease sites with special focus on those specific lease blocks where industry has expressed specific interest in the pre-lease phases of the leasing process. Particular attention should be given to critical life history stages. Eggs and larvae are most sensitive to oil spills, and seismic exploration has been documented to cause mortality of eggs and larvae in close proximity.
2) Identification of on-site species designated as endangered, threatened, or of special concern, such as shortnose sturgeon, striped bass, blueback herring, American shad, sea turtles, marine mammals, pelagic birds, and all species regulated under federal fishery management plans.
3) Determination of impacts of all exploratory and development activities on the fisheries resources prior to MMS approval of any applications for permits to drill in the Exploratory Unit area, including effects of seismic survey signals on fish behavior, eggs and larvae; temporary preclusion from fishing grounds by exploratory drilling; and permanent preclusion from fishing grounds by production and transportation.
4) Identification of commercial and recreational fishing activities in the vicinity of the lease or Exploratory Unit area, their season of occurrence and intensity.
5) Determination of the physical oceanography of the area through field studies by MMS or the applicant, including on-site direction and velocity of currents and tides, sea states, temperature, salinity, water quality, wind storms frequencies, and intensities and icing conditions. Such studies must be required prior to approval of any exploration plan submitted in order to have an adequate informational database upon which to base subsequent decision making on-site specific proposed activities.

6) Description of required existing and planned monitoring activities intended to measure environmental conditions, and provide data and information on the impacts of exploration activities in the lease area or the Exploratory Unit area.
7) Identification of the quantity, composition, and method of disposal of solid and liquid wastes and pollutants likely to be generated by offshore, onshore, and transportation operations associated with oil and gas exploration development and transportation.
8) Development of an oil spill contingency plan which includes oil spill trajectory analyses specific to the area of operations, dispersant-use plan including a summary of toxicity data for each dispersant, identification of response equipment and strategies, establishment of procedures for early detection and timely notification of an oil spill including a current list of persons and regulatory agencies to be notified when an oil spill is discovered, and well defined and specific actions to be taken after discovery of an oil spill.
9) Studies should include detailing seasonal surface currents and likely spill trajectories.
10) Mapping of environmentally sensitive areas (e.g., spawning aggregations of snappers and groupers); coral resources and other significant benthic habitats (e.g., tilefish mudflats) along the edge of the continental shelf (including the upper slope); the calico scallop, royal red shrimp, and other productive benthic fishing grounds; other special biological resources; and northern right whale calving grounds and migratory routes, and subsequent deletion from inclusion in the respective lease block(s).
11) Planning for oil and gas product transport should be done to determine methods of transport, pipeline corridors, and onshore facilities. Siting and design of these facilities as well as onshore receiving, holding, and transport facilities could have impacts on wetlands and endangered species habitats if they are not properly located.
12) Develop understanding of community dynamics, pathways, and flows of energy to ascertain accumulation of toxins and impacts on community by first order toxicity.
13) Determine shelf-edge down-slope dynamics and resource assessments to determine fates of contaminants due to the critical nature of canyons and steep relief to important fisheries (e.g., swordfish, billfish, and tuna).
14) Discussion of the potential adverse impacts upon fisheries resources of the discharges of all drill cuttings that may result from activities in, and all drilling muds that may be approved for use in the lease area or the Exploration Unit area including: physical and chemical effects upon pelagic and benthic species and communities including their spawning behaviors and effects on eggs and larval stages; effects upon sight feeding species of fish; and analysis of methods and assumptions underlying the model used to predict the dispersion and discharged muds and cuttings from exploration activities.
15) Discussion of secondary impacts affecting fishery resources associated with on-shore oil and gas related development such as storage and processing facilities, dredging and dredged material disposal, roads and rail lines, fuel and electrical transmission line routes, waste disposal, and others.

The following section addresses the recommendations, concerns and issues expressed by the South Atlantic Council (Source: Memorandum to Regional Director, U.S. Fish and Wildlife Service, Atlanta, Georgia from Regional Director, Gulf of Mexico OCS Region dated October 27, 1995):

"The MMS, North Carolina, and Mobil entered into an innovative Memorandum of Understanding on July 12, 1990, in which the MMS agreed to prepare an Environmental Report (ER) on proposed drilling offshore North Carolina. The scope of the ER prepared by the MMS was more comprehensive than and EIS would be. The normal scoping process used in preparation of a NEPA-type document would not only "identify significant environmental issues deserving of study" but also "deemphasize insignificant issues, narrowing the scope" (40 CFR 1500.4) by scoping out issues not ripe for decisions.

Of particular interest to North Carolina are not the transient effects of exploration, but rather the downstream and potentially broader, long-term effects of production and development. The potential effects associated with production and development would normally be "scoped out" of the (EIS-type) document and would be the subject of extensive NEPA analysis only after the exploration phase proves successful, and the submittal of a full-scale production and development program has been received for review and analysis. The ER addressed three alternatives: the proposed Mobil plan to drill a single exploratory well, the no-action alternative; and the alternative that the MMS approve the Mobil plan with specific restrictions (monitoring programs and restrictions on discharges). The ER also analyzes possible future activities, such as development and production, and the long-term environmental and socioeconomic effects associated with such activities. The MMS assured North Carolina that all of the State's comments and concerns would be addressed in the Final ER (MMS, 1990).

The MMS also funded a Literature Synthesis study (USDOI MMS, 1993a) and a Physical Oceanography study (USDOI MMS, 1994), both recommended by the Physical Oceanography Panel and the Environmental Sciences Review Panel (ESRP). Mobil also submitted a draft report to the MMS titled, Characterization of Currents at Manteo Block 467 off Cape Hatteras, North Carolina. The MMS also had a Cooperative Agreement with the Virginia Institute of Marine Science to fund a study titled, Seafloor Survey in the Vicinity of the Manteo Prospect Offshore North Carolina (USDOI MMS, 1993b). The MMS had a Cooperative Agreement with East Carolina University to conduct a study titled, Coastal North Carolina Socioeconomic Study (USDOI MMS, 1993c). The above-mentioned studies were responsive to the ESRP's recommendations as well as those of the SAFMC and the State of North Carolina.

Citations:

USDOI, MMS. 1990. Atlantic Outer Continental Shelf, Final Environmental Report on Proposed Exploratory Drilling Offshore North Carolina, Vols. I-III.

USDOI, MMS. 1993a. North Carolina Physical Oceanography Literature Study. Contract No. 14-35- 0001-30594.

USDOI, MMS. 1993b. Benthic Study of the Continental Slope Off Cape Hatteras, North Carolina. Vols. I-III. MMS 93-0014, -0015, -0016.

USDOI, MMS. 1993c. Coastal North Carolina Socioeconomic Study. Vols. I-V. MMS 93-0052, -0053, -0054, -0055, and -0056.

USDOI, MMS. 1994. North Carolina Physical Oceanographic Field Study. MMS 94-0047.

Copies of these studies can be acquired from the address below:

Minerals Management Service, Technical Communication Services
MS 4530
381 Elden Street
Herndon, VA 22070-4897 (703) 787-1080

5.2.2.3 SAFMC Policy Statement on Ocean Dumping

The SAFMC is opposed to ocean dumping of industrial waste, sewage sludge, and other harmful materials. Until ocean dumping of these materials ceases, the SAFMC strongly urges state and Federal agencies to control the amount of industrial waste, sludge, and other harmful materials discharged into rivers and the marine environment , and these agencies should increase their monitoring and research of waste discharge. The SAFMC requests that the Environmental Protection Agency continue to implement and enforce all legislation, rules, and regulations with increased emphasis on the best available technology requirements and pretreatment standards. The SAFMC requests that EPA require each permitted ocean dumping vessel (carrying the above described material) to furnish detailed information concerning each trip to the dump site. This might be monitored with transponders, locked Loran C recorder plots of trips to and from dump sites, phone calls to the EPA when a vessel leaves and returns to port, or other appropriate methods. Also the EPA should take legal action to enforce illegal (short or improper) dumping. The SAFMC requests that fishermen and other members of the public report to the EPA, Coast Guard, and the Councils any vessels dumping other than in approved dump sites. The SAFMC supports the phase out of ocean dumping of the above described materials.

5.3 Activity Based Policies

5.3.1 Docks and Piers

Docks and piers, whether built over or floating on the water, are generally acceptable methods of gaining access to deep water. General considerations include:

a. Docks and piers should be constructed so that waterflow restriction and blockage of sunlight on wetland surfaces is avoided or minimized;

b. Docks and piers should be of adequate length to reach navigational depths without increasing dredging needs; and

c. Docks and piers should be designed and located to avoid areas that support submerged aquatic vegetation, shellfish beds and harvest areas, and other fragile and productive habitats.

5.3.2 Boat Ramps

a. Sites should be located along shorelines that do not support wetland vegetation and where adjacent waters have adequate navigational depths. Acceptable sites may include existing marinas; bridge approaches and causeways (with highway agency approval) where construction access channels exist; and natural and previously created deep water habitats;

b. Preferably, sites should be restricted to areas that do not require dredging to gain access to navigable waters. When located in the vicinity of seagrass beds, adequate navigation channels must exist and should be clearly marked. Boat ramps should not be located in areas where boats will encroach on sensitive and productive habitats;

c. Ramps should not be located in areas where encroachment into wetlands is likely to occur. Sites should contain adequate upland area for parking and for boat launching/removal; and

d. Adequate waste collection facilities should be required at public facilities.

5.3.3 Marinas

All marinas adversely affect aquatic habitats to some degree. These effects can be minimized through proper location and design. In addition to applicable recommendations for boat ramps, bulkheads, and seawalls, the following apply:

a. Marinas should be located in areas where suitable physical conditions exist. For example, potential sites should be located close to navigable waters and in locations where marina-related activities would not affect living marine resource forage, cover, harvest, and/or nursery habitats. Attention also should be given to sediment deposition rates and maintenance dredging requirements;

b. Marinas should be located at least 1,000 feet from shellfish harvest areas, unless state regulations or other considerations specify differently;

c. Dry-stack storage is generally preferable to wet mooring of boats. Open dockage extending into deep water is generally preferable to basin excavation;

d. Mooring basins should be sited in uplands rather than wetlands, and they should be designed so that water quality degradation does not occur. This may require consideration of basin flushing characteristics and incorporation of other design features such as surface and waste water collection and treatment facilities;

e. Turning basins and navigation channels should not create sumps and other slack-water areas that could degrade water quality nor should they be located in areas where circulation is poor. Depths generally should not exceed those of adjoining waters and, where practicable, they should provide for light penetration that is capable of sustaining benthic plant life. Dissolved oxygen levels in channels and basins should be adequate for fish and macroinvertebrate survival;

f. Consideration should be given to aligning access channels and configuring marinas to take full advantage of circulation from prevailing summer winds;

g. Permanent dredged material disposal sites (for use in initial and maintenance dredging) that do not impact wetland areas should be identified and acquired. Suitable disposal alternatives include placing dredged material on uplands, and using dredged material to create/restore wetlands. Projects that lack permanent disposal sites should not be authorized if maintenance dredging is needed and disposal sites/options are not available;

h. Catchment basins for collecting and storing surface runoff should be included as components of the site development plan. Marine railways or upland repair facilities should be equipped with hazardous material containment facilities so that biocides such as marine paints, oil and grease, solvents, and related materials are not directly or indirectly discharged into coastal waters and wetlands;

I. Consideration should be given to parking and other support facilities when it appears that available uplands are not adequate to support such needs and wetland encroachment is anticipated;

j. Marinas with fueling facilities should be designed to include practical measures for reducing oil and gas spillage into the aquatic environment. Spill control plans may be needed when marina facilities are to be located in the vicinity of large, emergent wetland areas, shellfish harvest sites, and other fragile/productive aquatic sites; and

k. Facilities for collection of trash and potential marine debris should be required. Where vessels with marine toilets will be moored, pump out facilities and notices regarding prohibition of sewage and other discharges should be provided.

5.3.4 Bulkheads and Seawalls

Bulkheads are used to protect adjacent shorelines from wave and current action and to enhance water access. Applications for bulkheads usually specify construction in open water followed by placing fill material behind the structure. Bulkheads may adversely impact wetlands through direct filling; through isolation; and through exacerbation of wave scour. Adverse impacts may be reduced by applying the following criteria:

a. Except in cases of recent and rapid erosion, structures should be aligned at or shoreward of the normal high waterline. Structures should be constructed so that reflective wave energy does not scour or otherwise adversely affect adjacent EFH or wetlands. For example, in areas that support fringing wetlands consideration should be given to the use of breakwaters (with regular openings -- see item c., below) or placement of riprap at the toe of the bulkhead or along the waterward edge of eroding wetlands;

b. Where possible, sloping (3:1) riprap, gabions, or vegetation should be used rather than vertical seawalls; and

c. Shoreline protection devices that are located in areas having fringe wetlands should have openings that allow for fish ingress and egress and water circulation. Recommended spacing for structure openings is no less than one linear foot per five linear feet of structure.

5.3.5. Cables, Pipelines, and Transmission Lines

Wetland excavation is sometimes required for installing submerged cables, pipelines, and transmission lines. Construction also may require temporary or permanent wetlands filling. The following recommendations apply:

a. Wetland crossings should be aligned along the least environmentally damaging route. Submerged aquatic vegetation, shellfish beds, coral reefs, etc., must be avoided;

b. Construction of permanent access channels should be avoided since they disrupt natural drainage patterns and destroy wetlands through direct excavation, filling, and bank erosion. The push-ditch method, in which the trench is immediately backfilled, reduces the impact duration;

c. Excavated wetlands should be backfilled with either the same material as removed or a comparable material that is capable of supporting suitable replacement wetlands. Original marsh elevations should be restored and, where practicable, excavated vegetation should be stockpiled, kept viable, and returned to the excavated site. After backfilling, erosion protection measures should be implemented where needed to prevent fish habitat degradation and loss;

d. Excavated materials should be stored on uplands. If storage in wetlands cannot be avoided, discontinuous stock-piles should be used to allow continuation of sheet flow. Where practicable, stockpiled materials should be stored on construction cloth rather than bare marsh surfaces. Topsoil and organic surface material such as root mats should be stockpiled separately and returned to the surface of the restored site;

e. In open-water areas, excavated materials should be deposited in discontinuous piles to preclude significant blockage of water movement. Back-filling is recommended if the excavated material would alter circulation patterns or interfere with fishing;

f. Use of existing rights-of-way should be recommended when use of these areas would lessen overall wetland encroachment and disturbance; and

g. Directional drilling, a technique that allows horizontal, sub-surface, placement of pipelines should be used in situations where normal trenching and backfill would cause unacceptable levels of habitat loss or alteration.

5.3.6. Transportation

State and federal highway agencies generally have the capability of conducting advanced planning with road, causeway, and bridge construction. To the extent possible, NMFS Branch Office and USFWS personnel should participate in early planning efforts. Since highway projects are generally considered to be in the public interest and frequently require wetland crossings, identification of mitigation needs, and development of suitable mitigation plans should be undertaken early in the planning process. The following criteria should be considered:

a. Transportation corridors/facilities should avoid wetlands. Where wetland crossings cannot be avoided, bridging should be used rather than filling, and the least environmentally damaging route, preferably along existing rights-of-way and road beds, should be followed;

b. Disrupting or reducing fish and invertebrate migration routes should be avoided. In areas that support or could support anadromous fish migrations, low, narrow, and/or dark passageways such as culverts and small bridges should not be utilized unless aligned and designed so that elimination of or significant reductions in fish migrations do not occur;

c. Structures should be designed to prevent shoaling and alteration of natural water circulation. Suitable erosion control and vegetation restoration should be implemented at wetland crossings; and

d. Transportation facilities should be designed to accommodate other public utilities, thus avoiding the need for additional wetland alteration. An example would be using bridges to support transmission lines and pipelines.

5.3.7. Navigation Channels and Boat Access Canals

Construction and maintenance of navigation channels and boat access canals may cause severe environmental harm. In addition to direct habitat losses associated with wetland and deepwater excavation and filling, these activities may significantly modify salinity and water circulation patterns. These changes could greatly modify the distribution and abundance of living marine resources. The following criteria should be followed:

a. Where possible, dredging should be minimized through the use of natural and existing channels;

b. Alignments should avoid sensitive habitats such as shellfish beds, finfish and invertebrate nurseries, submerged aquatic vegetation, and emergent wetlands;

c. Permanent dredged material disposal sites should be located in non-wetland areas. Where long-term maintenance excavation is anticipated, disposal sites should be acquired and maintained for the entire project life;

d. Boat access canals should be designed to ensure adequate flushing and should be uniform in depth or made progressively deeper in the direction of receiving waters. Where possible, they should be aligned to take advantage of wind and lunar tides;

e. Construction techniques that minimize turbidity and dispersal of dredged materials into sensitive wetland areas (e.g., submerged grasses and shellfish beds) are encouraged. Work should be scheduled to avoid periods of high biological activity such as fish and invertebrate migration and spawning;

f. Care should be taken to avoid adverse alteration of tidal circulation patterns, salinity regimes, or other factors that influence local ecological and environmental conditions;

g. Channels and access canals should not be constructed in areas known to have high sediment contaminant levels. If construction must occur in these areas, consideration should be given to the use of silt curtains or other techniques needed to contain suspended contaminants; and

h. Use of sidecast dredges should be confined to areas such as inlets and open water areas where benthic communities are limited and hopper or pipeline dredging is not possible.

5.3.8. Disposal of Dredged Material

Previous and on-going disposal of dredged material is a major contributor to wetland losses in marine and estuarine ecosystems. Recognizing that most navigation channels and access canals require periodic maintenance dredging, it is important that long-range plans be developed and that they provide for mitigation of unavoidable adverse environmental impacts. Implementing the following criteria would minimize adverse impacts associated with most dredged material disposal activities:

a. Dredged material should be viewed as a potentially reusable resource and beneficial uses of these materials should be encouraged. Materials that are suitable for beach replenishment, construction, or other useful purposes should be placed in accessible non-wetland disposal areas;

b. Disposal sites that are located in unprotected coastal areas and adjacent to wetlands are especially susceptible to wind and water erosion. These forces can carry substantial quantities of dredged material into aquatic habitats. If located near wetlands, disposal site surfaces should be stabilized using vegetation or other means to eliminate possible erosion or encroachment onto adjacent wetlands;

c. Dredged material should be placed in contained upland sites or approved open-water locations where adverse impacts to living marine resources are minimal. When placed in open water, dredged material should be used to enhance marine fishery resources. For example, materials could be used to renourish eroding wetlands or to fill previous borrow sites;

d. The capacity of existing disposal areas should be used to the fullest extent possible. This may necessitate increasing the elevation of embankments to augment the holding capacity of the site and applying techniques that render dredged material suitable for export or for use in reestablishing wetland vegetation;

e. Where possible, outfalls should be positioned so that they discharge into the dredged area or other sites that lack biological/ecological significance. When evaluating potential upland disposal sites, the possibility of saltwater intrusion into ground water and surrounding freshwater habitats should be assessed by the construction/regulatory agencies. Groundwater contamination could necessitate redesign of disposal practices, with subsequent harm to living marine resources; and

f. Toxic and highly organic materials should be disposed in impervious containment basins located on upland. Effluent should be monitored to ensure compliance with state and federal water quality criteria and measures should be incorporated to ensure that surface runoff and leachate from dredged material disposal sites do not enter aquatic ecosystems.

5.3.9. Impoundments and Other Water-Level Controls

A. Wetland impoundments:

Thousands of wetland acres are impounded each year in the Southeast for purposes such as waterfowl habitat creation, aquaculture, agriculture, flood control, hurricane protection, mosquito control, and control of marsh subsidence and erosion. Projects range in size from minor, such as repair of existing embankments, to large-scale marsh management projects where constructing dikes and water- control structures may affect thousands of wetland acres.

Proposals to impound or control marsh water levels should contain water management plans with sufficient detail to determine the accessibility of impounded areas to marine organisms and the degree to which detrital and nutrient export into adjacent estuarine areas will be affected. Significant adverse impacts can be avoided or minimized with implementation of the following recommendations:

a. Proposals to impound or reimpound previously unimpounded wetlands are unacceptable unless designed to accommodate (1) normal access and wetland use by marine fish and invertebrates and (2) continuation of other biological interaction, such as nutrient exchange, and other similarly important physical and chemical interactions; and

b. Proposals to repair or replace water control structures will be assessed on a case-by-case basis.

B. Watershed Impoundments:

Water-development agencies sometimes propose impounding rivers, bayous, and tributaries for such purposes as flood control or creation of industrial, municipal, and agricultural water supplies. Activities of this type are usually unacceptable because associated alteration of the quality, quantity, and timing of freshwater flow into estuaries may cause large-scale adverse modification or elimination of estuarine and marine habitats. Such actions also may block fish and invertebrate migrations.

5.3.10. Drainage Canals and Ditches

Drainage canals may be important components of upland development. Their potential to shunt polluted runoff and fresh water directly into tidal waters requires intermediate connection to retention ponds or wetlands. This allows natural filtration and assimilation of pollutants and dampening of freshwater surges prior to discharge into tidal waters. Recommendations include:

a. Drainage canals that dewater or cause other adverse wetland impacts are unacceptable and should not be built;

b. Drainage canals and ditches from upland development generally should not extend or discharge directly into wetlands;

c. Constructing upland retention ponds and other water management features such as sheet-flow diffusers is encouraged. A retention pond or other pollution elimination/assimilation structure should be required if the effluent contains or may contain materials that are toxic to marsh vegetation or other aquatic life,

d. Excavated materials resulting from canal and retention pond construction should be placed on upland or used to restore wetlands;

e. Proposed drainage plans should be in accordance with comprehensive flood plain management plan(s) and applicants should be encouraged to consult with the EPA and appropriate state agencies to ensure that federal and state water quality standards are met;

f. Locating mosquito control ditches in wetlands should be discouraged. If built, they should be designed so that they do not drain coastal wetlands. They also should be designed to avoid water stagnation, and they should provide access for aquatic organisms that feed on mosquito larvae; and

g. Use of innovative techniques such as rotary ditching, spray dispersal of dredged materials, and open-water marsh management should be encouraged where appropriate.

5.3.11 Oil and Gas Exploration and Production

Exploration and production of oil and gas resources in wetlands usually have adverse impacts since excavation and filling are generally required to accommodate access and production needs. In open marine waters, dredging and filling is usually not necessary, but special stipulations are required to minimize adverse impacts to living marine resources. In addition to the above recommendations for navigation channels, access canals, and pipeline installation, the following apply:

A. In coastal wetlands:

a. Activities should avoid wetland use to the extent practicable. Alternatively, the use of uplands, existing drilling sites and roads, canals, and naturally deep waters should be encouraged. When wetland use is unavoidable, work in unvegetated and disturbed wetlands is generally preferable to work in high quality and undisturbed wetlands;

b. Temporary roadbeds (preferably plank roads) generally should be used instead of canals for access to well sites;

c. Water crossings should be bridged or culverted to prevent alteration of natural drainage patterns;

d. Culverts or similar structures should be installed and maintained at sufficient intervals (never more than 500-feet apart) to prevent blockage of surface drainage or tidal flow;

e. Petroleum products, drilling muds, drill cuttings, produced water, and other toxic substances should not be placed in wetlands;

f. If the well is productive, the drill pad and levees should be reduced to the minimum size necessary to conduct production activities; and

g. Defunct wells and associated equipment should be removed and the area restored to the extent practicable. Upon abandonment of wells in coastal wetlands, the well site, various pits, levees, roads, and work areas should be restored to preproject conditions by restoring natural elevations and planting indigenous vegetation whenever practicable. Abandoned well access canals should generally be plugged at their origin (mouths) to minimize bank erosion and saltwater intrusion, and spoil banks should be graded back into borrow areas or breached at regular intervals to establish hydrological connections.

B. In open estuarine waters:

Activities in estuarine waters should be conducted as follows:

a. Existing navigable waters already having sufficient width and depth for access to mineral extraction sites should be used to the extent practicable;

b. Petroleum products, drilling muds, drill cuttings, produced water, and other toxic substances should not be placed in wetlands; and

c. Defunct equipment and structures should be removed.

C. On the continental shelf:

Activities should be conducted so that petroleum-based substances such as drilling mud, oil residues, produced waters, or other toxic substances are not released into the water or onto the sea floor. The following measures may be recommended with exploration and production activities located close to hard banks and banks containing reef building coral:

a. Drill cuttings should be shunted through a conduit and discharged near the sea floor, or transported ashore or to less sensitive, NMFS-approved offshore locations. Usually, shunting is effective only when the discharge point is deeper than the site that is to be protected;

b. Drilling and production structures, including pipelines, generally should not be located within one mile of the base of a live reef;

c. All pipelines placed in waters less than 300 feet-deep should be buried to a minimum of three feet beneath the sea floor, where possible. Where this is not possible and in deeper waters where user-conflicts are likely, pipelines should be marked by lighted buoys and/or lighted ranges on platforms to reduce the risk of damage to fishing gear and the pipelines. Pipeline alignments should be located along routes that minimize damage to marine and estuarine habitat. Buried pipelines should be examined periodically for maintenance of adequate earthen cover.

5.3.12. Other Mineral Mining/Extraction

a. Proposals for mining mineral resources (sand, gravel, shell, phosphate, etc.) from or within 1,500 feet of exposed shell reefs and vegetated wetlands, and within 1,500 feet of shorelines are unacceptable except when the material is to be used for oyster cultch; and

b. All other proposals will be considered on a case-by-case basis.

5.3.13. Sewage Treatment and Disposal

Urbanization and high density development of coastal areas has resulted in a substantial increase in proposals to construct sewage treatment and discharge facilities in coastal wetlands. Since many of these facilities utilize gravity flow systems for movement of waste water and materials, wetlands and other low-lying areas are often targeted as sites for placement of pipelines and treatment facilities. Since pipelines and treatment facilities are not water dependent with regard to positioning, it is not essential that they be placed in wetlands or other fragile coastal habitats. The guidance provided in Section 5.3.5., "Cables, Pipelines, and Transmission Lines," also applies to sewage collector and discharge pipelines. The following guidance should be considered with other aspects of sewage treatment and discharge:

a. Discharges should be treated to the maximum extent practicable, including implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances;

b. Use of land treatment and upland disposal/storage techniques should be implemented where possible. Use of vegetated wetlands as natural filters and pollutant assimilators for large scale discharges should be limited to those instances where other less damaging alternatives are not available and the overall environmental and ecological suitability of such an action has been demonstrated;

c. Discharging into open ocean waters is generally preferable to discharging into estuarine waters since discharging into estuarine waters is more likely to result in living marine resources contamination and nutrient overloading. Discharge points in coastal waters should be located well away from shellfish beds, seagrass beds, coral reefs, and other similar fragile and productive habitats. Proposals to locate outfalls in coastal waters must be accompanied by hydrographic studies that demonstrate year round dispersal characteristics and provide proof that effluents will not reach or affect fragile and productive habitats.

5.3.14. Steam-Electric Plants and Other Facilities Requiring Water for Cooling or Heating

Facilities that require substantial intake and discharge of water, especially heated and chemically-treated discharge water, are generally not suited for construction and operation in estuarine and near-shore marine environments. Major adverse impacts may be caused by impingement of organisms on intake screens; entrainment of organisms in heat-exchange systems or discharge plumes; and through the discharge of toxic materials in discharge waters. Protected Species Branch personnel should be notified of such projects early in the planning process since the operation of steam-electric plants often affects endangered species such as shortnose sturgeon and West Indian manatee. Projects that must be sited in the coastal zone and utilize estuarine and marine waters are subject to the following recommendations:

a. Facilities that rely on surface waters for cooling should not be located in areas such as estuaries, inlets, or small coastal embayments where fishery organisms are concentrated. Discharge points should be located in areas that have low concentrations of living marine resources, or they should incorporate cooling towers that employ sufficient safeguards to ensure against release of blow-down pollutants into the aquatic environment;

b. Intakes should be designed to minimize impingement. Velocity caps that produce horizontal intake/discharge currents should be employed and intake velocities across the intake screen should not exceed 0.5 feet per second;

c. Discharge temperatures (both heated and cooled effluent) should not exceed the thermal tolerance of the majority of the plant and animal species in the receiving body of water;

d. The use of construction materials that may release toxic substances into receiving waters should be minimized. The use of biocides (e.g., chlorine) to prevent fouling should be avoided where possible and least damaging antifouling alternatives should be implemented; and

e. Intake screen mesh should be sized to avoid entrainment of most larval and post-larval marine fishery organisms. Acceptable mesh size is generally in the range of 0.5 mm and rarely exceeds 1.0 mm in estuarine waters or waters that support anadromous fish eggs and larvae.

5.3.15. Mariculture/Aquaculture

The culture of estuarine and marine species in coastal areas can reduce or degrade habitats used by native stocks of commercially and recreationally important fisheries. The following criteria should be employed to reduce or eliminate adverse impacts:

a. Facilities should be located on upland. Tidally influenced wetlands should not be enclosed or impounded for mariculture purposes. This includes hatchery and grow-out operations;

b. Water intakes should be designed to avoid entrainment and impingement of native fauna;

c. Water discharge should be treated to avoid contamination of the receiving water, and should be located only in areas having good mixing characteristics;

d. Where cage mariculture operations are undertaken, water depths and circulation patterns should be investigated and should be adequate to preclude the buildup of waste products, excess feed, and chemical agents; and

e. Mariculture sites should be stocked with hatchery-reared organisms only. Non-native species should be certified to be disease free, and project design features that minimize escape or accidental release of cultured species should be required. The rearing of ecologically undesirable species is unacceptable since escape and accidental release of these species is virtually assured.

5.3.16. Mitigation

Sections 5.3.1 - 5.3.15 provide specific guidance for avoiding and reducing adverse impacts to fishery resources and their habitats. Compensatory mitigation is considered in cases where a resource is not unique and irreplaceable and only after a project has been demonstrated to be water-dependent, has no feasible alternative, is clearly in the public interest, and all significant impacts are found to be unavoidable. In all cases, mitigation shall comply with the definition of mitigation that is provided at 40 CFR 1508.20 of the Council on Environmental Quality Recommendations. Those recommendations define mitigation as a sequential process whereby impacts are avoided, minimized, rectified, reduced over time, or are offset through compensation.

Despite increasing use of mitigation to offset wetland and other losses, there are situations (e.g., projects affecting seagrass) where the affected habitats are of such enormous value that the anticipated adverse impacts cannot be offset. In instances involving such unique and irreplaceable resources, mitigation is not acceptable. There is also disagreement over the functional equivalency of created and natural wetlands and it should not be assumed they are equivalent in habitat value.

As a general rule, mitigation that restores previously existing habitats is more desirable and likely to succeed than that which seeks to create new habitat. The numerous impacted wetlands that exist in the Southeast provide substantial opportunity for wetlands restoration. Restoration may be relatively simple, such as restoring tidal flows to an impounded wetland area, or more complex such as restoring dredged cuts and disposal areas. Restoration of destroyed emergent and, to a lesser degree, submerged vegetation is a feasible and recognized option when implemented with the services of experienced restoration personnel.

The creation of new wetland habitat involves conversion of uplands or, in some situations, submerged bottom to vegetated wetlands or another desirable habitat such as oyster reef. Generation of wetland habitat should not involve converting one valuable wetland type to another. For example, building emergent wetlands in shallow water is unacceptable unless it can be demonstrated that the site is insignificant with regard to habitat or water quality function(s) or it previously supported wetland vegetation and restoration is desirable in terms of the ecology of the overall hydrological unit (e.g., estuary). Regardless of which option is used (restoration or creation), a ratio of at least two acres of mitigation for each acre of habitat destroyed should be recommended.

Four basic considerations involved in the planning for habitat generation are type of habitat to be created, and its location, size, and configuration. Each of these considerations must be applied to the specific ecological setting and in accordance with the following recommendations:

a. Habitat type - As a general rule the created habitat should be vegetatively, functionally, and ecologically comparable to that which is being replaced. For example, a smooth cordgrass marsh should be created if a smooth cordgrass marsh is eliminated. The principal exception would be those cases where a different habitat is shown to be more desirable based on overall ecological considerations.

b. Location - Except in the case of overriding ecological considerations, the new site should be located as near as possible to the site that would be eliminated. In any event, the new site should be in the same estuarine system as the habitat that is being replaced. The replacement wetland should consider physical implications such as shoaling and existing circulation and drainage patterns.

NMFS and USFWS considers the overall ecological and environmental implications of its recommendations, including upland impacts. Mitigation that may alleviate impacts to aquatic environments, but cause significant adverse impacts to important upland habitats should be carefully evaluated.

c Size - The habitat to be restored or created should be at least twice the (areal) size of that which would be destroyed. This requirement is designed to offset differences in productivity and habitat functions that may exist between established project site wetlands and newly developed replacement wetlands. This size difference is also designed to address the possibility that the overall, long-term functional and ecological value of replacement habitats may be less than those of the impacted wetlands at the worksite.

d. Configuration - The configuration of replacement habitats is determined by the ecological setting and physical factors such as existing drainage and circulation patterns. Consideration should be given to maximizing edge habitat and to the needs of desirable biota that may inhabit the site.

Interest in the use of "mitigation banks" or created/restored wetlands that are intended for use in offsetting anticipated future wetland losses is increasing nationwide. Because of the complexity of developing and administering mitigation banks, guidance concerning their creation is beyond the scope of this document. NMFS Southeast Region Habitat Conservation Division Branch Office personnel that are participating in such efforts should consult early with other NMFS office personnel that have undertaken or are involved in such efforts since reliance on existing mitigation banking agreements may be beneficial. Habitat Conservation Division Branch Office personnel also should notify other participating agencies that signatory authority for mitigation bank agreements rests with the Regional Director. In all cases, consideration of mitigation banks should be guided by the principle that no net-loss of wetlands would be incurred.

5.3.17 Detailed listing of non-fishing activities that may adversely impact habitat, including EFH, of managed species.

A. Physical Alterations

1. Hydrologic modifications
    - (a). Navigation channel construction/expansion
    - (b). Canals and ditches
    - (c). Dams and water control structures
        - (1). Hydropower operations
        - (2). Flood control
        - (3). Water supply
        - (4). Navigation
        - (5). Water diversion
    - (d). Levees, embankments, and impoundments
        - (1). Water management
        - (2). Wildlife Management
        - (3). Aquaculture
    - (e). Utility crossings and right-of-ways
    - (f). Roads, causeways, and bridges
    - (g). Alteration of freshwater inflow
    - (h). Ground water withdrawals
    - (i). Interbasin transfers/surface water withdrawals

2. Dredged material disposal and fills
    - (a). Open water disposal
    - (b). Placement of confined/unconfined material in wetlands
    - (c) Burial of nearshore habitats
3. Excavation
    - (a). Removal/alteration of wetlands and submerged bottoms
4. Minerals exploration and mining
    - (a). Removal/alteration of wetlands and submerged bottoms
5. Placement of structures in the coastal environment
    - (a). Industrial and Commercial
        - (1). Petroleum exploration and production platform operations
        - (2). Port development waterfront facilities
        - (3). Municipal wastewater outfall structures
    - (b). Navigation
        - (1). Breakwaters
        - (2). Jetties
        - (3). Anchorage/mooring areas
    - (c). Recreational/Environmental Structures
        - (1). Artificial reefs
        - (2). Fishing piers
    - (d). Beach Erosion Control Structures

(1). Jetties
(2). Groins
(3). Bulkheads
(4). Special purpose structures

6. Ocean dumping
   (a). Dredged materials
   (b). Hazardous materials
   (c). Municipal solid waste
   (d). Municipal wastewater/sludge
7. Introduction of exotic species
   (a). Pet and agriculture (including mariculture) related industries
   (b). Ship ballast water releases
   (c). Incidential relocation on vessels, machinery, and animals
8. Watershed land use practices
   (a). Agriculture
   (b). Silviculture
9. Erosion/Subsidence
   (a). Channel and shoreline erosion from vessel wakes.
   (b). Shoreline erosion caused by manmade structures
      (1). Jetties
      (2). Groins
      (3). Breakwaters
   (c). Faulting induced by ground water extraction
   (d). Relative sea level rise
   (e). Reduced sediment renourishment
   (f). Barrier islands and shorelines
10. Recreational boating impacts
   (a). Propeller scarring
   (b). Anchor scarring
   (c). Grounding
   (d). Trash
   (e). Oil and gasoline spillage
   (f). Boat wakes
11. Military Facilities
   (a). Degaussing facilities
   (b). Ordnance disposal areas
   (c). Special training areas, bombing ranges

B. Water Quality Issues

1. Non-point-source Pollution (Percent)
   (a). Agriculture
   (b). Urbanization
   (c). Silviculture
2. Point-source Pollution (PS)
   (b). Industrial discharges
   (c). Municipal wastewater discharges
   (d). Urban stormwater discharges
   (e). Vessel wastewater discharges

(f). Thermal effluents from electric power generation facilities

3. Oil spills
    (a). Hydrocarbon pollution
    (b). Toxic substances in cleaning materials
4. Chemical contaminant spills
5. Air emissions
6. Ocean dumping
7. Salinity
8. Turbidity
9. Recreational boating impacts
    (a). Fuel/oil contamination
    (b). Overboard discharges
    (c). Prop and anchor damage to reefs/bottoms

5.4 Interagency and Interstate Policies

5.4.1 Joint Agency Habitat Statement

The SAFMC has endorsed a "Joint Statement to Conserve Marine, Estuarine, and Riverine Habitat" to promote interagency coordination in the preservation, restoration, and enhancement of fishery habitat. This statement as adopted by state, Federal, and regional bodies concerned over fishery habitat, is presented in Appendix VII of The Fishery Management Plan for Shrimp (SAFMC 1993a).

5.4.2 Atlantic States Marine Fisheries Commission Seagrass Policy/ Implementation Plan.

The Atlantic States Marine Fisheries Commission seagrass policy and implementation plan for the seagrass policy is also presented in Appendix I.

5.5 Federal Habitat Protection Laws, Programs, and Policies.

See Appendix J for a listing and brief description of environmental laws directly, or indirectly protecting marine resources and the habitat they depend on.

5.6 State Habitat Protection Programs

5.6.1 North Carolina

The Coastal Area Management Act was passed in 1974 to protect North Carolina's fragile coastal resources through planning and management at the state and local level. The Department of Environment, Health and Natural Resources administers the program. Policy direction is provided by the Coastal Resources Commission, a group of citizens appointed by the Governor. The Division of Coastal Management (DCM), under authority from the Coastal Resources Commission (CRC), is responsible for implementing the North Carolina Coastal Management Program for the protection, preservation, orderly development and management of the state's twenty coastal counties. DCM is part of the Department of Environment, Health and Natural Resources. Present activities of DCM include: Permitting and enforcing regulations in Areas of Environmental Concern; Reviewing consistency of government and larger private activities in the coastal zone for compliance with the Coastal Area Management Act; Planning for the Ocean Resources in North Carolina's jurisdictional waters; Providing for effective disposal of boat sewage; Identifying high priority watersheds; Developing strategies for managing secondary and cumulative impacts; Transferring technology and information to local governments; Identifying wetlands in the coastal area; Assessing the relative significance of wetlands on the landscape; and Identifying and prioritizing wetland restoration sites.

5.6.2 South Carolina

The Office of Ocean and Coastal Management implements the Coastal Management Act. The Office has authority to formulate and implement a comprehensive coastal management program and direct control through a permit program that oversees activities in critical areas that include coastal waters, tidelands, beaches, and primary ocean-front sand dunes. Indirect management authority of coastal resources is granted to the Office in counties containing one or more of the critical areas. In issuing permits, the Coastal Management Act requires that the Office consider the effects of proposed alterations on the production of fish, shrimp, oysters, crab, or any marine life, wildlife, or other natural resources.

5.6.3 Georgia

On April 22, 1997, Governor Miller signed the Georgia Coastal Management Act into law which established the Department of Natural Resources Coastal Resource Division as the authority to create the program, receive and dispense funds, and to coordinate with federal and state agencies regarding Coastal Management issues. On January 26, 1998 the Georgia Coastal Management Program received official approval. This approval marks the end of a six year combined effort by state and local government in partnership with private citizens to develop an integrated, networked program. The program uses existing State laws to manage Georgia's critical coastal resources. With the approval of the Georgia Coastal Management Program comes over $1 million in federal funds annually. Most of the funds will be allocated to local communities and organizations through the "Coastal Incentive Grant" program. The Coastal Resources Division has completed and submitted the first grant award request and expects to began dispersing the Coastal Incentive Grants in the eleven county service area April 1, 1998. Incentive grants will be presented to local governments and universities to address critical local issues in coastal Georgia such as water management, local government planning and small scale construction projects.

5.6.4 Florida

The Florida Legislature adopted the Florida Coastal Management Act in 1978. This act authorized the development of a coastal management program and its submittal to the appropriate federal agency. In 1981, the Florida Coastal Management Program (FCMP) was approved by the Secretary of the United States Department of Commerce. Florida's goal in creating the FCMP was not to create a new agency or new statutes concerned with coastal issues, but instead to use existing agencies and laws to address Florida's coastal needs. Florida's rules and laws adequately protected the coast, but were not always effectively implemented because of breakdowns in communication between agencies and administrative shortcomings. The FCMP was created to bridge these gaps and to open the lines of communication among the agencies so that their actions could be coordinated.

The FCMP, as it exists today, is a network of ten state agencies and five water management districts using 23 statutes to protect Florida's coastal interests. The agencies most directly involved in issues that affect Essential Fish Habitat are listed below.

The Department of Community Affairs (DCA) is the lead agency for the FCMP, serving as coordinator of coastal issues and as the liaison between the state agencies and the federal government. DCA also houses the State Clearinghouse and serves as the state's land planning agency and emergency management agency.

The Department of Environmental Protection(DEP), formed by the merger of the former Department of Environmental Regulation and the former Department of Natural Resources, serves as the state's chief environmental regulatory agency and the manager and steward of many of its natural resources. Among the natural resources over which the DEP has jurisdiction are submerged lands within state estuarine and marine waters. The Department of Health regulates on-site sewage disposal. The Marine Fisheries Commission exercises jurisdiction over saltwater fisheries and marine mammals. The five water management districts, organized along watershed lines, act in partnership with DEP in regulating activities in wetlands and waters of the state and the use of water resources.

5.7 Threatened and Endangered Species

The Sustainable Fisheries Act of 1996 established certain requirements and standards the Councils and the Secretary must meet in managing fisheries under the Magnuson-Stevens Act. Implementing the provisions in the SFA will not have any negative impacts on the listed and protected species under the Endangered Species Act (ESA) and Marine Mammals Protection Act (MMPA) including:

	Whales:	Date Listed
(1)	Northern right whale- *Eubalaena glacialis* (ENDANGERED)	12/2/70
(2)	Humpback whale- *Magaptera novaeangliae* (ENDANGERED)	12/2/70
(3)	Fin whale- *Balaenoptera physalus* (ENDANGERED)	12/2/70
(4)	Sei whale- *Balaenoptera borealis* (ENDANGERED)	12/2/70
(5)	Sperm whale- *Physeter macrocephalus* (ENDANGERED)	12/2/70
(6)	Blue whale- *Balaenoptera musculus* (ENDANGERED)	

	Sea Turtles:	Date Listed
(1)	Kemp's ridley turtle- *Lepidochelys kempii* (ENDANGERED)	12/2/70
(2)	Leatherback turtle- *Dermochelys coriacea* (ENDANGERED)	6/2/70
(3)	Hawksbill turtle- *Eretmochelys imbricata* (ENDANGERED)	6/2/70
(4)	Green turtle- *Chelonia mydas* (THREATENED/ENDANGERED)	7/28/78
(5)	Loggerhead turtle- *Caretta caretta* (THREATENED)	7/28/78

	Other Species Under U.S. Fish and Wildlife Service Jurisdiction:	Date Listed
(1)	West Indian manatee- *Trichechus manatus* (ENDANGERED)	3/67
	(Critical Habitat Designated)	1976
(2)	American crocodile - *Crocodulus acutus* (ENDANGERED)	9/75
	(Critical Habitat Designated)	12/79

Recent research efforts identifying use of *Sargassum* habitat by juvenile sea turtles is summarized in Appendix R.

6.0 ESSENTIAL FISH HABITAT RESEARCH NEEDS

6.1 Essential Fish Habitat Research and Monitoring Program

The following constitutes the basic structure of the Council's essential fish habitat (EFH) research and monitoring program. This general structure provides recommendations, for research the Council, the National Marine Fisheries Service (NMFS) and other habitat partners in the South Atlantic region view as necessary for carrying out the EFH management mandate. This Section will be refined after public hearing to better identify and support South Atlantic habitat partners research efforts to describe, map, and document use of EFH by managed species. In addition, subsequent drafts of this document will better efforts of habitat partners to define non-fishing and fishing threats and their impacts on EFH.

The Council has determined that the NMFS, in cooperation with other Federal, State and regional habitat partners in the South Atlantic region, will develop the necessary understanding, using basic and applied research and literature syntheses, to help conserve, protect, and restore EFH of living marine resources managed by the Council. Statutes and international conventions and treaties which authorize the NMFS to conserve and restore marine habitat include but are not limited to the Magnuson Fishery Conservation and Management Act, the Endangered Species Act, the Fish and Wildlife Coordination Act, the National Marine Sanctuaries Act, the Clean Water Act, the Comprehensive Environmental Response, Compensation, and Liability Act ("Superfund"), and Oil Pollution Act (OPA).

Additional research is necessary to insure sufficient information is collected to support a higher level of description and identification of EFH (see Appendices O and P). In addition, research is needed to identify and evaluate existing and potential adverse effect on EFH, including but not limited to, direct physical alteration; impaired habitat quality or function; cumulative impacts from fishing; or indirect adverse effects such as sea level rise, global warming and climate shifts; and non-gear related fishery impacts.

The Council recommends NMFS apply their adopted Habitat Research Plan to direct and conduct research and transfer results to management components within NMFS. The Council coordinates with NMFS management components to provide information on permit and policy activities, fishery and EFH information for fishery management plans. The NMFS plan is designed to develop the necessary expertise to accomplish or oversee the restoration, creation, or acquisition of habitat to benefit living marine resources. The plan provides guidance in four areas: ecosystem structure and function, effects of alterations, on habitat development of habitat restoration methods, and development of indicators of impact and recovery of habitat. A fifth area is the need for synthesis and timely transfer of scientific information to managers.

The Habitat Research Plan of the NMFS (Thayer et al., 1996) serves as a base from which this Section will be revised. After public hearing this Section using this base structure will be revised to further define needs by individual EFH type or EFH-HAPC, as well as by species or species complex. The Council will work with NMFS and other NOAA programs, including the Office of Ocean and Coastal Resource Management, Coastal Ocean Program, Coastal Services Center (Charleston, SC), and National Sea Grant Program, to meet the goals of NOAA. NMFS will work closely with other federal agencies to increase cooperation and partnerships, maximize research information, and reduce potential duplication of research efforts. The Council has adopted the same general structure for the research and monitoring program. In addition, the following draft lists of research needs for habitat or managed species are included for comment.

6.1.1 Ecosystem Structure and Function

Understanding the structure and function of natural ecosystems, their linkages to one another, and the role they play in supporting and sustaining living marine resources, their abundance, distribution, and health -- is critical. Knowing when and how systems are affected, assessing the cause and degree of impact, and providing the basis for restoring and maintaining these systems are integral to this research area, and must be evaluated in terms of landscape ecology. Research on ecosystem structure and function will provide the necessary foundation for linking all areas to provide the basis for making fundamentally sound management decisions. Thus, assessment of habitat impacts; development of restoration methods and evaluation of restoration effectiveness, development of indicators of impact and recovery, and synthesis and transfer of information for the development of management policy and regulations all are dependent on a comprehensive understanding of ecosystem structure and functioning.

Research in this area will include studies on the relationship between habitat and yield of living marine resources including seasonality and annual variabilities and the influence of chemical and physical fluxes on these relationships. These research efforts will be dependent upon knowledge of basic life histories, habitat structural integrity and limiting factors, and must be evaluated within the context of habitat mosaics or habitat heterogeneity. Therefore, data on habitat location are integral to this research area. Information on essential fish habitat, variability in yield of fishery resources as a function of material fluxes, habitat type, location and scale should be generated. This research area provides the foundation for understanding cause and effect relationships and development and evaluation of protection and restoration strategies.

6.1.2 Effect of Habitat Alterations

Knowledge of the causes of damage to ecosystems is critical to restoring past losses and preventing future degradation and loss of habitats essential for maintaining and enhancing living marine resources. Therefore, quantification of the response of habitats and living marine resources to natural and anthropogenic alterations is not only a prerequisite to determining the degree of impact, predicting the rate of recovery, and recommending the most effective restoration procedures, but it also is a requisite to establishing effective protective measures.

The basis for determining cause and effect relationships depends on an understanding of the natural structure and function of an ecosystem. Individual living marine resource requirements and population characteristics. The Council is interested in both maintaining sustainable living marine resource populations and protecting the essential fish habitat they depend upon. Habitat partners should conduct research to relate non-fishing impacts observed at the individual level to effects at the population level which would link habitat impacts ultimately to living marine resource populations.

Studies should include cause and effect research designed to evaluate responses of living marine resource and habitats to physical and chemical modifications of coastal and estuarine systems. Research is encouraged that considers downstream responses to upland modification, the role of buffers zones, as well as living marine resource and habitat responses to physical and waterflow alterations and water quality modifications. Information should be generated on responses to both individual and cumulative impacts so as to provide the basis for policy statements, guidelines, and regulations to protect habitats. These cause and effect databases will furnish information pertinent not only to permit-related activities and other consultations, but also to NMFS mandated responsibilities in restoration planning and implementation.

6.1.3 Habitat Restoration Methods

While methods for restoring certain habitats (e.g., salt marshes and seagrass meadows) exist, most have not been rigorously tested under experimental conditions throughout wide geographic areas and at different scales. Additionally, for other habitats (e.g., coral reefs, intertidal and subtidal substrates, riparian habitat) only limited methodology exists and little emphasis has been placed on rapidly restoring biodiversity and monitoring for success and persistence. (As a consequence, a significant proportion of restoration actions has been viewed with skepticism relative to their success and concerns for rates of habitat recovery or development.) Current methods to cleanup, restore or create productive living marine resource habitats must be improved, and new, innovative techniques must be developed and evaluated using statistically rigorous approaches.

Research topics and areas of concern include analyses of the success of contaminant sequestration; assessment of bioremediation techniques; development and evaluation of new habitat restoration techniques; experiments on transplant species culture techniques; and evaluation of the role and size of buffers and the importance of habitat heterogeneity in the restoration process. Research on restoration will lead to scientific information on trajectories of recovery and stability of created and restored systems including physical, chemical and biological components and processes. Assessments of new techniques and evaluation of current techniques over geographic regions and scales will provide bases for success evaluation. Most importantly, guidelines for improved best management practices and improved restoration planning will be generated.

6.1.4 Indicators of Habitat and Living Marine Resources Impacts and Recovery

Increasing and extensive exploitation of coastal resources demands that indicators be used to simplify the process of determining whether an ecosystem, habitat, or living marine resource is healthy, degraded, or is recovering. The development of indicators of habitat/living marine resource impacts and recovery is critical for managers judging the status of essential fish habitat or fishery resources, and determining the need for corrective actions.

The development of habitat or resource indicators must be based on information derived from comparative research on the structure and function of disturbed, natural, and/or restored habitats of different ages and geographical locations for a suite of biological, chemical, and physical parameters; time-dependent biotic population analyses; and contaminant level follow-up evaluations for sediment, biota, and water. This type of research will help managers identify essential fish habitat status; standardize indicators for specific habitats through comparisons across geographic gradients and scales; and develop recommendations on chemical "cleanup" techniques and most appropriate measures to assess success. The Council encourages NMFS, in cooperation with the other habitat partners in the Southeast, to utilize such guideposts to develop and improve best management practice approaches.

6.1.5 Synthesis and Information Transfer

The synthesis and timely transfer of information derived from research findings and the existing literature is a key element of the essential fish habitat research and monitoring program. Decisions on permitting, regulation, enforcement, redirection of research efforts, and development and implementation of restoration plans must be made with the best available information. Scientists must step back from their research long enough to provide timely information syntheses to habitat managers. Likewise, it is imperative that State and Federal habitat managers recognize that generic information generated by the scientific community does have powerful application to their site-specific problems.

Technology and information transfer will be expedited through the use of all available information sources and the application of "user-friendly" information bases. Geographical Information Systems provide the opportunity to amass and array large quantities of complex data, thereby, providing potential for relational observations by decision-makers; such use is strongly encouraged. Many areas of synthesis and transfer have been indicated in the earlier four research areas and will not be repeated here. Additional examples include information syntheses on essential fish habitat and essential fish habitat-habitat areas of particular concern and modes of protection and restoration, and synthesis of available information on landscape approaches to basinwide management including permitting and restoration. Such collations of current and evolving information bases are important to the Council and those charged with the conservation and management of fishery resources as well as to State and Federal habitat managers concerned about developing and implementing policy. These syntheses could be done within NMFS, through partnerships with other agencies, and by contract. It is important, however, that syntheses be provided in a useable format and even published in outlets available to both scientific and management communities. The scientific community must participate in the synthesis and transfer process.

6.1.6 Implementation

The five interlinked areas provide a framework for the type of research and continuity needed to effectively manage EFH. In some instances this linkage between research areas may be hierarchical. Research on ecosystem structure and function provides the foundation for linking all areas. For example, knowledge of the structure and function of the ecosystem must be known before one can actually determine the effects of habitat alterations, develop restoration methods, or develop indicators of impact and recovery. Continuity of information from each research area is required to develop a comprehensive data base for making important resource decisions. Research founded on this approach will provide State and Federal habitat managers with a broad information base that is scientifically and ecologically credible, and responsive to management needs. The Council will coordinate with and support NMFS Southeast Regional Office and Fisheries Science Centers in their effort to determine habitat research and management priorities. Research conducted to address the EFH mandate in the southeast region should: address regional management and research needs pertinent to the Council, NMFS or other habitat partner responsible for conservation or management of EFH or species which depend on EFH; be consistent with the Council's, NMFS's and other habitat partner's long-term goals or habitat policies; and provide information about the benefit of protecting EFH or living marine resources.

Cooperative efforts between NMFS research and management staffs and with other federal/state agencies, industry, and academia are encouraged. This approach will create greater and improved partnerships, which will be required if we are to meet the Council's, NOAA's, and NMFS's goal to protect, conserve, and restore essential fish habitat through sound habitat research and management. In addition, the Council will support programmatic EFH research proposals when requested from and developed by NMFS SEFSC.

6.2 Research Needs Identified in Fishery Management Plans

6.2.1 Research Needs Identified in SAFMC Fishery Management Plans

Habitat and species specific research needs identified in Council fishery managment plans are presented below for the following species or species complexes - penaeid and deepwater shrimp, red drum, spiny lobster, coastal migratory pelagics, coral, coral reefs and live hard bottom habitat, golden crab, the snapper grouper complex, calico scallops and pelagic *Sargassum* habitat.

Shrimp Research Needs:

Rock Shrimp

The following research needs are listed in no particular priority order:

1. Recruitment processes and life history strategy.
2. What are the settlement patterns of juveniles with respect to depth? What are the subsequent development and mortality rates, and how do they vary across depths?
3. Growth rates. Accurate, detailed laboratory experiments to test effects of ecological variables are particularly desirable.
4. Reproductive cycle.
5. Seasonal movements.
6. Habitat preferences. Basic ecological questions concerning physiological ecology, refuges and foraging habits, trophic dynamics, and community relationships remain largely unanswered.
7. Basic physiology of rock shrimp, biogeography, and systematics.

Additional fishery management related items include:

8. Estimate potential yield.
9. Document economic and social information of fishermen and dealers.
10. Identification of the extent of existing bottom habitat suitable for rock shrimp in the South Atlantic Council's area.
11. Bycatch characterization of the rock shrimp fishery.

Shrimp Bycatch Research Needs:

The research needs listed below are specified to bycatch.

1. Characterization of bycatch in the rock and royal red shrimp fisheries.
2. Determine the impact of shrimp trawl bycatch on the habitat and all non-target species of fish and invertebrates (i.e., include impacts on habitat and all incidental species, not just the impact on other "fishery resources").

The following research needs are summarized from recommendations presented in the bycatch characterization report for the South Atlantic region (SEAMAP 1996):

1. Shrimp effort data needs to be collected to provide estimates based on time fished (or number of tows), rather than at the trip level. Future sampling needs to be improved with respect to collection of both shrimp effort and bycatch characterization data.
2. Future characterization effort should be expanded to include important strata for which no observer data is available and strata which have low sample sizes.
3. Bycatch monitoring should be conducted regularly if data are to be used in stock assessments. Conduct characterization for 5 years after implementation of state and federal

bycatch reduction regulations to determine the effectiveness of the gears used, and to establish new baseline bycatch estimates for stock assessments.
4. Long-term characterization data sets should be funded.

Red Drum Research Needs:
Research priorities include the following list from the stock assessment for Atlantic coast red drum:
1. Direct the improvement in catch, effort and length frequency statistics from the recreational and commercial fisheries.
2. Direct additional effort in intercepting recreational fishermen through the MRFSS who fish nighttime hours.
3. Increased tagging efforts on age 3-5 year old red drum, with directed effort to recapture subadult and adult red drum to determine if disappearance is due in part to offshore emigration.
4. Standardize sampling of the Atlantic coast subadult red drum population to develop a long-term index of recruitment.
5. Develop a more reliable maturity schedule for population level analyses.
6. Determine relationships between annual egg production and female length or weight for Atlantic coast red drum.
7. Develop a more reliable estimate of natural mortality through directed sampling of the adult population.

Other research needs identified in Section 5.7 of the Source Document for the Atlantic coast red drum fishery management plan include:
1. Determine escapement levels of juvenile red drum to the spawning stock by state.
2. Determine natural and fishing mortality rates.
3. Determine stock structure.
4. Determine survival rate of released red drum.
5. Develop a fishery independent index of relative abundance.
6. Determine inshore/offshore, as well as coastwide, migration patterns through enhanced mark-recapture studies, aerial surveys and sonic tagging efforts.
7. Determine spawning areas.
8. Determine the economic value of the Atlantic coast recreational red drum fishery.
9. Assess and modify, as needed, MRFSS procedures to more accurately survey red drum. recreational catch and effort.
10. Document and characterize schooling behavior for Atlantic coast red drum.
11. Encourage current efforts to continue collection of socioeconomic data in the MRFSS and to collect socioeconomic data in the commercial fishery, where available.

Red Drum Habitat Research Needs:
1. Identify optimum red drum habitat and environmental conditions.
2. Quantify relationships between red drum production and habitat.
3. Identify the effects of water quality degradation on red drum production.
4. Identify areas of particular concern for red drum.
5. Determine habitat conditions that limit red drum production.
6. Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production.

7. Encourage research in developing bio- or photo-degradable plastic products to reduce impact of refuse on the inshore, nearshore, offshore marine environments utilized by red drum at various stages of development.
8. Quantify impacts of acid rain on estuarine systems vital to red drum production.
9. Determine research that could be incorporated into a biological and socioeconomic impact assessment quantifying the effects of oil, gas and mineral exploration, development or transportation on red drum, their essential offshore, nearshore and estuarine habitat and the Atlantic coast red drum fishery.
10. Determine the impacts of dredging nearshore and offshore sand bars for beach renourishment on red drum spawning activity. In addition, the impacts of any type of dredging activity on all life history stages of red drum.

Snapper Grouper Research Needs:

To understand the causes of fishery declines and better predict the effects of human activities on fishery populations, the following research needs relative to snapper grouper habitat are provided so that state, federal, and private research efforts can focus on those areas that would allow the South Atlantic Fishery Management Council to develop measures to better manage snapper grouper and their habitat:

1. Identify optimum snapper grouper habitat and environmental and habitat conditions that limit snapper grouper production (e.g., what are the critical fisheries habitats for food, cover, spawning, nursery areas, and migration?);
2. Determine the relationship between juvenile snapper grouper and estuarine habitat. If an obligatory relationship is found, determine the distributions, rates of change, and documented causes of loss for estuarine habitat types;
3. Quantify the relationships between snapper grouper production and habitat (e.g., what are the key trophic pathways in the ecosystem, and how does the flux of essential nutrients, carbon compounds, and energy through these systems influence fisheries productivity?);
4. Determine the relative effects of fishing, pollution, and natural mortality on fishery population dynamics. Also determine the effects of cumulative habitat loss on fisheries productivity and economic value;
5. Determine methods for restoring snapper grouper habitat and/or improving existing environmental conditions that adversely affect snapper grouper production. The 29 recommendations for future studies in Bohnsack and Sutherland (1985) are supported here; and
6. Identify essential fish habitat - habitat areas of particular concern for snapper grouper.

King Mackerel Research Needs:

1. Continued refinement of estimates of sustainable yield, condition of the stock, and stock structure. This requires improved estimates of age composition of catches, recruitment, natural mortality, total catch, growth rate, and standing stock.
2. Develop fishery independent methods of assessing stock abundance.
3. Develop and refine estimates of economic value of the recreational and commercial fisheries on the mackerel resources, including effects of regulations on these values.
4. Determine impact of bag limits on the total catch and consider release mortality.
5. Compile king and Spanish mackerel price data by gear type.

Spanish Mackerel Research Needs:
1. Continuing refinement of estimates of sustainable yield, refinement of subgroups, and condition of stock. This requires improved estimates of age composition of catches, recruitment mortality rates, total catch, growth rate, and standing stock.
2. Develop fishery independent methods of assessing stock abundance.
3. Develop and refine estimates of the economic values of the recreational and commercial fisheries on the Spanish mackerel resource, including effects of regulations on these values.
4. Determine impact of bag limits on the total catch and consider release mortality.

Cobia and Dolphin Research Needs:
1. Increase general life history information.
2. Determine status of stocks.

Spiny Lobster Research Needs:
Biological
1. Determine whether a relationship between the magnitude of postlarval recruitment and subsequent fishery yield exists and, if so, monitor long-term for establishing optimal harvesting strategies.
2. The eggs per recruit ratio in relation to overfishing definition should be defined and monitored.
3. Estimates of growth, mortality (M and F), and better indices of effort.
4. Determination of the relationship between the reproductive cycle characteristics in Florida and in the Caribbean, with postlarval recruitment in Florida.
5. Determination whether a relationship between juvenile habitat quality and abundance and magnitude of harvest exists on fishery-wide scale.
6. Estimate the impact that loss of nursery habitat may have on recruitment to the fishery.

Economic
7. Economic assessment of status of commercial and recreational fisheries including production (cost) and demand considerations.
8. Evaluation of the economic and social impacts of efforts limitation systems for traps.
9. Quantification annually of Florida recreational landings, effort, and CPUE.

Data
10. An evaluation of available catch and effort by geographic area, distance from shore, and number of traps fished per craft is needed.
11. Spanish lobster landings need to be sampled for size frequency and sex ratios.

Golden Crab Research Needs:
The following research needs (Items 1-8 taken from Lindberg and Wenner, 1990) are listed in no particular priority order:
1. Recruitment processes and life history strategy.
2. What are the settlement patterns of juveniles with respect to depth? What are the subsequent development and mortality rates, and how do they vary across depths?

3. Growth rates. Accurate, detailed molt staging should be incorporated into future sampling regimes, while controlled laboratory experiments to test effects of ecological variables are particularly desirable.
4. Reproductive cycle. Age at first reproduction is poorly known. Comparative studies and experimentation are needed to resolve questions of this basic life history trait.
5. Seasonal movements, encounter rates among potential mates and competitors, movement by mated pairs, and takeover attempts all need to be documented to test golden crab mating strategies.
6. Habitat preferences. Basic ecological questions concerning physiological ecology, refuges and foraging habits, trophic dynamics and community relationships remain largely unanswered.
7. Home ranging versus nomadism needs to be examined.
8. Questions of basis physiology of deep-dwelling organisms, biogeography and systematics, or parasitology and symbiosis.

Additional fishery management related items include:

9. Estimate potential yield.
10. Document economic and social information of fishermen and dealers.
11. Document information on market structure, development, and consumer acceptance of product.
12. Determine whether there is any substitutability with other crustaceans.
13. Identification of existing bottom habitat suitable for golden crabs in the South Atlantic Council's area would be useful.
14. Biodegradable panel research - determine the rate at which specified material degrades and evaluate materials/methods to meet objective of degrading within 14-30 days.
15. Bioprofile sampling - data on size, molt and reproductive status, etc.
16. Gear impacts and refugia.

Pelagic Sargassum Habitat Research Needs:

Additional research is necessary to insure sufficient information is collected to support a higher level of description and identification of pelagic *Sargassum* habitat. In addition, research is needed to identify and evaluate existing and potential adverse effect on pelagic *Sargassum* habitat, including but not limited to, direct physical loss or alteration; impaired habitat quality or function; cumulative impacts from fishing; and non-gear related fishery impacts.

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.

Calico Scallop Research Needs:

1. Growth and mortality factors need further quantification to refine the critical size estimates.
2. The size frequency of individual calico scallop beds as they are fished, mature, and die is needed to further refine the minimum size specified.
3. There is a lack of information concerning the percentage of calico scallops that can be opened during an at-sea processing operation. The Council supports this research need because it addresses one of the issues and can be completed in a relatively short period of time and at low cost.
4. Survival rate of released calico scallops is required to further evaluate at-sea processing. There is at present only one boat processing at-sea but this could increase in the future. This research need addresses one of the issues and should be undertaken in the very near future given the low cost and short time frame required.
5. Information is needed to address the following areas concerning parasitic nematodes: (1) occurrence of the nematode; (2) survival of the nematode; (3) effect of processing, food handling, reconditioning and associated problems; and (4) consumer perception. Research on the parasitic nematode is aimed at addressing one of the issues and should be supported. Florida Sea Grant and the calico scallop fishing industry have expended some effort in this area.
6. The effect of ocean disposal of at-sea processing waste on the scallop beds should be investigated. Concern has been expressed that this could increase calico scallop losses due to predators. This addresses Issue Number 4 and given the potential increase in at-sea processing more information is needed by the Councils to properly evaluate the situation.
7. The effect of the removal of such a large quantity of hard substrate (shells) that could provide attachment sites for spat settlement should be investigated. This addresses one of the issues and it is recognized that this is a long-term research effort.

6.2.2 Interjurisdictional Prioritized Research Needs

The following habitat and select species specific research needs were identified in Special Report No. 62 published by the Atlantic States Marine Fisheries Commission "Prioritized Research Needs in Support of Interjurisdictional Fisheries Management" (ASMFC 1997).

American Shad and River Herring:

- Review studies dealing with the effects of acid deposition on anadromous alosids.
- Conduct turbine mortality studies and downstream passage studies.
- Determine the effects of pollution, passage impediments, and other anthropogenic impacts on all other life history stages of shad and river herring.
- Conduct and evaluate historical characterization of socio-economic development (potential pollutant sources and habitat modification) of selected shad rivers along the east coast.
- Identify and quantify potential American shad spawning and rearing habitat not presently utilized and conduct an analysis of the cost of recovery.

Atlantic Menhaden:
- Monitor fish kills along the Atlantic coast and use the NMFS Beaufort Laboratory as a repository for these reports.
- Study the ecological role of menhaden (predator/prey relationship, nutrient enrichment, oxygen depletion, etc.) in major Atlantic coast embayments and estuaries.
- Determine how loss / degradation of critical estuarine and nearshore habitat affects growth, survival and abundance of juvenile Atlantic menhaden.

Atlantic Sea Herring:
- Establish critical spawning habitat areas or special management zones to protect spawning aggregations of herring and/or demersal egg masses.

Atlantic Sturgeon:
- Standardize and obtain baseline data on habitat for important sturgeon rivers. Data should include assessment of spawning and nursery habitat.
- Establish environmental tolerance levels (D.O., pH, temperature, etc.) for different life stages.
- Determine the effects of contaminants on early life stages.

Red Drum:
- Determine habitat preferences, growth rates, and food habits of larval and juvenile red drum.
- Quantify relationships between red drum production and habitat.
- Identify the effects of water quality degradation on red drum production,
- Determine the methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production.
- Determine the impacts dredging nearshore and offshore sand bars for beach renourishment on red drum spawning activity. In addition, the impacts of any type of dredging activity on all life history stages of red drum.

Spanish Mackerel:
- Conduct migration studies to determine normal Spanish mackerel migration routes and changes therein, and the climatic or other factors responsible for the changes in the environmental and habitat conditions which may effect the habitat and availability of stocks.

Spotted Seatrout:
- Identify essential habitat requirements.

Red Drum:
1. Conduct standardized fishery independent sampling of subadult red drum on an interstate basis to develop a long term index of recruitment.
   Improve catch, effort and length frequency statistics from the recreational and commercial fisheries.
2. Conduct tagging studies to estimate fishing and total mortality, and to determine inshore/offshore migration patterns.
   Research efforts on adult red drum should focus on the definition of unit stock for red drum in the South Atlantic using methods such as mark-recapture and genetic discrimination.

Determine escapement levels of juvenile red drum to the spawning stock by state.

3. Develop a more reliable estimate of natural and fishing mortality and minimum size in managing fisheries.
4. Examine the effectiveness of controlling fishing mortality and minimum size in managing fisheries.
5. Quantify relationships between red drum production and habitat.
6. Increase intercepts of recreational fishermen through the MRFSS who fish nighttime hours.
7. Maintain annual length age keys.
   Determine the survival rate of released red drum.
8. Research on stock assessment should focus on genetic implications and cost benefits. The introduction of unmarked fish should be discouraged until present efficacy of such an approach is validated.
   - Determine Habitat preferences, environmental conditions, growth rates and food habits of larval and juvenile red drum.

   Identify the effects of water quality degradation on red drum production.
   - Determine the methods for restoring red drum and/or improving existing environmental conditions that adversely affect red drum production.
9. States with significant fisheries should be encouraged to collect socio-economic data on red drum fisheries through ad-ons to the MRFSS or by other means so as to determine the economic value of the Atlantic coast recreational red drum fishery.
10. Assess the effects of environmental factors on stock densities.
11. Document and characterize schooling behavior for Atlantic coast red drum.
    - Determine the impacts of dredging nearshore and offshore sand bars for beach renourishment for red drum spawning activity. In addition, the impacts of any type of dredging activity on all life history stages of red drum.
12. Conduct yield modeling on red drum.
    Refine maturity schedules between sampling programs, determine relationships between annual egg production and female length/weight. And determine spawning areas in order to increase accuracy and precision of SSBR estimates.

Prioritized Research Needs for Spanish Mackerel
High Priority:

- Length, sex, age and CPUE data are needed to improve the 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.
- Weight and especially length at age for Spanish mackerel needs to be evaluated.
- Develop fishery independent methods of monitoring stock size of Atlantic Spanish mackerel (consider aerial surveys used in south Florida waters).
- More timely reporting of mid-Atlantic catches is needed 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.
- Methodology for predicting year class strength should be developed, and the relationship between larva abundance and subsequent year class strength should be examined and defined.

Medium Priority:

- Yield per recruit analyses need to be conducted relative to alternative selective fishing patterns.
- Determine the bycatch of Spanish mackerel in the directed shrimp fishery in the Atlantic coastal waters.
- Evaluate the potential bias of the lack of appropriate stratification of the data used to generate age-length keys for Atlantic and Gulf Spanish mackerel.
- Evaluation of CPUE indices related to standardization methods and management history, with emphasis on greater temporal and spatial resolution in estimates of CPUE.
- Encourage the considerations of MRFSS ad-ons or other mechanisms for the collection of socioeconomic data for recreational and commercial fisheries.
- Conduct migration studies to determine normal Spanish mackerel migration routes and changes therein, and the climactic or other changes responsible for changes in the environmental and habitat conditions which may effect the habitat or availability of the stocks.
- Determine if any the migration of prey species (i.e., the engraulids, clupieds, carangids), and the migration patterns of the Spanish mackerel stock.

Low Priority:

- Identification of Spanish mackerel stocks through multiple research techniques needs to be compiled.
- Research needs to be completed on the application of assessment and management models relative to dynamic species such as Spanish mackerel.
- Temporal and spatial sampling to delineate spawning areas and areas of larval abundance should be initiated.

6.2.3 Research on the Effects of Fishing Activities

The effects of fishing are the subject of numerous, mostly site specific and fishery specific, investigations that focus largely on economic and social factors. Most early fisheries management efforts deal with increased yields, gear, and identifying and locating new target species and markets. With the world wide decline of many fish stocks emphasis has shifted, in recent years, to stock management and recovery. This change in management emphasis has gradually led to realization that reductions in the size and quality of fishery habitats have reached critical levels. It has also furthered the view that, in certain situations, fishing itself may be profoundly changing the physical and biological character of fish harvest and life requisite areas.

Trawling and other fishing activities that involve direct contact between fishing gear and the aquatic environment can alter the structural character of fish habitats. When the change is sufficient enough to preclude or limit use by fishery directed or target species, declines in catch abundance and individual fish size may occur. Although a clear cause and effect relationship is evident, determination of the level of effect inducted by physical change may be complex. Relevant factors, in addition to the magnitude of the direct physical change, may include disturbance frequency and duration, seasonality, and other environmental, ecological, and physiological processes that control recovery and recruitment of requisite species of the community. As noted by Auster and Langton (1998) "... mobile fishing gear reduced habitat complexity by (1) directly removing epifauna or damaging epifauna leading to mortality, (2) smoothing sedimentary bedforms and reducing bottom roughness, and (3) removing taxa which produce structure (i.e., taxa which produce burrows and pits)."

Primary information is lacking for us to strategically manage fishing impacts on Essential Fish Habitat without invoking precautionary measures. Priority studies should include a number of areas where primary data are lacking, which would allow better monitoring and improved experimentation, ultimately leading to predictive capabilities including:

- The spatial extent of fishing induced disturbance. While many observer programs collect data at the scale of single tows or sets, the fisheries reporting systems often lack this level of spatial resolution. The available data makes it difficult to make observations, along a gradient of fishing effort, in order to assess the effects of fishing effort on habitat, community, and ecosystem processes.

- The effects of specific gear types, along with a gradient of effort on specific habitat types. These data are the first order needs to allow an assessment of how much effort produces a measurable level of change in structural habitat components and the associated communities.

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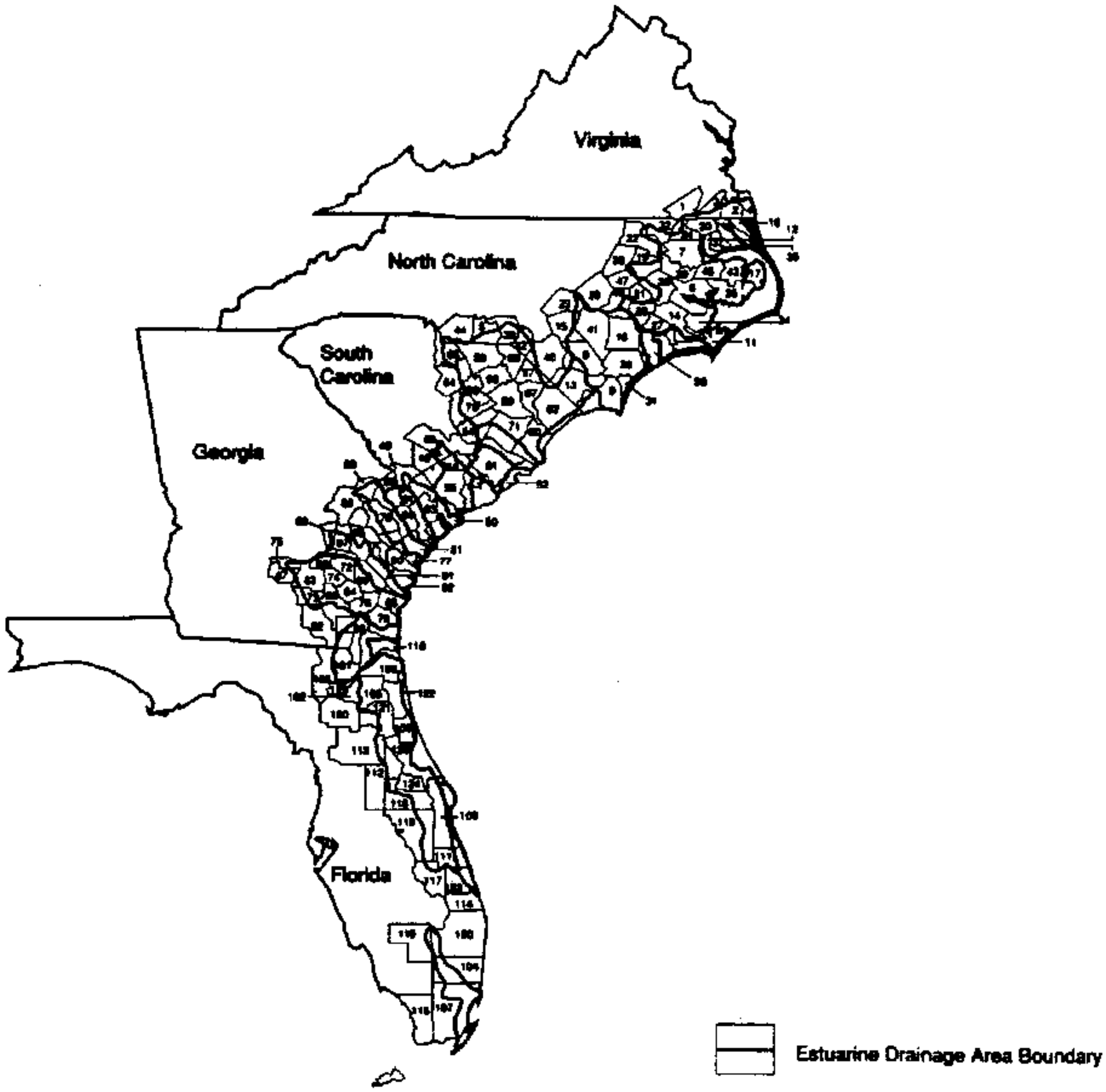
9.0 APPENDICES

Appendix A. Coastal wetland acreage in south Atlantic states (NOAA 1991a)



Appendix A. Wetland Distribution by State by County (Source: NOAA 1991a).

Coastal wetlands by county (Acres X 100)

State/County[a]	Salt Marsh: Brackish	Salt Marsh: Unsp.	Salt Marsh: Subtotal[b]	Fresh Marsh: Non Tidal	Fresh Marsh: Tidal	Fresh Marsh: Unsp.	Fresh Marsh: Subtotal[b]	Forested and Scrub-Shrub: Sal.	Forested and Scrub-Shrub: Fresh (Unsp.)	Forested and Scrub-Shrub: Non Tidal Fresh	Forested and Scrub-Shrub: Tidal Fresh	Forested and Scrub-Shrub: Subtotal[b]	Tidal Flats[b]	Total
VIRGINIA														
1 Southampton (100)	0	0	0 (0)	0	0	0	0 (0)	0	0	182	0	182 (100)	0 (0)	182
2 Chesapeake (100)	0	16	16 (2)	2	0	0	2 (0)	0	0	712	93	805 (98)	1 (0)	[illegible]
3 Suffolk (100)	0	39	39 (8)	[illegible]	0	0	1 (0)	0	0	449	1	[illegible] (91)	4 (1)	[illegible]
4 Virginia Beach (90)	0	[illegible]	99 (33)	12	0	0	12 (4)	0	0	60	112	172 (58)	15 (5)	[illegible]
Subtotal	0	154	154 (9)	14	0	0	15 (1)	0	0	1,394	[illegible]	1,601 [illegible]	20 (1)	1,779
NORTH CAROLINA														
5 Anson	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6 Beaufort (88)	0	80	80 (8)	27	0	0	27 (3)	14	0	940	0	[illegible] (90)	0 (0)	1,062
7 Bertie (21)	0	0	0 (0)	1	0	0	1 (0)	0	0	361	0	361 (100)	0 (0)	362
8 Bladen	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 Brunswick (30)	0	105	105 (18)	53	14	2	69 (10)	2	138	340	7	483 (72)	16 (2)	674
10 Camden (16)	0	16	16 (12)	0	0	0	0 (0)	2	0	116	0	116 (88)	0 (0)	134
11 Carteret (88)	169	394	563 (31)	15	2	0	17 (1)	77	0	[illegible]	2	1,019 (56)	[illegible] (12)	[illegible]
12 Chowan (4)	0	0	0 (0)	0	0	0	0 (0)	0	0	0	0	0 (0)	0 (0)	0
13 Columbus (4)	0	0	0 (0)	1	0	0	1 (2)	0	0	43	0	43 (97)	0 (0)	44
14 Craven (50)	1	16	17 (2)	16	0	0	16 (2)	2	0	773	0	775 (96)	4 (0)	811
15 Cumberland	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16 Currituck (57)	0	139	139 (37)	4	0	0	4 (1)	4	0	235	20	259 (61)	5 (1)	[illegible]
17 Dare (80)	104	180	284 (14)	172	0	0	172 (8)	132	0	1,453	0	1,585 (76)	36 (2)	2,077
18 Duplin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19 Edgecombe (12)	0	0	0 (0)	0	0	0	0 (1)	0	0	52	0	52 (99)	0 (0)	52
20 Gates	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21 Greene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22 Halifax	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 Harnett (1)	0	0	0 (0)	0	0	0	0 (0)	0	0	1	0	1 (100)	0 (0)	1
24 Hertford	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25 Hyde (81)	[illegible]	115	415 (18)	61	0	0	61 (3)	[illegible]	0	1,792	0	[illegible] (78)	40 (2)	[illegible]
26 Johnston (2)	0	0	0 (0)	0	0	0	0 (0)	0	0	14	0	14 (100)	0 (0)	14
27 Jones (22)	0	0	0 (0)	0	0	0	0 (0)	0	0	[illegible]	0	[illegible] (100)	0 (0)	[illegible]
28 Lenoir	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29 Martin (30)	0	0	0 (0)	0	0	0	0 (0)	0	0	[illegible]	0	[illegible] (100)	0 (0)	[illegible]
30 Nash (4)	0	0	0 (0)	0	0	0	0 (0)	0	0	[illegible]	0	[illegible]	0 (0)	27
31 New Hanover (99)	0	76	76 (17)	21	[illegible]	[illegible]	27 (6)	5	0	320	5	330 (74)	16 (4)	449
32 Northampton (6)	0	0	0 (0)	0	0	0	0 (0)	0	0	16	0	16 (100)	0 (0)	16
33 Onslow (39)	0	116	116 (25)	6	0	0	6 (1)	13	0	342	0	[illegible]	21 (4)	470
34 Pamlico (89)	17	191	208 (18)	42	0	0	43 (4)	19	6	860	0	879 (75)	47 (4)	1,178
35 Pasquotank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
36 Pender (29)	0	79	79 (8)	8	0	0	8 (1)	0	0	730	0	730 [illegible]	16 [illegible]	[illegible]
37 Perquimans (14)	0	0	0 (0)	1	0	0	1 (0)	0	0	10	0	10 [illegible]	0 (0)	11
38 Pitt (3)	0	0	0 (1)	1	0	0	1 (2)	0	0	[illegible]	0	[illegible]	0 (1)	[illegible]
39 Richmond	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40 Robeson	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
41 Sampson	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
42 Scotland	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Abbreviations: Unsp., Unspecified; Sal., Saltwater; NA, Not Available
a. Values in parentheses represent the percent of county grid sampled by NOAA. Areas with less than 100 percent coverage may not be completely mapped by the U.S. Fish and Wildlife Service.
b. Values in parentheses represent the percent of total county wetlands grid sampled by NOAA.

Coastal wetlands by county (Acres X 100)

State/County*	Salt Marsh: Brackish	Salt Marsh: Unsp.	Salt Marsh: Subtotal[a]	Fresh Marsh: Non-Tidal	Fresh Marsh: Tidal	Fresh Marsh: Unsp.	Fresh Marsh: Subtotal[a]	Forested and Scrub-Shrub: Est.	Forested and Scrub-Shrub: Fresh (Unsp.)	Forested and Scrub-Shrub: Non-Tidal Fresh	Forested and Scrub-Shrub: Tidal Fresh	Forested and Scrub-Shrub: Subtotal[a]	Tidal Flats[b]	Total
NORTH CAROLINA (cont.)														
43 Tyrrell (81)	0	7	7 (0)	7	0	0	7 (0)	1	0	1,427	0	1,428 (99)	0 (0)	1,441
44 Union	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
45 Washington (99)	0	0	0 (0)	27	0	0	27 (4)	0	0	[illegible]	0	[illegible] (96)	0 (0)	[illegible]
* Wake (5)	0	0	0 (0)	0	0	0	0 (0)	0	0	20	0	20 (100)	0 (0)	20
46 Wayne (11)	0	0	0 (0)	2	0	0	2 (0)	0	0	95	0	95 (99)	0 (0)	97
47 Wilson (42)	0	0	0 (0)	1	0	0	1 (0)	0	0	182	0	182 (100)	0 (0)	183
Subtotal	[illegible]	1,[illegible]	2,138 (14)	[illegible]	32	3	[illegible] (3)	297	135	12,[illegible]	35	12,[illegible]	440 (3)	15,[illegible]
SOUTH CAROLINA														
48 Allendale (5)	0	0	0 (0)	0	0	2	2 (3)	0	60	4	0	64 (97)	0 (0)	66
49 Bamberg (30)	0	0	0 (0)	0	0	10	10 (2)	0	378	40	0	424 (98)	0 (0)	434
50 Beaufort (100)	0	1,231	1,231 (72)	37	24	4	65 (4)	9	5	288	27	330 (20)	88 (5)	1,714
51 Berkeley (96)	0	74	74 (3)	82	78	0	160 (8)	0	24	1,800	63	1,881 (88)	0 (0)	2,125
* Calhoun (2)	0	0	0 (0)	0	0	0	0 (3)	0	16	0	0	16 (97)	0 (0)	16
52 Charleston (100)	0	1,302	1,302 (48)	125	18	1	144 (5)	18	0	1,030	41	1,088 (40)	198 (7)	2,728
53 Chesterfield	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
54 Clarendon (10)	0	0	0 (0)	0	0	2	2 (2)	0	51	28	0	78 (98)	0 (0)	80
55 Colleton (94)	0	387	387 (13)	123	112	15	250 (9)	8	504	1,560	60	2,125 (77)	5 (0)	2,747
56 Darlington	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
57 Dillon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
58 Dorchester (100)	0	10	10 (1)	5	3	24	31 (2)	1	475	950	0	1,426 (97)	0 (0)	1,466
59 Florence (44)	0	0	0 (0)	0	0	3	3 (1)	0	802	0	0	802 (99)	0 (0)	805
60 Georgetown (95)	0	304	304 (15)	112	263	5	380 (18)	1	8	858	480	1,348 (67)	25 (1)	1,997
61 Hampton (74)	0	0	0 (0)	4	0	8	12 (1)	0	640	178	0	818 (99)	0 (0)	830
62 Horry (93)	0	18	18 (1)	46	5	0	51 (2)	1	136	1,958	250	2,344 (97)	8 (0)	2,420
63 Jasper (100)	0	353	353 (18)	23	18	78	118 (6)	5	1,025	417	5	1,452 (75)	5 (0)	1,926
64 Kershaw	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
65 Lancaster	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
66 Lee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
67 Marion (45)	0	0	0 (0)	2	2	7	11 (2)	0	354	253	[illegible]	[illegible] (98)	0 (0)	[illegible]
68 Marlboro	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
69 Orangeburg (45)	0	0	0 (0)	3	0	13	16 (1)	0	1,444	3	0	1,447 (99)	0 (0)	1,463
70 Sumter (2)	0	0	0 (0)	0	0	1	1 (2)	0	24	0	0	24 (98)	0 (0)	25
71 Williamsburg (94)	0	0	0 (0)	14	0	20	34 (2)	0	985	418	14	1,417 (98)	0 (0)	1,452
Subtotal	[illegible]	3,[illegible]	3,[illegible] (16)	575	[illegible]	198	1,[illegible] (6)	[illegible]	6,031	9,[illegible]	1,[illegible]	17,[illegible] (77)	[illegible] (1)	22,[illegible]
GEORGIA														
72 Appling	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
73 Atkinson (80)	0	0	0 (0)	7	0	0	7 (2)	0	0	453	0	453 (98)	0 (0)	461
74 Bacon (24)	0	0	0 (0)	5	0	0	5 (4)	0	0	97	0	97 (96)	0 (0)	101
75 Ben Hill (32)	0	0	0 (0)	2	0	0	2 (4)	0	0	62	0	62 (96)	0 (0)	64
76 Brantley (100)	0	1	1 (0)	14	0	0	14 (1)	0	0	1,027	1	1,028 (99)	0 (0)	1,043
77 Bryan (80)	0	34	34 (4)	18	4	0	22 (3)	0	0	748	30	777 (93)	0 (0)	834
78 Bulloch (83)	0	0	0 (0)	14	0	0	14 (1)	0	0	[illegible]	0	[illegible] (99)	0 (0)	1,004
* Burke (10)	0	0	0 (0)	2	0	0	2 (3)	0	0	75	0	75 (98)	0 (0)	77

Abbreviations: Unsp., Unspecified; Est., Estuarine; NA, Not Available
* Non coastal county not within EDA boundaries.
a. Values in parentheses represent the percent of county grid sampled by NOAA. Areas with less than 100 percent coverage may not be completely mapped by the U.S. Fish and Wildlife Service.
b. Values in parentheses represent the percent of total county wetlands grid sampled by NOAA.

Coastal wetlands by county (Acres X 100)

State/County*	Salt Marsh: Brackish	Salt Marsh: Unsp.	Salt Marsh: Subtotal[a]	Fresh Marsh: Non-Tidal	Fresh Marsh: Tidal	Fresh Marsh: Unsp.	Fresh Marsh: Subtotal[a]	Forested and Scrub-Shrub: Est.	Forested and Scrub-Shrub: Fresh (Unsp.)	Forested and Scrub-Shrub: Non-Tidal Fresh	Forested and Scrub-Shrub: Tidal Fresh	Forested and Scrub-Shrub: Subtotal[b]	Tidal Flats[a]	Total
GEORGIA (cont.)														
79 Camden (100)	20	733	754 (42)	54	16	0	70 (4)	14	0	732	100	846 (50)	38 (1)	1,754
* Candler (10)	0	0	0 (0)	0	0	0	0 (0)	0	0	39	0	39 (100)	0 (0)	39
80 Charlton (25)	0	0	0 (0)	13	0	0	13 (3)	0	0	334	43	377 (97)	0 (0)	391
81 Chatham (7)	0	80	80 (87)	0	0	0	0 (0)	1	2	3	0	6 (6)	7 (7)	[illegible]
82 Clinch (23)	0	0	0 (0)	5	0	0	5 (1)	0	0	432	0	432 (99)	0 (0)	437
83 Coffee (36)	0	0	0 (0)	6	0	0	6 (3)	0	0	330	0	330 (97)	0 (0)	336
84 Effingham (100)	0	0	0 (0)	2	0	0	2 (0)	0	342	794	0	1,137 (100)	0 (0)	1,138
85 Emanuel (17)	0	0	0 (0)	1	0	0	1 (1)	0	0	81	0	81 (99)	0 (0)	81
* Evans (59)	0	0	0 (0)	1	0	0	1 (1)	0	0	135	0	135 (99)	0 (0)	136
86 Glynn (99)	43	816	859 (60)	23	22	0	45 (3)	7	0	487	80	573 (44)	30 (2)	1,310
87 Irwin (37)	0	0	0 (0)	8	0	0	8 (6)	0	0	134	0	134 (94)	0 (0)	142
88 Jeff Davis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
89 Jenkins (93)	0	0	0 (0)	7	0	0	8 (2)	0	0	434	0	434 (98)	0 (0)	441
* Lanier (12)	0	0	0 (0)	1	0	0	1 (3)	0	0	34	0	34 (97)	0 (0)	35
90 Liberty (53)	0	0	0 (0)	8	0	0	8 (1)	0	0	578	0	578 (99)	0 (0)	586
91 Long (10)	0	0	0 (0)	1	0	0	1 (1)	0	0	91	0	91 (99)	0 (0)	92
92 McIntosh (50)	19	383	402 (45)	42	43	0	85 (10)	1	0	187	208	397 (44)	8 (1)	893
93 Montgomery (66)	0	0	0 (0)	6	0	0	6 (3)	0	0	174	0	174 (97)	0 (0)	180
94 Pierce (98)	0	0	0 (0)	21	0	0	21 (3)	0	0	612	0	612 (97)	0 (0)	633
95 Screven (92)	0	0	0 (0)	23	0	2	25 (3)	0	108	798	0	905 (97)	0 (0)	930
96 Tattnall (43)	0	0	0 (0)	8	0	0	8 (3)	0	0	230	0	230 (97)	0 (0)	238
97 Toombs (47)	0	0	0 (0)	5	0	0	5 (5)	0	0	100	0	100 (95)	0 (0)	105
98 Ware (55)	0	0	0 (0)	36	0	0	36 (4)	0	0	1,000	0	1,000 (96)	0 (0)	1,036
99 Wayne (37)	0	0	0 (0)	7	0	0	7 (1)	0	0	881	7	888 (99)	0 (0)	894
* Wheeler (3)	0	0	0 (0)	0	0	0	0 (0)	0	0	32	0	32 (100)	0 (0)	32
Subtotal	65	1,888	1,941 (13)	341	84	4	431 (3)	24	544	11,800	807	13,174 (84)	76 (0)	16,331
FLORIDA														
100 Alachua (8)	0	0	0 (0)	12	0	0	12 (15)	0	0	68	0	68 (85)	0 (0)	80
101 Baker (6)	0	0	0 (0)	0	0	0	0 (0)	0	0	71	0	71 (100)	0 (0)	71
102 Bradford (39)	0	0	0 (0)	8	0	0	8 (6)	0	0	148	0	148 (94)	0 (0)	156
103 Brevard (95)	0	5	5 (0)	1,282	57	0	1,348 (68)	30	0	564	18	613 (31)	22 (1)	1,989
104 Broward (70)	0	0	0 (0)	2,438	0	0	2,436 (73)	18	0	875	0	897 (27)	1 (0)	3,335
105 Clay (71)	0	1	1 (0)	35	0	0	35 (8)	0	0	430	0	440 (92)	0 (0)	477
106 Columbia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
107 Dade (49)	0	280	282 (8)	1,308	0	0	1,808 (63)	387	0	744	0	1,141 (38)	17 (1)	2,939
108 Duval (87)	0	330	330 (27)	40	0	0	40 (3)	7	0	836	12	856 (68)	19 (1)	1,245
109 Flagler (100)	0	36	36 (3)	88	0	0	88 (8)	6	0	978	2	986 (88)	2 (0)	1,180
110 Hendry	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
111 Indian River (97)	0	3	3 (0)	388	0	0	388 (46)	44	0	401	0	445 (54)	0 (1)	835
112 Lake (36)	0	0	0 (0)	107	0	0	107 (14)	0	0	632	0	632 (86)	0 (0)	739
113 Marion (33)	0	0	0 (0)	75	0	0	75 (22)	0	0	270	0	270 (78)	0 (0)	345
114 Martin (83)	0	0	0 (0)	482	0	0	482 (74)	22	0	138	0	160 (25)	4 (1)	646
115 Monroe (0)	0	0	0 (0)	0	0	0	0 (0)	0	0	0	0	0 (0)	0 (0)	0
116 Nassau (63)	0	248	248 (30)	11	3	0	14 (2)	7	0	488	80	565 (64)	28 (3)	855

Abbreviations: Unsp., Unspecified; Est., Estuarine; N/A, Not Available

* Non coastal county not within EDA boundaries

a. Values in parentheses represent the percent of county grid sampled by NOAA. Areas with less than 100 percent coverage may not be completely mapped by the U.S. Fish and Wildlife Service

b. Values in parentheses represent the percent of total county wetlands grid sampled by NOAA.

Coastal wetlands by county (Acres X 100)

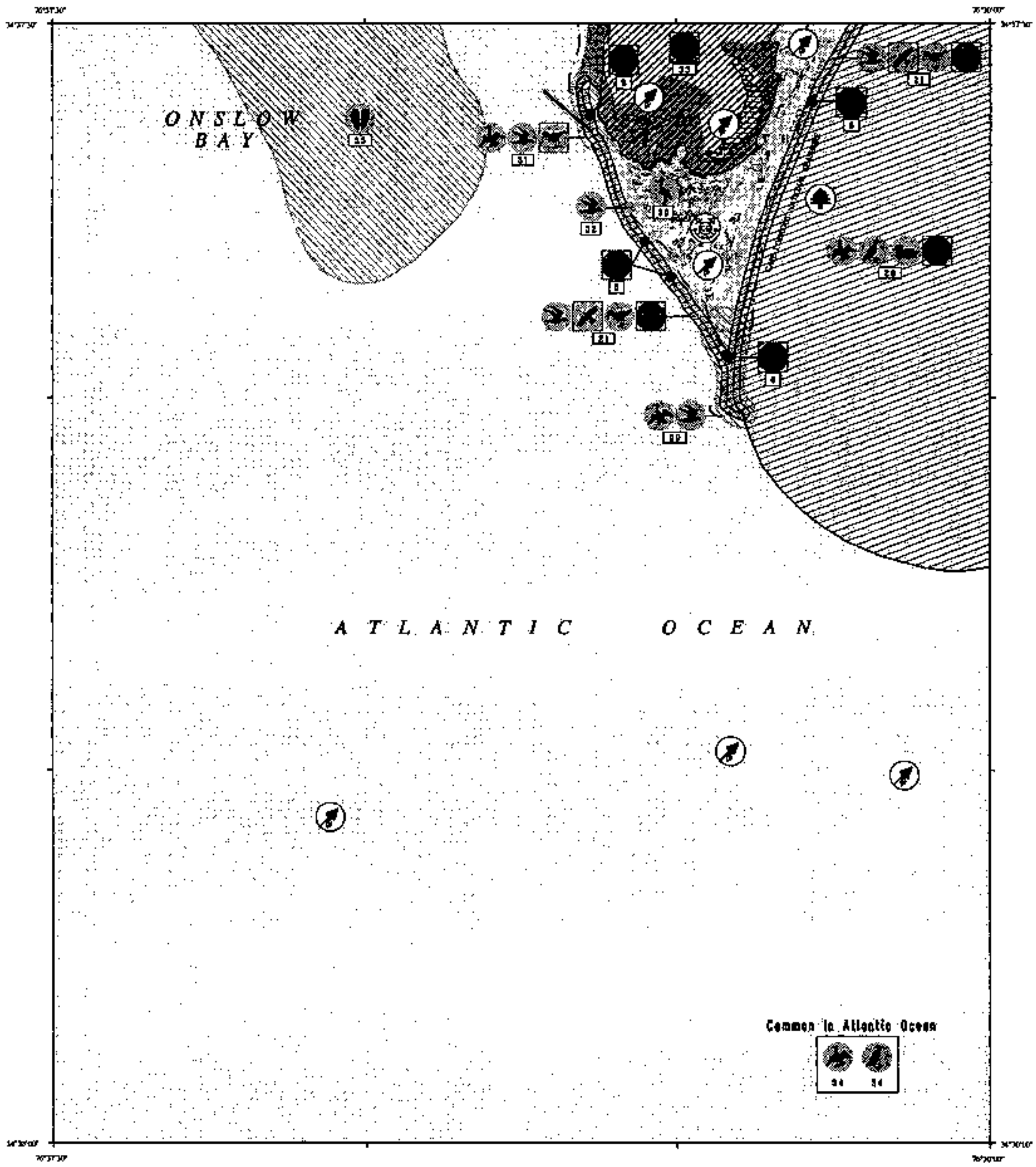
State/County[a]	Salt Marsh: Brackish	Salt Marsh: Unsp.	Salt Marsh: Subtotal[b]	Fresh Marsh: Non Tidal	Fresh Marsh: Tidal	Fresh Marsh: Unsp.	Fresh Marsh: Subtotal[b]	Forested and Scrub-Shrub: Est.	Forested and Scrub-Shrub: Fresh (Unsp.)	Forested and Scrub-Shrub: Non Tidal Fresh	Forested and Scrub-Shrub: Tidal Fresh	Forested and Scrub-Shrub: Subtotal[b]	Tidal Flats[b]	Total
FLORIDA (cont.)														
117 Okeechobee (46)	0	0	0 (0)	299	0	0	299 (63)	0	0	170	0	170 (37)	0 (0)	469
118 Orange (76)	0	0	0 (0)	235	0	0	235 (24)	0	0	727	0	727 (76)	0 (0)	962
119 Osceola (59)	0	0	0 (0)	429	0	0	429 (33)	0	0	866	0	866 (67)	0 (0)	1,295
120 Palm Beach (86)	0	0	0 (0)	2,388	0	0	2,388 (62)	5	0	1,481	0	1,486 (38)	6 (0)	3,880
121 Putnam (98)	0	0	0 (0)	108	0	0	108 (10)	0	0	974	0	974 (90)	0 (0)	1,082
122 St. Johns (100)	0	198	198 (1[illegible])	59	1	0	60 (5)	12	0	1,128	1	1,140 (80)	27 (2)	1,425
123 St. Lucie (91)	0	11	11 (2)	274	0	0	274 (57)	49	0	137	1	187 (39)	5 (1)	477
124 Seminole (100)	0	0	0 (0)	158	0	0	158 (30)	0	0	378	0	376 (70)	0 (0)	534
125 Union	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
126 Volusia (92)	0	27	27 (1)	413	5	0	418 (18)	72	0	1,808	1	1,880 (80)	18 (1)	2,344
Subtotal	0	1,880	1,880 (6)	10,888	56	1	10,894 (40)	888	1	14,394	165	15,088 (54)	197 (1)	27,284
South Atlantic Total	672	4,270	4,942 (11)	12,278	637	197	13,115 (16)	1,084	7,310	48,148	1,880	58,432 (72)	1,016 (1)	[illegible]

Abbreviations: Unsp., Unspecified; Est., Estuarine; N/A, Not Available

a Values in parentheses represent the percent of county grid sampled by NOAA. Areas with less than 100 percent coverage may not be completely mapped by the U.S. Fish and Wildlife Service.

b Values in parentheses represent the percent of total county wetlands grid sampled by NOAA.

ENVIRONMENTAL SENSITIVITY INDEX MAP



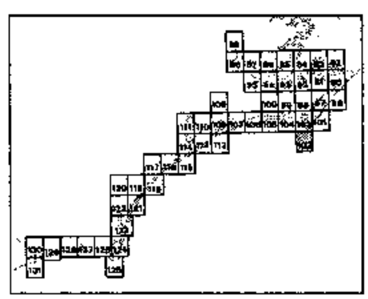
Prepared for:

NATIONAL OCEANIC and ATMOSPHERIC ADMINISTRATION

Hazardous Materials Response and Assessment Division
Seattle, Washington

Coastal Services Center
Charleston, South Carolina

Strategic Environmental Assessments Division
Silver Spring, Maryland

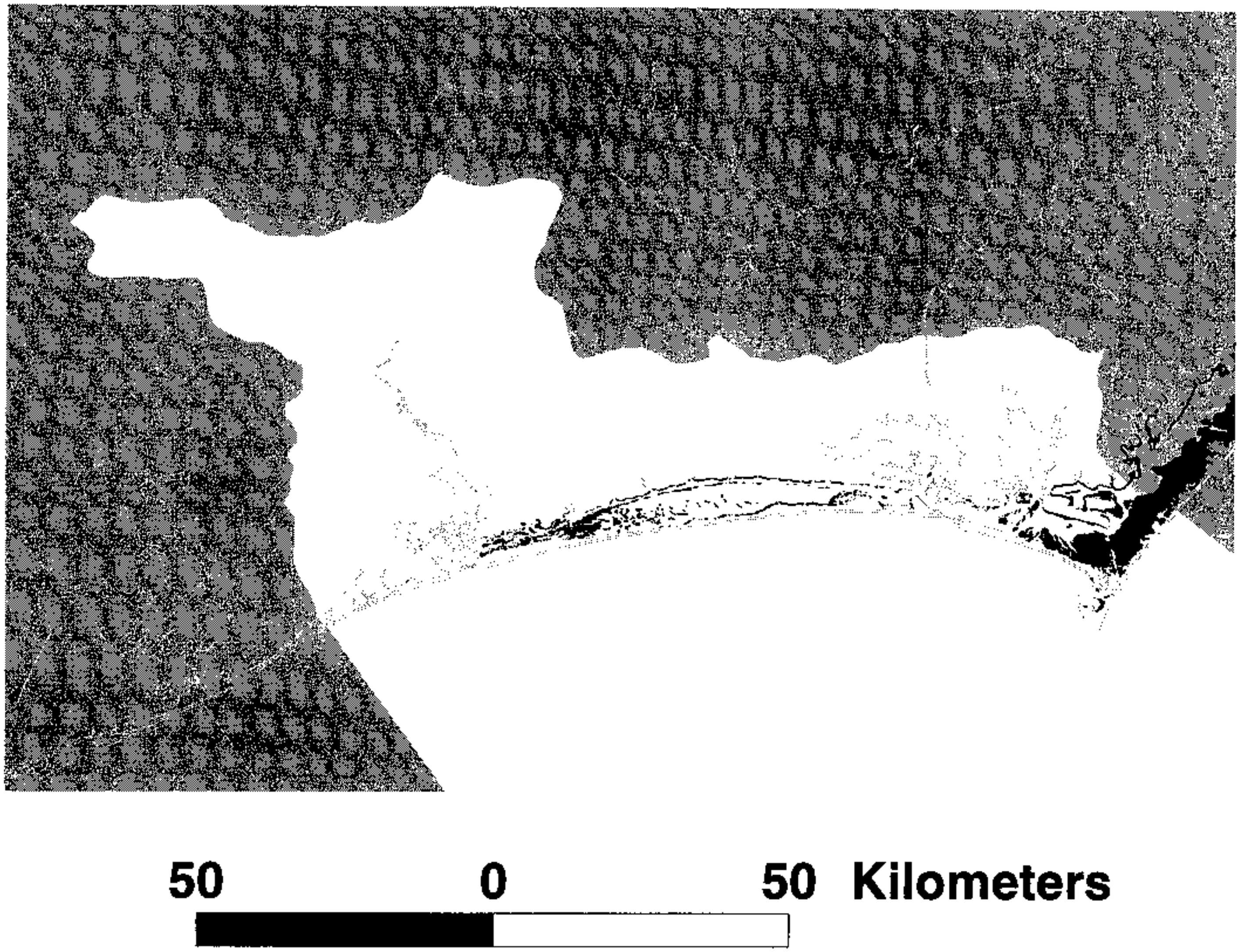


Not For Navigation
Published: November 1996

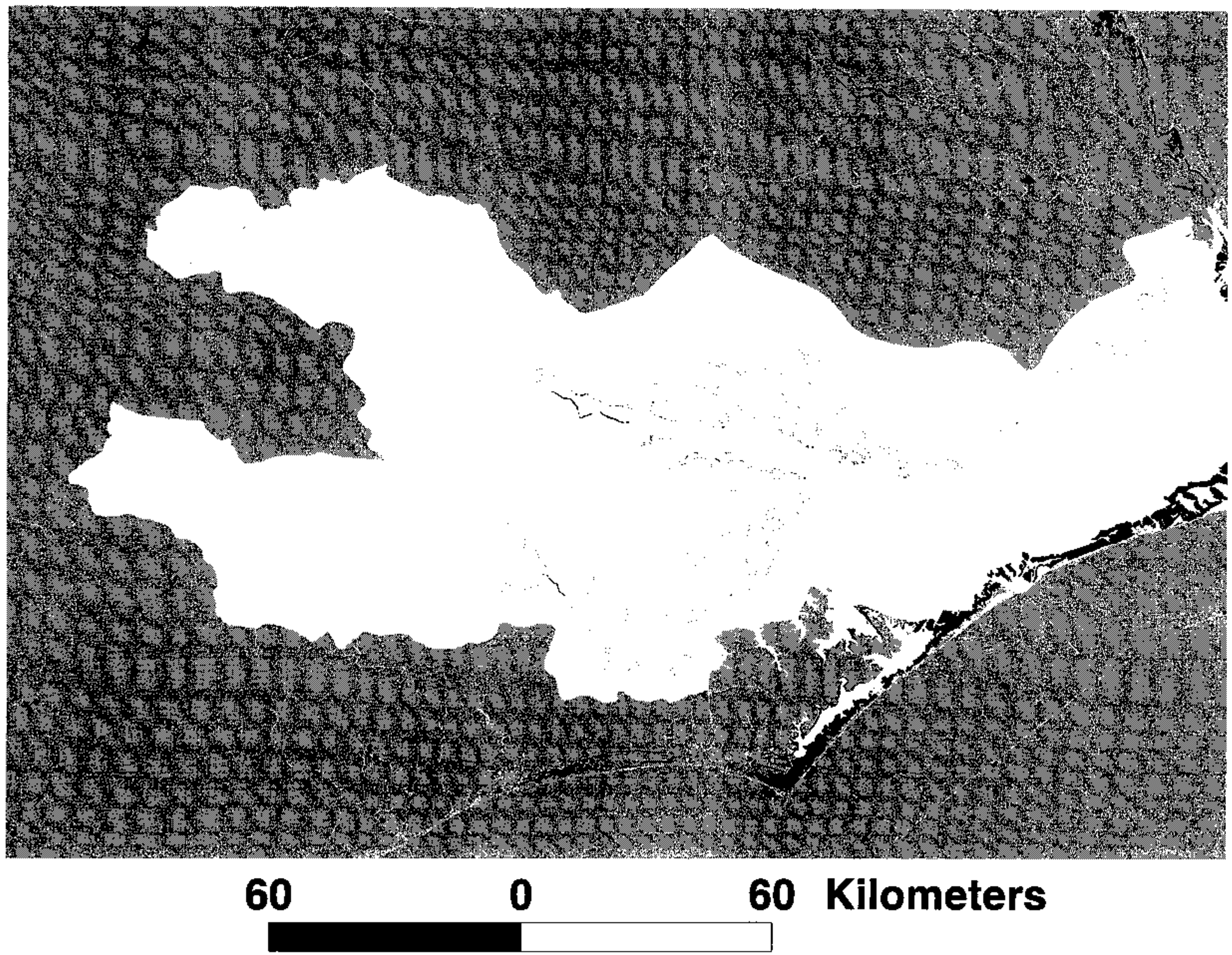
CAPE LOOKOUT, N.C. (1951) NC-102

Appendix C. Seagrass Distribution Maps for North Carolina and Florida by Watershed (NMFS SEFSC 1998).

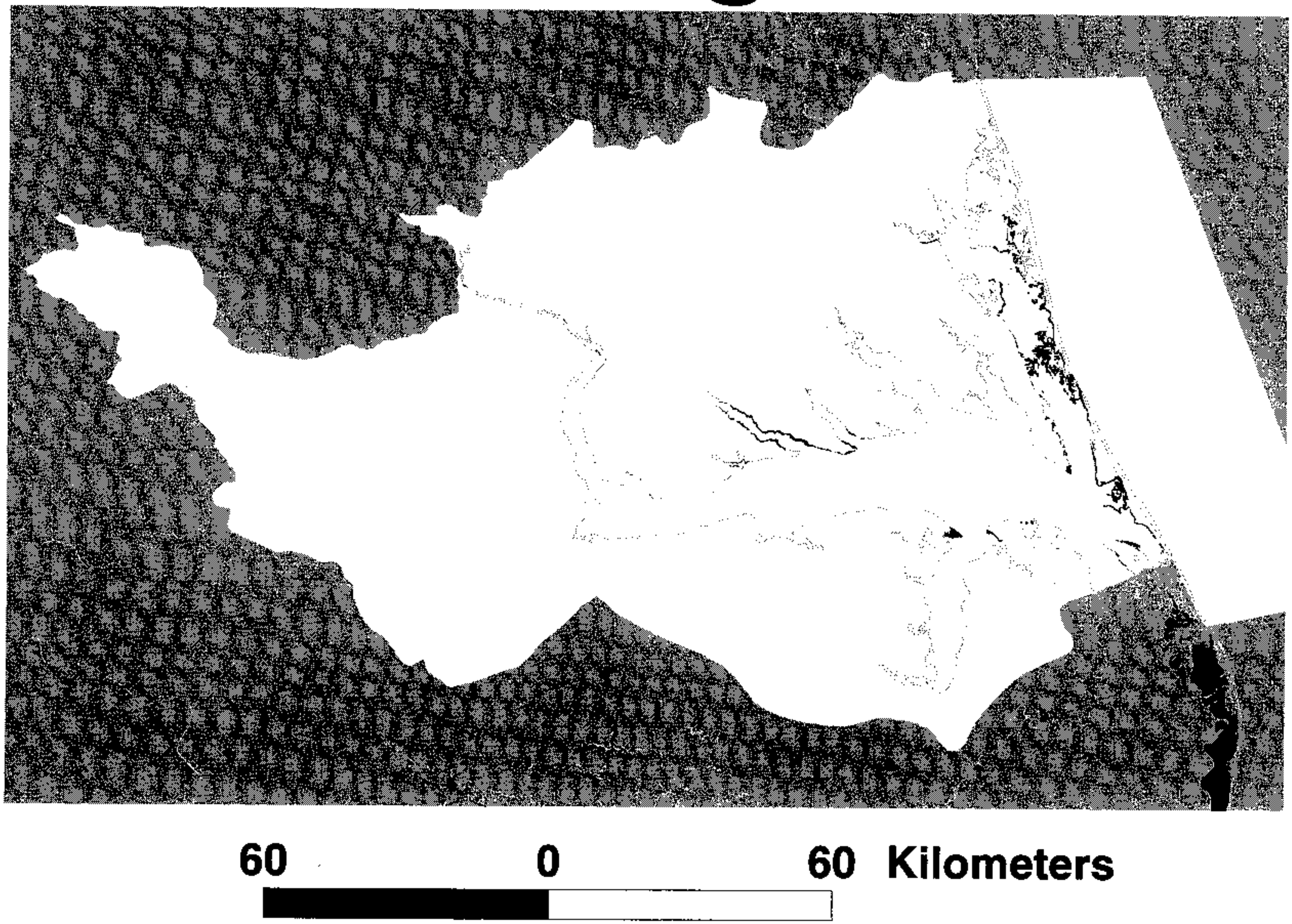
Bogue Sound Seagrass

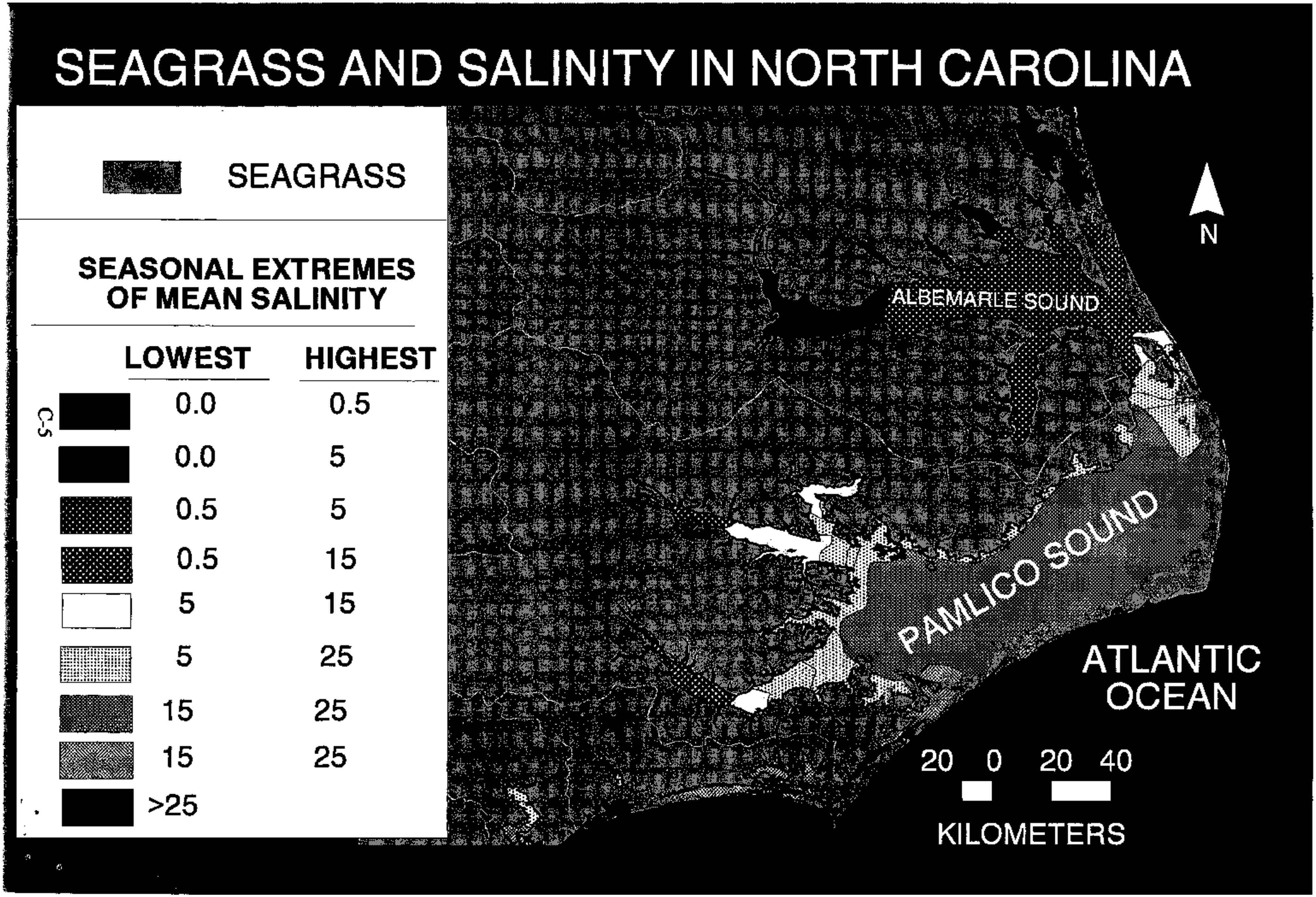


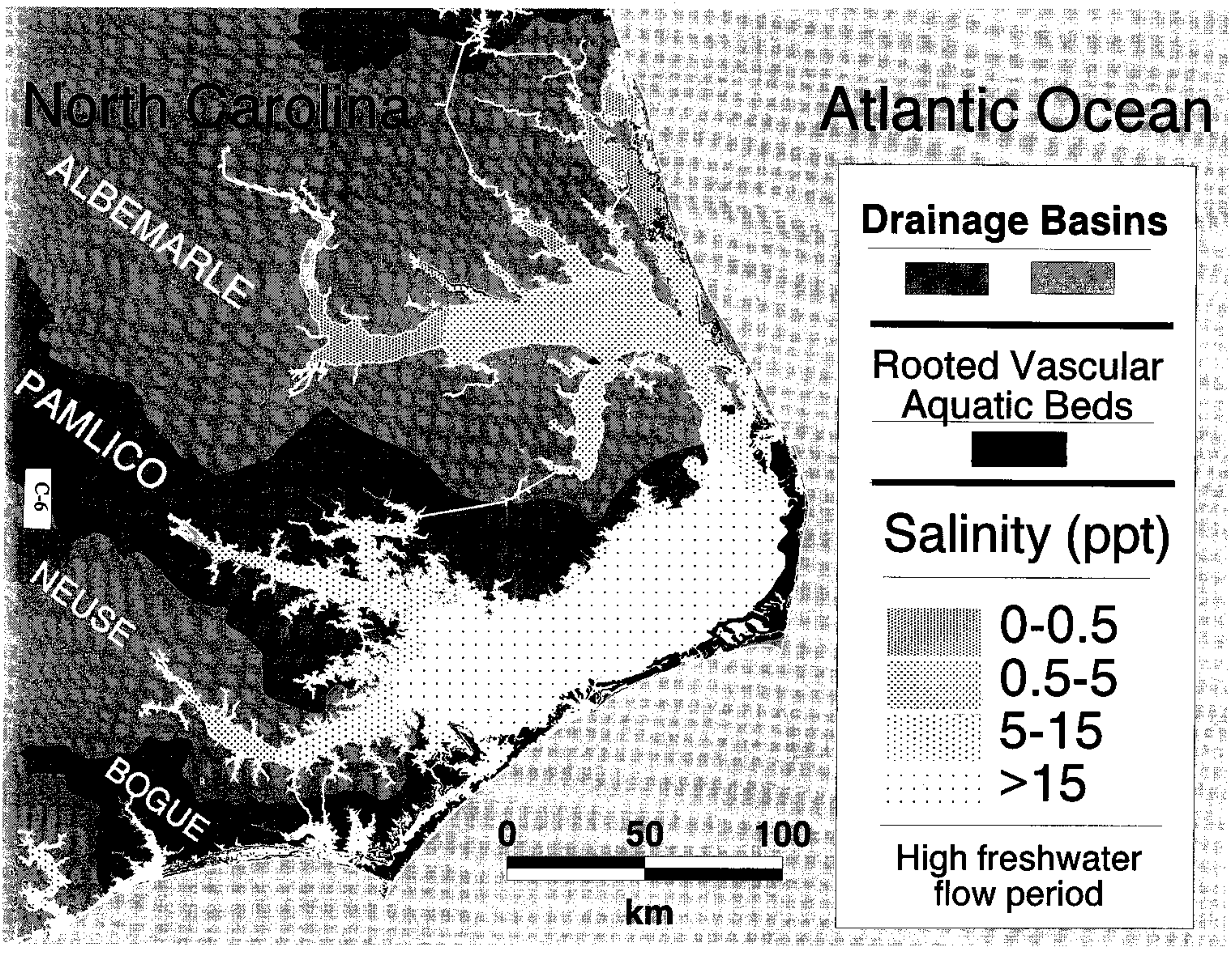
Pamlico/Pungo Seagrass

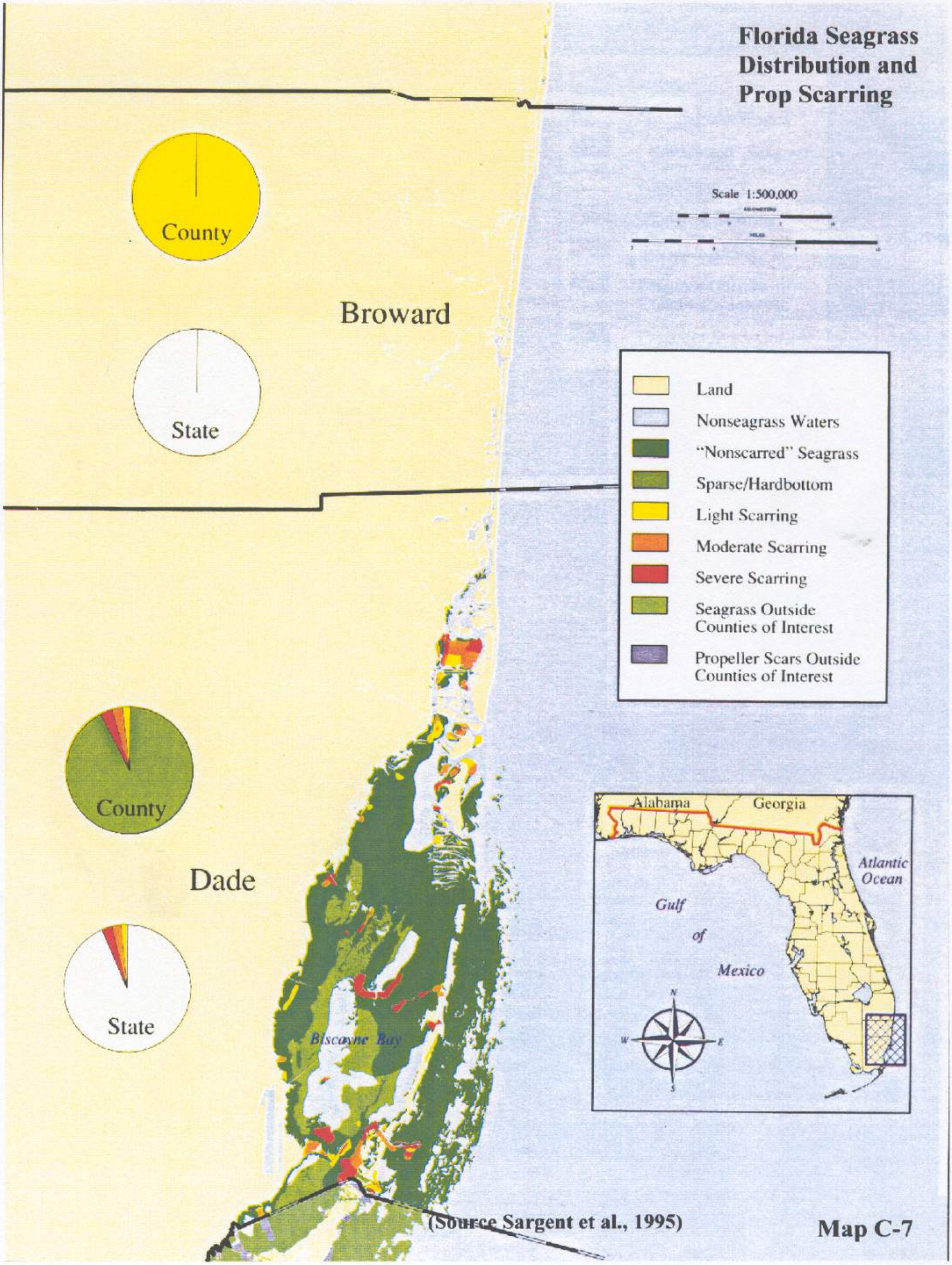


Albemarle Sound Seagrass

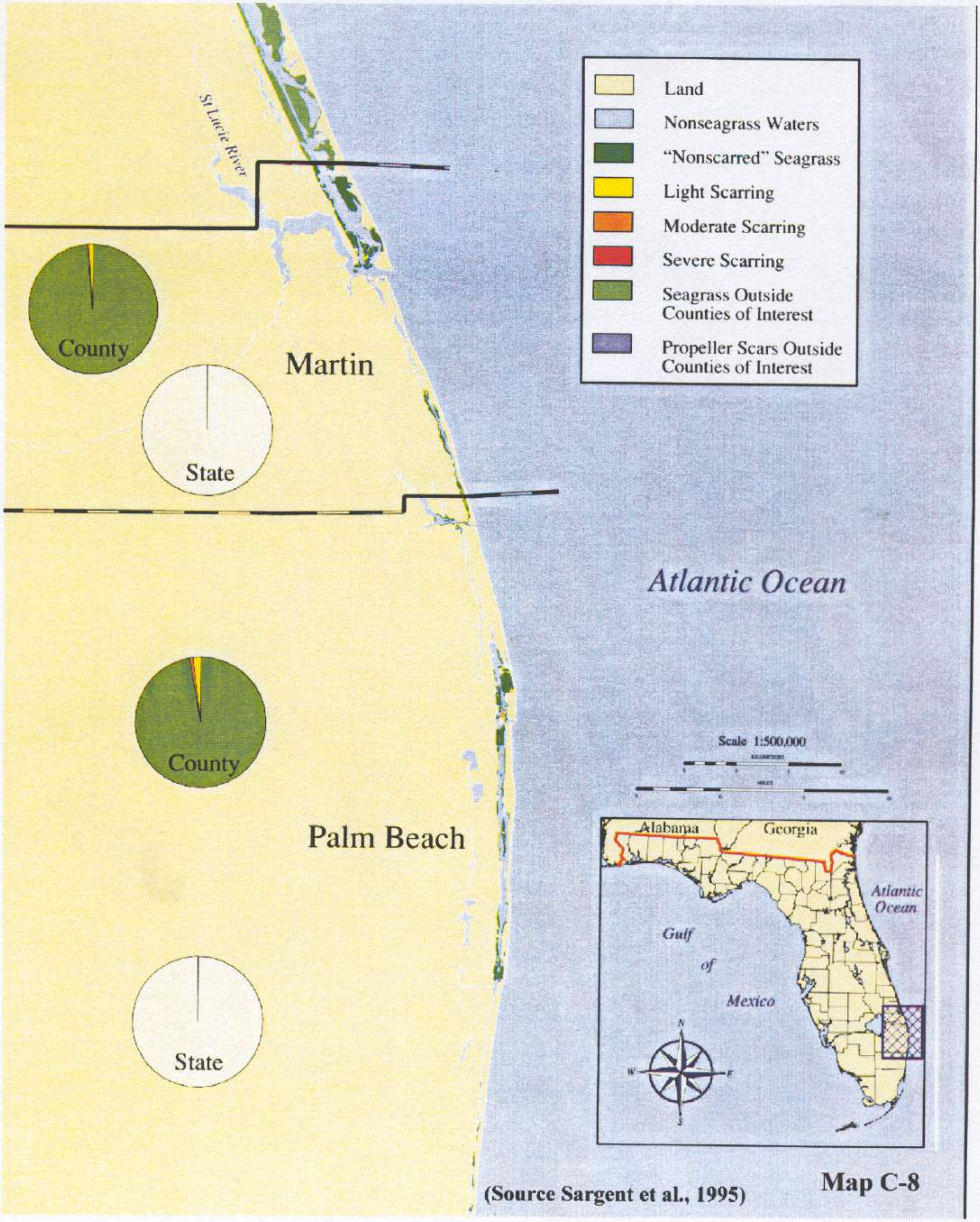



SEAGRASS AND SALINITY IN NORTH CAROLINA
SEAGRASS
SEASONAL EXTREMES OF MEAN SALINITY
LOWEST HIGHEST
0.0 0.5
0.0 5
0.5 5
0.5 15
5 15
5 25
15 25
15 25
>25
N
ALBEMARLE SOUND
PAMLICO SOUND
ATLANTIC OCEAN
20 0 20 40
KILOMETERS


North Carolina
Atlantic Ocean
ALBEMARLE
PAMLICO
NEUSE
BOGUE
Drainage Basins
Rooted Vascular Aquatic Beds
Salinity (ppt)
0-0.5
0.5-5
5-15
>15
High freshwater flow period
0 50 100
km

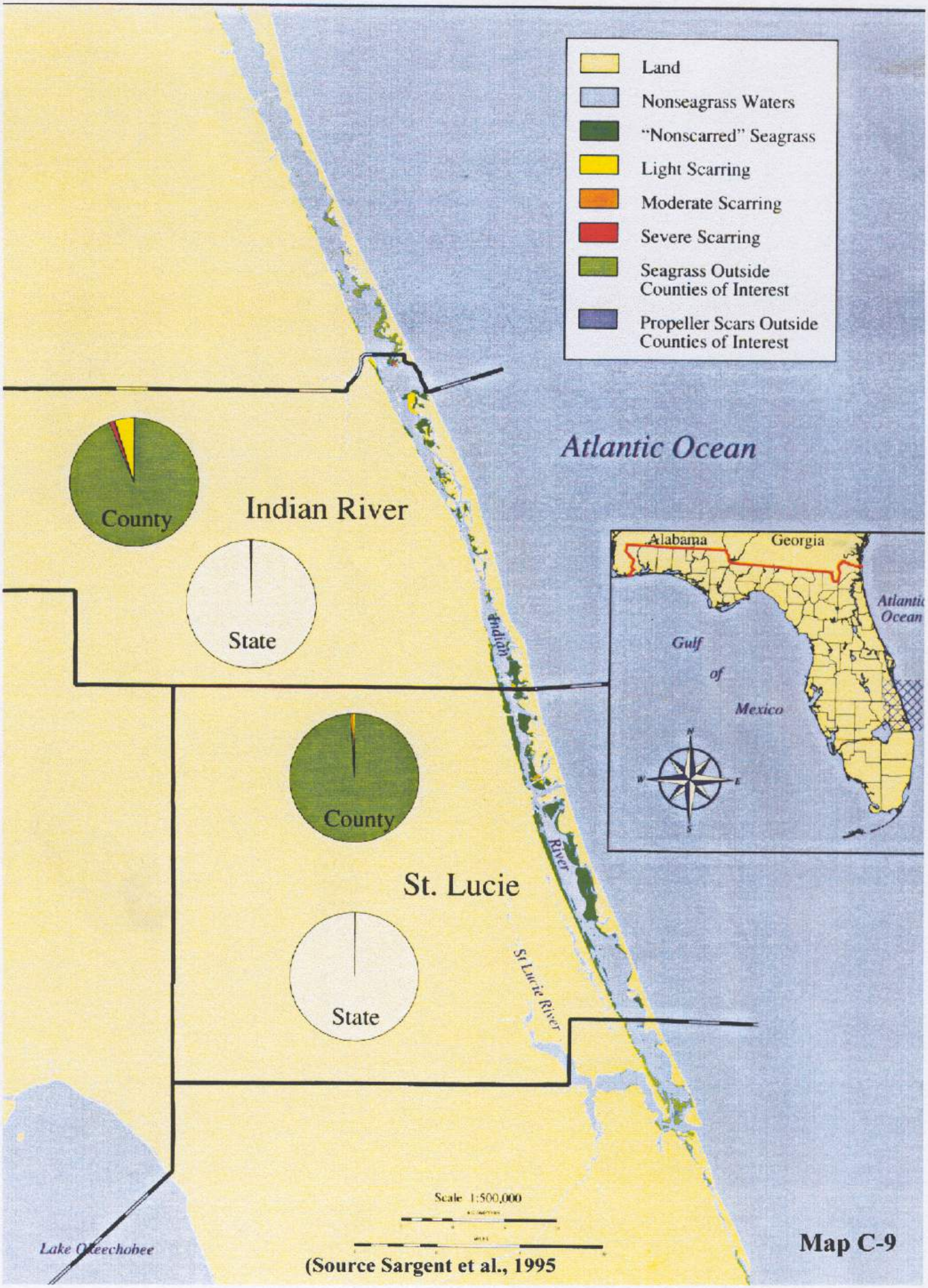


Florida Seagrass Distribution and Prop Scarring
Scale 1:500,000
Broward
County
State
Dade
County
State
Biscayne Bay
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Sparse/Hardbottom
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
S
E
W
(Source Sargent et al., 1995)
Map C-7



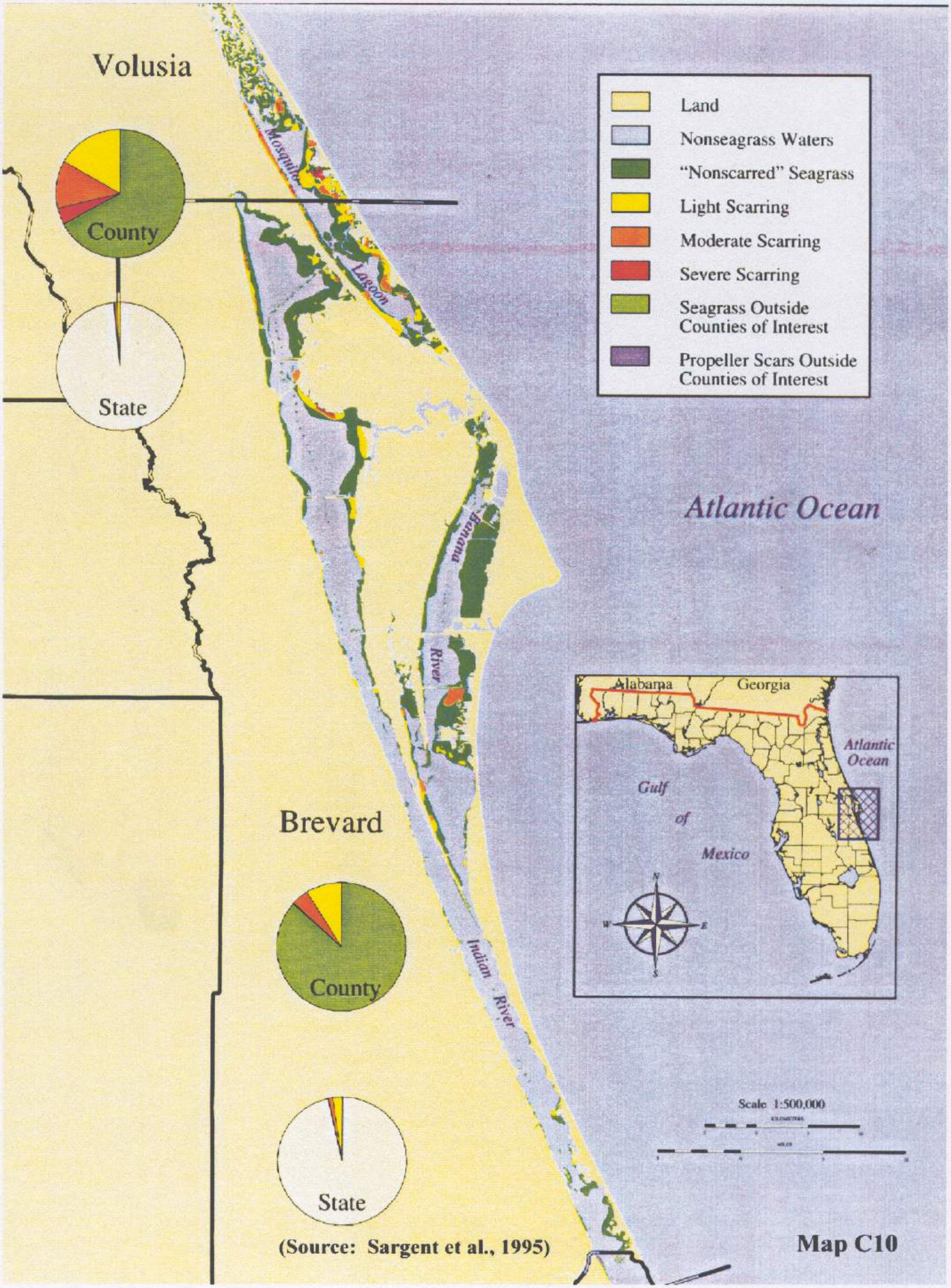
(Source Sargent et al., 1995)

Map C-8



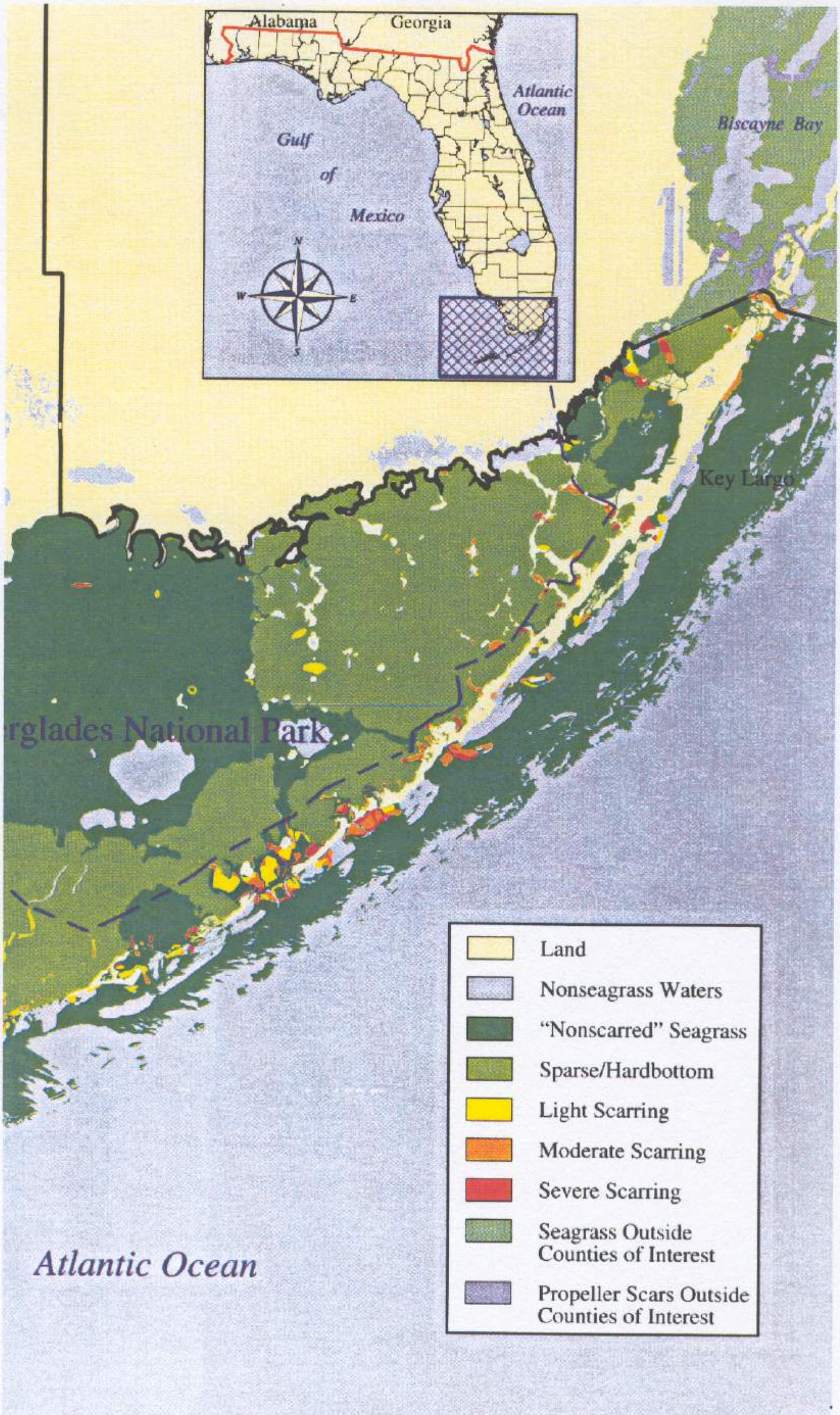
Map C-9

(Source Sargent et al., 1995



(Source: Sargent et al., 1995)

Map C10



Map C-11

(Source Sargent et al., 1995)

(Source: Sargent et al., 1995)

Map C-12

Appendix D. Oyster/Shell Habitat Distribution in North and South Carolina Estuaries (Source: NCDMF and SCDNR 1998) (SC Sample Only).

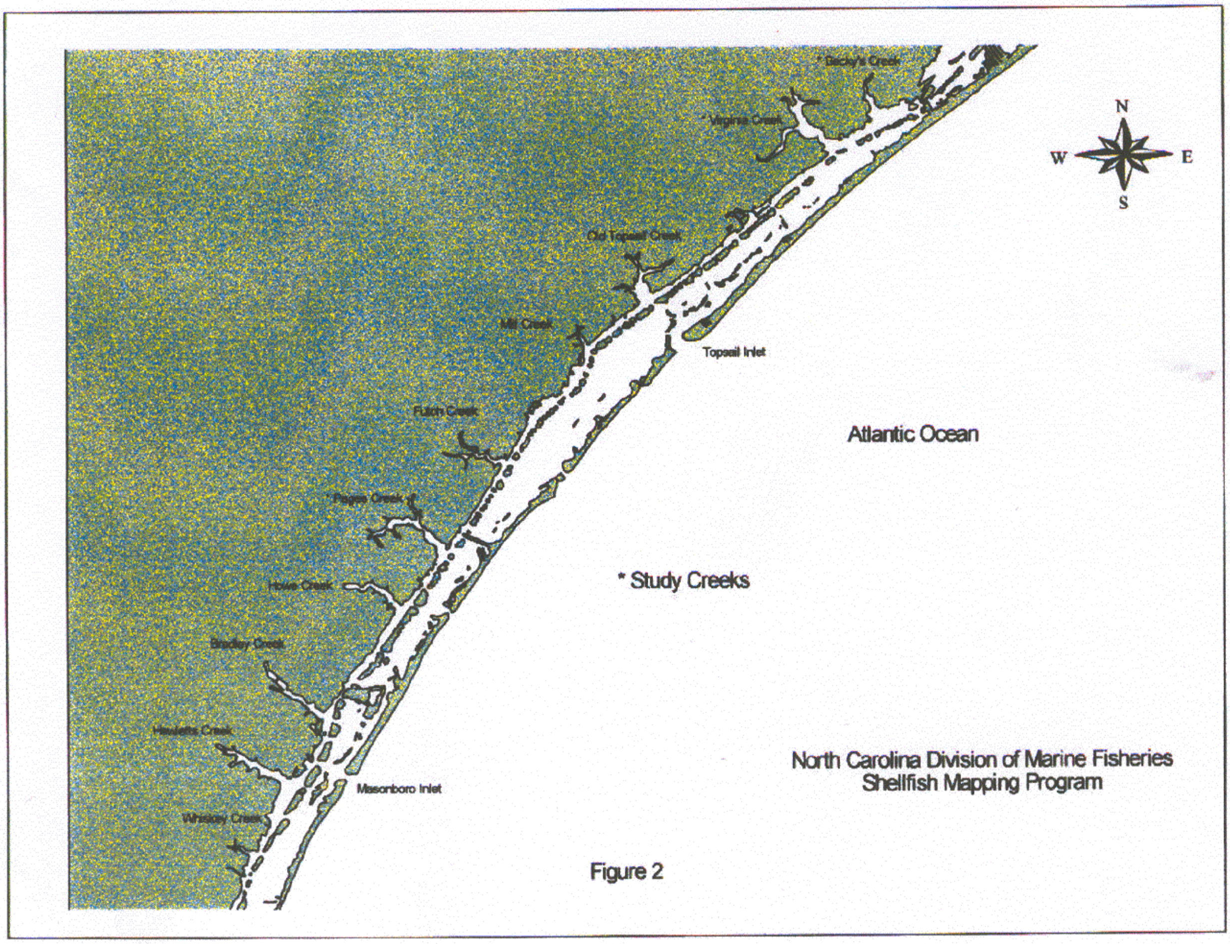


Figure 2

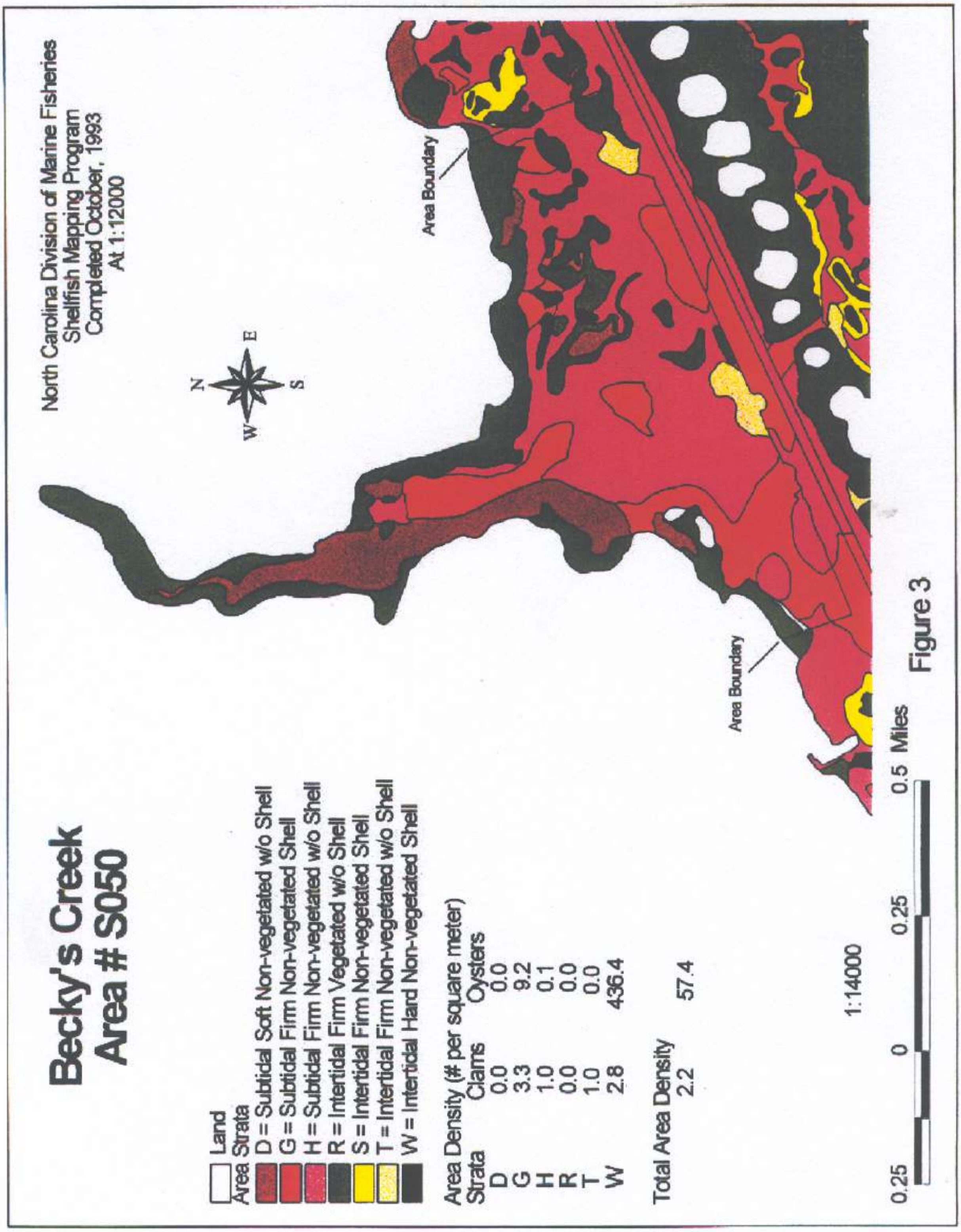

Becky's Creek
Area # S050
Land
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
G = Subtidal Firm Non-vegetated Shell
H = Subtidal Firm Non-vegetated w/o Shell
R = Intertidal Firm Vegetated w/o Shell
S = Intertidal Firm Non-vegetated Shell
T = Intertidal Firm Non-vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
Area Density (# per square meter)
Strata Clams Oysters
D 0.0 0.0
G 3.3 9.2
H 1.0 0.1
R 0.0 0.0
T 1.0 0.0
W 2.8 436.4
Total Area Density
2.2 57.4
1:14000
0.25 0 0.25 0.5 Miles
North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed October, 1993
At 1:12000
N
E
S
W
Area Boundary
Area Boundary

Figure 3

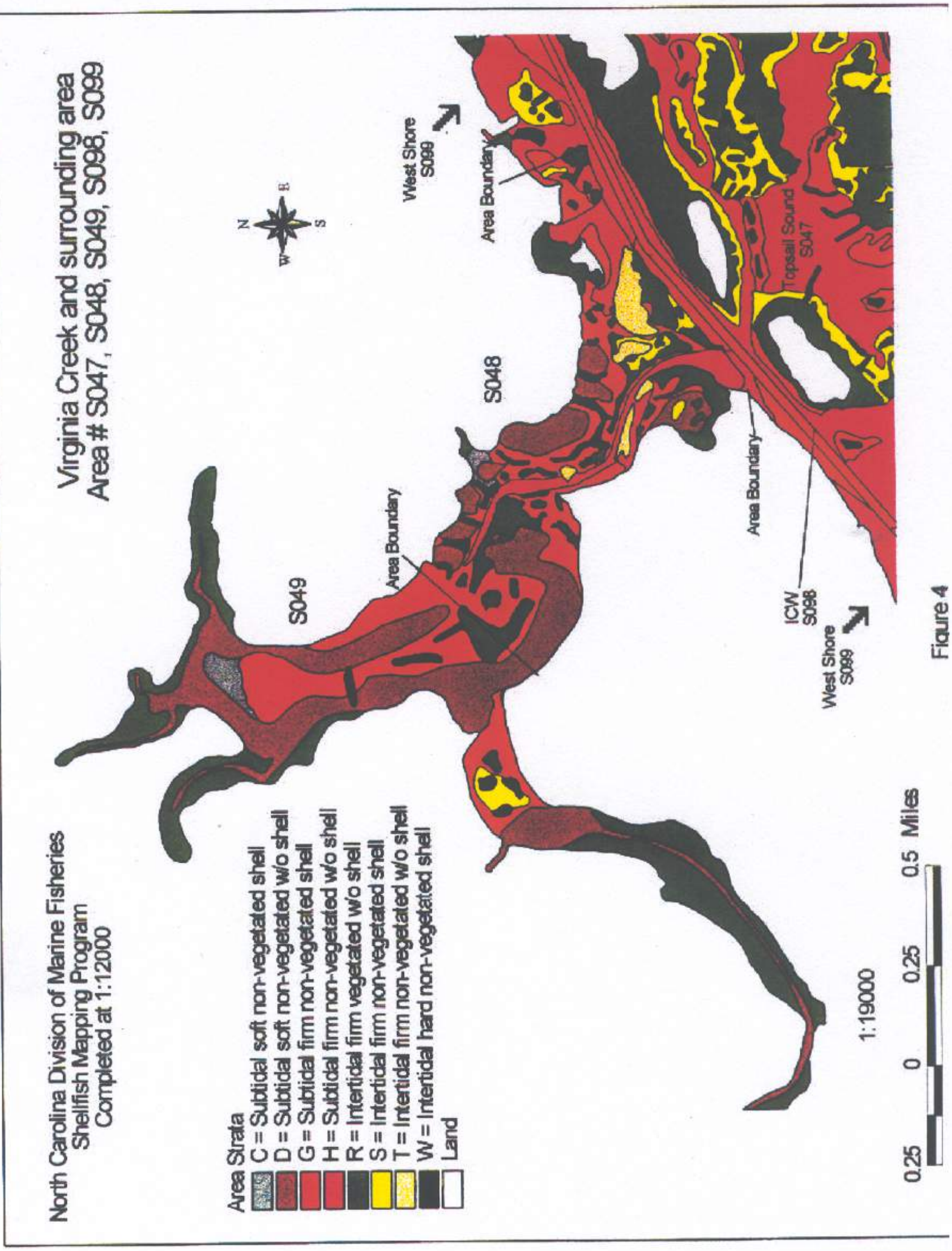
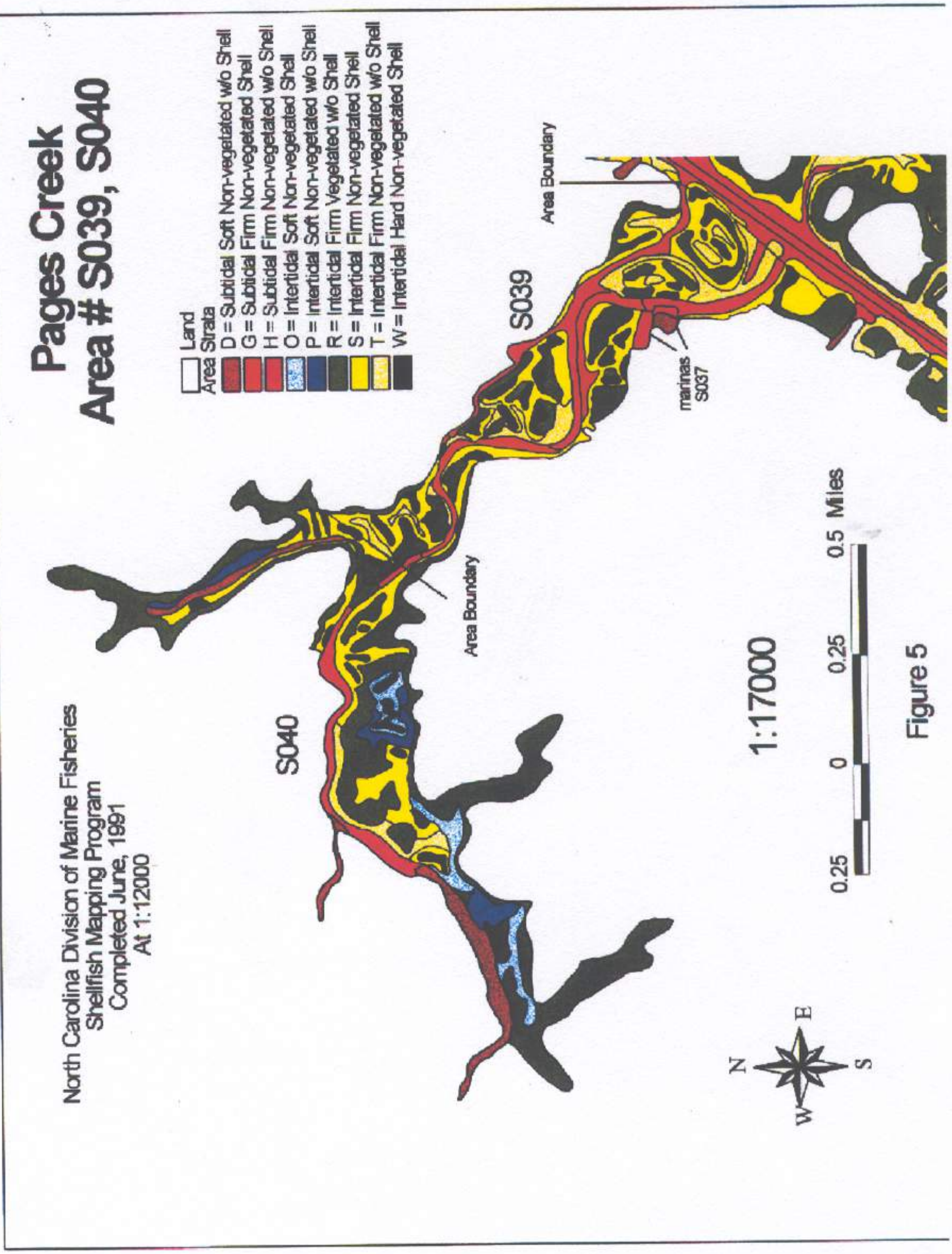
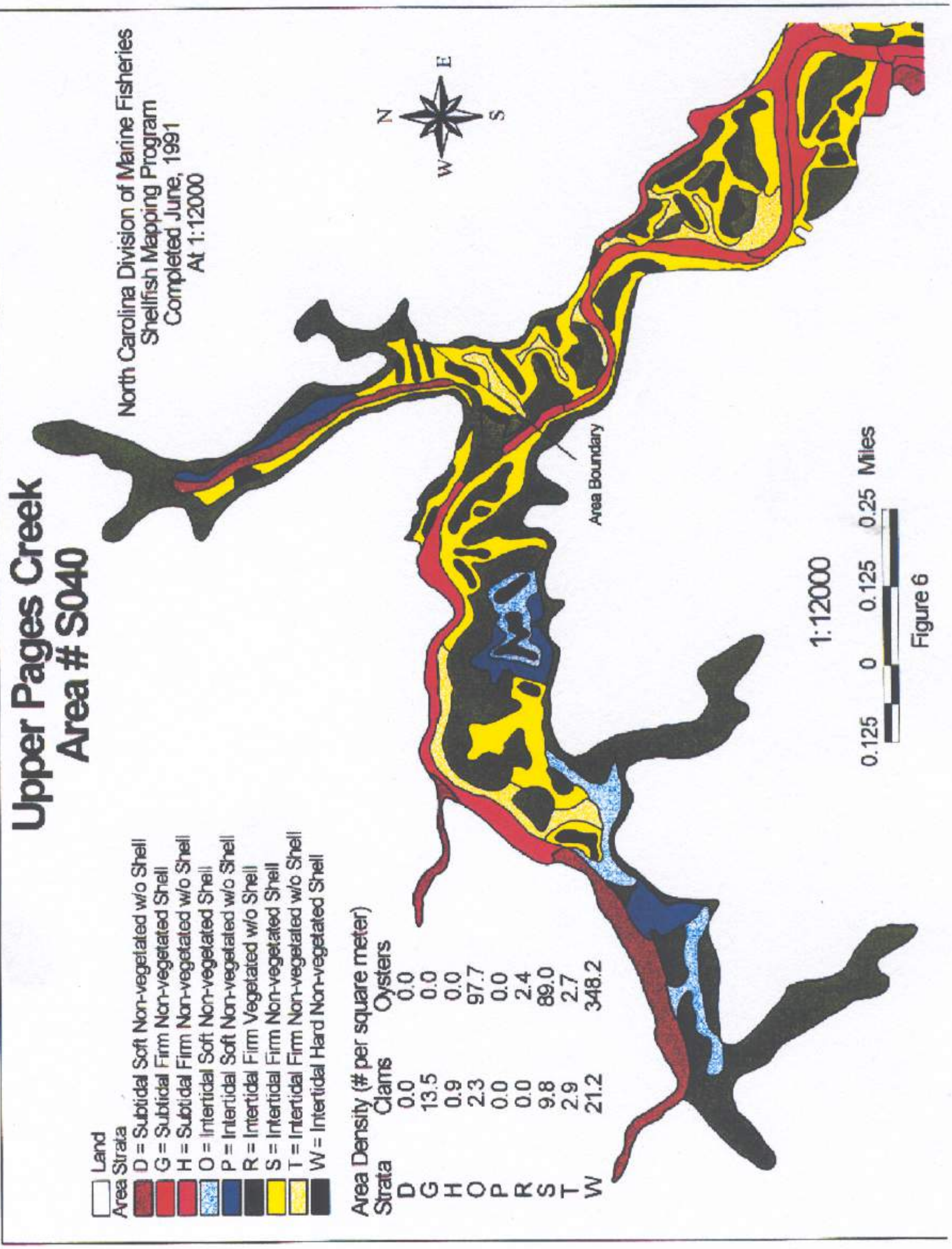

Virginia Creek and surrounding area
Area # S047, S048, S049, S098, S099
North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed at 1:12000
Area Strata
C = Subtidal soft non-vegetated shell
D = Subtidal soft non-vegetated w/o shell
G = Subtidal firm non-vegetated shell
H = Subtidal firm non-vegetated w/o shell
R = Intertidal firm vegetated w/o shell
S = Intertidal firm non-vegetated shell
T = Intertidal firm non-vegetated w/o shell
W = Intertidal hard non-vegetated shell
Land
S049
S048
Area Boundary
Area Boundary
Area Boundary
West Shore
S099
Topsail Sound
S047
ICW
S098
West Shore
S099
N
E
S
W
1:19000
0.25
0
0.25
0.5 Miles

Figure 4


Pages Creek
Area # S039, S040
Land
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
G = Subtidal Firm Non-vegetated Shell
H = Subtidal Firm Non-vegetated w/o Shell
O = Intertidal Soft Non-vegetated Shell
P = Intertidal Soft Non-vegetated w/o Shell
R = Intertidal Firm Vegetated w/o Shell
S = Intertidal Firm Non-vegetated Shell
T = Intertidal Firm Non-vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed June, 1991
At 1:12000
S040
S039
Area Boundary
Area Boundary
marinas
S037
1:17000
0.25
0
0.25
0.5 Miles
N
E
S
W
Figure 5


Upper Pages Creek
Area # S040
North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed June, 1991
At 1:12000
Land
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
G = Subtidal Firm Non-vegetated Shell
H = Subtidal Firm Non-vegetated w/o Shell
O = Intertidal Soft Non-vegetated Shell
P = Intertidal Soft Non-vegetated w/o Shell
R = Intertidal Firm Vegetated w/o Shell
S = Intertidal Firm Non-vegetated Shell
T = Intertidal Firm Non-vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
Area Density (# per square meter)
Strata Clams Oysters
D 0.0 0.0
G 13.5 0.0
H 0.9 0.0
O 2.3 97.7
P 0.0 0.0
R 0.0 2.4
S 9.8 89.0
T 2.9 2.7
W 21.2 348.2
N
E
S
W
Area Boundary
1:12000
0.125 0 0.125 0.25 Miles
Figure 6

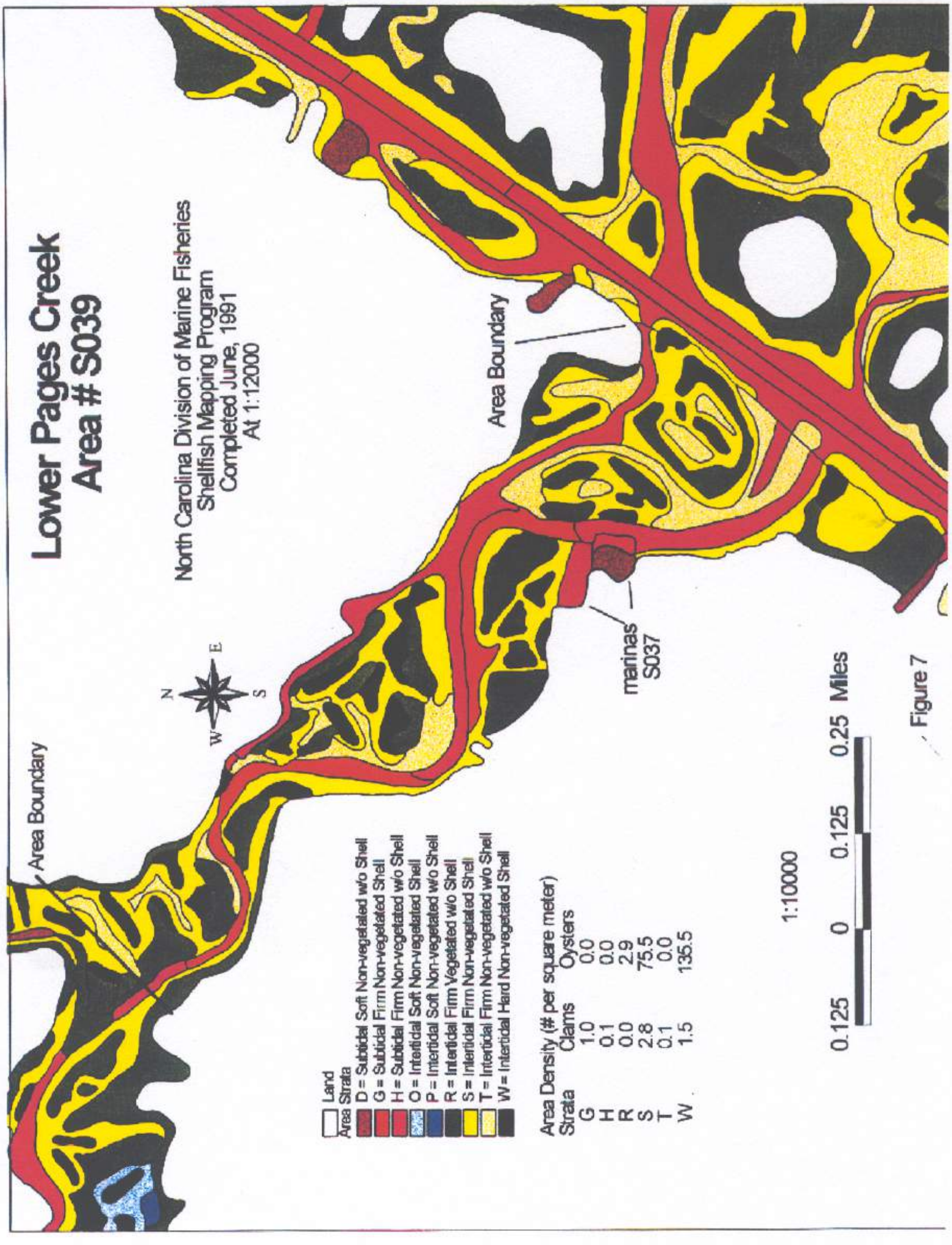
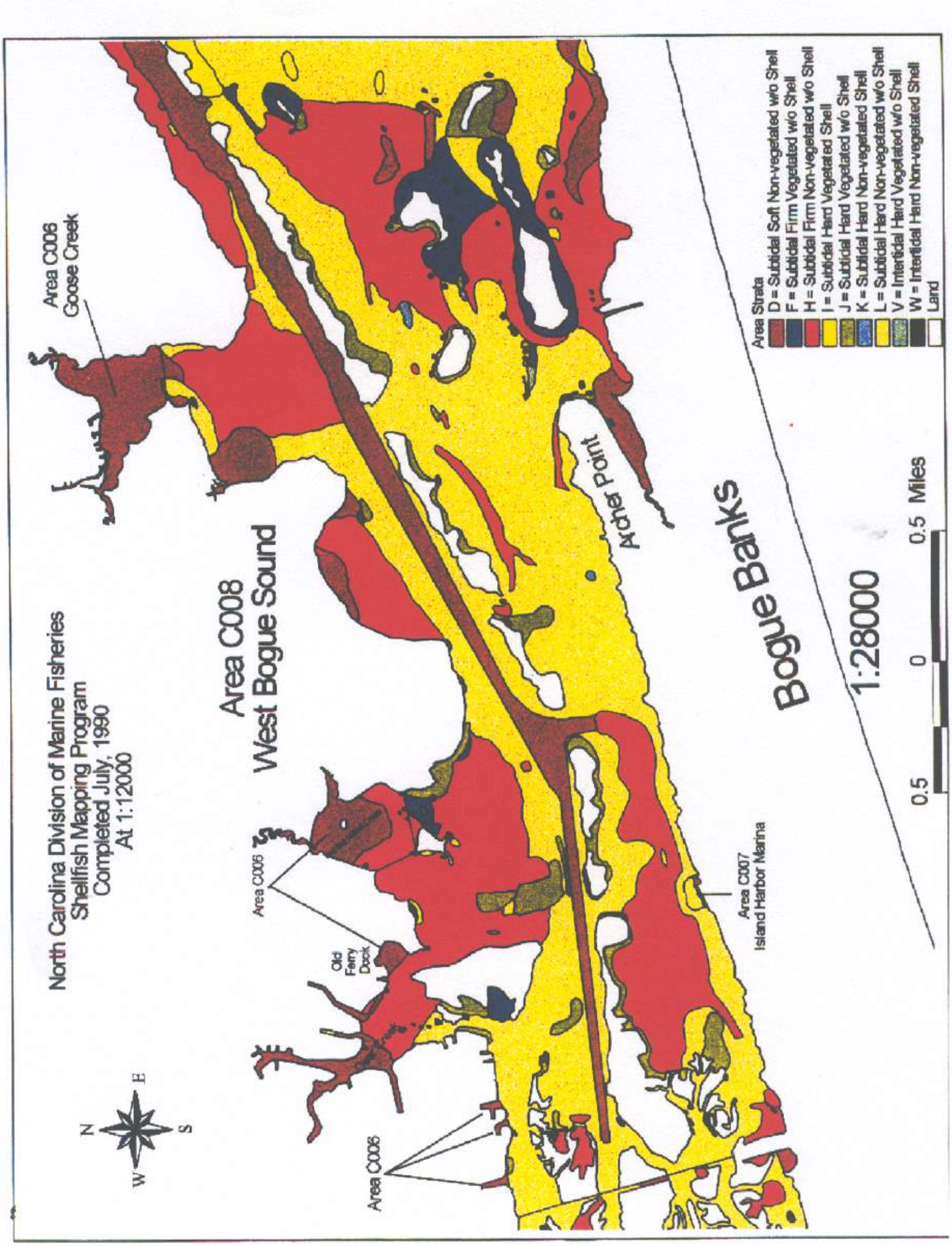
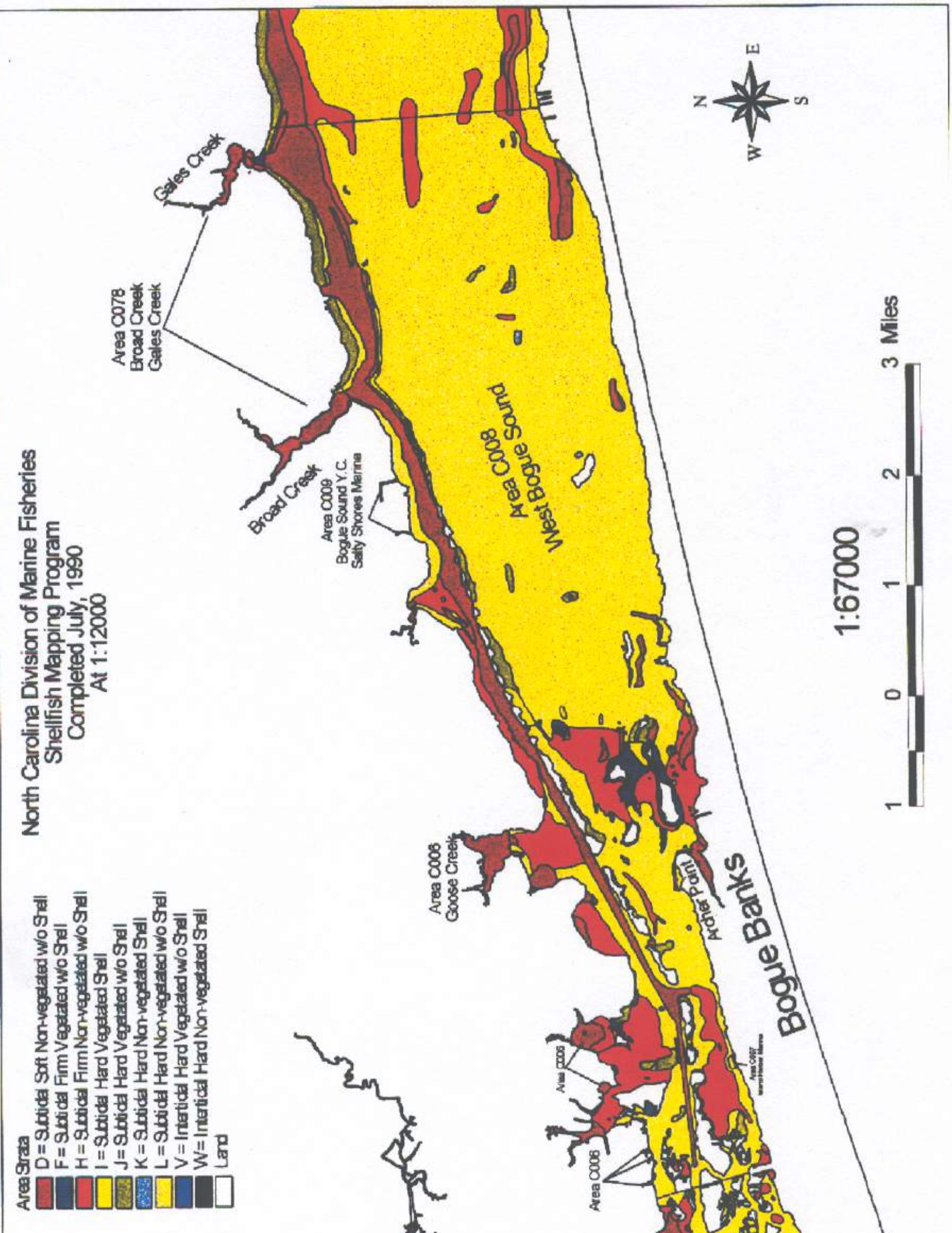

Lower Pages Creek
Area # S039
North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed June, 1991
At 1:12000
Area Boundary
Area Boundary
marinas
S037
Land
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
G = Subtidal Firm Non-vegetated Shell
H = Subtidal Firm Non-vegetated w/o Shell
O = Intertidal Soft Non-vegetated Shell
P = Intertidal Soft Non-vegetated w/o Shell
R = Intertidal Firm Vegetated w/o Shell
S = Intertidal Firm Non-vegetated Shell
T = Intertidal Firm Non-vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
Area Density (# per square meter)
Strata Clams Oysters
G 1.0 0.0
H 0.1 0.0
R 0.0 2.9
S 2.8 75.5
T 0.1 0.0
W 1.5 135.5
1:10000
0.125 0 0.125 0.25 Miles
N E S W

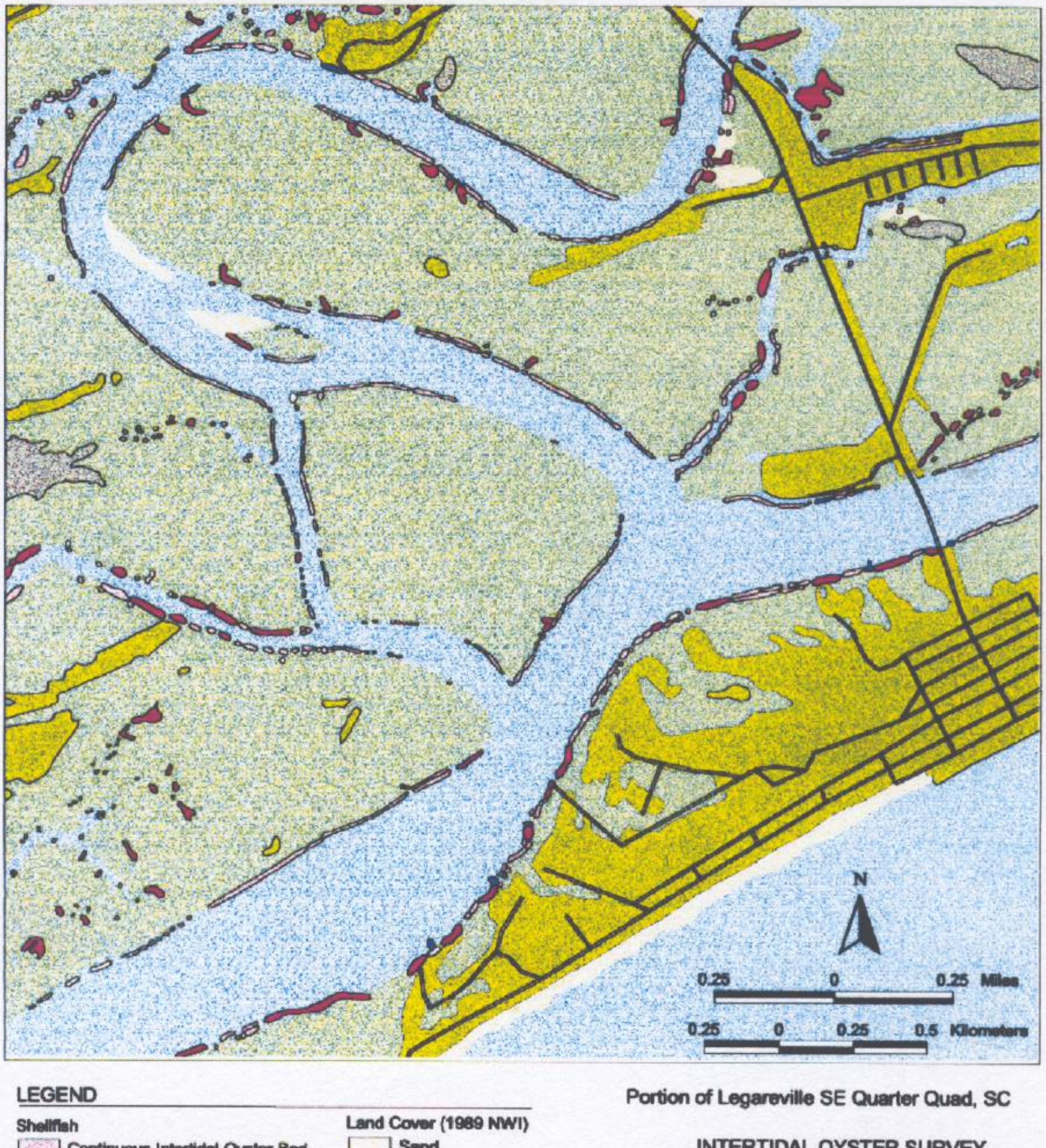
Figure 7


North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed July, 1990
At 1:12000
Area C008
West Bogue Sound
Area C006
Goose Creek
Area C006
Old Ferry Dock
Area C006
Area C007
Island Harbor Marina
Archer Point
Bogue Banks
1:28000
0.5
0
0.5 Miles
N
E
S
W
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
F = Subtidal Firm Vegetated w/o Shell
H = Subtidal Firm Non-vegetated w/o Shell
I = Subtidal Hard Vegetated Shell
J = Subtidal Hard Vegetated w/o Shell
K = Subtidal Hard Non-vegetated Shell
L = Subtidal Hard Non-vegetated w/o Shell
V = Intertidal Hard Vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
Land


North Carolina Division of Marine Fisheries
Shellfish Mapping Program
Completed July, 1990
At 1:12000
Area Strata
D = Subtidal Soft Non-vegetated w/o Shell
F = Subtidal Firm Vegetated w/o Shell
H = Subtidal Firm Non-vegetated w/o Shell
I = Subtidal Hard Vegetated Shell
J = Subtidal Hard Vegetated w/o Shell
K = Subtidal Hard Non-vegetated Shell
L = Subtidal Hard Non-vegetated w/o Shell
V = Intertidal Hard Vegetated w/o Shell
W = Intertidal Hard Non-vegetated Shell
Land
Area C078
Broad Creek
Gales Creek
Gales Creek
Broad Creek
Area C009
Bogue Sound Y.C.
Salty Shores Marina
Area C008
West Bogue Sound
Area C006
Goose Creek
Archer Point
Bogue Banks
Area C006
Area C006
N
E
S
W
1:67000
1
0
1
2
3 Miles

INTERTIDAL OYSTER STUDY

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES
OFFICE OF FISHERIES MANAGEMENT
SHELLFISH MANAGEMENT PROGRAM



LEGEND

Shellfish

- Continuous Intertidal Oyster Bed
- Two or More Intertidal Oyster Beds
- Intertidal Oyster Flat
- Intertidal Oysters on Rip-Rap
- Washed Shell Accumulations

Land Cover (1989 NWI)

- Sand
- Upland
- Water
- Wetland
- Transitional

Portion of Legareville SE Quarter Quad, SC

INTERTIDAL OYSTER SURVEY
Shellfish Data Collected 1980 to Present
Not for Navigation or Surveying Purposes
Data is dynamic and may change frequently
Contact SCDNR-OFM for most recent information
April 30, 1998

Appendix E. SEAMAP Hardbottom Maps for the South Atlantic Region (Source: FMRI 1997).

Southeast Area Monitoring and Assessment Program
Bottom Mapping Project

In 1985, the Southeast Area Monitoring and Assessment Program (SEAMAP-South Atlantic) established a Bottom Mapping Work Group to develop a regional database that describes the location and characteristics of hard-bottom habitat on the continental shelf off the southeastern United States (NC-FL). These diverse areas represent essential fish habitat for a wide variety of species that are commercially and recreationally harvested in the South Atlantic region. In order for state and federal resource agencies to better maintain these fisheries, there is a need to identify the location and extent of reef habitat, determine the carrying capacity of these habitats, and obtain more information on the ecological relationships of the resources supported by hard-bottom reef habitat. This knowledge will also assist resource managers in evaluating the effects of past and future fishery regulations and anthropogenic stresses on these valuable resource areas. Recent consideration of the establishment of marine fisheries reserves will also benefit from the knowledge of how reef and non-reef habitats are distributed in the region.

The primary objectives of the Work Group are to:

(1) conduct an extensive search of existing databases to identify all known reef habitats on the continental shelf off the southeastern U.S. coast from the North Carolina/Virginia border to the Florida Keys and from the beach out to 200 m in depth; and

(2) summarize the bottom type information into flexible, easy to use databases which will provide managers and researchers with pertinent information concerning the location and extent of these areas, types of data used in determining bottom type, and data sources.

Intensive efforts to compile and analyze existing data sources began in 1992 after efforts were completed to (1) identify agency needs, (2) finalize the format and structure of the bottom mapping database, and (3) standardize the approach for evaluating each type of data. Primary efforts have focussed on evaluating data available from state and federal agencies and other sources that have conducted scientific assessments of bottom resources in the region. Non-scientific sources, such as recreational diver records and commercial fishing maps, have not been incorporated into the database to date. The data sources vary in information content and accuracy in the location of the reef habitat. Criteria for evaluating some data types (e.g. finfish collections) have varied slightly in each portion of the region due to latitudinal differences in the distribution and ecology of some species. Additionally, new types of data (e.g. sediment cores, aerial photography) have been incorporated into some of the more recent data sets evaluated.

The databases from all study phases completed to date have been compiled in a single database using a PC-compatible format (D-Base,) according to procedures developed by the Bottom Mapping Work Group. The database has also been incorporated into ArcView, files for analysis and viewing using Geographic Information Systems (GIS) and into Portable Document Format (PDF) files for use in viewing summary maps of the data with software provided on this CD product. This latter effort was completed by the Florida Marine Research Institute.

To date, 65,727 data records have been compiled from databases obtained off North Carolina, South Carolina/Georgia, and Florida in three major study phases. A brief summary of the records available off each of the states is provided in the following table.

Summary of Bottom Mapping Records By State and Bottom Type

State	N. Carolina	S. Carolina	Georgia	Florida	Totals
Bottom Type:					
Hard Bottom	2,006	4,414	1,206	4,058	21,684
Possible Hard Bottom	1,527	1,261	894	3,292	6,974
No Hard Bottom	9,224	5,700	1,664	19,648	36,236
Artificial Reef	113	147	119	312	691
Artificial Reef / Hard Bottom	0	12	0	2	14
Not Applicable	0	0	3	105	108
Total Number of Records	12,890	11,534	3,886	37,417	65,727

Information on the specific databases evaluated and the methods used for analyzing and tabulating the data were summarized in three final reports submitted to the SEAMAP-SA Committee. Each of these reports is reproduced in this CD.

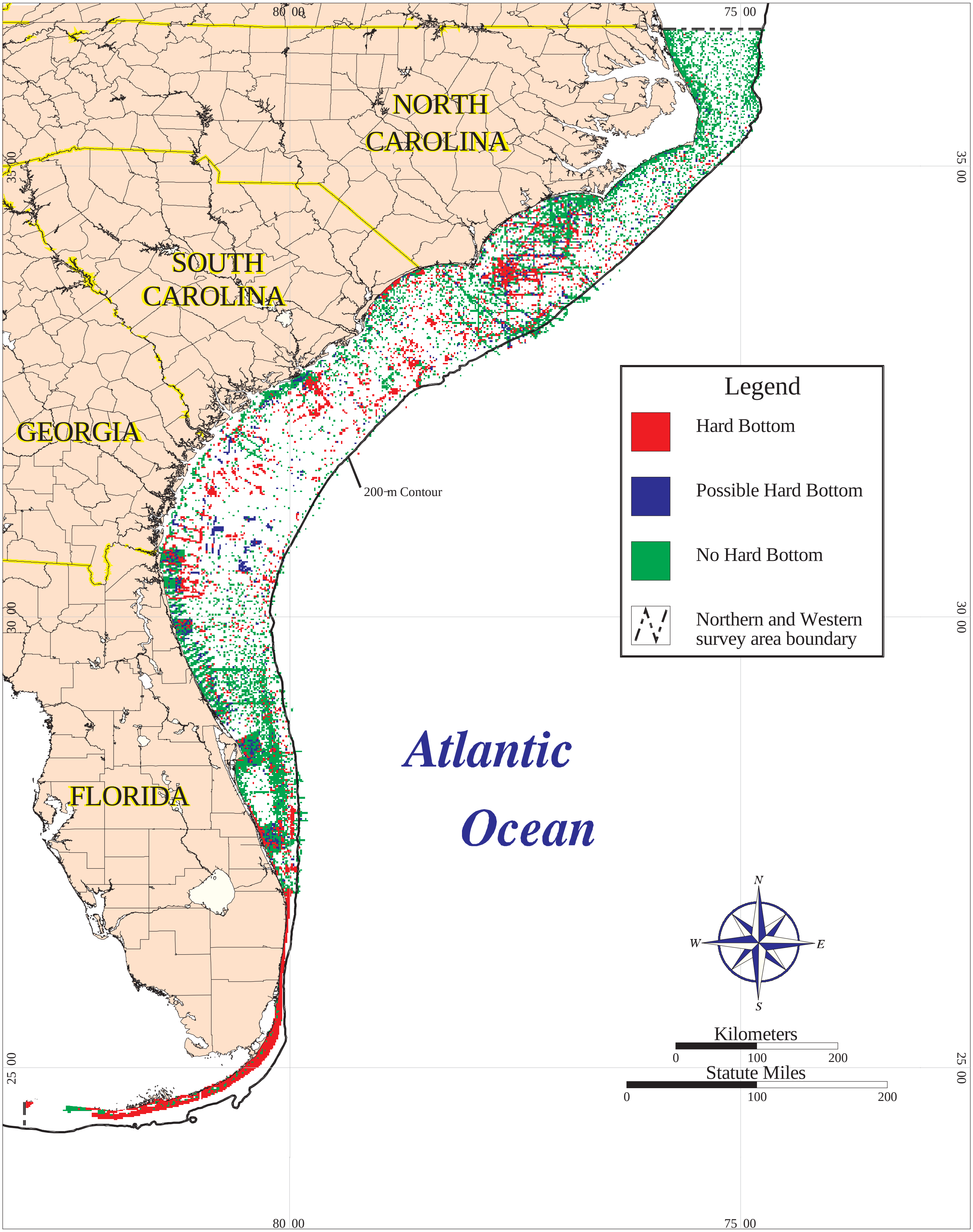
Many individuals have contributed significantly to the bottom mapping effort. Current members of the Bottom Mapping Workgroup are:

Name	Affiliation	Representing
Bob Van Dolah (Chairman)	South Carolina Marine Resources Division	South Carolina
Fred Rohde	North Carolina Division of Marine Fisheries	North Carolina
Steve Ross	Center for Marine Science Research	North Carolina
Charles Barans	South Carolina Marine Resources Division	South Carolina
Jim Henry	Georgia Southern University	Georgia
Henry Norris	Florida Dept. of Environmental Protection	Florida
Bill Lyons	Florida Dept. of Environmental Protection	Florida
Roger Pugliese	South Atlantic Fishery Management Council	SAFMC
Richard Parker	National Marine Fisheries Service	NMFS
Ken Savastano	National Marine Fisheries Service	NMFS

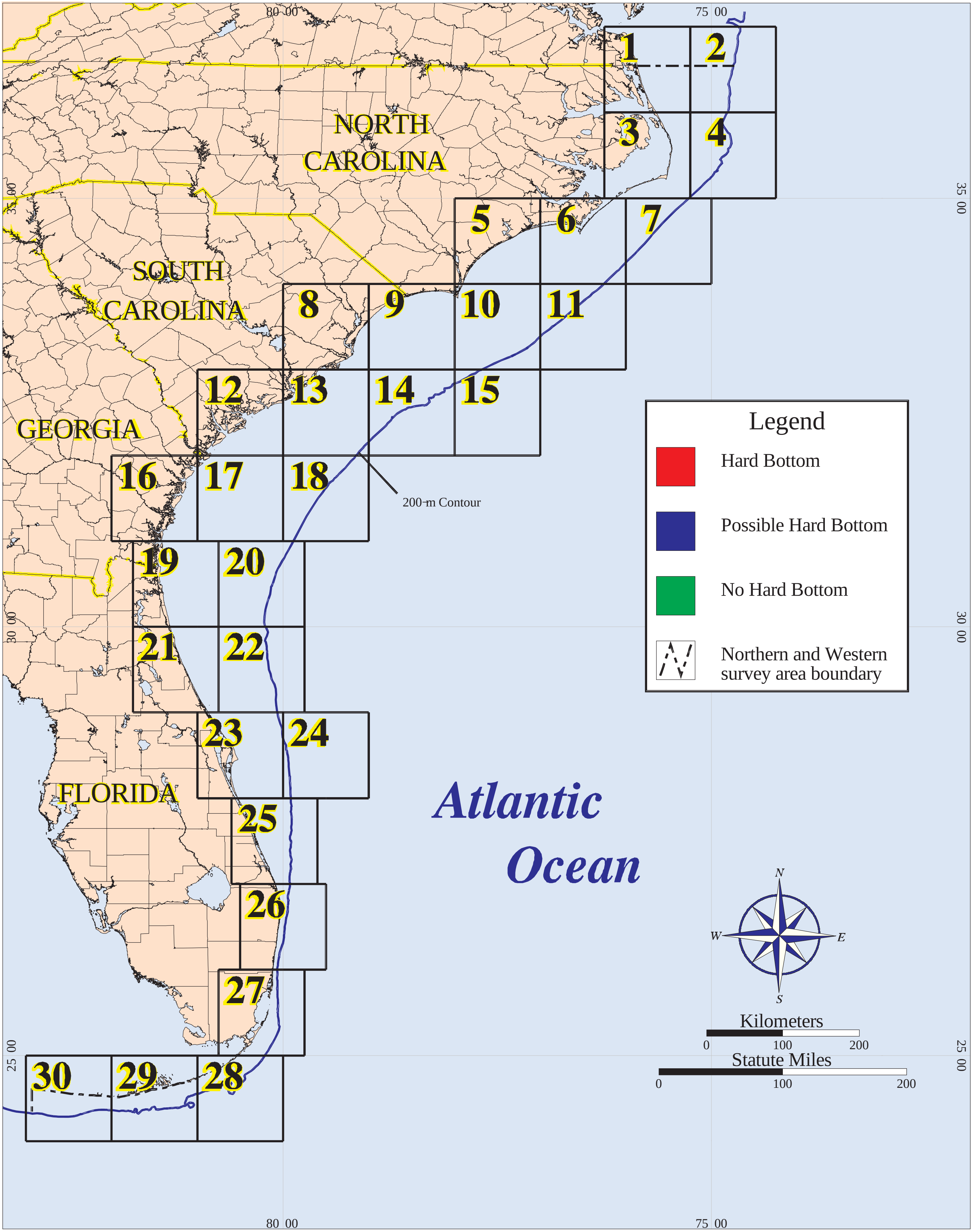
Other individuals who have greatly assisted the workgroup in developing the database include: H. Ansley, T. Azarovitz, A. Bury, J. Boylan, D. Camp, M. Clise, M. Colby, R. Dentzman, E. Foell, R. Gilmore,Jr., C. Jackson, M. Leiby, D. Machowski, P. Maier, R. Matheson,Jr., M. Moser, R. Minkler, B. O'Gorman, T. Perkins, P. Phalen, J. Reed, F. Sargent, J. Scurry, G. Sedberry, S. Snyder, B. Welsh, and D. Wilder.

The Bottom Mapping Workgroup is continuing efforts to acquire and analyze new and existing data on bottom characteristics in the regions that could not be processed within the available budget and time constraints. Recommendations to the SEAMAP-SA Committee for mapping unexplored bottom areas, and expanding the database to deeper water habitats are also being considered.

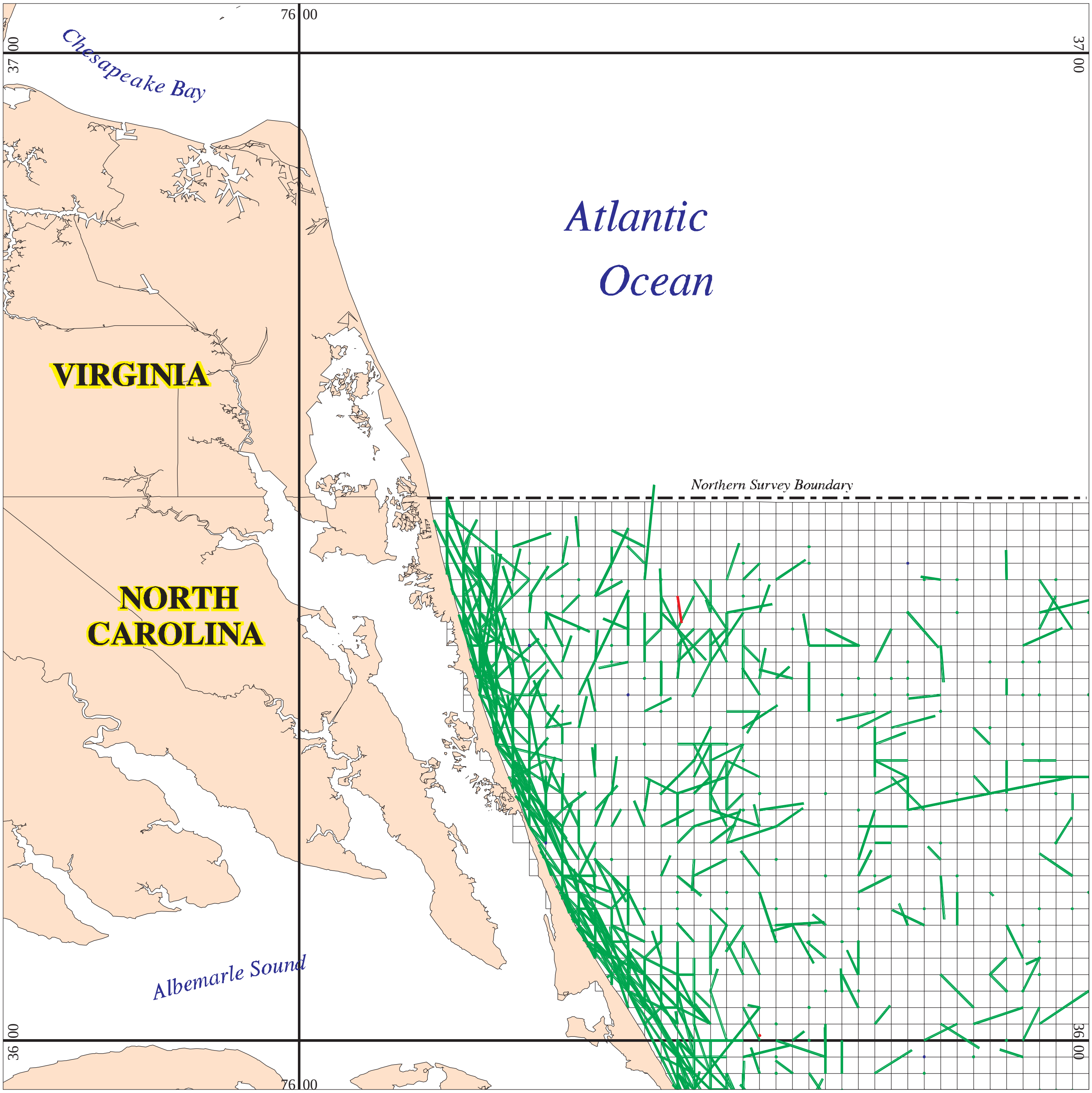
Extent of South Atlantic Bight SEAMAP survey area showing one-minute grid.



Distribution of grid cells in the survey area that contain information on bottom type.



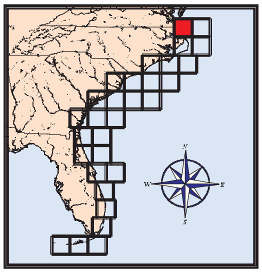
Index of South Atlantic Bight area divided into regions to provide expanded detail of data.



Hard Bottom

Possible Hard Bottom

No Hard Bottom



REGION 1

Kilometers
0 10 20

Statute Miles
0 10 20

SEAMAP
Bottom−Mapping Project

Figure 1. Location of point and line data that provide information on bottom type of the survey area shown.

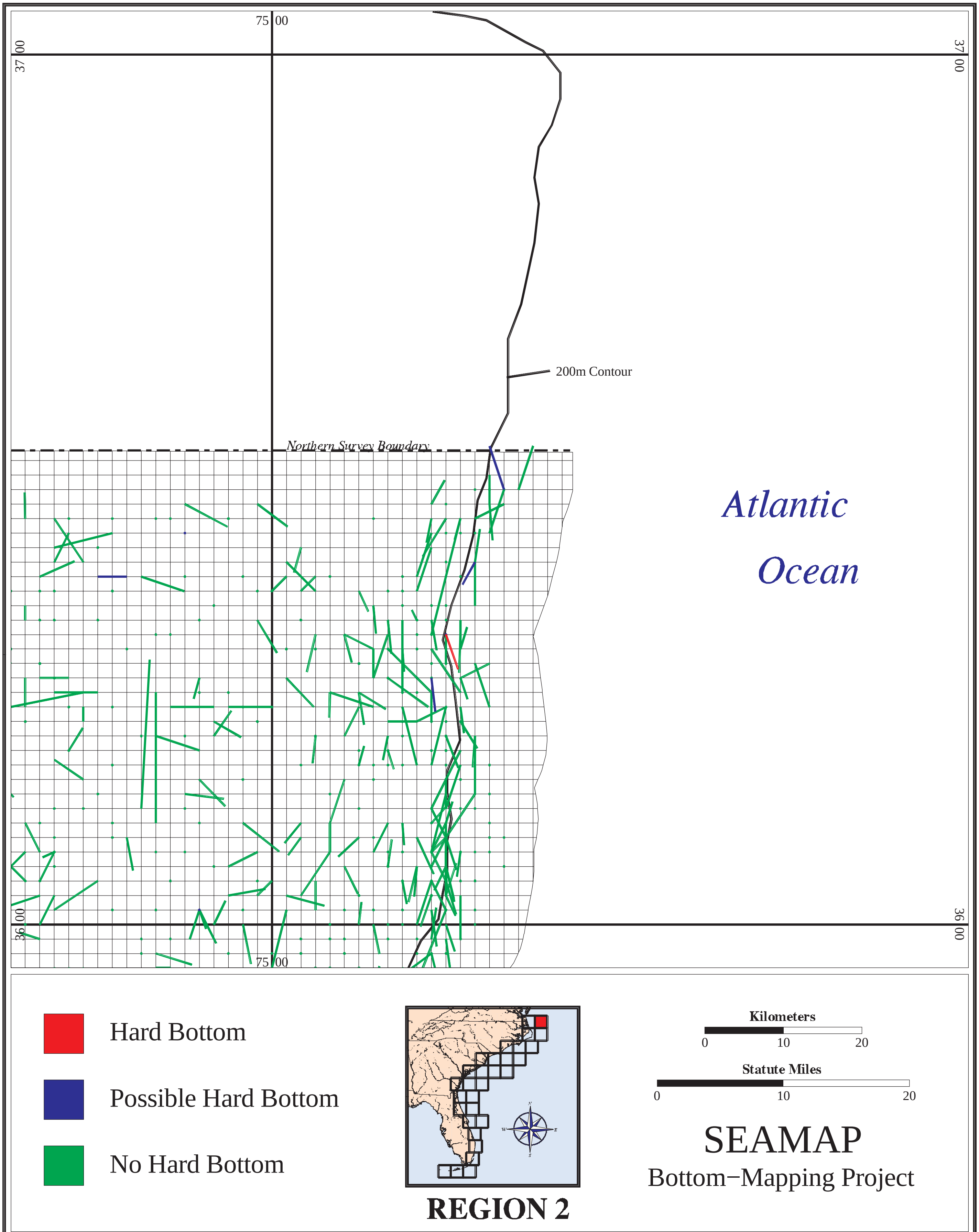
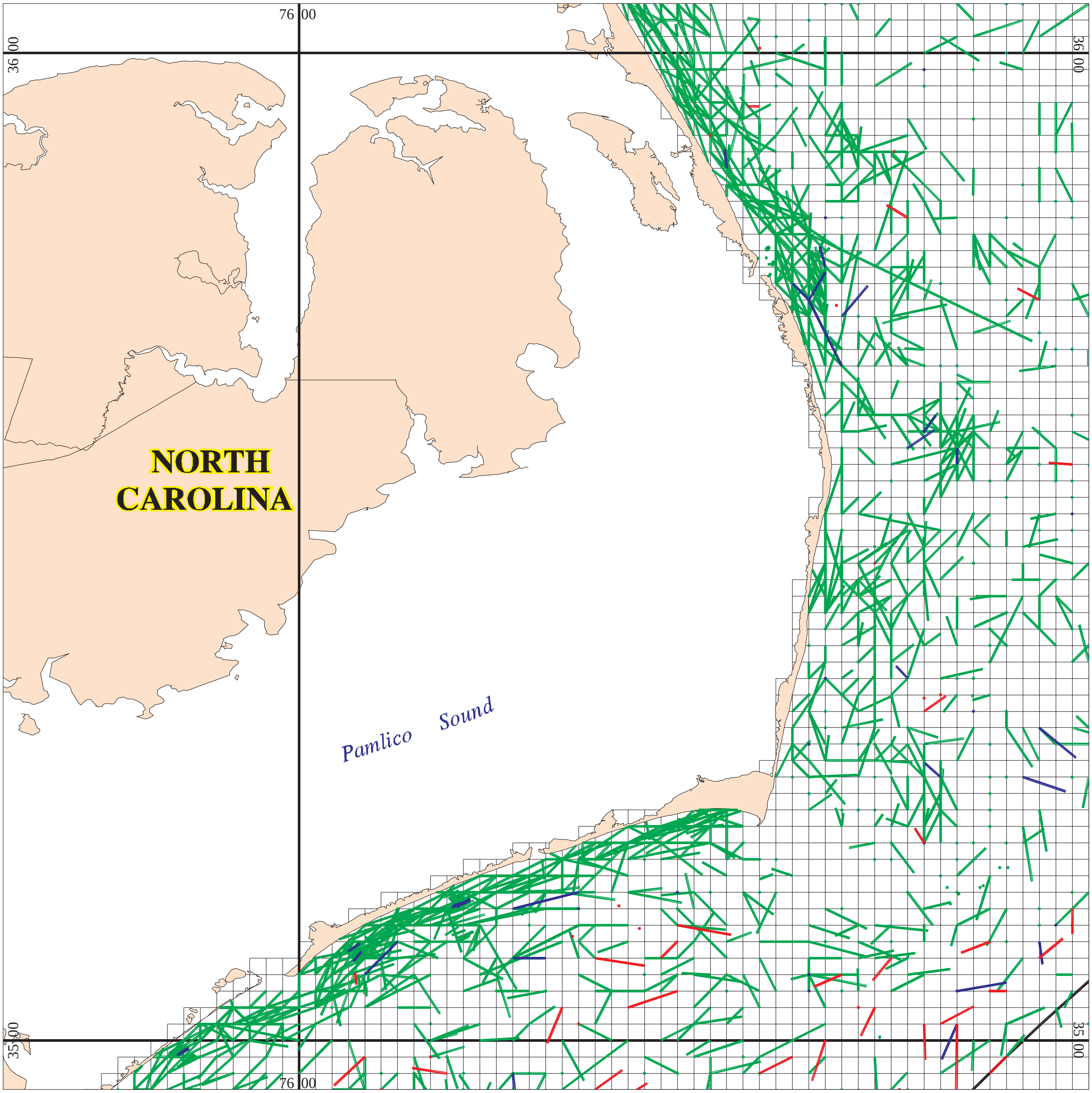


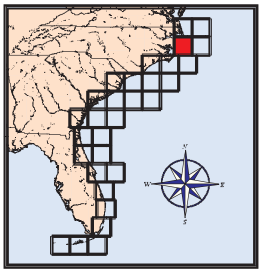
Figure 2. Location of point and line data that provide information on bottom type of the survey area shown.



Hard Bottom

Possible Hard Bottom

No Hard Bottom



REGION 3

Kilometers
0 10 20

Statute Miles
0 10 20

SEAMAP
Bottom−Mapping Project

Figure 3. Location of point and line data that provide information on bottom type of the survey area shown.

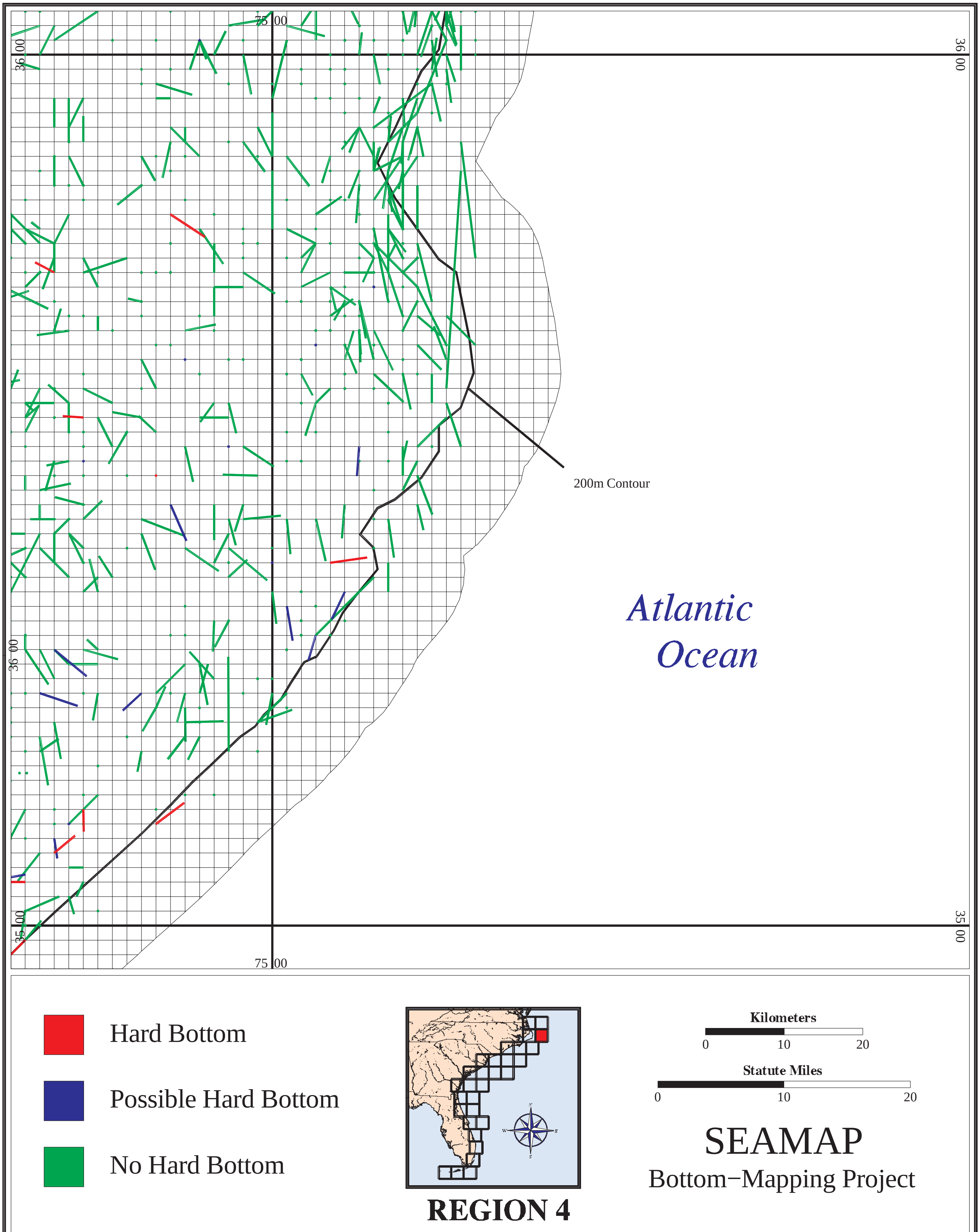


Figure 4. Location of point and line data that provide information on bottom type of the survey area shown.

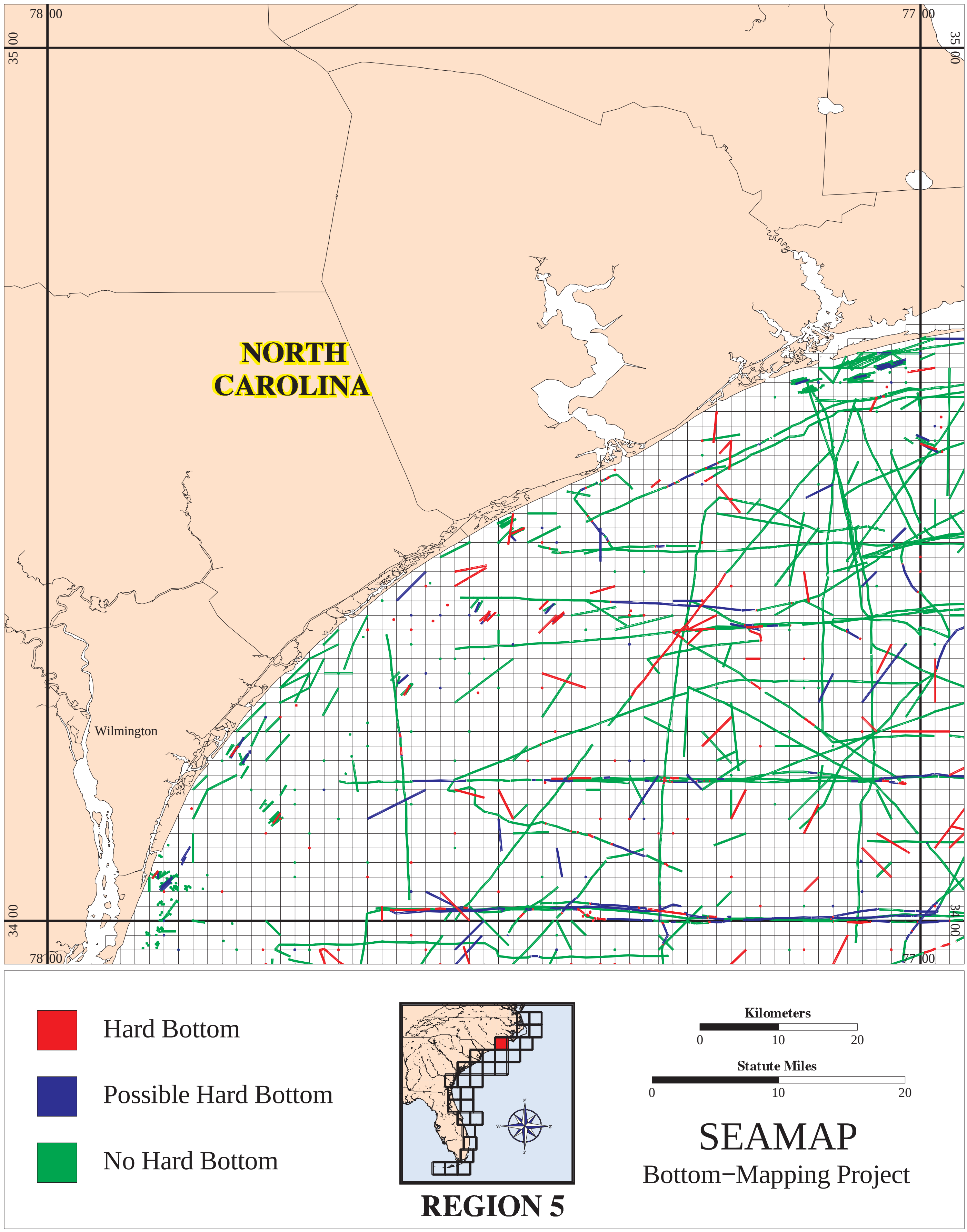


Figure 5. Location of point and line data that provide information on bottom type of the survey area shown.

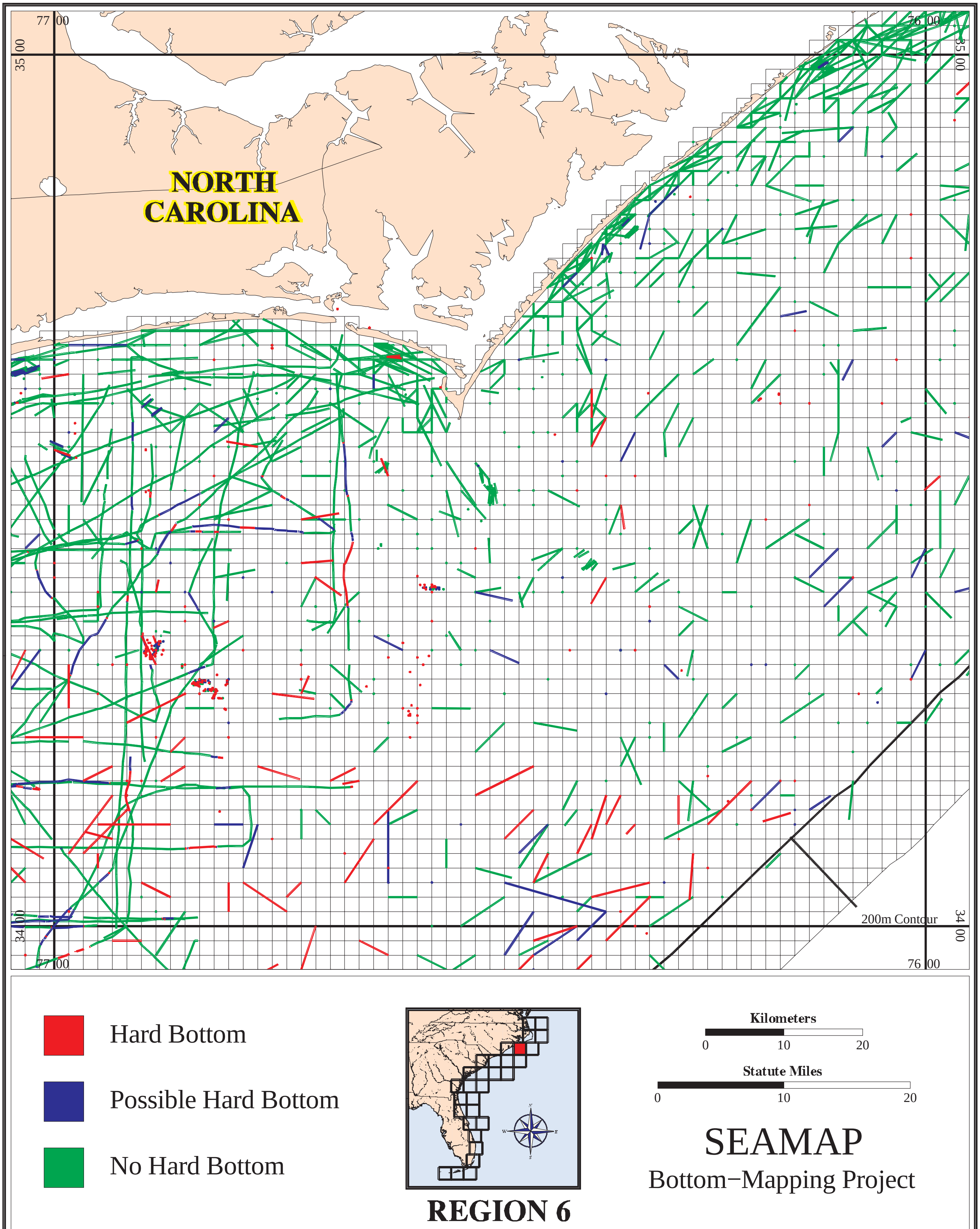


Figure 6. Location of point and line data that provide information on bottom type of the survey area shown.

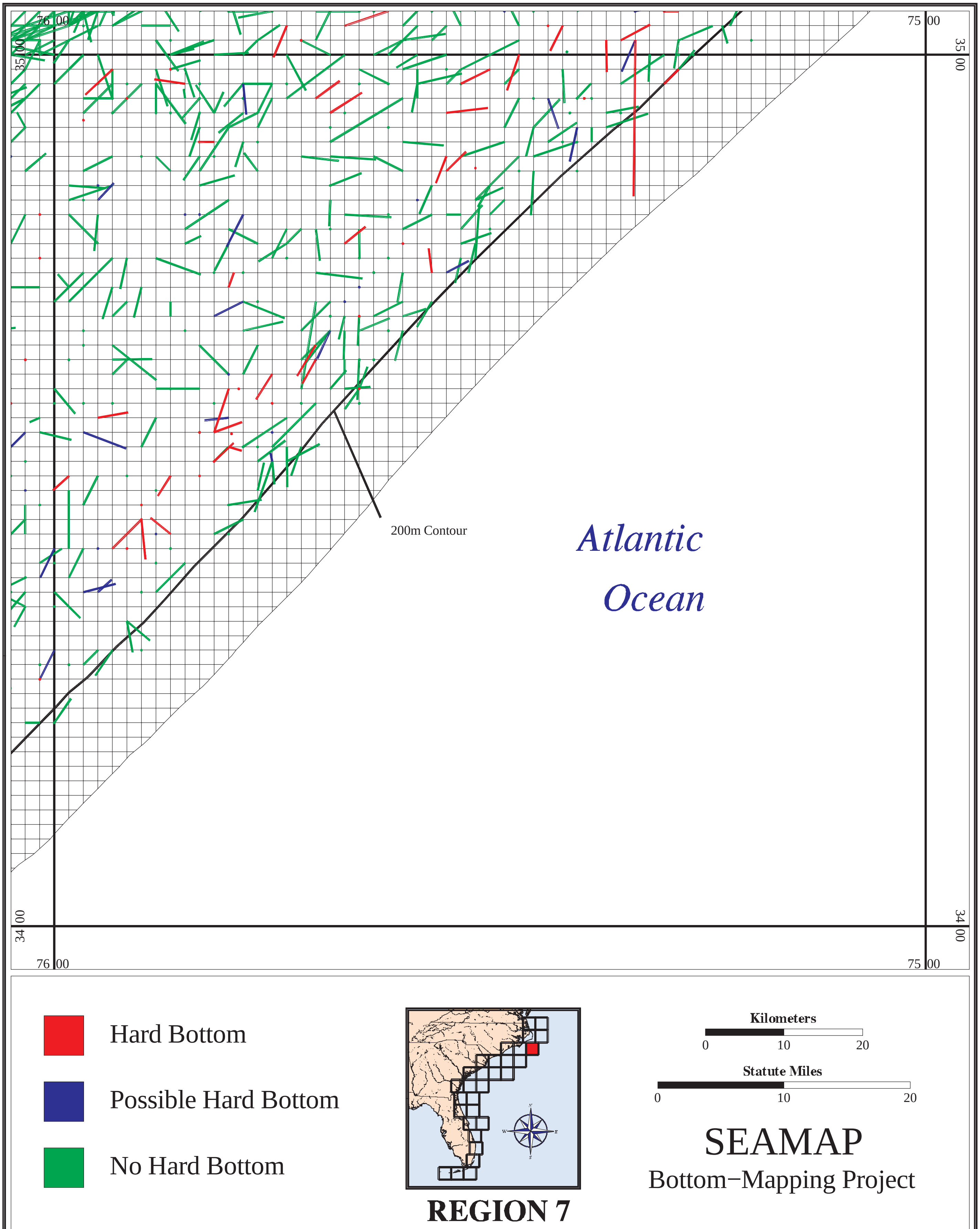


Figure 7. Location of point and line data that provide information on bottom type of the survey area shown.

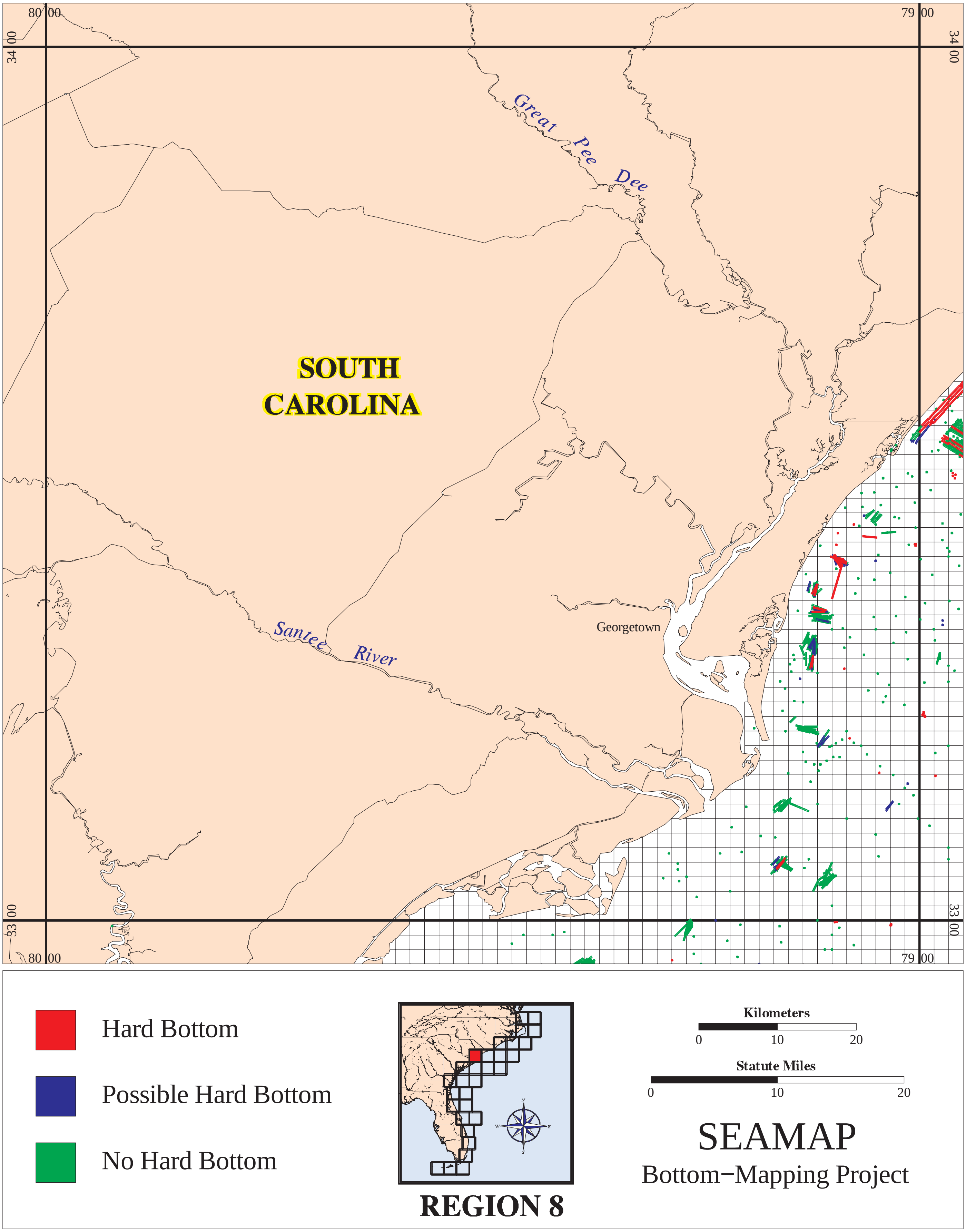


Figure 8. Location of point and line data that provide information on bottom type of the survey area shown.

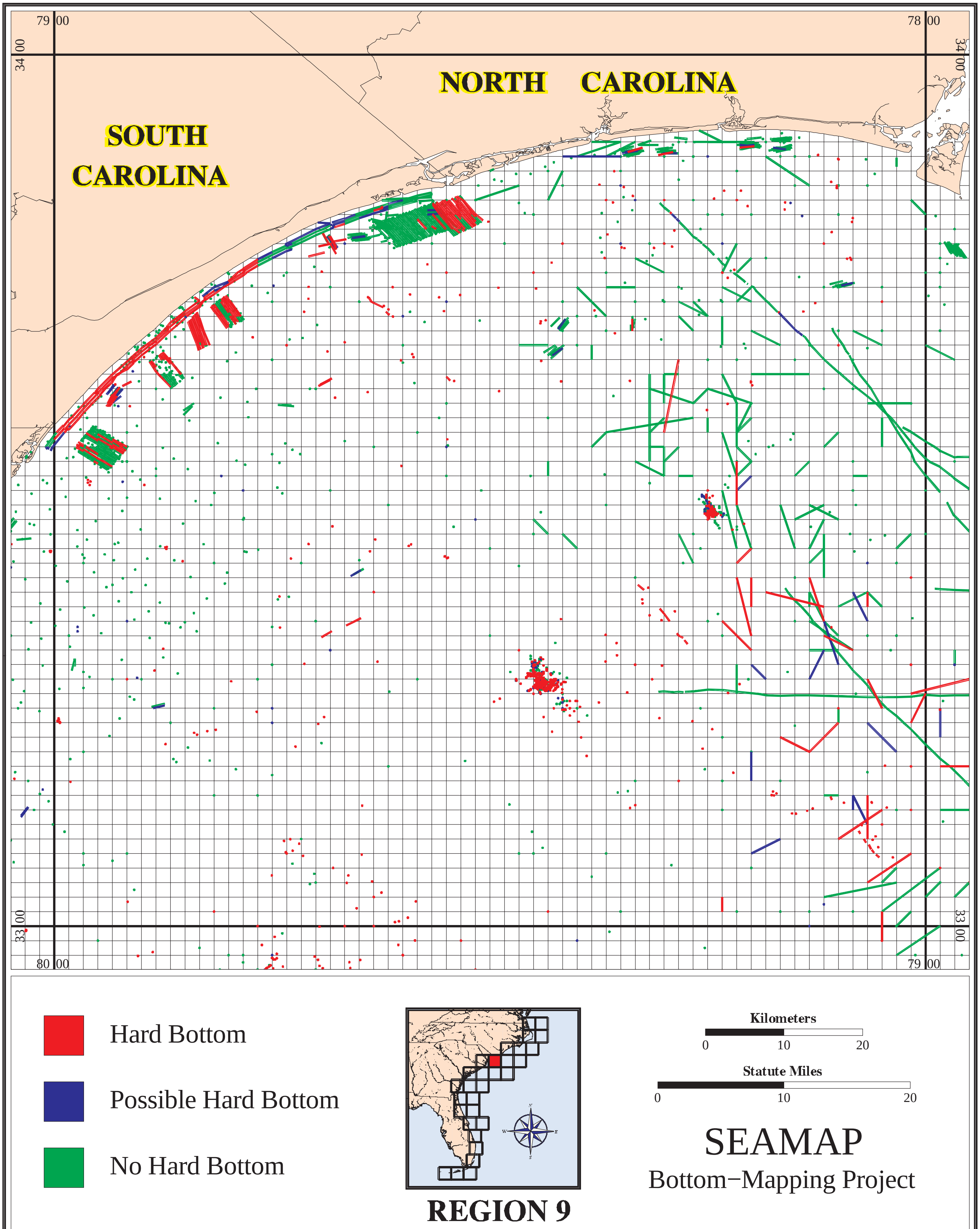


Figure 9. Location of point and line data that provide information on bottom type of the survey area shown.

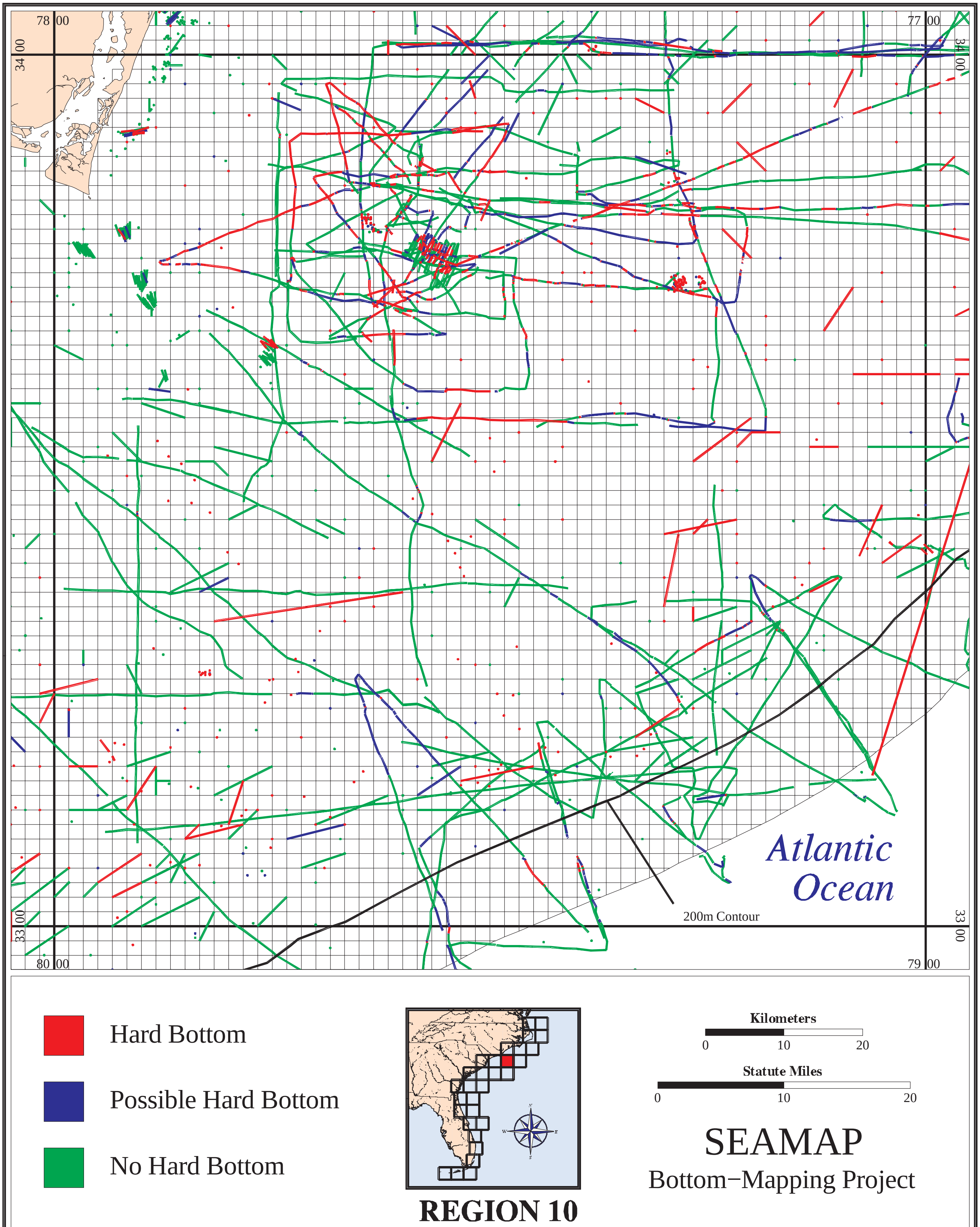


Figure 10. Location of point and line data that provide information on bottom type of the survey area shown.

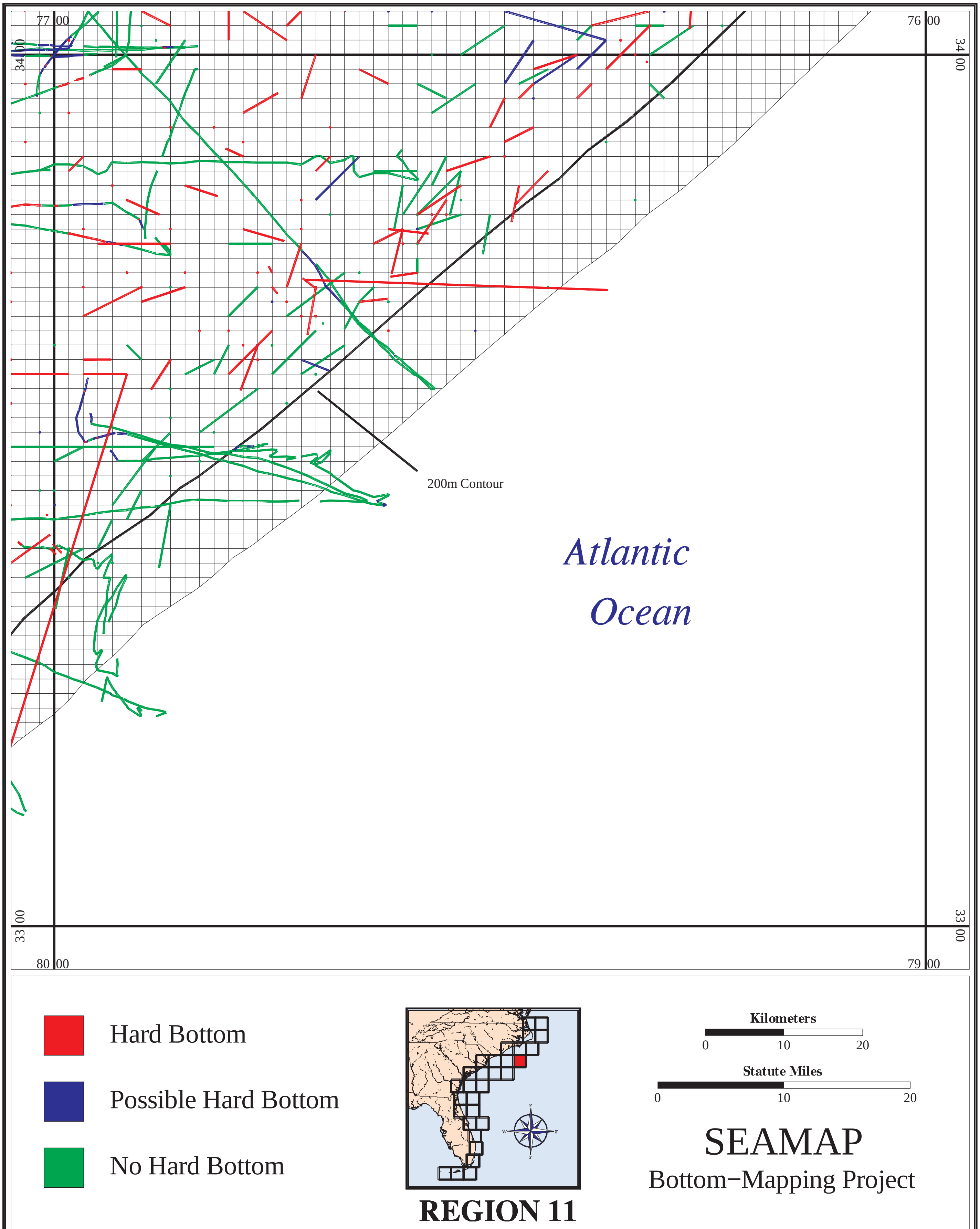


Figure 11. Location of point and line data that provide information on bottom type of the survey area shown.

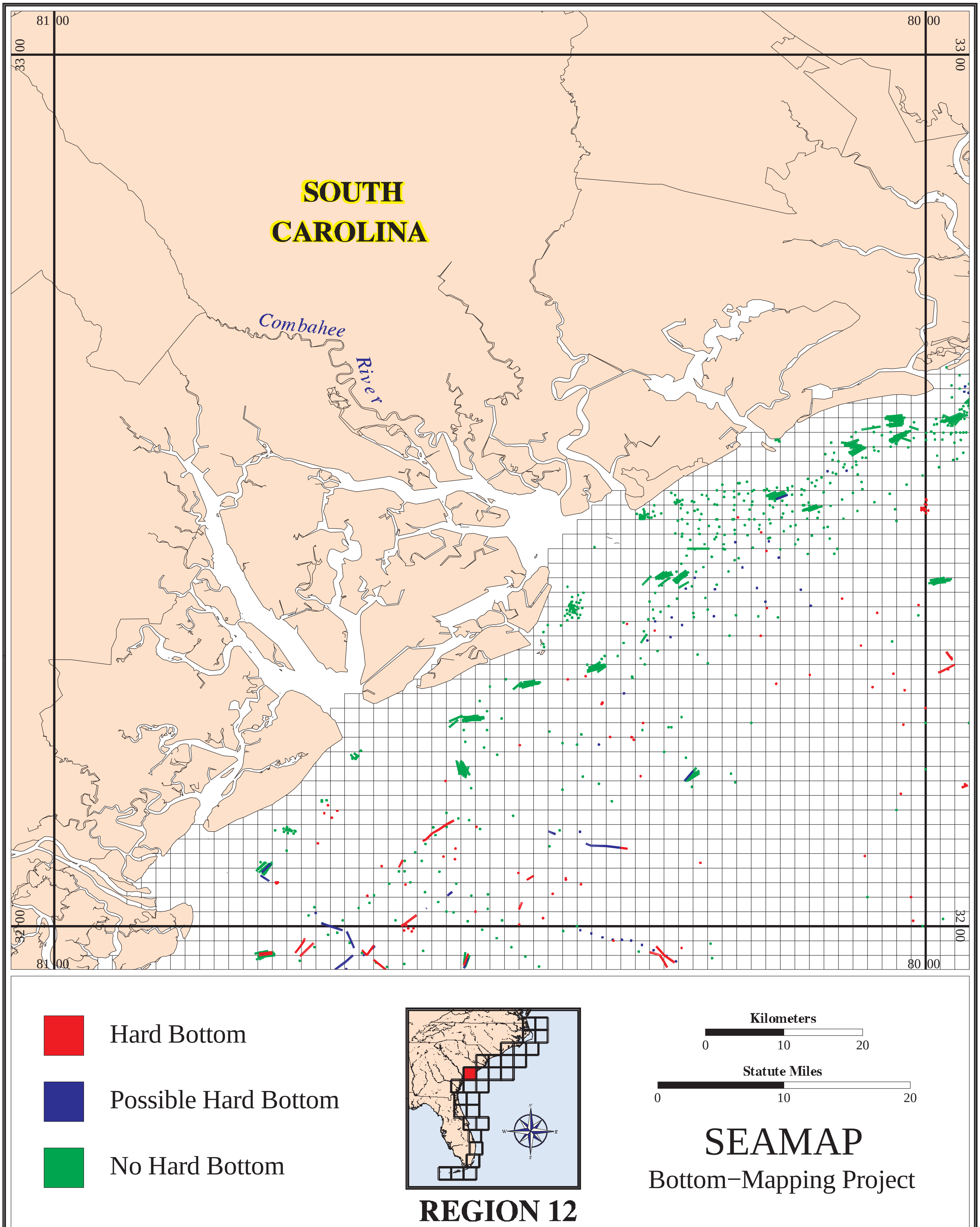


Figure 12. Location of point and line data that provide information on bottom type of the survey area shown.

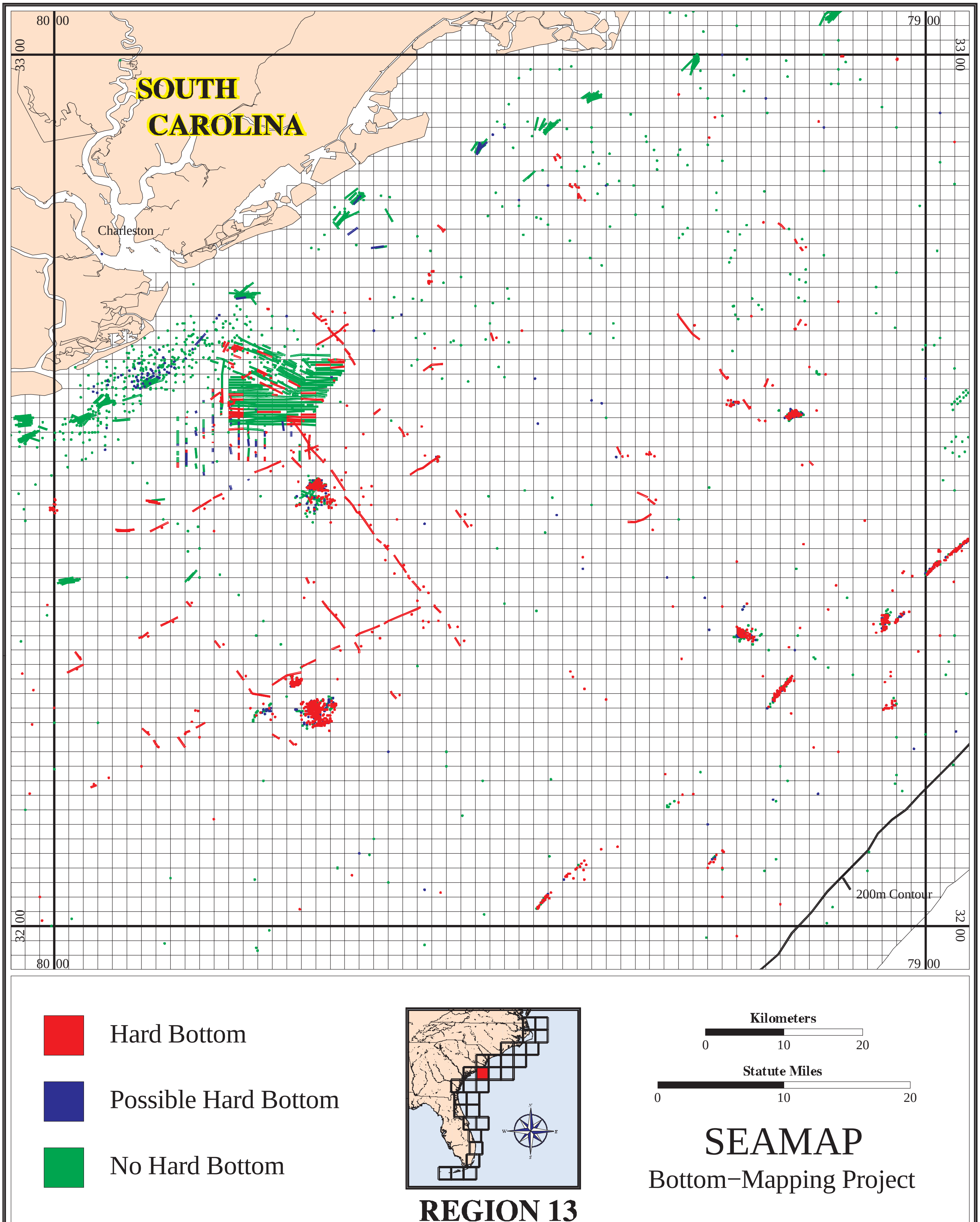


Figure 13. Location of point and line data that provide information on bottom type of the survey area shown.

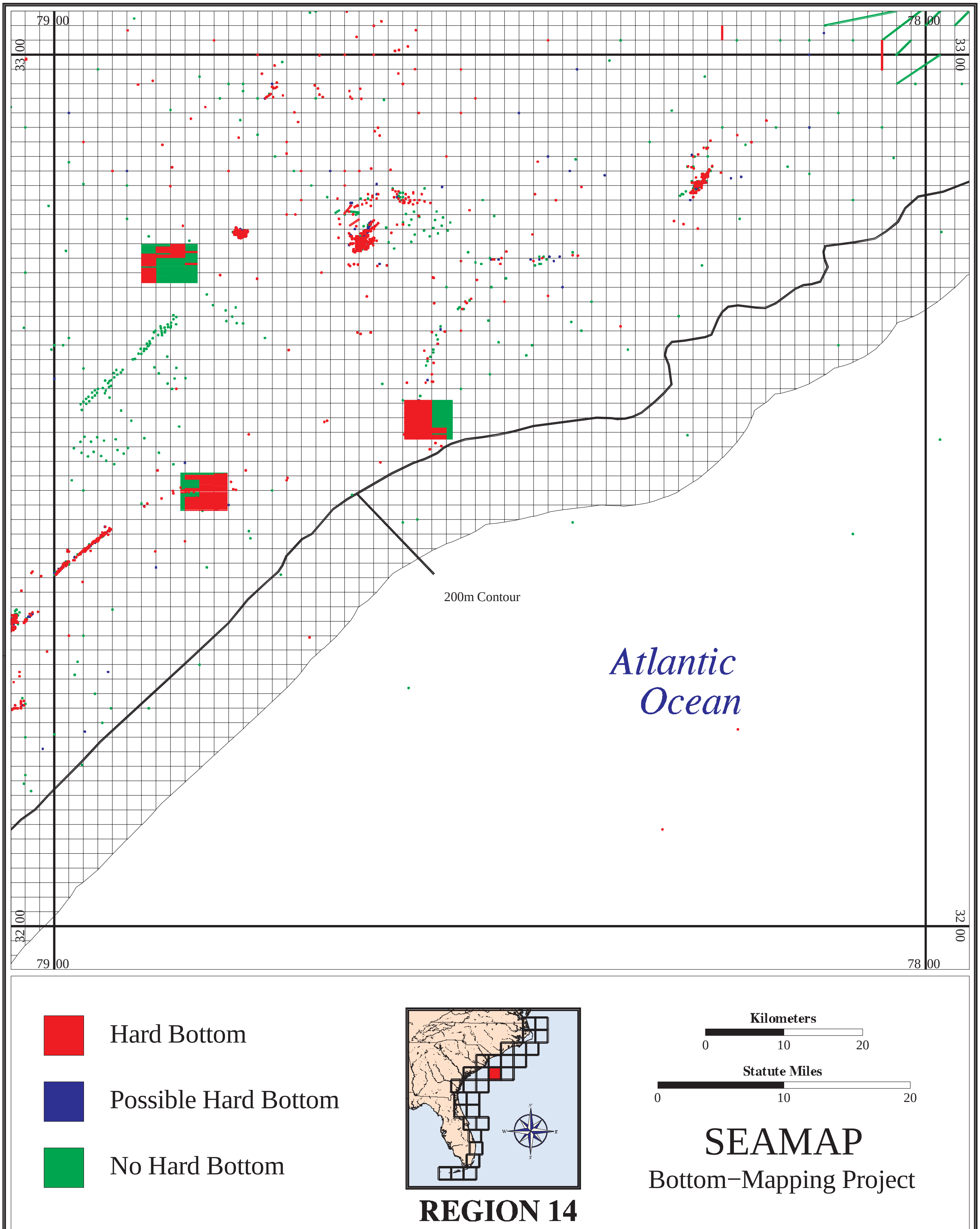


Figure 14. Location of point and line data that provide information on bottom type of the survey area shown.

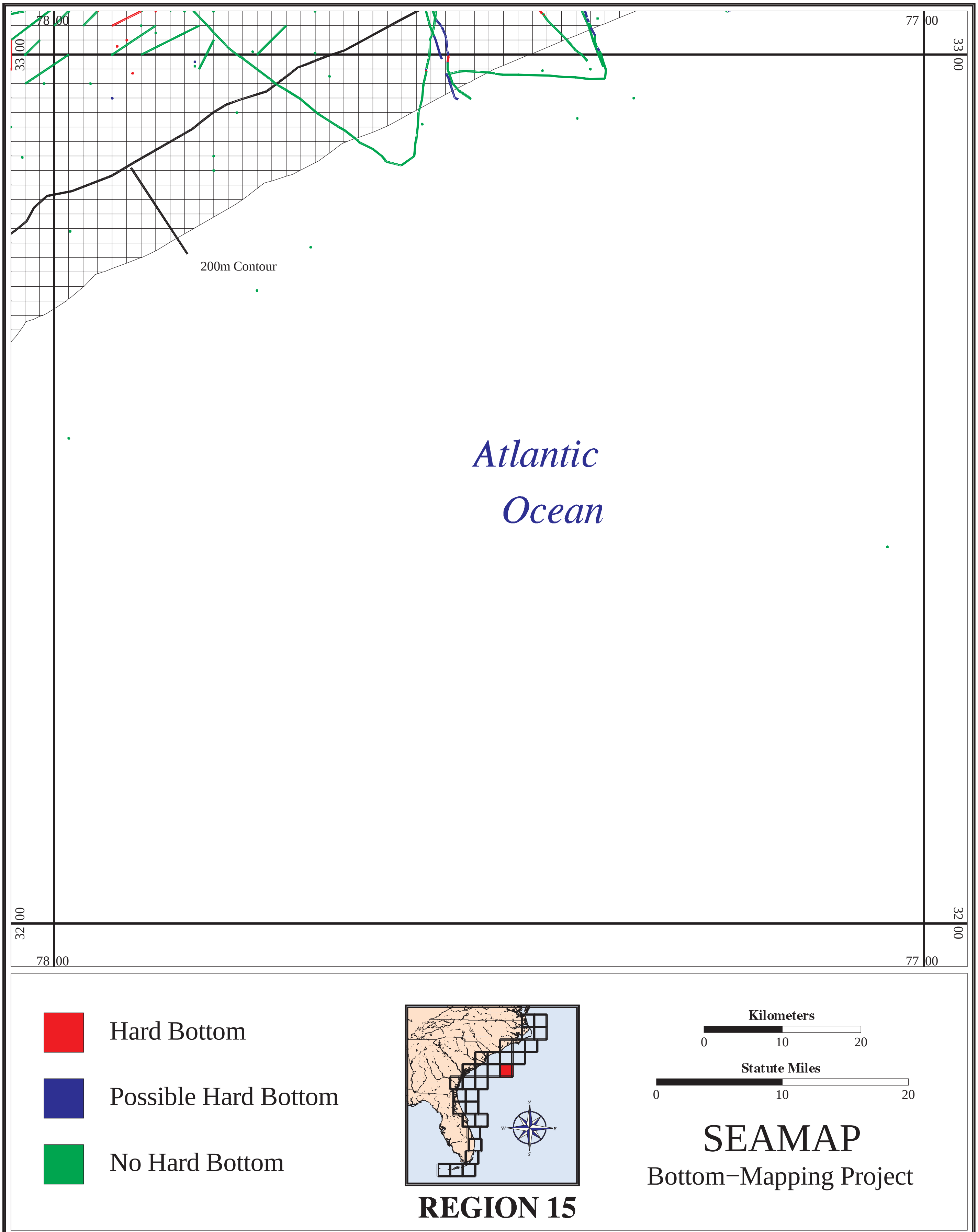


Figure 15. Location of point and line data that provide information on bottom type of the survey area shown.

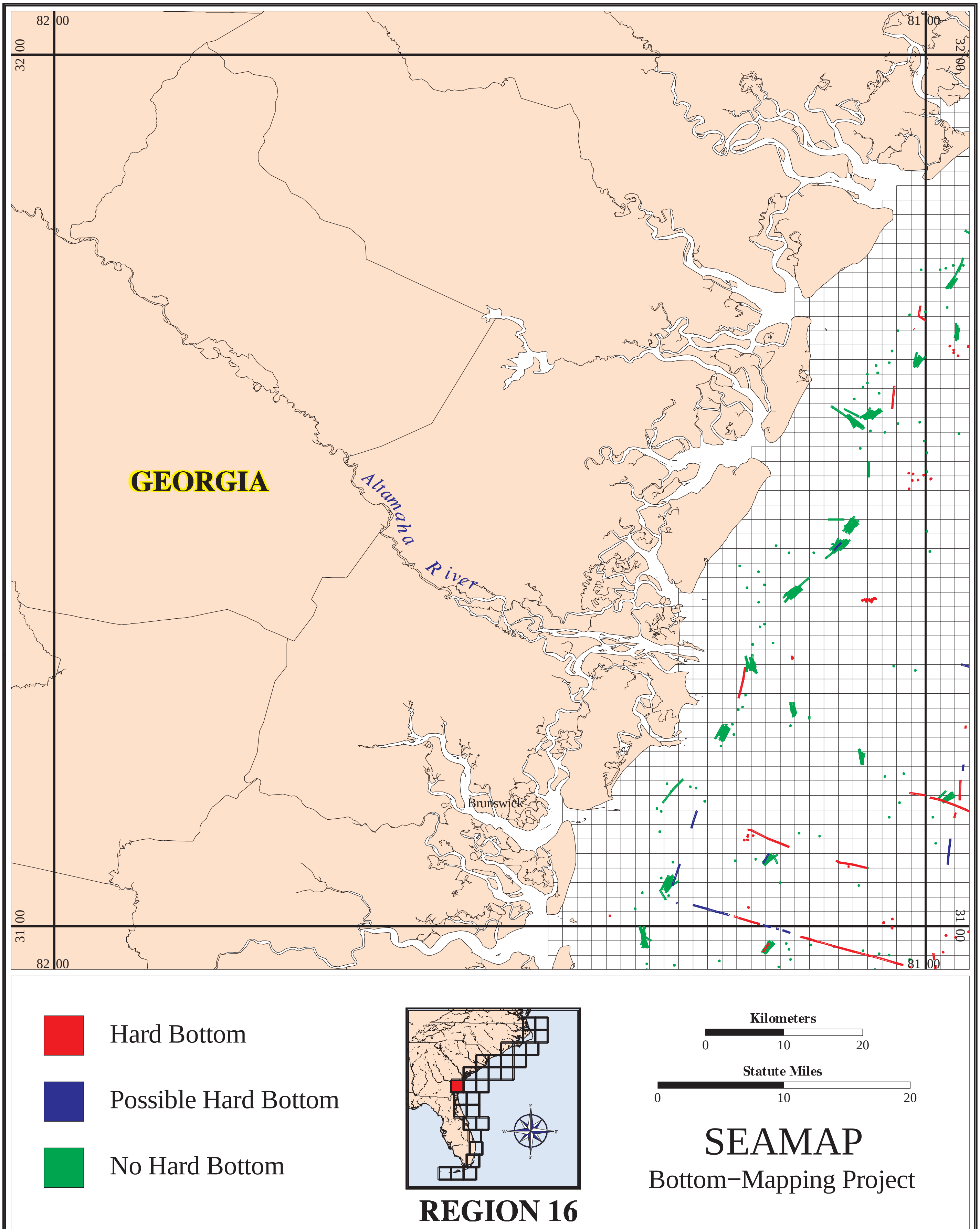
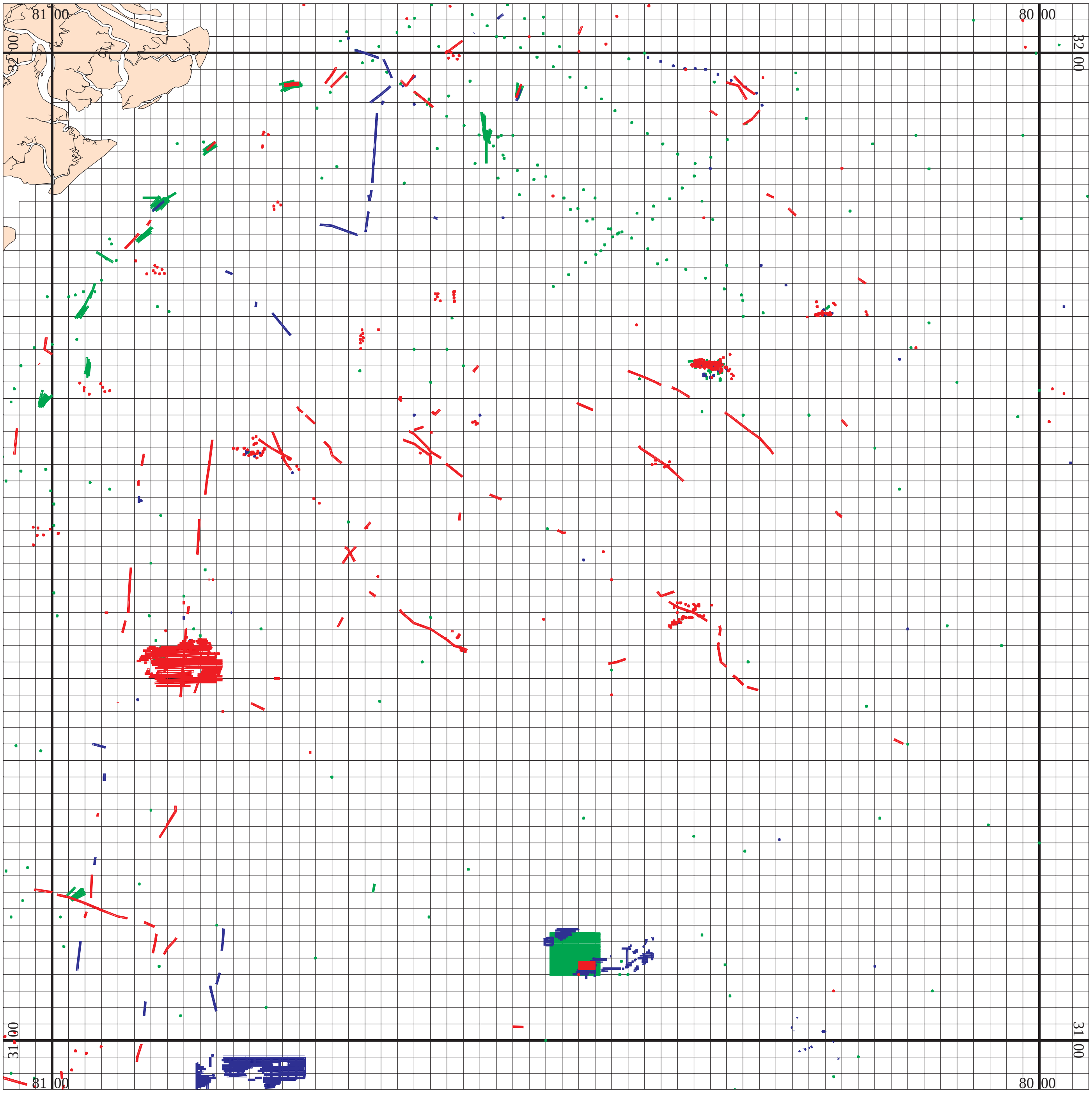


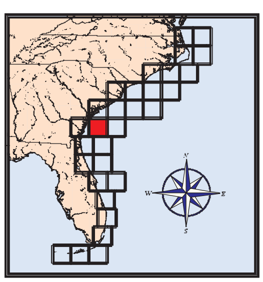
Figure 16. Location of point and line data that provide information on bottom type of the survey area shown.



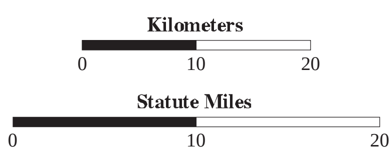
Hard Bottom

Possible Hard Bottom

No Hard Bottom



REGION 17



SEAMAP

Bottom−Mapping Project

Figure 17. Location of point and line data that provide information on bottom type of the survey area shown.

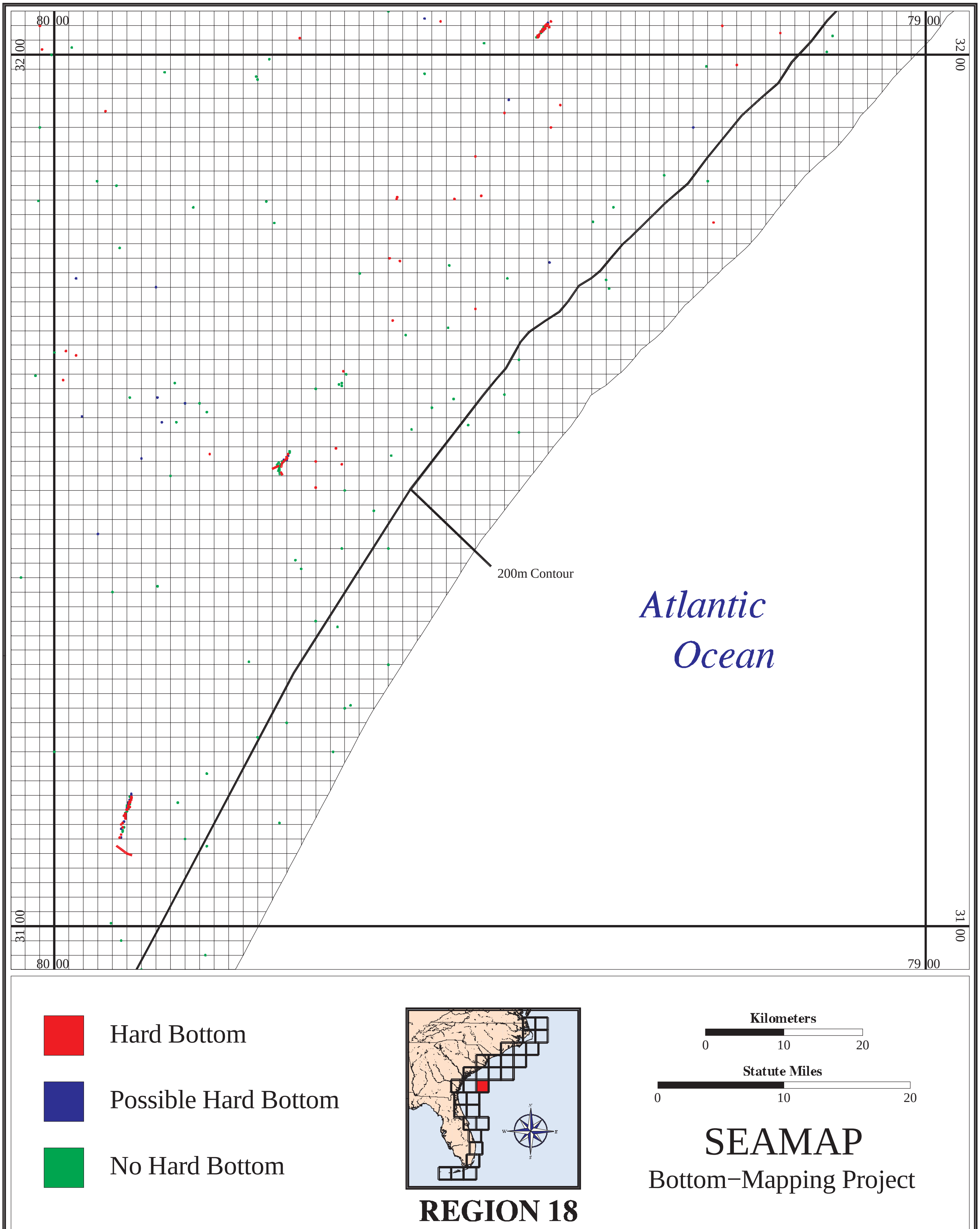


Figure 18. Location of point and line data that provide information on bottom type of the survey area shown.

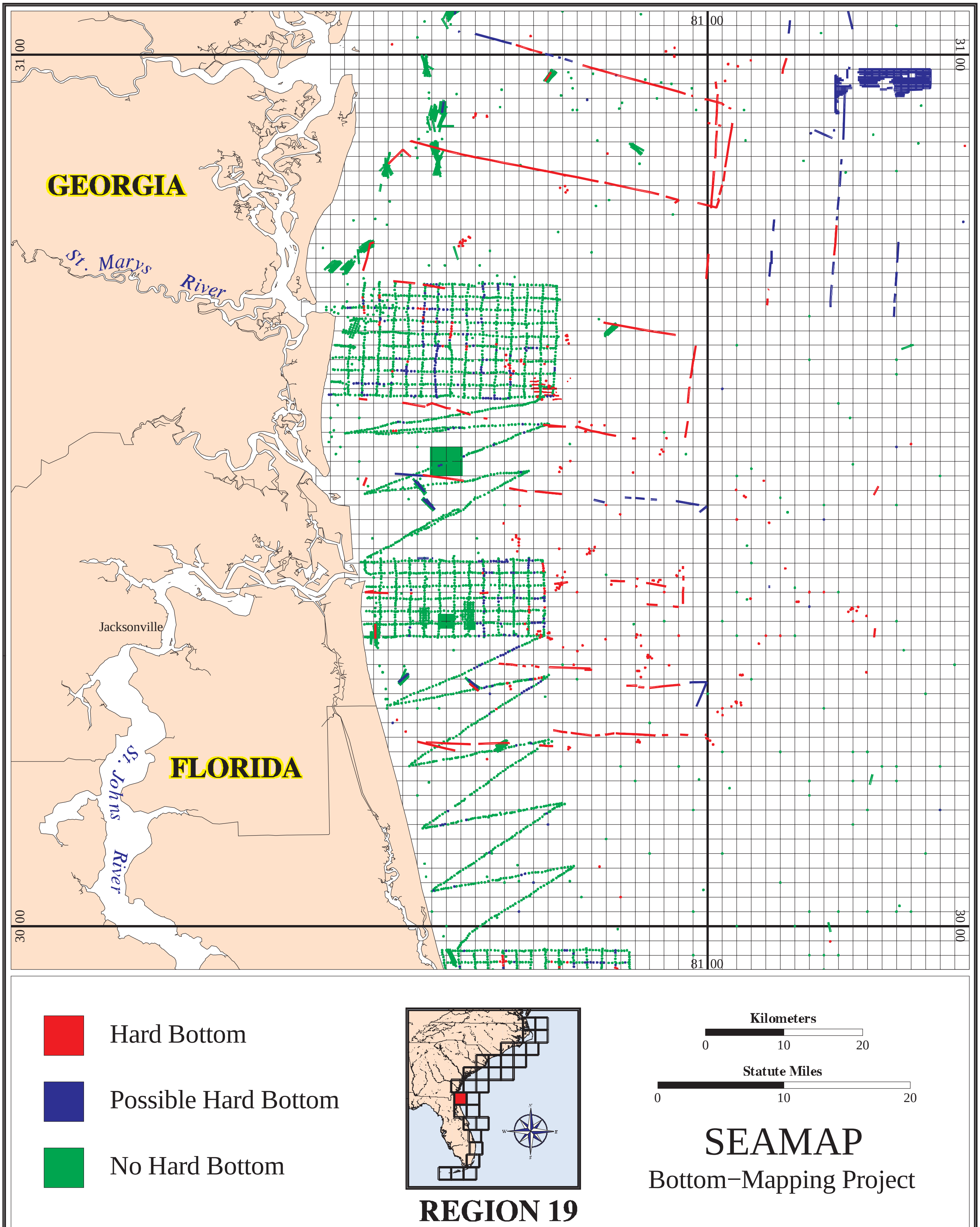


Figure 19. Location of point and line data that provide information on bottom type of the survey area shown.

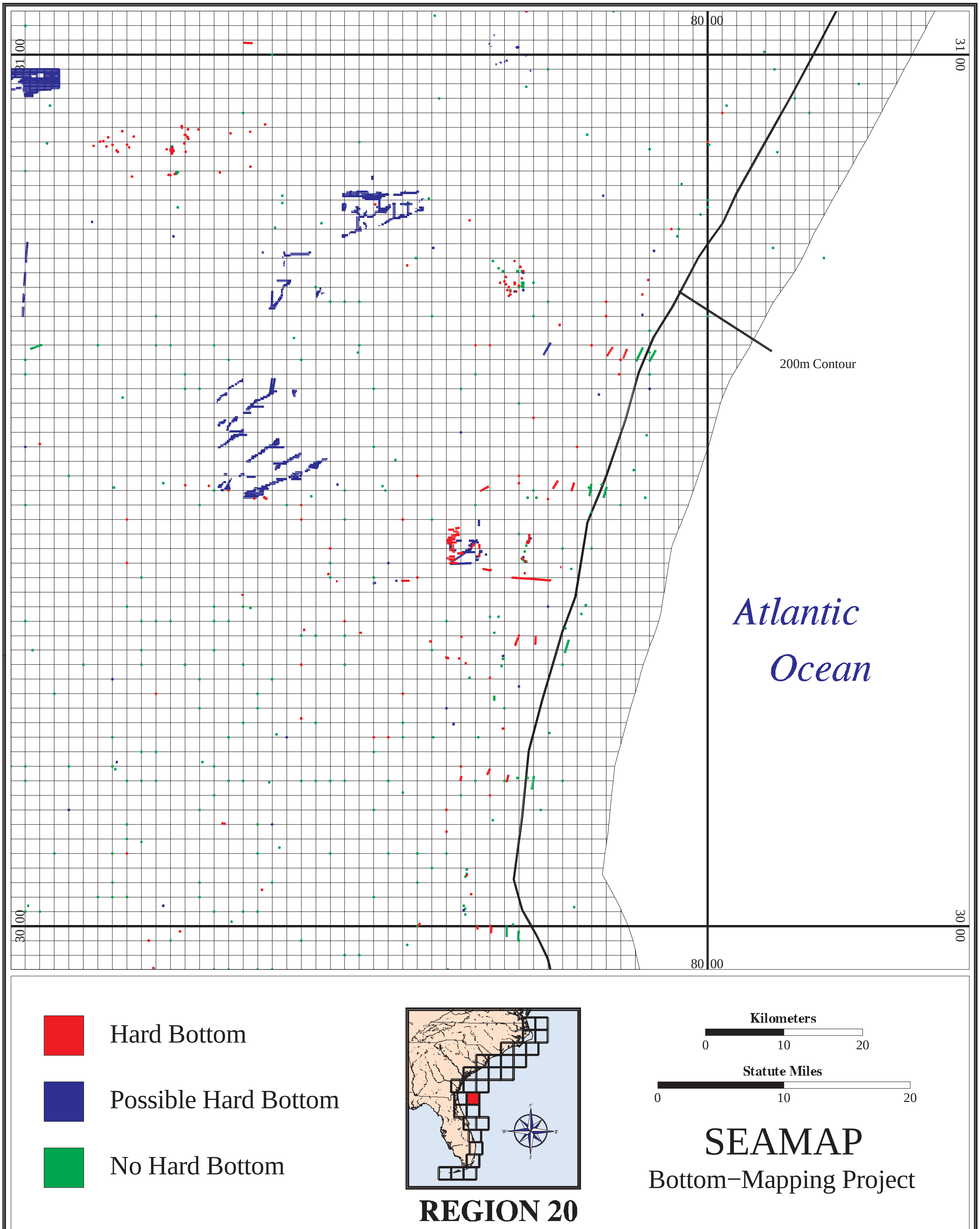


Figure 20. Location of point and line data that provide information on bottom type of the survey area shown.

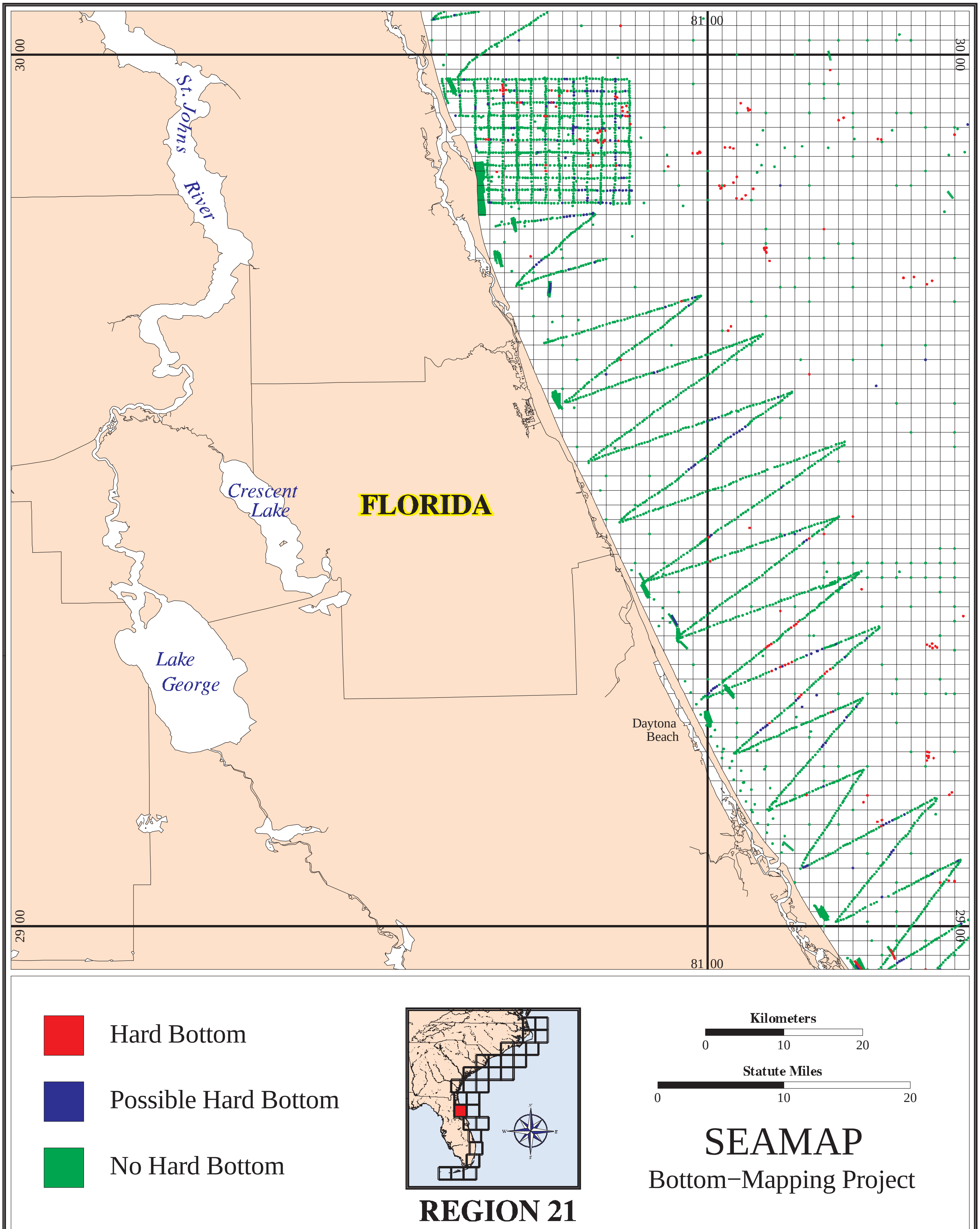


Figure 21. Location of point and line data that provide information on bottom type of the survey area shown.

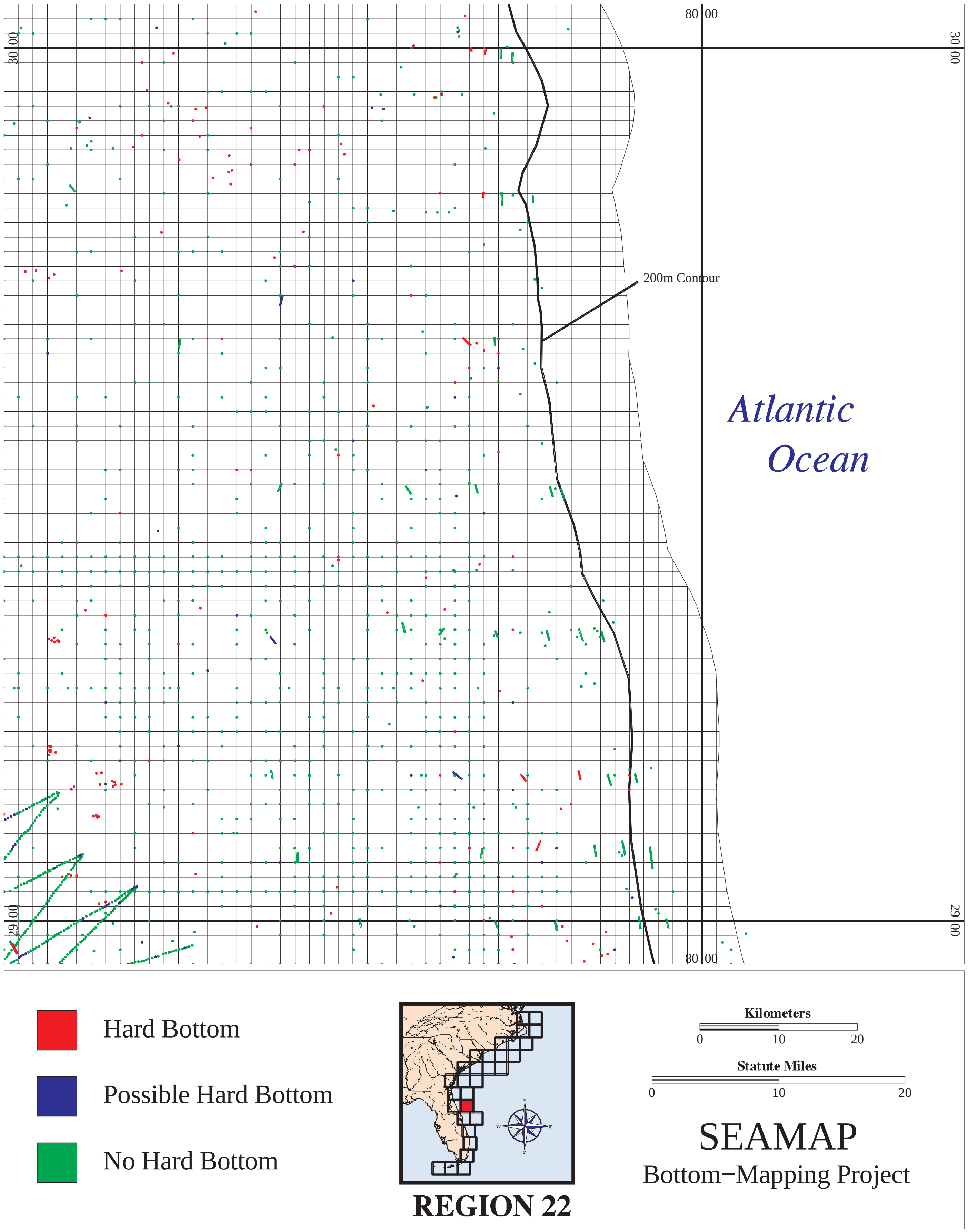


Figure 22. Location of point and line data that provide information on bottom type of the survey area shown.

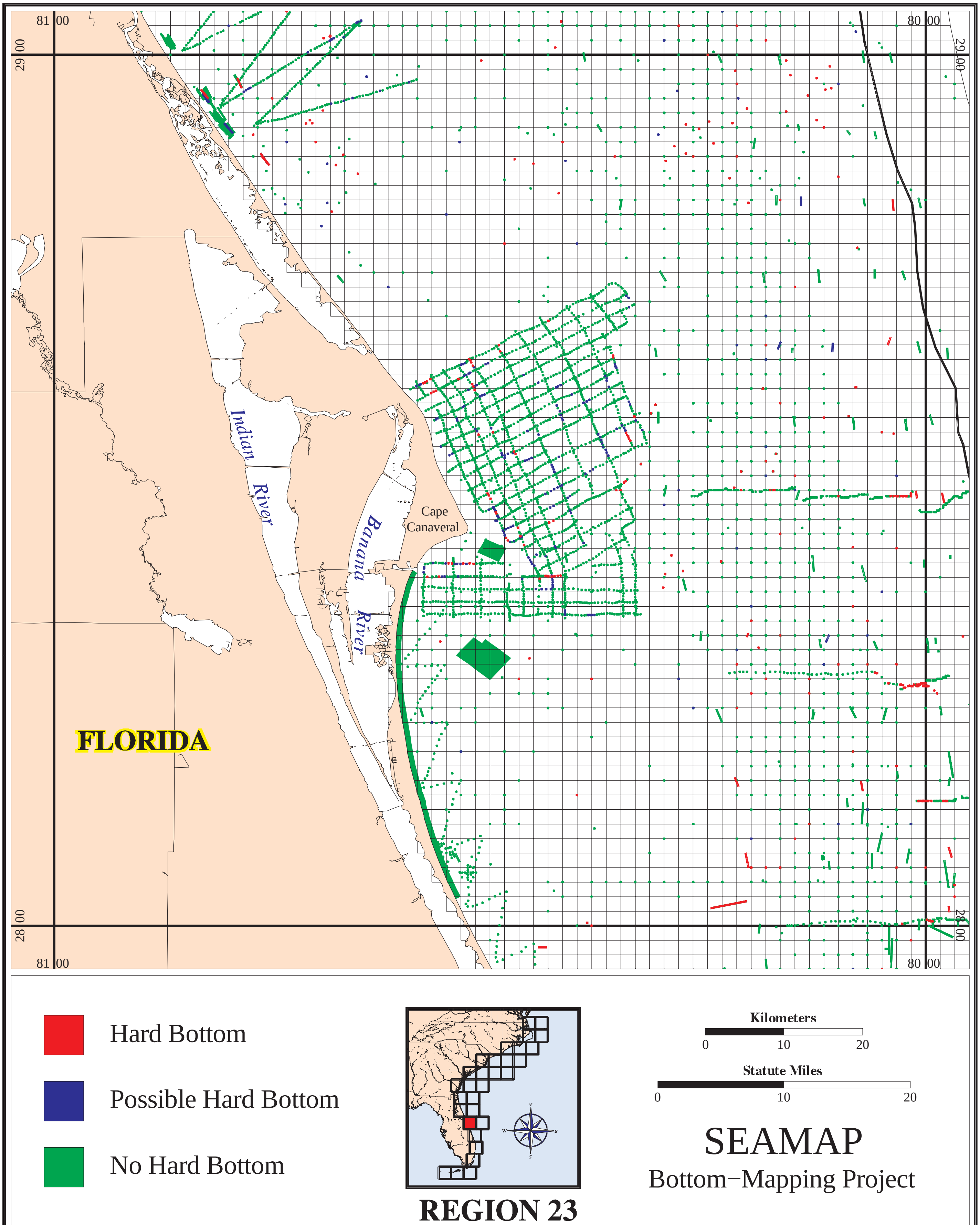


Figure 23. Location of point and line data that provide information on bottom type of the survey area shown.

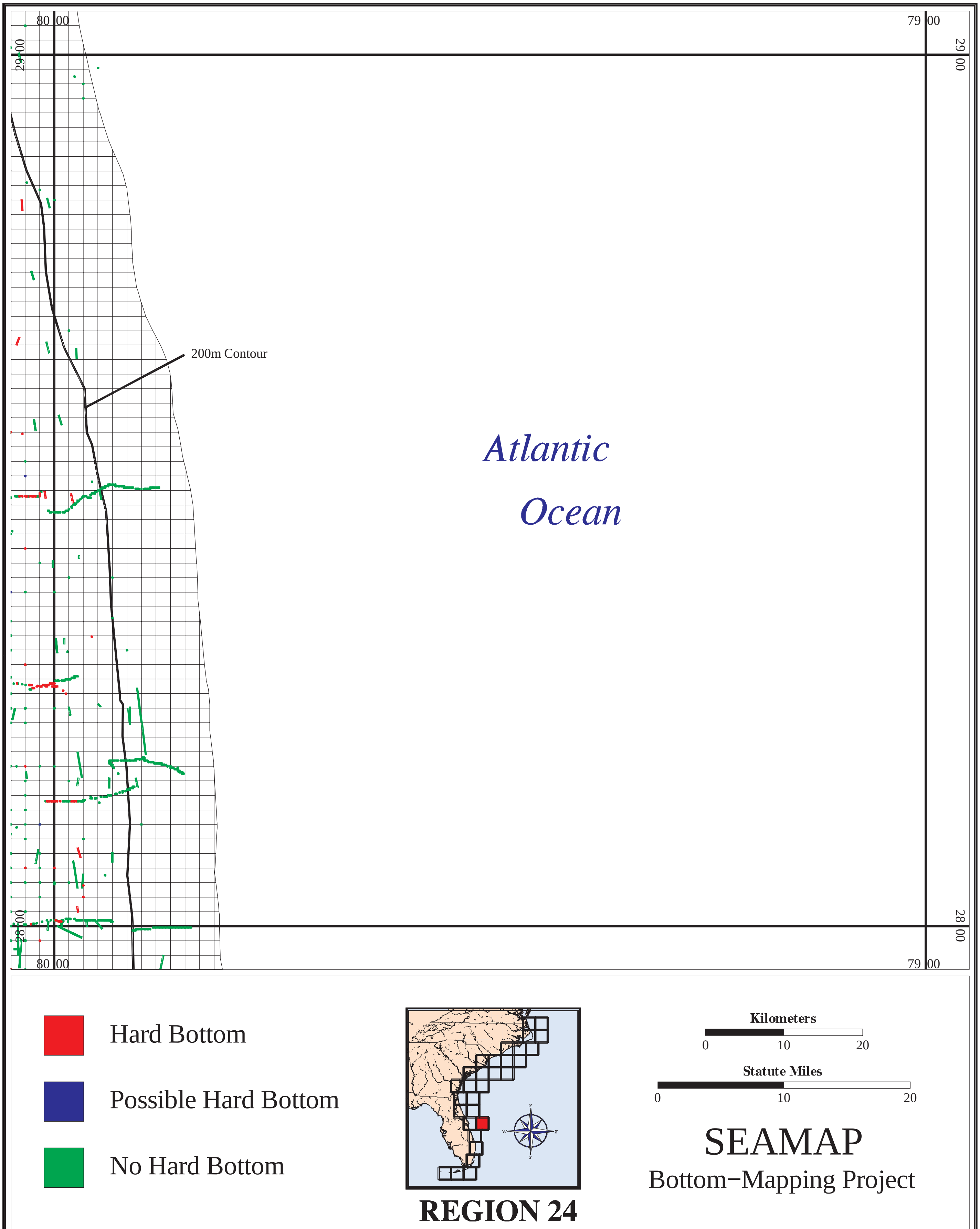


Figure 24. Location of point and line data that provide information on bottom type of the survey area shown.

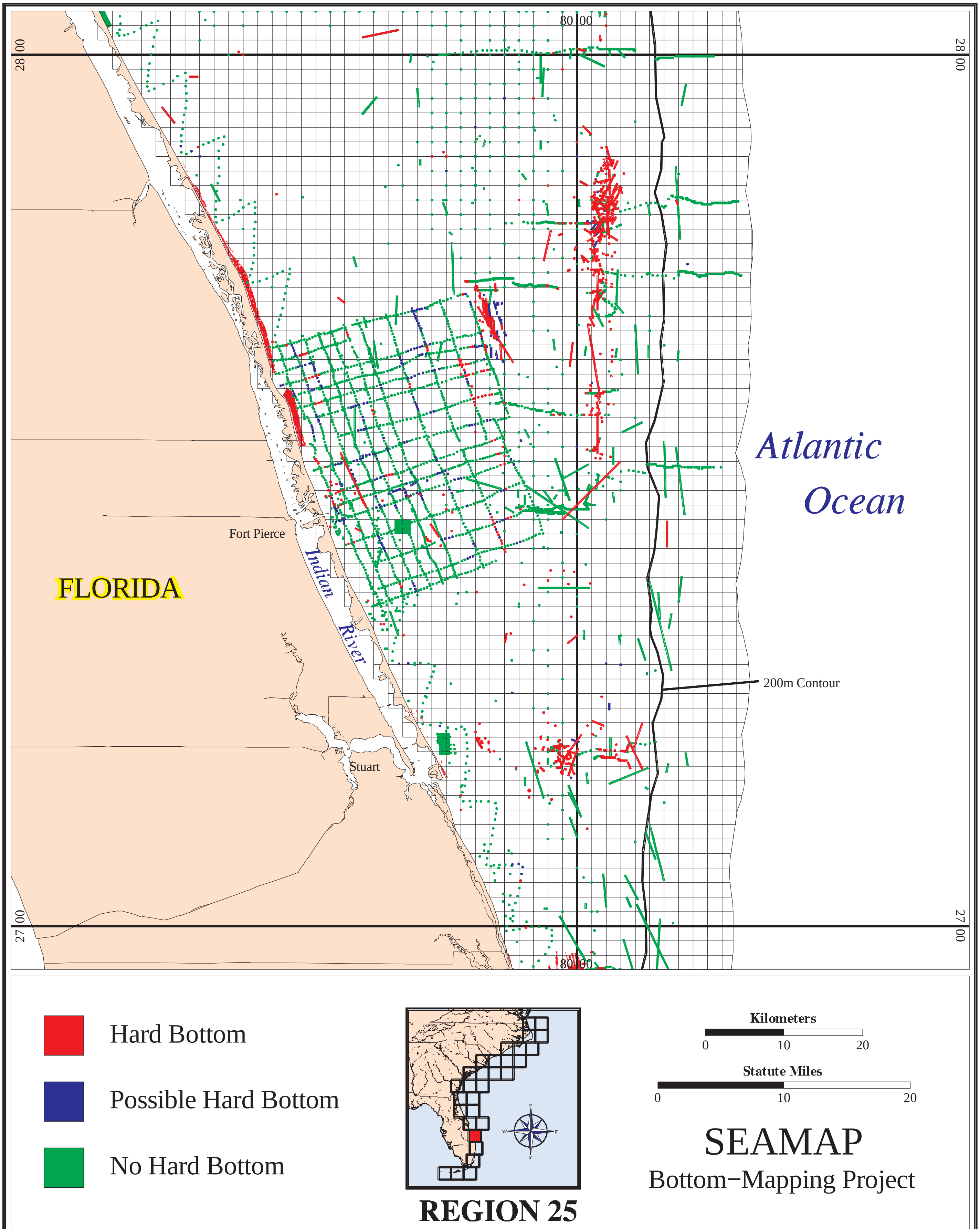


Figure 25. Location of point and line data that provide information on bottom type of the survey area shown.

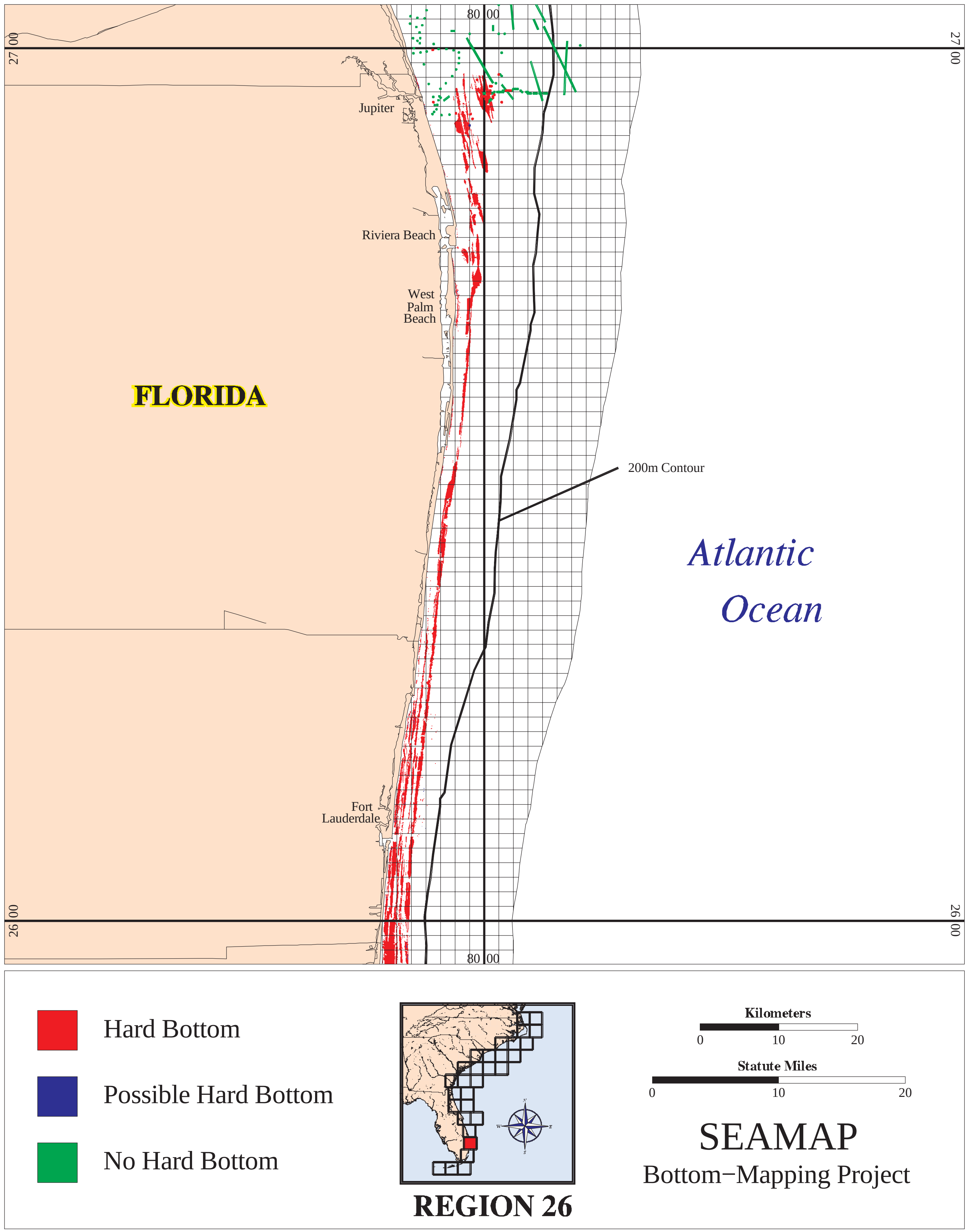


Figure 26. Location of point and line data that provide information on bottom type of the survey area shown.

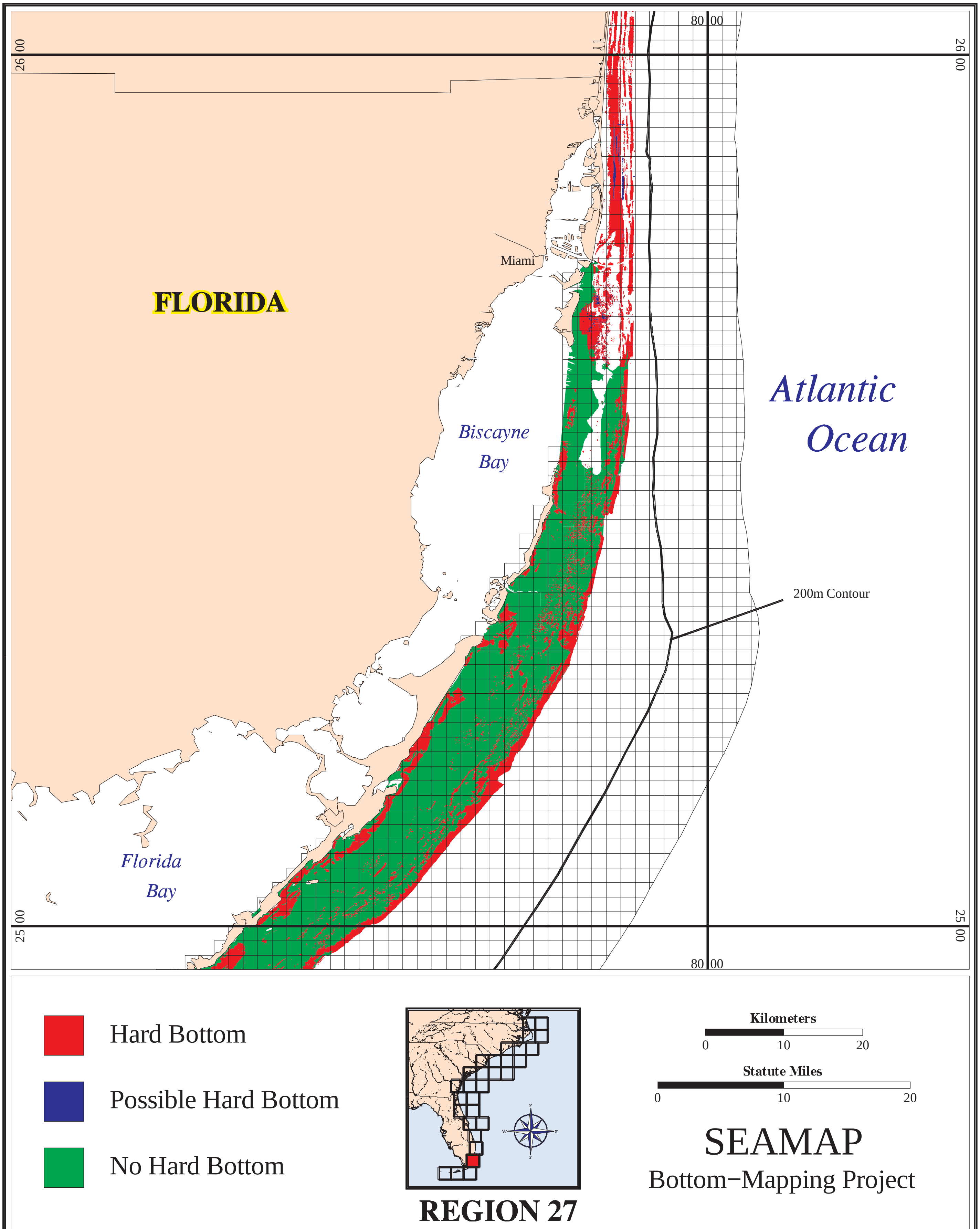
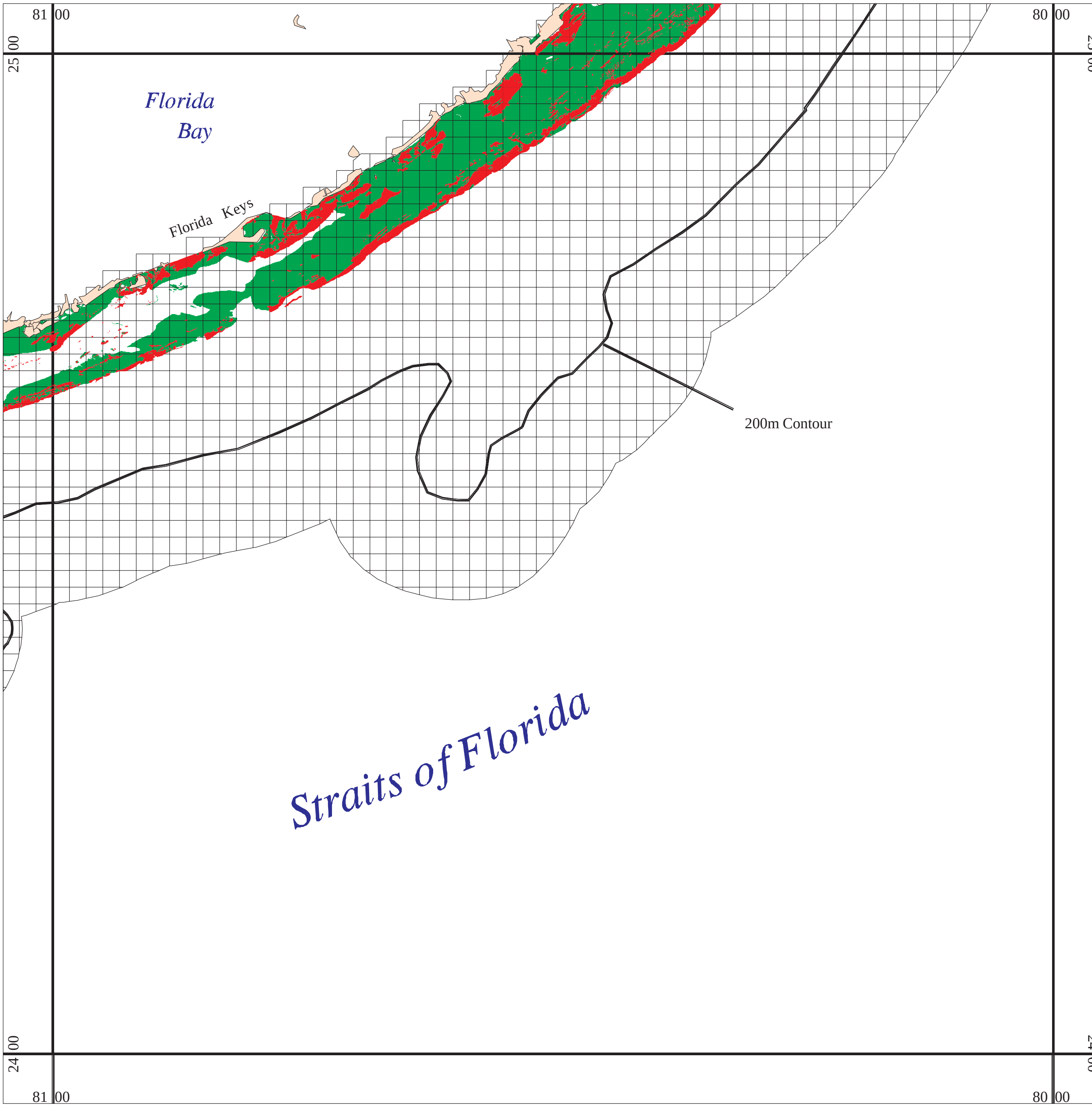


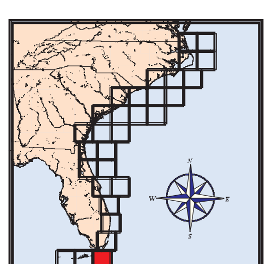
Figure 27. Location of point and line data that provide information on bottom type of the survey area shown.



Hard Bottom

Possible Hard Bottom

No Hard Bottom



REGION 28

Kilometers
0 10 20

Statute Miles
0 10 20

SEAMAP
Bottom−Mapping Project

Figure 28. Location of point and line data that provide information on bottom type of the survey area shown.

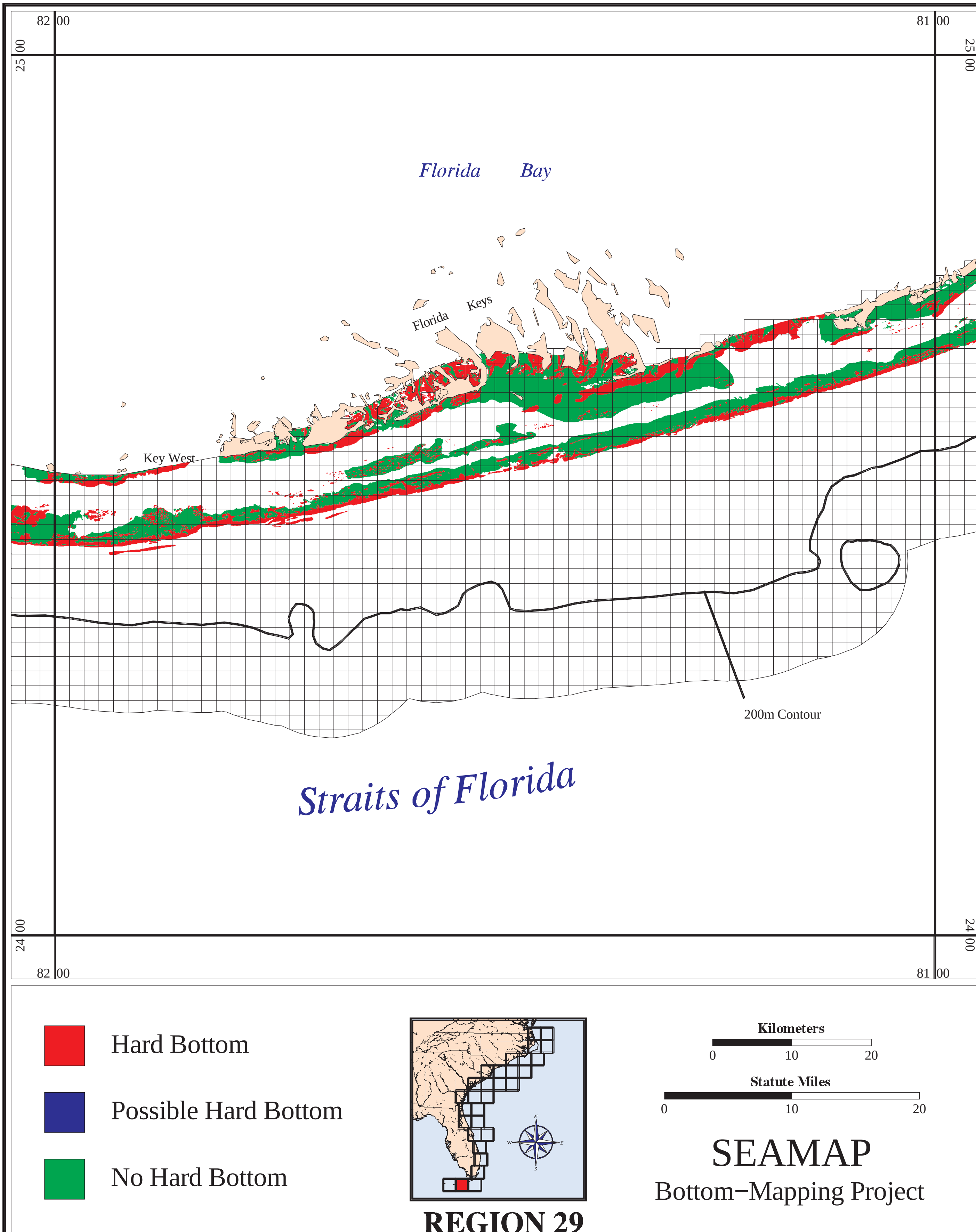
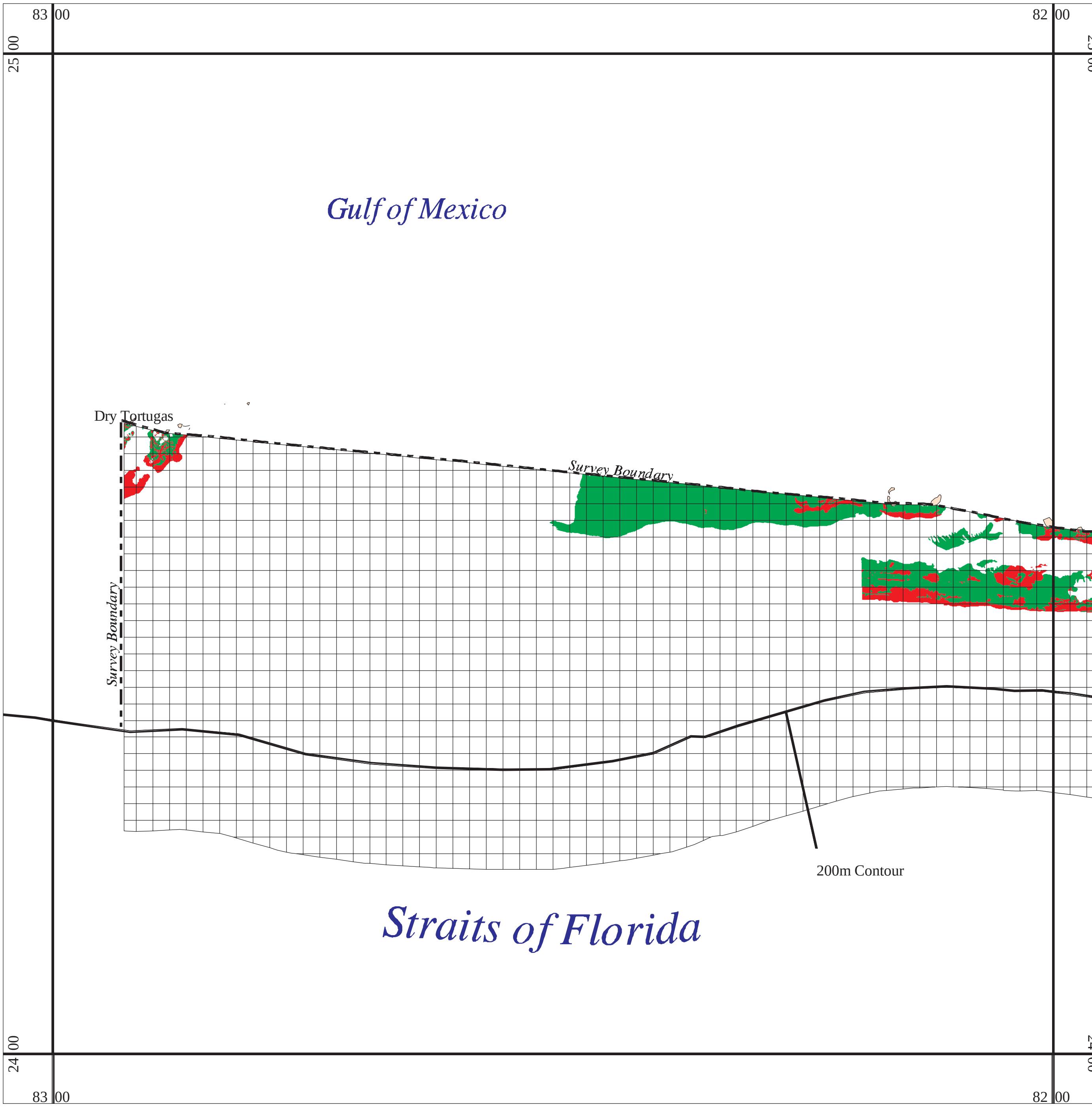


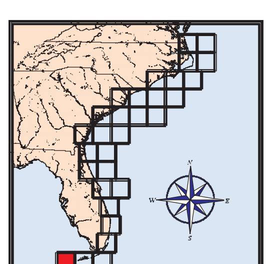
Figure 29. Location of point and line data that provide information on bottom type of the survey area shown.



Hard Bottom

Possible Hard Bottom

No Hard Bottom



REGION 30

Kilometers
0 10 20

Statute Miles
0 10 20

SEAMAP

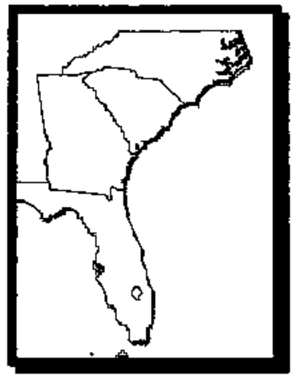
Bottom−Mapping Project

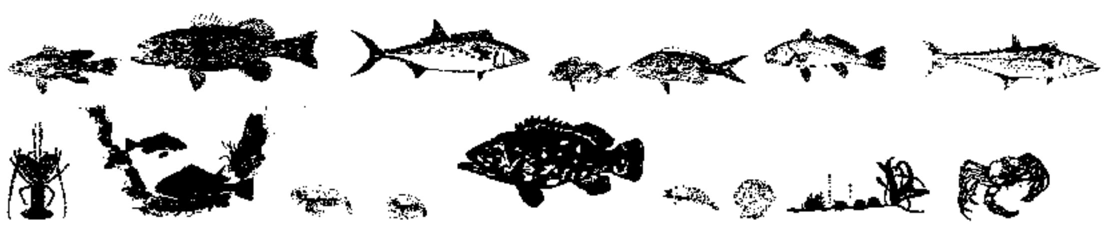
Figure 30. Location of point and line data that provide information on bottom type of the survey area shown.

Appendix F. Estuarine Living Marine Resources Habitat Utilization Maps (Source: NOAA SEA Division 1998).

[Color maps and other Essential Fish Habitat information used in developing the Habitat Plan and Comprehensive Habitat Amendment can be viewed at the SAFMC Habitat Homepage on the Council web site- http://www.safmc.noaa.gov]

Products and Services for the Identification of Essential Fish Habitat in the South Atlantic Region





Submitted to

The South Atlantic Fishery Management Council
by
Strategic Environmental Assessments Division
National Ocean Service

February 4, 1998

This document describes the first suite of products developed by NOAA SEA Division for the South Atlantic Fishery Management Council to identify Essential Fish Habitat (EFH) in the south Atlantic region. For a complete description of the joint NOAA and Council effort, please refer to the Work Plan: Products and Services for the Identification of Essential Fish Habitat in the South Atlantic Region (SEAD/SAFMC 1997), available from NOAA's SEA Division.

PRODUCT OVERVIEW

This document describes the products developed cooperatively by the National Oceanic and Atmospheric Administration's (NOAA's) National Ocean Service (NOS), and the South Atlantic Fishery Management Council (SAFMC) to identify Essential Fish Habitat (EFH) in the Southeastern US. In addition, the SAFMC is cooperatively developing the remainder of the South Atlantic EFH products with state partners, the NMFS - Beaufort Lab, and NOS's Coastal Services Center. The results of the NOS work and other products will be used by the South Atlantic Fishery Management Council to develop the habitat plan that will serve as the source document for the comprehensive habitat amendment in accordance with the EFH requirements of the re-authorized Magnuson-Stevens Fisheries Conservation and Management Act.

Nationwide, NOS is conducting the following four tasks to support EFH work.

Task 1. Conduct EFH needs assessment.
Task 2. Provide Digital Spatial Framework for EFH mapping.
Task 3. Provide existing biological and habitat databases.
Task 4. Accelerate development of ArcView species mapping tool.

The items listed below were developed cooperatively by NOS and the SAFMC to support EFH work in the Southeast.

Item 1. Needs assessment.
Item 2. Work plan.
Item 3. Digital Spatial Framework.
Item 4. Additional Data compilation.
Item 5. ELMR species/estuary tables.
Item 6. Selected estuarine species maps.
Item 7. Digitized atlas maps for offshore species.
Item 8. Estuary/embayment habitat maps.
Item 9. Offshore habitat maps.
Item 10. Regional salinity and relative abundance maps.
Item 11. Species Life history tables

Areas Covered. Information and maps were developed for both estuarine and offshore areas in the U.S. Exclusive Economic Zone. Twenty estuaries in the South Atlantic region were studied (Table 1)

Table 1. South Atlantic estuaries for EFH mapping of species and habitat. Habitat information will be organized by estuarine and coastal drainage areas (SEAD 1997).

Albemarle Sound, NC
Pamlico Sound, NC
Pamlico/Pungo Rivers, NC
Neuse River, NC
Bogue Sound, NC
New River, NC
Cape Fear River, NC
Winyah Bay, SC
North/South Santee River, SC
Charleston Harbor, SC
St. Helena Sound, SC
Broad River, SC
Savannah River, GA
Ossabaw Sound, GA
St. Catherine/Sapelo Sound, GA
Altamaha River, GA
St. Andrew/St. Simon Sound, GA
St. Johns River, FL
Indian River, FL
Biscayne Bay, FL

Table 2. Seven estuarine ELMR species identified as high-priority for South Atlantic Essential Fish Habitat designation (SEAD 1997).

Invertebrates (3):
- Brown shrimp
- Pink shrimp
- White shrimp

Fishes (4):
- Cobia
- Gray snapper
- Spanish mackerel
- Red drum

Table 3. South Atlantic Fishery Management Council managed species, and priorities for EFH product development. The seven ELMR species identified as high-priority for EFH product development (Table 2) are indicated.

FMP/Species	Priority[1]
Shrimp Fishery	
Brown shrimp (ELMR)	X
Pink shrimp (ELMR)	X
Rock shrimp	O
Royal red shrimp	O
Seabob shrimp	O
White shrimp (ELMR)	X
Golden crab	O
Spiny lobster	O
Coastal Migratory Pelagics	
Cero	O
Cobia (ELMR)	X
Dolphin	O
King mackerel	X
Little tunny	O
Spanish mackerel (ELMR)	X
SAtl Snapper- Grouper[2]	
Gray triggerfish	X
Queen triggerfish	O
Ocean triggerfish	O
Yellow jack	O
Blue runner	O
Crevalle jack	O
Bar jack	O
Greater amberjack	X
Lesser amberjack	X
Almaco jack	O
Banded rudderfish	O
Spadefish	O
Black margate	O
Porkfish	O
Margate	O
Tomtate	O
Smallmouth grunt	O
French grunt	O
Spanish grunt	O
Cottonwick	O
Sailors choice	O
White grunt	O
Blue stripe grunt	O
Hogfish	X
Puddingwife	O
Black snapper	O
Queen snapper	O
Mutton snapper	X
Schoolmaster	O
Blackfin snapper	O
Red snapper	X

FMP/Species	Priority[1]
SAtl Snapper-Grouper (Cont.)	
Cubera snapper	O
Gray snapper (ELMR)	X
Mahogany snapper	O
Dog snapper	O
Lane snapper	O
Silk snapper	O
Yellowtail snapper	X
Vermilion snapper	X
Blueline tilefish	O
Golden tilefish	O
Sand tilefish	O
Wreckfish	O
Bank sea bass	O
Rock sea bass	O
Black sea bass	X
Rock hind	O
Graysby	O
Speckled hind	O
Yellowedge grouper	O
Coney	O
Red hind	O
Jewfish	O
Red grouper	O
Misty grouper	O
Warsaw grouper	O
Snowy grouper	O
Nassau grouper	O
Black grouper	O
Yellowmouth grouper	O
Gag	X
Scamp	X
Tiger grouper	O
Yellowfin grouper	O
Sheepshead	O
Grass porgy	O
Jolthead porgy	O
Saucereye porgy	O
Whitebone porgy	O
Knobbed porgy	O
Red porgy	X
Longspine porgy	O
Scup	O
Red Drum	
Red drum (ELMR)	X
Calico Scallops	
Calico scallops	O

[1]Priority codes:
X - high priority; products to be developed under this work plan
O - lower priority; products to be developed in the future

[2]Snapper-Grouper complex will be represented by location of hard-bottom habitat.

STATUS: Listed below are the EFH tasks and their summary descriptions from the work plan. The status and results of the initial products delivered to the Council are described.

1. Needs Assessment. Meetings and telephone calls will be conducted to identify the types of EFH products to be developed for the South Atlantic, and to determine how NOS can support their development.

COMPLETED Oct. 1997

2. Work Plan. A detailed description of products and services, estimated costs, and schedule has been developed. This document is the draft Work Plan, completed November 1997 (SEAD/SAFMC 1997).

COMPLETED Nov. 1997

3. Digital Spatial Framework. This item is the South Atlantic portion of the nation-wide Digital Spatial Framework. It will contain watersheds, river reaches, estuarine and coastal embayment boundaries, estuarine isohalines, and offshore boundaries. It will be used for all species and habitat mapping. Map scales will range between 1:250K for regional maps, 1:80K for state maps, and 1:24K for maps of individual estuaries.

COMPLETED Dec. 1997 (1:24 K & 1:250 K digital shoreline available)

4. Additional Data Compilation. Many of the major fishery-independent data sets for the South Atlantic have already been obtained and processed into a usable form by SEA Division (e.g., state trawl surveys), but some additional data sets will be obtained and processed for the EFH project. The SCDNR Estuarine Survey, Charleston Harbor, Cooper and Santee River studies will be used to update the species distribution data in the ELMR South Atlantic component. In Florida, data will be obtained and processed from the Florida Marine Research Institute Fishery Independent Monitoring Program and data from the University of Miami. In marine waters the MARMAP and SEAMAP data bases will be used to produce GIS coverages of selected species distribution and habitat maps.

COMPLETED Dec. 1997

(**Note:** SCDNR data have not been included in initial products due to time constraints)

5. ELMR Species/Estuary Tables. ELMR species/estuary tables will be updated to contain data for relative abundance (highly abundant, abundant, common, rare, not found, and no data) in each estuary, by five life stages (adult, spawning, egg, larva, and juvenile), and month for three (0-0.5, 0.5-25, >25 ppt) to five (0-0.5, 0.5-5, 5-15, 15-25, and >25 ppt) seasonal salinity zones for the existing ELMR species. Seven existing ELMR species are high-priority species for South Atlantic EFH work (Table 3). For adults and juveniles, these updates will be developed by compiling relevant state resource survey data sets; analyzing the compiled data to determine relative abundance scales (based on density data) and relative abundances by estuary, salinity zone, and month; estimating relative abundances where adequate data are not available; and conducting peer review in each state. For larvae, spawning, and eggs, the existing ELMR information (Nelson et al. 1991) will be revised using literature and peer review, to reflect the three to five seasonal salinity zone spatial framework. The species/estuary tables will be provided in a digital format suitable for developing tables and maps.

The updates to the North Carolina and Georgia ELMR data were reviewed while developing NOAA's Environmental Sensitivity Index database. The ELMR data for South Carolina is from the orginal ELMR data set, as no new estuarine data were avaiable within the EFH timeframes. The ELMR data for Florida were updated for a few selected species based on FMRI and University of Miami data. All salinity data were updated and mapped based on 3 to 5 seasonal salinity zones if applicable.

COMPLETED Jan. 1998 FOR 7 PRIORITY SPECIES

(**Note:** additional 33 ELMR species/life stages draft tables completed and now under review)

6. Selected Estuarine Species Maps. Arc/Info digital and hardcopy maps will be developed by estuary for the seven estuarine species (Table 2). These maps will portray the updated ELMR data organized by estuary by state. They will be developed using the ELMR species/estuary tables from item 5 above.

COMPLETED Jan. 1998

7. Digitized Atlas Maps of the Offshore Distribution of Species. Arc/Info covers will be developed by digitizing existing maps of managed species in NOAA's 1980 *East Coast Data Atlas* (Ray et al. 1980). Four databases from the SCDNR will complement the Atlas maps. The SCDNR species ingress data will be mapped for a few high priority species (e.g., gag grouper, Spanish mackerel). In addition, the SCDNR will provide MARMAP tag, trawl, and trap data. SEA will develop a series of standardized maps for selected managed species that have been tagged or collected.

COMPLETED Jan. 1998 for Atlas species.

(**Note:** SCDNR data have not been included in initial products due to time constraints)

8. Estuary/Embayment Habitat Maps. Mapping estuarine and coastal embayment salinity and wetlands will be addressed. Salinity maps will be developed and printed for each estuary and coastal embayment, and will consist of three to five salinity zones (0-0.5, 0.5-5, 5-15, 15-25, and >25 ppt) for four salinity seasons (low, increasing, high, and decreasing). SEA Division has provided its National Coastal Wetlands Inventory report (Field et al. 1991) to the Council. This report provides acreage data by wetland type found in each estuarine drainage area and associated coastal counties of the South Atlantic. The national responsibility for assessing seagrass distributions in the Southeast Region for the EFH program has been assigned to the NMFS laboratory in Beaufort, North Carolina.

COMPLETED Jan. 1998 for estuarine salinity habitat maps.

9. Offshore Habitat Maps. SEA Division will provide a digital database and maps of salinity and temperature by 10 x 10 min grid cells for seven depth zones for the South Atlantic Region. This robust database was recently completed for SEA under contract by Dynalysis of Princeton. The compiled digital database was derived from hydrographic casts.

COMPLETED Jan. 1998 - salinity, temperature by depth summary data delivered. Final digital data on CD rom available Feb. 20, 1998.

10. Regional Salinity and Relative Abundance Maps. Mapping approaches will be developed to portray salinity and species relative abundances for estuaries and coastal embayments on state and/or regional maps. Depending on data availability, the maps will be produced at various scales: 1:24K, 1:80K, and 1:250K. For species relative abundances, these maps will be developed only for juveniles of estuarine species (Table 2) (Nelson et al. 1991). The species maps will show the highest juvenile relative abundance in any salinity zone by season for each estuary.

COMPLETED Jan. 1998

11. Life History Tables. Tabular descriptions of habitat associations will be prepared by life stage for each of the seven high-priority species (Table 2). SEA will have primary responsibility for this item, and SAFMC in cooperation with the NMFS-Beaufort Lab and the University of Miami will provide review of the information. These tables will show how each species uses the environment, and will provide the information needed to assess the relative importance of different habitat types. The three tables developed are: 1) Biological Attributes; 2) Habitat Associations; and 3) Reproduction. For the seven ELMR species designated as high-priority EFH (Table 3), these are based on tables developed for these species in the Gulf of Mexico, with some revisions (Pattillo et al. 1997).

COMPLETED Jan. 1998

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Appendix G. Sources of Energy and Predators and Associations of Corals (Source: GMFMC and SAFMC 1982).

SOURCES OF ENERGY IN CORALS

1.0 Scleractinia

1.1 Light

Fundamental to the flow of energy through the reef ecosystem is the symbiotic relationship with zooxanthellae characteristic of all shallow-water hermatypic corals. These algae are capable of producing more oxygen that is consumed by the algae and coral host combined (Yonge, et al., 1932; Odum and Odum, 1955; Kanwisher and Wainwright, 1967). But more important to corals, and the communities which they form, is the carbon fixed during the process of photosynthesis. Evidence that zooxanthellae can release photosynthetically fixed organic compounds to their hosts is well documented, as is the effect of zooxanthellae on nutrient recycling and enhancement of calcification (reviewed by Muscatine, 1973). The indispensability of the symbiosis, however, is one of the sources of controversy noted above.

While it appears that supplemental sources of nutrition are taken in addition to the amount supplied by zooxanthellae, the overall question of indispensability of such exogenous food to the existence of scleractinians is still debated. Yonge and Nicholls (1931) concluded that scleractinians can live for several months in complete darkness as long as food is provided. Conversely, Kawaguti (1964) observed that four genera of Pacific corals kept for more than 15 months in the light but without food appeared healthy and increased their numbers of polyps (note: although zooplankton were withheld as a food source, bacteria may have been present and consumed in Kawaguti's work]. Franzisket (1969; 1970) showed that Hawaiian corals performed in the same fashion and noted that corals kept in the dark for two months exhibited symptoms of atrophy. Connell (in Muscatine, 1973) excluded light from a section of the Great Barrier Reef using an opaque dome without affecting ambient currents and food supply. During three and one-half months in the shade, corals expelled their zooxanthellae and all colonies died. Control colonies under transparent domes survived. Lewis (1974) found that planulae of *Favia fragum* could not survive more than three months if not provided with both food (*Artemia*) and light (12h:12h, light:dark photoperiod).

1.2 Zooplankton

Opinions differ on the adequacy of zooplankton in satisfying the food requirements of coral and other benthic invertebrates on reefs (Lewis, 1977). Johannes (1974) has argued that the biomass of zooplankton over coral reefs is insufficient to supply energy needs although it may be important as a source of essential nutrients. In this view reef corals are "autotrophic" and depend extensively upon energy supplied by their zooxanthellae.

The early papers of Sargent and Austin (1949, 1954) indicated that the zooplankton biomass of surrounding waters at Rongelap in the Pacific were too small to support all the benthic invertebrates on the reef. Johannes, et al. (1970) calculated that zooplankton on a Bermuda reef were not sufficiently abundant to support the energy needs of the corals present as indicated by their rates of respiration. Johannes and Tepley (1974) found that the zooplankton biomass present could supply only 20 percent of the daily requirements for respiration in the Pacific coral, Porites lobata, and Porter (1974) estimated that during a two-hour feeding period at sunset, the small star coral (Montastraea annularis) could capture only between 0.2 percent and 11 percent of the total daily food required for energy used in respiration.

Although the supply of oceanic zooplankton appears to be inadequate to support reef secondary production, reefs undoubtedly produce their own zooplankton (Porter, et al., 1977;

Porter and Porter, 1977). Sale, McWilliam and Anderson (1976) found that there was a resident plankton community at Heron Island, Australia, which was more abundant and richer in species than the offshore community.

They suggested that this plankton community was retained on the reef by local circulation or by behavioral responses and was a potential source of food for the sessile reef organisms. This aspect of reef zooplankton ecology may be of quantitative significance when its impact is more fully evaluated.

The view that reef corals are not wholly "autotrophic" in their nutrition has been summarized by Goreau, et al. (1971). They regard corals as specialized carnivores without structural modifications for an autotrophic existence depending primarily upon zooplankton for their food. The work of Coles (1969) supports this view. He found that reef corals were able to ingest more than sufficient numbers of brine shrimp to cover their energy expenditure in respiration with energy left for storage and growth. Furthermore, Goreau, et al. (1971) considered that reef corals may act as unspecialized detritus feeders upon a wide range of organic matter or may even utilize dissolved or colloidal organic matter. Lewis and Price (1975) discussed suspension feeding strategies in Atlantic reef corals.

The general conclusions regarding the importance of zooplankton to support reef production indicate that while there is a substantial removal of plankton by benthic organisms, zooplankton biomass from oceanic water flowing over reefs is too low even to supply the daily energy requirements of the corals present. Additional food must be supplied by resident plankton and other external sources.

1.3 Bacteria

It has been pointed out by DiSalvo (1973) and Sorokin (1973c) that there are very few quantitative data on the role of microbial populations in the productivity of coral reefs. One cannot conceive of such complex systems without micro-organisms functioning as organic decomposers, nitrogen fixers and in biogeochemical processes. Large numbers of bacteria on reef surfaces were reported by Odum and Odum (1955) and bacteria have been implicated in the high respiration rates of coral communities noted by Sargent and Austin (1949). The work of DiSalvo (1973, 1974) has been concerned with the diversity and abundance of bacteria on coral reefs while Sorokin (1973a, b; 1974) has emphasized the role of bacteria in secondary production in reef organisms, i.e., in transforming detritus to microbial biomass.

DiSalvo (1973, 1974) suggested that the finely divided sediments in reef spaces and cavities functioned as "regenerative surfaces" and that the rapid rates of oxygen consumption occurring in these cavities indicated rapid organic decomposition. Plate count of sediments at the bases of coral heads showed densities of 10^7 to 10^8 bacteria/g dry matter and among them were forms capable of digesting chitin and other organic compounds, reducing nitrates and digesting gelatin and agar.

The bacteria In reef sediments and in internal cavities are considered to have a role in nutrient regeneration (DiSalvo, 1974). Pools of dissolved nitrogen and amino nitrogen were found in sediments and in dead coral heads. Quantitative estimates gave value of 33 g-atoms of phosphorus and 30 moles of amino nitrogen/m^2 dead coral surfaces. His results show that bacteria may thus be important in cycling of nutrients in the reef system.

Sorokin (1973a, b, c; 1974) has stressed that the biomass of bacteria in reef sediments and in shallow coastal water corresponds with their importance in processes of mineralization and nutrient cycling on reefs. They are also considered important as food for secondary consumers. Results of feeding experiments (Sorokin, 1973a) showed that six species of reef corals could consume bacterioplankton. Other forms which were able to filter bacterioplankton from water were the tunicate Ascidia nigra, the sponge Toxadocea violacea, and the oyster *Crassostrea gigas*. Sorokin (1973a) regarded the bacterioplankton as being a high-quality food adequate in amount to supply a large percentage of the total energy needs of suspension feeders on the reef. A general scheme illustrating trophic relationships has been attempted by Sorokin (1973c). This study emphasized the importance of micro-organisms and the process of decomposition. It also suggested a shortage of phytoplankton as primary producers in the reef ecosystem and hence the minor importance of the phytoplankton/zooplankton trophic relationship.

1.4 Detritus

The quantitative significance of detritus as food for coral and other benthic organisms on the reef has not been evaluated. However, there Is a good deal of evidence to Indicate that suspended detritus is abundant in the water flowing over reefs.

Glynn (1973) found that dry biomass of suspended matter passing over a reef in Puerto Rico exceeded the dry biomass of net plankton by an order of magnitude or more. Evidence from examination of Millipore filters, plankton-pigment concentrations and productivity measurements indicated that the suspended matter was primarily detritus. The flux of suspended matter amounted to between 20 to 40g dry wt/m^2/day and there was no evidence of depletion of detrital material within the water mass flowing over the reef. In fact, there are a number of studies which show an increase in detritus available to suspension feeders after water has crossed a reef (Lewis, 1977).

Atlantic reef corals have been shown by Lewis and Price (1975, 1976) to behave as suspension feeders. By means of nets and strands of mucus they are able to capture a wide range of particulate material and larger plankton with their tentacles. Thus, when the biomass of zooplankton is too low to support the nutritional needs of corals (Johannes, 1974; Porter, 1974), other sources of food may be available to them. While those species with long active tentacles obtain food by means of tentacle capture and by mucus filaments, species with short tentacles such as the *Agariciidae* appear to feed entirely by suspension feeding. Lewis (1976, 1977) has shown experimentally that some Atlantic reef corals are able to clear the surrounding water of particulate material in amounts just enough to supply their daily maintenance requirements.

Some interest has been shown in the potential nutrient significance of the mucus that is produced in copious amounts by most reef corals. Johannes (1967) observed mucus released by corals and the subsequent formation of aggregates of mucus and entrapped particles. Marshall (1972) found considerable quantities of zooxanthellae in mucus discharged from coral heads. Suspended mucus strings were examined by Coles and Strathmann (1973) and found to have significantly higher organic carbon and nitrogen contents than suspended particles in the surrounding water. Benson and Muscatine (1974) found that the mucus from a variety of corals contained wax esters and they also observed that reef fish fed on the coral mucus. This is apparently one route by which energy-rich products of coral metabolism are transferred to higher trophic levels.

This raises the possibility of a detritus-based food chain such as exists in mangrove swamps (Odum and Heald, 1975). Feeding strategies for particulate food sources other than zooplankton are different from strategies in which zooplankton is the main food source (Jorgensen, 1966). Filter feeding, a type of suspension feeding, is one way of capturing particulate matter and Crisp (1975) has commented on the fact that suspension feeders require less energy for feeding than do zooplankton feeders. The proportion of ciliary-mucoid suspension feeders (including corals) and filter feeders on reefs has been estimated by Glynn (in Lewis, 1977). Glynn also found that the total biomass of the macrobiota at Panama was 441 g protein/m^2. Of this, 285.5 g consisted of corals and 14.6 g of other suspension feeders. If, as Crisp (1975) suggests, suspension feeders are intrinsically efficient converters of energy, then such a feeding strategy based on suspended detritus is particularly suitable for zooplankton-poor tropical waters. With this view in mind Lewis (1977) outlined trophic relationships within a coral reef community, incorporating detritus as a food source.

1.5 Dissolved Organics

As yet there is no conclusive proof that corals use dissolved organic matter as food. Stephens and Schinske (1961) and Stephen (1962, 1968) discussed the problems that must be overcome in determining the extent of net utilization of a particular dissolved organic substance. As stated by Muscatine (1973), experiments have yet to be conducted with appropriate concentrations. Release as well as uptake of the material has not been determined, so that net gain, if any, is unknown. Finally, there is no documentation that absorbed organic material participates in the metabolism of the host.

2.0 Alcyonaria

Alcyonarian corals have been considered carnivorous along with the rest of the coelenterates (Hyman, 1940). There is evidence that at least in some species, this statement is valid. Both Bayer (1956) and Grigg (1970) reported that Leptogorgia virgulata and Muricea spp., respectively, prey extensively on shelled bivalve larvae. Grigg found through hypochlorite digests of polyps that this item constituted 90 percent of the diet of both *M. californica* and *M. fruticosa* but concluded that only one percent of metabolic needs were met in this fashion. Experimental work showed that microzooplankton and particulate organic matter were also consumed and probably represented the bulk of the diet of these species.

On the other hand, Pratt (1906) described the morphological "reduction" of the digestive areas in the alcyonacean octocorals Lobophytum, Sacrophyton, Alcyonium and Sclerophytum, correlating this in each species with an increase in numbers of zooxanthellae. Pratt conjectured that the needs of growing colonies of Sclerophytum could not be satisfied by the small amount of zooplankton actually captured and that nutrition of these species was supported by zooxanthellae. Gohar (1940, 1948) added members of the family Xeniidae to the species observed by Pratt as having a rich flora of zooxanthellae and also noted that xeniids lacked digestive zones of the mesenterial filaments. These animals were never observed to feed in the laboratory or in the field or to trap and paralyze zooplankters brought into contact with the surface of the animal. Since pulsating colonies ceased to move when placed in the dark but resumed movement when returned to the light, Gohar conjectured that "combustible energy-giving material" is normally supplied by zooxanthellae, rather than zooplankton. Wainwright (1967) reported the gorgonia expanded during the day when plankton was scarce but remained contracted at night showing little feeding activity when zooplankton was most abundant. This was considered to be an adaptation favoring photosynthesis by zooxanthellae during the day, implying a nutritional role for the algae. Similar to the case with scleractinian corals, Kinzie (1970, 1973) has shown that 73 percent of symbiotic gorgonians died after being placed in a light-tight aquarium with running seawater for 83 days. A non-symbiotic species (Diodogorgia) was alive and apparently healthy throughout the experiment. Bayer (1954) found evidence that the gorgonians *Plexaura flexuosa* and *Psammogorgia antipathes*, which have especially abundant zooxanthellae, have lost most, if not all of their nematocysts. In addition, they seem to show a reduction of gastrodermal gland cells, as in the case of the tropical alcynonaceans.

The data here are no less equivocal than in the stony corals. The arguments concerning the daylight expansion of the polyps in so-called "hermatypic gorgonians" (Wainwright, 1967) is countered by Theodor (1977) who found that members of the genus *Pseudopterogorgia* tend to be expanded at night and contracted during the day. The arguments for lack of feeding are often made with the assumption that only animal food is taken. However, Wilson (1884) and Roushdy and Hansen (1961) have both found evidence that octocorals are capable of feeding on phytoplankton. Diatom or detritus capture does not require nematocysts. This correlates well with electron-microscopic observations by Mariscal and Bigger (1977) who found that even asymbiotic octocorals have few nematocysts and no gastrodermal microvilli. In any case, no direct experimental approach has been employed in attempting to define the nutritional requirements in symbiotic *Octocorallia.*

3.0 Antipatharia

Inspection of the tentacular apparatus of *Cirripathes* or any other antipatharian in the study area will reveal large numbers of nematocyst batteries. Thus it is not surprising that Grigg (1965) was able to experimentally feed polyps of *Antipathes grandis* from Hawaii with various zooplankters.

However, Dantan (1921) reported that polyps of a *Leiopathes* contained large numbers of diatoms, often broken and apparently in a state of digestion, along with algal fragments. Although the data do not warrant antipatharians being considered herbivores, omnivorism cannot be ruled out, particularly in view of the recent studies by Lewis (1978) who notes that antipatharians are capable of feeding on fine suspended particulates by means of mucous strands and nets.

PREDATORS AND ASSOCIATIONS OF CORALS

1.0 Scleractinian Predators and Their Effects

1.1 Fishes

Studies by Robertson (1970), Salvini-Plawen (1972) and Patton (1973, have shown that the number of animals specialized to feed on the Scleractinia has been underestimated (Wells, 1957; Yonge, 1963). Some of the observed effects also go far beyond the negligible damage claimed by Yonge (1968). Since many of the known coral predators have been described only relatively recently, it is likely that continued study will add to our knowledge of this feeding habit. The following review will no doubt soon be supplemented by now discoveries.

In Randall's (1967) survey of the food habits of reef fishes small volumes of coral were found in the alimentary tracts of four species: *Scarus coelestinus* Cuvier and Valenciennes and *Sparisoma aurofrenatum* (Cuvier and Valenciennes) (Scaridae), *Chaetodipterus faber* (Broussonet) (Ephippidae), and *Microspathodon chrysurus* (Cuvier and Valenciennes) (Pomacentridae). The only specific coral identifi-noted was that of Oculina diffusa, a fragment consumed by C. faber. In some localities coral consumption by fishes appears greater than indicated by Randall's (1967) study. For example, in Panama (Bakus, 1969) and Bermuda (Gygi, 1969), the rasping of live corals by scarids is commonplace. Scarus guacamaia Cuvier rasps *Siderastrea siderea* with fair regularity along much of the north coast of Panama. The summits of large hemispherical colonies are commonly scraped to depths of 2-3 mm; such feeding is often performed by relatively small schools of S. guacamaia (five to 15 individuals) which appear to range over extensive areas. *Microspathodon chrysurus* though predominantly herbivorous on epontic diatoms and filamentous algae, frequently feeds on *S. siderea* as well. Juveniles and adults of this fish bite the surface of the corallum vigorously, removing primarily the extended polyps. Corals preyed upon in this manner can be distinguished by the characteristic circular lesions left behind (Glynn, 1973). Juveniles and adults of Microspathodon commonly feed on the hydrocoral Millepora in Florida (Ciardelli, 1967), adults nest on it, and both juveniles and adults attack *Millepora complanata* in Panama. Other corals observed in Panama with deep rasping marks, similar to those produced by S. guacamaia, are *Montastraea annularis, Acropora palmata, A. cervicornis, Agaricia agaricites,* and *Porites furcata.* Mixed schools of *Scarus croicensis, Acanthurus chirurgus* (Bloch), *Chaetodon capistratus* Linnaeus, and other species occasionally feed on A. cervicornis. Such incidental feeding forays can lead to coral rasping by the scarid and selective removal of polyps by the latter two species (Glynn, 1973). On one occasion a scarid, possibly *Scarus vetula* Bloch and Schneider, was observed to bite off a terminal 2-cm tip of *Porites porites*. On same areas of the reef, *Porites* colonies commonly have many of their terminal branches broken off. This feeding habit was reported long ago in Haiti by Beebe (1928), who observed that scarids (most likely *S. guacamaia*) break off and ingest the terminal branches of corals. The effects of fish predators on *Porites astreoides* have not been reported in the Caribbean, but according to Gygi (1969) *Sparisoma viride* (Bonnaterre) commonly feeds on this coral at Bermuda, removing up to 200 mg with each bite. In addition to direct browsing, Glynn (1974) believes that indirect activity causes detachment of several coral species, notably *Siderastrea radians* and *Favia fragum.* This may be the cause of rounded, mobile coralliths often seen in lagoonal patch reef specimens.

As Yonge (1963) suggested, nematocysts must certainly deter some fishes from feeding on corals. That *Microspathodon* regularly consumes large amounts of the hydrocoral *Millepora,* however, indicates that certain fish species can cope with this potent means of defense. Possibly another effective deterrent that would tend to discourage fish predators is the presence of sharply projecting septa, often with serrated edges, on the corallites of *Mussa, Scolymia, Isophyllastrea, Mycetophyllia* and *Isophyllia.* It may therefore be significant that the coral species most often consumed by large fishes have relatively smooth and unobtrusive surfaces. Reese (1977) has studied the relationship between feeding behavior, substrate type, and coral morphology in the Chaetodontidae fishes of three Pacific areas.

1.2 Invertebrates

Six invertebrate coral predators have been discovered in the Caribbean region since 1962. These include the amphinomid polychaete *Hermodice carunculata* (Pallas), the majid decapod *Mithrax* (Mithraculus) *sculptus* (Lamarck), the gastropod mollusks *Coralliophila abbreviata* Lamarck, C. caribea

Abbott, and *Calliostoma javanicum* Lamarck, and the echinoid *Diadema antillarum* Philippi. *Hermodice* was first described by Marsden (1962, 1963) to be a habitual predator of *Porites porites* and *P. asteroides*. Subsequent work by Ott and Lewis (1972) and Shinn (1976) showed that several other coral species are preyed upon (although *Hermodice* was found most often on the colonial anemone Palythoa). Ebbs (1966) noted that coral browsing may occur in all Atlantic members of the Amphinomidae. Both P. furcata and P. porites are attacked by Mithrax, which severs the polyps with its chelae. This feeding habit, first observed in Puerto Rico (Glynn, 1962), was also seen in Panama, where Mithrax commonly preyed upon ramose species of Porites (Glynn, 1973). Ward (1965) believed that the mode of feeding of *Coralliophila abbreviata,* involving the dissolution and ingestion of soft tissues, can lead to the death of polyps and eventual destruction of the colony of *Montastraea annularis* (small star coral). On the other hand, Robertson (1970) maintains that this species is a well-adapted parasite, causing little damage to polyps. This conclusion is challenged by Ott and Lewis (1972) who documented some damage by C. abbreviate to several different corals, especially *M. annularis.* Miller in Glynn (1973) found *Coralliophila abbreviate* and *C. caribea* associated with 14 hermatypes at Discovery Bay, Jamaica, and suggested that the gastropods may feed on plankton ingested by the corals. *Calliostoma javanicum* feeds on *Mussa angulosa* in the laboratory and on *Agaricia spp.* (lettuce coral) in the laboratory and field (Lang, 1970), with a preference for the latter group. Small circular lesions are produced, but it is not yet known which of the soft parts of the coral are ' consumed. *Diadema antillarum* preys on coral at night (Bak and van Eys, 1975) at the same time that it preys on Thalassia producing the well known halo effect around patch reefs. Like the scarids (parrot fish), Diadema inflict substantial mechanical damage to the corallum, but their impact is greater due to their slow movement and continual feeding pattern.

From the foregoing, it is obvious that several reef animals are adapted to feed on the Scleractinia. Though the actual quantities of coral consumed appear to be slight, there is good evidence that the damaged areas of the corallum that do not undergo regeneration are invaded by other organisms which may overgrow and eventually smother the entire colony. Continuing observations of the rasped surfaces of *Siderastrea siderea* have shown that, while repair normally takes place rapidly (two to three months), some areas suffer irreparable damage. The latter are often invaded initially by a variety of filamentous algae, including members of the Cyanophyceae, Chlorophyceae, Rhodophyceae, and Phaeophyceae, and epontic diatom growths. Large colonies of Montastraea annularis with their surfaces in various stages of invasion provide a concrete example of the course of destruction. Scarid nicks often contain mixed growths of filamentous algae and these can be traced through a successional continuum to surfaces highly eroded by boring clionid sponges (Glynn, 1973). Another type of algal invasion is induced by continuous attack on *Acropora cervicornis* (staghorn coral) and *Montastraea annularis* (small star coral) by the threespot damselfish, *Eupomacentrus planifrons*. As described by Kaufman (1977), the fish's continual attack on living and dead corals prevents regeneration of coral tissue and allows "algal lawns" to become established. Feddern (1979, personal communication) claims these "lawns" are cultivated year-round. These "lawns" in turn serve as a food source and egg cultivation space for the fish. Ott and Lewis (1972) find that the blue-green alga *Lyngbia sp.* invades regions of coralla which have been injured due to predation by the polychaete Hermodice (see Antonius, 1975). There is no evidence that the algae can expand past the site of injury; however, Antonius (1973, 1976) has described a blue-green alga, *Oscillatoria submembranacea*, which appears to be capable of rapid coenenchymal lysis, and spreading once a foothold on a corallum is gained.

2.0 Other Scleractinian Associations

There is a good deal of evidence from the field indicating that competition for living space is acute among the long-lived benthic populations of coral reefs. It appears that many groups of reef organisms have evolved body morphologies that tend to maximize the area of exposure to light and currents. Certain minimum levels of exposure are necessary for both photosynthetic and suspension feeding forms. Therefore, it is not surprising to find that a variety of strategies are employed to ensure the acquisition of space and access to the surrounding medium, and a subsequent hold on this resource once obtained.

2.1 Competition Among Scleractinian Species

To the rapid and spreading mode of growth employed by many corals as a means of reducing competition for space and light, must now be added the newly discovered adaptation of extra-coelenteric feeding (Lang, 1973). She has found that certain species will extend their mesenterial filaments and digest any living coral tissue from a colony of another species which they can touch, up to about 2 cm away. The species can be arranged in an aggressive hierarchy, each species attacking all others below it in the hierarchy and being attacked by all ranked higher. In general, the massive species of the families Mussidae, Meandrinidae, and Faviidae rank higher than those of other families. This agrees with Connell's (1973) findings that slow-growing massive colonies are not overgrown by the faster growing branching ones, and that in some instances, foliaceous species may inhibit massive ones.

While such competitive interactions can be observed among adult corals, they probably also play an important role among young growing forms. An active feeder, for example, would preclude the establishment of subordinate species within its feeding radius. Competitive exclusion by means of predatory interactions occurs most noticeably in the densely populated zones. *Montastraea annularis*, one of the principal reef-building species, is moderately active in extracoelenteric feeding and perhaps owes its presence in the buttress zone and along the seaward slope in part to its ability to compete successfully with more rapidly growing ramose and foliaceous forms (Glynn, 1973).

2.2 Boring Organisms

The importance of boring organisms in corals has been noted in reviews by Otter (1937), Yonge (1963), Goreau and Hartman (1963) and Lewis (1977). A wide variety of organisms including sponges, sipunculid and polychaete worms, molluscs, crustacea and algae are able to bore into corals, by either mechanical or chemical means (or both). Sponges are perhaps the most widespread borers on coral reefs. Rutzler (1971) has found that members of the adociid genus Siphonodictyon can excavate both into the living and nonliving portions of colonies of several coral genera. Pre-existing damage to the coral is apparently not a prerequisite for attack. Glynn (1973) noted that when a section of *Cliona sp.* was transplanted from an infected *Siderastrea* to the algal-covered scars of uninfected colonies, the sponge was able to expand over undamaged coral surfaces. The implanted sponge began to grow immediately and expanded 2 cm peripherally in a nine-month period, killing the underlying coral tissue. Neumann (1966) estimated that the sponge *Cliona lampa* can excavate carbonate at the rate of 1 to 1.4 cm yr-1, Hein and Risk (1975) and MacGreachy (1975) estimate that three to 70 percent of the whole corallum may be reworked by clionids, while Hudson (1977) anticipates that a one-meter high coral head could be completely converted to sediment in 150 years or less based on scleroband measurements.

Rates of erosion of reef surfaces are difficult to estimate but Goreau and Hartman (1963) considered the activity of clionid sponges to be a widespread and significant force in the maintenance and formation of Jamaican deep reef communities. In shallow water, weakening of the bases of coral colonies by sponge excavation is perhaps counterbalanced by rapid calcification rates; in deeper water (>30 m or 100 ft), however, calcification is slow, corals become flattened and attached on an edge, the topography is steep, and there is a paucity of frame-cementing biota. All of these factors tend to magnify the effect of boring sponges in this environment.

2.3 Interactions between Corals and Other Sessile Organisms

Careful observation of benthic reef populations reveals frequent instances of unrelated organisms approaching each other in growth and then one overgrowing and excluding its neighbor. While certain corals can coexist for long periods in close contact with alien species, for example, the beneficial association of *Montastraea annularis* with the sponge Mycale laevis (Carter) reported by Goreau and Hartman (1966), it appears that there is a tendency for some of the larger algae, sponges, octocorals, and zoanthideans to displace coral growth. This seems to take place in the absence of any detectable pre-existing damage to the coral as noted earlier for destruction initiated through the activities of predators. Some examples follow.

Among algae, *Halimeda opuntia* (Linnaeus) Lamouroux, *Caulerpa racemosa var. macrophysa* (Kutzing) Taylor, and *Peyssonnelia rubra* (Irgebille) J . Agardh are commonly found covering large areas of Porites furcata. The brown alga *Lobophora variegate* (Lamouroux) Womersley often proliferates over extensive populations. *Chondrilla nucula*, an encrusting sponge and the colonial anemone *Palythoa sp.* can overgrow large tracts of *Porites furcata* and entire colonies of *Siderastrea radians* and *Diploria clivosa. Porites* is usually invaded from below, by way of the dead branches; massive corals are invaded from their periphery (Glynn, 1973). The scleraxonians *Briareum asbestinum* (Kinzie, 1970) and *Erythropodium caribaeorum* (Antonius, 1977) may function in the same manner, as may certain dideminid ascidians (Antonius, 1977).

3.0 Gorgonian Predators and Associates

The gorgonian octocorals are an important component of the reef and bank community in the study area. Their prominence has enabled them to provide shelter and food for a wide array of casual associates, epizoa and commensals and other symbionts, ranging from other coelenterates to fishes (Bayer, 1961; Salvini-Plawen, 1972). The associates of western Atlantic shallow-water gorgonians, particularly predators and parasites, are described below. The snail *Neosimnia uniplicata* and the shrimp *Neopontonoides beaufortensis* both feed on surface debris and material shed by the gorgonian *Leptogorgia virgulata* off North Carolina. The gastropod appears to incorporate spicular pigments into its own shell, thus acquiring concealing coloration. The nudibranch *Tritonia wellsi* probably feeds directly on *Leptogorgia* tissue (Patton, 1972). Cyclopoid copepods of the family Lamippidae are known to parasitize various octocorals (Zulueta, 1911) and have also been found in the polyps of *Leptogorgia* (Patton, 1972). Several species of Cyphoma, an ovulid gastropod, are conspicuous associates of *Pseudopterogorgia, Plexaura, Plexaurella* and related genera (Bayer, 1961). Kinzie (1970, 1974) has shown that Cyphoma is a predator which strips the coenenchyme, laying bare the axial skeleton. He has also described "herding" behavior, whereby cyphomas in groups of up to 24 individuals were capable of completely denuding several gorgonian colonies in a five-week period. Kinzie estimates that damage by Cyphoma may be less than the gorgonians' capacity for regeneration. Ott and Lewis (1972) and Birkland (1974) have also noted that the amphinomid worm *Hermodice carunculata* consumes gorgonians in addition to other corals. Morse, et al. (1977) describe algal tumors infesting *Gorgonia ventalina* in the Netherlands Antilles. Bagby (1978) reports considerable numbers of tumors from species of *Pseudoplexaura, Pseudopterogorgia, Plexaurella, Plexaura* and *Muriceopsis* from patch reefs off Key Largo, Florida. Randal1 (1967) found that the scrawled filefish Alutera scripta was the most prominent piscine gorgonian predator among 212 species examined. Ten other fish species had small amounts of gorgonian material in their stomachs but Randall concluded that gorgonians, in spite of their prominence, do not form a significant part of the diets of West Indian reef fishes.

The direct effect of predators and parasites is difficult to assess. However, mechanical damage to the coenenchyme by several sources appears to disrupt the antibiotic properties of the tissue (Burkholder, 1973), allowing the establishment of a variety of invading organisms, particularly *Millepora alcicornis*. Once established, *Millepora* spreads, killing the gorgonia before it. Kinzie (1970) estimated the spreading rate at 244 cm^2 yr^{-1} on a colony of Gorgonia ventalina and 1.4 to 0.7 cm yr^{-1} on two tips of a *Plexaurella species*. He also noted that an unidentified keratosid sponge was capable of similar action on deep reef gorgonians in Jamaica. Whether any of these biological interactions is significant compared to periodic storm damage (Cary, 1914) or toppling due to the weakening of the substratum by boring organisms (Kinzie, 1970, 1974), remains to be determined.

4.0 Antipatharian Predators and Associates

Little is known of relationships between black corals and other organisms. Salvini-Plawen (1972) notes a nurse shark, Nebrius concolor, feeding on an unnamed antipatharian. Cyclopoid copepods of the family Vahiniidae appear to parasitize the polyps of antipatharians (Humes, 1967). A coralliophilid gastropod, *Rhizochilus antipathicus*, feeds on *Antipathes ericoidea* (Salvini-Plawen, 1972). Other symbionts involving various species and the antipatharian whip *Cirrhipathes* have been described (Davis and Cohen, 1968; Humes, 1973). None of these involve western Atlantic species, although further work on this neglected group will undoubtedly reveal a number of associations in this region. This expectation is heightened by the apparent absence of antibiotic activity in the tissues of a species of *Antipathes sp.* tested by Burkholder (1973).

Appendix H. Habitat Subcommittee recommendations to the North Carolina Marine Fisheries Commission concerning the habitat impacts of specific commercial and recreational gears used in North Carolina.

NORTH CAROLINA
MARINE FISHERIES
MORATORIUM

FINAL REPORT

OF THE

FISHERIES MORATORIUM STEERING COMMITTEE

TO THE

JOINT LEGISLATIVE COMMISSION ON SEAFOOD AND AQUACULTURE

OF THE

NORTH CAROLINA GENERAL ASSEMBLY

Sea Grant
National Sea Grant College Program

NORTH CAROLINA SEA GRANT COLLEGE PROGRAM
UNC-SG-96-11

iv.

Habitat Subcommittee Report

The Habitat Subcommittee proposals as a whole received more supportive comment from speakers at the Committee's public meetings than any other set of recommendations, because there is a widespread consensus that critical coastal fisheries habitats have been substantially degraded in North Carolina. To solve this problem, the Habitat Subcommittee proposes, as the linchpin of its recommendations, that Department of Environment, Health, and Natural Resources Divisions having habitat and water quality responsibilities prepare a joint Coastal Habitat Protection Plan ("HPP"), which must then be implemented, through rulemaking, by the State's principal environmental Commissions. HPP sections will delineate and establish restoration and protection strategies for critical coastal fisheries habitats, with a goal of "no net functional loss" of each habitat. In addition, under the recommendations a dedicated "Habitat Staff" will be established in the Division, processes will be implemented to provide for public and private protection of critical fisheries habitats, a statewide citizen water quality monitoring program will be established, and all state agencies will be required to ensure that agency rules and policies do not significantly contribute to the loss of habitats critical to coastal fisheries.

Appendix I: Habitat Subcommittee Recommendations to the North Carolina Marine Fisheries Commission Concerning the Habitat Impacts of Specific Commercial and Recreational Gears Used in North Carolina.

DESCRIPTION OF GEAR	RECOMMENDATIONS		
	Habitat Impact & Recommendations	***Bycatch Impact & Recommendations***	***Protected Species Impact & Recommendations***
Hook and Line: The customary "rod and reel" method of fishing, used as the "up and down" bottom rig in the reef fish fishery. "Electro-mate" reels are customarily used for rapid line retrieval.	Virtually no habitat impacts, but see comments at right on monofilament fishing line and other relevant equipment. No recommendations at present.	Some bycatch impacts. A fishhook cannot be attuned to a size limit or a prohibited species, but generally, a catch-and-release policy works fairly well. Some species do not respond well to being caught, and some deep-water species do not survive being taken. Commercial and recreational fishermen tend to leave an area where the catch is predominately undersized. No recommendations at this time.	Some impacts. In 1995, one stranded turtle had a fishhook that had entered its body through the eye socket. Mammals and turtles will from time-to- time take a bait and are damaged somewhat in the release process. There is some entanglement with discarded monofilament line. Recommend promoting education and regulation on disposal of fishing line.
Trolling Gear: Fishing lines attached to a reels or directly to a boat and "trolled" through the water. Used when fishing for king mackerel, tuna, *etc*.	No known habitat impacts. No recommendations at this time.	Slight bycatch impacts. The problems that exist are generally caused by a prohibited species or an undersized fish taking the bait. Usually these can be released successfully. No recommendations at this time.	Some impacts, as from discarded fishing line. The biggest potential problem is perhaps from boat propellers. Recommend promoting education and implementing regulations on the discarding of monofilament fishing line.
Long-line System: Fishing lines used for top-water, underwater or bottom fishing.	Virtually no habitat impacts when used as a top-water gear. Impact of bottom gear can range from minor on sand bottoms to significant when used in live rock (coral) formations. Recommend that bottom gear should be prohibited in coral formations.	Same problem as with any "hooking" system (no selectivity). Since this gear holds captured catch in place for attack by predators, timeliness in checking the long-line can decrease bycatch. No recommendations at this time.	Little is known about the impacts of this gear on sea turtles and marine mammals, but sea turtles are more prone to be attracted to the bait (or captured fish) from surface longlines than are other protected species. No recommendations at this time.
Trot Line: Lines used in estuarine waters to catch crabs and fish, consisting of a long multi- or monofilament line baited at intervals, with or without hooks, used much like an ocean long-line.	No known habitat impacts. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommen-dations at this time.
Cast Net:	No known habitat impacts. No	No known bycatch impacts. No	No known impacts. No recommen-

Small net thrown by hand and used to catch "schooled fish", such as mullet, and used by bait-fish dealers and individual fishermen to net bait-fish and shrimp.	recommendations at this time.	recommendations at this time.	dations at this time.
Long haul seine: Usually a long seine, heavily leaded (weighted) and dragged by boats in estuarine waters to catch fish.	Some damage to SAV beds may occur from the heavily leaded bottom line being dragged through the grass beds. Damage to SAV beds by the boat motor propellers may be significant in shallow waters. There is concern over the use of this gear in PNAs (where use is currently prohibited) and near oyster rocks. Recommend: (1) a study be implemented to determine the actual bottom damage and whether the damage is short-term or long-lasting; (2) all oyster grounds, PNAs, and SAV beds be permanently marked; and (3) a study be conducted into the effects of long haul seine activities in these areas.	No bycatch impacts when catch is culled immediately. Recommend that immediate culling of the catch be required.	No impacts when catch is culled immediately. Recommend that immediate culling of the catch be required.
Hand Seine: Small mesh net used to catch bait. Usually pulled by hand, but sometimes a boat is used to spread the seine.	No known habitat impacts. Recommend increasing allowable hand seine sizes to thirty (30) feet.	Some bycatch impacts, in that virtually all of the directed and incidental catch from hand seines would be considered bycatch in other fisheries. "Fingerlings" and juvenile foodfish are retained for use as bait. There is typically an intense hand seining effort made in the winter and early spring targeting juvenile mullet for crab bait and bait for red drum fishermen. Recommend a study to demonstrate: (1) how to make use of "scrap" fish for bait, (2) which juvenile fish are reasonable to use as bait, and (3) how to make better use of artificial bait.	No known impacts. No recommendations at this time.
Beach Seine: Net generally used to corral mullets. A beach seine can also be used on such fish as striped bass and spot. Sometimes a beach seine is used in conjunction with a "stop"	No known habitat impacts. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.

net. Net usually spread around fish with a boat and then pulled to the shore. Pulling power can be by hand or by vehicle. This is one of the most historic methods of fishing.			
Fish Pot: A wire trap having directed (one-way) openings whereby fish may enter to get to bait. Fish pots are generally used in the ocean harvesting of black sea bass. Fish pots are also used to harvest catfish in the Albemarle Sound area.	Very little habitat impact. Impact can increase in coral formations. "Lost" pots become habitat when used correctly with biodegradable panels. Pots in estuarine waters do not adversely affect oyster grounds or SAV beds. Recommend that biodegradable escape panels be required for all fish pots.	Very little bycatch impact when used for a targeted species such as black sea bass. Either the mesh size of the pot or proper size culling rings or panels can insure proper size catch. Recommend mesh size or culling ring consistent with fish size requirements.	No known impacts. No recommendations at this time.
Eel Pot: A wire trap that looks like a crab pot, but has smaller wire mesh.	No known habitat impacts. If escape panels are used, the lost pots become habitat. Okay to use in SAV beds or oyster grounds. Recommend that biodegradable escape panels be required for eel pots.	No known bycatch impacts. No recommendations at this time.	Some concern over the diamondback terrapin as a species of special concern. A study is underway by the N.C. Wildlife Resources Commission to address these concerns. No recommendations at this time.
Crab Pot: A wire trap similar to a fish pot. This is the usual method for catching crabs in North Carolina.	Very little habitat impact. Main habitat impact is from discarded bait cartons. It is generally okay to use crab pots in SAV beds, PNAs or oyster grounds. Anecdotal reports indicate the use of anti-fouling solution or "cleansing" solutions aboard boats or near the waters edge to treat crab pots. Also anecdotal evidence exists to indicate that zinc used in crab pots to minimize rusting may contribute to heavy metal pollution in estuarine systems. Recommend: (1) a requirement that bait boxes be returned to shore; (2) a requirement that biodegradable escape panels be used in crab pots [Note: There is work being done that indicates that "tagged" crabs left in a crab pot with no food subsequently appear in other baited pots]; (3) prohibition of the use of any	There is a small bycatch, usually small flounders that become food for crabs. No recommendations at this time.	Some concern for impacts to diamondback terrapin as a species of concern. No recommendations while study being conducted by the N.C. Wildlife Resources Commission is ongoing.

	anti-fouling solution aboard a vessel or within seventy-five (75) feet of the shoreline; and (4) a study of the effects of zinc used to coat crab pots in terms of estuarine pollution.		
Shrimp Pot: A wire trap used as a special type of underwater trap or pot to catch shrimp.	No known habitat impacts. Okay to use in SAV beds, PNAs or oyster grounds. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Ocean Sink Gill Net: These are offshore gill nets that may be heavily anchored or not, as is appropriate to the area and fishery.	Sink nets have very little habitat impact unless gear becomes entangled with live rock formations. Lost or discarded webbing can become a danger for continued fishing until webbing becomes encrusted. Recommend better, more positive identification of net owners.	Gill nets are very selective as to size. Problems arise when a fishery is pursued near striped bass stocks, such as the dogfish shark and weakfish fisheries. Recommend mandatory attendance of nets when there is a significant potential for bycatch and size limits are not compatible, or when an incidental catch quota is not available.	Some impact from contacts with marine mammals and sea turtles. No recommendations at this time.
Ocean Drift Net: Usually a monofilament gill net constructed so as to be tended from the top down. Ocean drift nets generally utilize a larger mesh size than bottom fishing nets. There is very little, if any, use of this gear in the ocean off North Carolina.	No known habitat impacts. No recommendations at this time.	Very little bycatch impact. Recommend mandatory attendance of nets when there is a significant potential for bycatch, such as in the dogfish shark and weakfish fisheries.	Surface fishing and usually larger mesh sizes make these nets subject to problems with marine mammals and sea turtles. Recommend that attendance be required at all times.
Fyke Net: A usually round net having a series of throats. Fyke nets are primarily used in the upper reaches of estuaries.	No known habitat impacts. No recommendations at this time.	Fyke nets are not a very selective net, but have little or no bycatch impact if culling at the scene is required. Recommend that immediate culling of nets be required.	There are some concerns with diamondback terrapins being taken in fyke nets. No recommendations at this time.
Trammel Net: A multi-walled net usually made with two outer walls of large mesh (6" to 12" stretch or more) made of heavy gauge monofilament, and an inner wall of small mesh monofilament. A fish "pockets" itself between the walls.	Only impact is from lost or discarded nets. Recommend that better, more positive identification of net owner be required.	Trammel nets are not a very selective net, but have little or no bycatch impact if culling at the scene is required. Recommend that immediate culling of nets be required.	No known impacts if on-scene culling is required. Recommend that immediate culling of nets be required.
Pound Net: A passive gear using netting "leads", which	No known habitat impacts. The poles used to support the pound net leads	Mesh size in pound nets can be changed to select different sized fish	There is some contact of pound nets with sea turtles, but they are easy to

the fish travel along to a net "pound", where they are captured. Captured fish can be culled alive. Mesh size in the pound can be fish size selective. This gear known also as "weirs", and is one of the oldest methods of fishing. Some states have specific laws protecting weirs.	and pound are permanent structures that can themselves become habitat, but abandoned or broken-off poles can become a hazard to navigation. No recommendations at this time.	and there should be no bycatch impacts from pound nets. Any bycatch can be culled live as the pound is emptied. Culling panels are required in flounder pounds. Recommend that pound net catches be required to be immediately culled and that flounder cull panels remain required.	release unharmed. No recommendations at this time.
Channel Net: A passive gear built like a shrimp trawl that is anchored in a specific area. Channel nets are used to catch shrimp in areas with strong tidal flow, which is required to hold the net open.	No known habitat impacts. No recommendations at this time.	There should be very little bycatch impact from channel nets. Recommend that catch should be culled frequently at the catch site. Culling at the dock should not be allowed.	There may be some contact of channel nets with protected species, but marine mammals and sea turtles can either swim back out of the net or can be easily released. No recommendations at this time.
Hand Clam Rake: A tool that usually has nine (9) teeth or less, and looks a lot like a garden rake. Most rakes have a handle, but they can consist merely of "metal fingers" that rest at the wrist and extend over the fingers. Clam rakes can be utilized to "scratch" for clams under water or for "signing" on tidal flats at low tide.	Very little habitat impact in most areas, but slight impacts occur in SAV beds. Clam rakes are difficult to use on most oyster rocks, but impact can be great when used to pull oysters into piles in order to get at the clams beneath. Recommend that: (1) no rakes be allowed in marked oyster rocks/beds [these oyster areas would be designated "clam seed management areas"]; and (2) during the normal oyster season, clams should be allowed as an unlimited, approved, incidental catch when harvesting oysters.	No known impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Hand Clamming: Refers to the clamming method wherein clammers are in the water on their hands and knees feeling for clams. Clammers typically use latex gloves as protection for their hands, but can use the "metal hands" noted under "Clam Rake", above.	Very little known habitat impact. Hand clamming is generally okay in SAV beds. Recommend that hand clamming on marked oyster grounds be prohibited except as part of the normal oyster season.	No known impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Bull Rake: A large, heavy clam rake, usually having eighteen (18) to twenty-eight (28) teeth. Handles range from ten (10) feet to forty (40) feet long.	Bull rakes have severe habitat impacts when used on oyster rocks, and can damage SAV beds. Recommend that bull rake clamming on marked oyster grounds and SAV beds be prohibited.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.

Gig: A spear with or without barbed points at its tip, used mostly to spear flounder at night, using underwater lights.	No known habitat impacts. No recommendations at this time.	No bycatch impacts unless intentional. No impact should be tolerated. No recommendations at this time.	No impacts unless intentional. No impact should be tolerated. No recommendations at this time.
Spear: Similar to a gig, but usually single pronged, used by underwater divers using scuba gear.	No known habitat impacts. No recommendations at this time.	No bycatch impacts unless intentional. No impact should be tolerated. No recommendations at this time.	No impacts unless intentional. No impact should be tolerated. No recommendations at this time.
Oyster Tongs: Hand held steel "forceps", typically used while standing in a boat to recover oysters from water ranging in depth from that barely deep enough to float a boat to ten (10) to twelve (12) feet.	No known habitat impacts. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Clam tongs: Hand held steel "forceps", used to recover clams from any and all types of bottom. Clam tong teeth tend to be longer and more closely spaced than the teeth on oyster tongs.	Some habitat impact in SAV beds. Impacts on oyster beds may be negated if clam and oyster seasons are combined at some future point. Recommend that clam tongs be prohibited on marked oyster rocks except during oyster harvest season.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Oyster Dredge: Usually heavy, large-toothed cages towed by a vessel to recover oysters from deeper waters. Oyster dredges are currently allowed only in Pamlico Sound, with a one-hundred (100) pound weight limit.	Habitat impacts of oyster dredges can be significant. Historically, such dredges have been used only on bottoms that were oyster beds. Dredges can plow down any mounds of shellfish and should not be allowed for use in SAV beds. Recommend maintaining present limits on usage and that steps be taken to ensure that the gear is used with adequate consideration of its habitat impacts.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Sea Scallop Dredge: An extremely heavy steel cage similar to an oyster dredge, that drags the bottom and is used in the ocean. These dredges are intended for use only on beds of scallops at sea.	These dredges have severe habitat impacts. Recommend that dredges continue to be prohibited in estuaries and on live bottom formations offshore [Note: This fishery is regulated under a federal FMP, and its impacts are not presently an issue in NC].	Flounder bycatch possible. No recommendations at this time.	No known impacts. No recommendations at this time.
Bay Scallop Dredge: A fairly light-weight (not >50 lbs.) steel	Very little habitat impact. It is generally okay to use these dredges in SAV	Small bycatch of "conchs" and pink shrimp. No recommendations at this	No known impacts. No recommendations at this time.

frame, without teeth, used in estuarine waters, and that has an attached, nylon webbing bag to accumulate the catch.	beds over a short scallop season. No recommendations at this time.	time.	
Patent Tongs: Very large steel "forceps" typically used to recover oysters from deep water.	The use of patent tongs is thought to have a major effect on shellfish beds and the bottom generally. Recommend collection of information on this gear, *e.g.*, the habitat impact experiences of other states which have or are presently allowing use of patent tongs.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Clam Kickers: Generally refers to the use of the propeller of a boat to blow the mud/silt off the clams and into a trawl having a heavy steel cage or bag made of rings. The gear is chained so that it plows up the clams as it is towed behind the vessel. Often the stern of the vessel is loaded so that the propeller "wash" is directed at a downwards angle.	The use of clam kicking has severe habitat impact on all bottoms. The gear causes severe damage to SAV beds and to oyster rocks. Recommend that gear continue to be prohibited in SAV beds and over marked oyster grounds.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Hydraulic Clam Dredge: Gear generally used to harvest clams, that employs a conveyer system that can be lowered to the bottom where jets of water uncover the clams. These dredges are allowed only in "mechanical clamming" areas. The gear is also used by mariculturists to harvest shellfish crops from their public bottom leases.	The use of this gear has severe impacts upon SAV beds and oyster grounds. Recommend that areas that may be used by these dredges not be expanded in public trust areas. However, employment in mariculture operations to recover shellfish crops should be considered a viable use of the gear if leases are located in an areas where the gear is already allowed, if adjacent leases would not be affected. Permits should be issued by the Division of Marine Fisheries on a case-by-case basis. During the oyster season, legal size oysters caught incidental to clamming should be allowed to be retained.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.
Purse Seine: Large net used to catch menhaden. A menhaden school is surrounded by the purse net and a large weight is then dropped to close, or "purse", the bottom of the net.	The use of purse seines has no habitat impacts as the net is fished entirely within the water column. No recommendations at this time.	Studies have shown that bycatch in the menhaden industry from the use of purse seines is extremely minimal. No recommendations at this time.	Purse seines have minimal impacts on threatened and endangered species. No recommendations at this time.

Estuarine Gill Net: A major gear used in North Carolina's internal coastal waters that captures fish by entangling them when they swim into the net. The net is often anchored to the bottom or attached to stakes. In some fisheries, gill nets are fished by drifting with the current. A variety of mesh sizes are used to take spot, flounder, American shad, river herring, mullet, striped bass and many other species. This gear is often used by recreational fishermen.	Estuarine gill nets have negligible habitat impacts. Such gear can be safely used in PNAs, SNAs and SAV beds. Proper identification of gear owners should be emphasized, along with regular tending of the fear to avoid wastage of fish. No recommendations at this time.	This gear is very size-selective, but there can be problems in capture of non-targeted species of similar sizes to the target species. Large catches can occasionally occur in gill nets used to fish recreationally, resulting in waste of part of the catch. Attendance of such recreationally fished nets may be appropriate under some conditions to minimize bycatch. No recommendations at this time.	There is a potential for this gear to impact marine mammals, principally bottlenose dolphins, and sea turtles. As more information becomes available on the distribution and movements of protected species, management actions may be needed to alter traditional fishing practices to avoid interactions between such species and estuarine gill nets. No actions are needed, or recommended, at the present time.
Otter Trawl: A cone-shaped net fashioned in one of the many patterns of "Otter Trawls", used primarily in North Carolina to catch shrimp. The gear is pulled from behind or alongside a vessel using "doors" or "gates" to keep the trawl open. The doors are sized (18" x 36" to 40" x 120") and weighted (50 lb. to 500 lb.) in direct ratio to the size of the trawl. Trawls skim the bottom, and shrimp are made to "pop" up into the net by a "tickler" chain pulled just ahead of the bottom line. Trawl doors ride along the bottom.	For all bottoms, the severity of habitat impacts from the use of shrimp trawls is related to the size the doors. Damage to oyster grounds is generally moderate to high. Studies are inconclusive on the question of whether trawling in other areas has significant habitat impacts. Recommend continuation of prohibition of trawling in marked oyster grounds. A study of the impact of trawling on different types of habitat should also be conducted.	Fish bycatch is the major issue related to trawling for shrimp in the State. The Division of Marine Fisheries, the N.C. Sea Grant Program and the National Marine Fisheries Service, in a cooperative effort with fishermen, have been addressing the bycatch issue for several years, by studying shrimp trawl bycatch under actual shrimping conditions. Since October 1992, North Carolina has required some sort of "finfish excluder" in all shrimp trawls. One study has demonstrated bycatch reduction rates averaging better than 50%. Experiments continue and currently indicate an even better reduction rate is possible. Recommend continued prohibition of trawling in PNAs, SAV beds, and, generally, in Special Secondary Nursery Areas. Also recommend that the State continues to fund and study excluder devices and require their use.	North Carolina shrimpers fishing in the Atlantic Ocean are required to equip each trawl with a Turtle Excluder Devices (TED). Compliance with this provision appears to be total. The only exemption in the United States to TED requirements is the area between Rich's and Brown's inlets in Pender County, North Carolina. Shrimpers in this area must adhere to seasonally adjusted "tow times" set by the NMFS. All other inside water shrimpers must use TEDs, unless they adhere to a thirty (30) minute tow time and have no form of mechanical advantage to retrieve their nets. No recommendations at this time.
Crab Trawl: A trawl consisting of larger mesh nets made like a shrimp trawl. The basic equipment is the same as a shrimp trawl except that the bottom leading edge of the trawl is laced with several loops of heavy chain so that the crabs are "plowed" out of the bottom where	The use of crab trawls has severe impacts on all bottoms, causing great damage to oyster grounds and moderate to severe damage in SAV beds. Crab trawling results in substantial sedimentation in the trawled area. Recommend that crab	Present tailbag size causes a high percentage of undersized flounder to be killed and catch of a high percentage of undersized crabs. Recommend the DMF adopt a 4 1/2" tailbag for use in this gear [Note that South Carolina uses a 4" bag].	This trawl is used inshore in the winter, where waters are cold. For that reason, there is no known impact of this gear on sea turtles. No recommendations at this time.

they have embedded themselves.	trawls be prohibited in marked oyster grounds. Because of heavy chain at the mouth of these trawls, there was much concern over potential damage to SAV beds. For that reason, also recommend a study of the effects of crab trawling on SAV beds.		
Skimmer Trawl: A trawl nets that utilizes a solid frame and a flat offshore "foot" in order to push a trawl through the water without using doors. Use of this gear is limited to areas where the depth of the water is no more than the size of the metal frame. Its use is highly successful in the "white shrimp" fishery.	Little known habitat impact. Skimmer trawls are generally okay to use in SAV beds, but should not be used in oyster grounds. Recommend that trawls be prohibited in marked oyster grounds and that the more widespread use of this gear be promoted in estuarine waters.	No recorded bycatch problems, but potential remains. Recommend implementation of requirement that a tailbag be dumped and culled every thirty (30) minutes.	No recorded problems. The tailbag of this gear can be dumped at any time, which eliminates most of the concern over bycatch or endangered species. Recommend implementation of requirement that a tailbag be dumped and culled every thirty (30) minutes.
Butterfly Trawl: In this gear, a solid frame holds a modified trawl in the top of the water column, acting like a channel net. Its use generally requires a good tidal flow and it is normally used only at night.	No known habitat impacts, but there have been complaints that these netters have failed to yield to boat traffic when working the Atlantic Intracoastal Waterway and marked channels. Recommend that the use of butterfly trawls be promoted, with a requirement that netters must yield to all boat traffic when utilizing navigation channels.	This gear should have no bycatch impacts if the tailbag is dumped and culled at least every thirty (30) minutes. Recommend implementation of the requirement that trawls be culled every thirty (30) minutes.	No known impacts if frequent culling occurs. Recommend implementation of requirement of culling every thirty (30) minutes.
Float Netting: This is done when a shrimp trawler "floats" its doors so that it can act as a butterfly or channel net, usually occurring in ebb tidal flow and at night.	No known habitat impacts, but complaints have been received of float nets being used in a manner that blocks navigation channels, and of failure to yield to boat traffic. Recommend that float netters be required to yield to boat traffic.	There should be no bycatch impacts if the tailbag is dumped and culled frequently. However, the nets cannot be checked until the tow is completed, so concerns about bycatch and endangered species impacts still remain. Recommend further study of bycatch of float nets and imposition of appropriate tow times.	None if frequent culling occurs. Recommend further study of bycatch of float nets and imposition of appropriate tow times.
Fish Trawls/Flynets: Usually large trawl nets, generally fished in ocean waters. Fish trawls may drag on the bottom, but also may utilize "mid-water technology." Fish trawling is not allowed in inside waters in North Carolina.	Use of this gear can seriously damage live rock formations. Recommend the continued prohibition of use in inside (internal) coastal waters. Federal rules should address the use of flynets in the EEZ.	Historically, flynets have landed large amounts of small, juvenile fish, too small to be marketed as seafood. This catch was sold for a variety of uses, such as animal food, and such harvests may have a long-term, adverse impact on fish stocks. Recommend a	Federal rules require TEDs in the ocean flounder trawl fishery. No recommendations for state action at this time.

		prohibition on the targeting, retaining and selling of food fish that are below a size marketable for human consumption.	
Stop Net: [See "Beach Seine", above] A term used for large mesh nets that are set out or "run" perpendicular to the beach. Stop nets are not intended to catch anything themselves, given that the mesh size in these nets is from six (6) to ten (10) inches. During the night, migrating mullet (or other fishes) gather against the stop net, which they perceive as an obstruction to travel. Other species may either swim through the stop net or go around it. A beach seine is used to gather the fish "encamped" at the stop net site. A recent DMF study showed that ninety-five percent (95%) of the fish "encamped" at the stop net are mullet.	No known habitat impacts. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts, except that marine mammals can become entangled in stop nets. No recommendations at this time.
Explosives: Pyrotechnic devices, such as dynamite, used to create a concussion, which causes the stunned or dead fish to rise to the surface where they are gathered. The use of explosives to fish is not legal in North Carolina.	Habitat effects of this practice are unknown, but would seem to potentially be significant. Recommend that this practice continue to be prohibited in North Carolina.	Any fish within the area of influence of the concussion will be affected. Recommend that practice continue to be banned in North Carolina.	No known impacts, but the potential impacts would appear to be significant. Recommend that the practice continue to be banned in North Carolina.
Electric Shocking: Refers to the use of mechanical devices that generate an electric current into coastal fishing waters, which stun the fish and cause them to rise to the surface. The practice of electric shocking is currently allowed only in a portion of the Cape Fear River, where it is used to catch catfish.	No known habitat impacts. No recommendations at this time.	Any fish within the area of influence of the charge will be shocked and stunned. Recommend that such a fishing practice be restricted by area and only allowed by special permit.	No known impacts. No recommendations at this time.
Dip Nets/Pier Net: Hand nets that are not usually used to catch fish by themselves, but rather, are used as tools in conjunction with other fishing gears. For example, a flounder fisherman may use a dip net to scoop up a flounder that is in his	No known habitat impacts. No recommendations at this time.	No known bycatch impacts. No recommendations at this time.	No known impacts. No recommendations at this time.

net but appears ready to fall out, or a fisherman may use a pier net to bring up catches of mullet too large to lift without danger of splitting his cast net, or to lift other species to keep from breaking the line on his fishing rod. However, large dip nets are used to catch river herring and shad in coastal streams.			
Crab Dredges: A crab dredge is much like an oyster dredge, except perhaps with longer teeth, and is used to dredge crabs from the bottom sediments during the winter months. Crab dredges are used in northern North Carolina waters from Long Shoal north.	Habitat impacts from the use of crab dredges can be significant, and the gear causes severe damage on oyster grounds or in SAV beds. Recommend that the current restrictions on the use of this gear be maintained, and that steps be taken to ensure that crab dredges are used with adequate regard to their effects on coastal fishery habitats.	Oysters and clams taken incidentally by this gear can be returned to the water if appropriate. No recommendations at this time.	No known impacts. No recommendations at this time.

Appendix I. ASMFC Habitat Statement and SAV Policy Statement and Implementation Plan (Source ASMFC 1998).

Atlantic States Marine Fisheries Commission
Submerged Aquatic Vegetation Policy
Implementation Plan

The ASMFC Submerged Aquatic Vegetation (SAV) Policy was adopted in May 1997. This policy outlines many actions for both ASMFC and its member states. This implementation plan was developed to assist in identifying activities that would accomplish designated actions for conserving SAV in state waters. Activities are grouped in the following sections: policy distribution, activities specific to policy action items, activities for accomplishing the implementation section of the policy, and activities to review policy effectiveness. Activity timeframes are estimated as follows: *Short term* - approximately 1 year; *Medium term* - approximately 2 years; *Long term* - more than 2 years. Quotations from the SAV Policy are indicated by bold and quotation marks.

Policy Distribution

1. Distribute 1 copy of policy to each Commissioner, board member, technical committee chair, and Management and Science Committee member. (short term)

2. Distribute 10 copies to NMFS Office of Habitat Conservation and NE and SE regions. Request that they distribute to NMFS satellite offices and laboratories. Distribute two copies each to the three Atlantic fishery management councils. (short term)

3. Distribute 10 copies to each USFWS Ecological Services office on the Atlantic coast and other FWS offices. (short term)

4. Advertise availability of the policy in *Fisheries Focus* and *Habitat Hotline Atlantic* in 2-3 concurrent issues, and also in the NMFS publication *Habitat Connections.* (short term)

5. Distribute policy to state and local governments and other statewide organizations by:
   a. State marine fishery agency directors review habitat managers database for their state;
   b. ASMFC staff drafts a transmittal letter;
   c. ASMFC provides policy copies, draft transmittal letter on disk, and labels to state fisheries director for distribution to state habitat managers. (medium term)

6. Distribute 1 copy to each federal habitat manager listed on the updated habitat managers database. (medium term)

7. Distribute 1 copy to each major Atlantic coast stakeholder, such as conservation and fishermen's groups which are not included on the habitat managers database. (medium term)

Activities for Policy Action Items

Section I. Assessing the Resource

1. Assist the NOAA Coastal Change Analysis Program (C-CAP), working through the NOAA Coastal Services Center, in identifying state partners for SAV mapping, including identifying ongoing programs and initiating new projects. (short term)

2. Assist in revision of C-CAP methodology, if necessary, or identify alternate methodology. Use the South Atlantic Fishery Management Councilís SAV/Seagrass EFH work group as an impetus and vehicle for this work. Methodology must be flexible and adaptable. Encourage monitoring programs to develop methodologies for identifying baseline variability. Programs should note any shift in vegetation from SAV to other plant species such as Ulva or Gracilaria. (medium to long term)

***State*: ìASMFC members should encourage their appropriate state agency or department to implement regular statewide or regional SAV monitoring programs which will identify changes in SAV health and abundance cumulatively on a coastwide basis. Surveys should optimally be on a five year basis at a minimum, and preferably annually, for areas considered to be especially at risk of severe declines from anthropogenic activities, disease, or other factors.î**

Activities

1. A summary of SAV activity within each state should be prepared by the state marine fisheries agency in consultation with other authorities and research agencies. This summary should include research (all sources), mapping, monitoring, and restoration activities, planning documents, etc.; and should identify the agencies or individuals undertaking these programs. The summary should be submitted to ASMFC for compilation into a coastwide compendium. This information will be the basis for identifying more specific implementation of this policy. (short term)

2. State marine fisheries agencies should initiate discussions on monitoring program implementation with the state agency that would be responsible for these activities if such activities do not already exist. States should notify ASMFC of these discussions. (medium term)

Section II. Protection of Existing Submerged Aquatic Vegetation
Action:
***ASMFC and member States*: ìReview and evaluate the effectiveness of existing regulatory, proprietary and resource management programs to protect existing SAV and their habitats (including mitigation, dredging, water quality standards, and vessel impacts such as elevated wakes, suspended sediments, placement of mooring fields, and direct impacts from hulls, mooring tackle, propellers, and personal watercraft).î**

Activities

1. Under Section I.1, the states should identify state agencies and other organizations responsible for or participating in SAV management or monitoring. (short term)

2. Develop model ordinances and regulations to protect SAV for use by state and local governments. (long term)

3. Inform state agencies in charge of regulating SAV that the ASMFC requests notification of any changes to regulations that may impact SAV. Respond to state agency requests for comments or notification of rulemakeing when proposed regulation changes may impact SAV. (medium term)

4. a. Adopt technical guidelines and standards for state programs against which effectiveness could be compared and evaluated. Include flexible measures based on permits, research, enforcement, fishery management, etc., as appropriate for each state. (medium term)

b. Review state programs every five years to update Ernst and Stephan 1997. (long term)

c. Review existing data and reports to identify information gaps and resource trends. (medium term)

5. Inform state agencies in charge of regulating and or managing recreational access and/or harbor facilities of appropriate measures for SAV conservation and protection. (short term)

***ASMFC*: ì1) Support and promote the development of water quality standards by the Environmental Protection Agency that member states can implement to protect SAV habitat (i.e. light attenuation, total suspended solids, chlorophyll a, dissolved inorganic nitrogen, dissolved inorganic phosphorus, critical life period).**

2) In partnership with National Marine Fisheries Service and Fish and Wildlife Service, develop technical guidelines and standards to objectively determine gear impacts, and develop standard mitigation strategies.î

Activities

1. Identify the process for development of EPA water quality standards. Include also annual loading limits for total nitrogen and criteria for nutrient concentrations. (medium term)

2. Develop a plan to implement the above process. (medium term)

3. Under the auspices of the ASMFC Management and Science Committee, with reference to recent AFS gear studies, develop technical guidelines and standards to objectively determine fishing gear and fishing activity (including prop scarring and anchoring) impacts and develop standard mitigation strategies where appropriate. (medium term)

4. Provide standards and mitigation strategies to relevant fishery management boards for their consideration in development of management plan compliance criteria. (medium term)

***State*: ìASMFC members should encourage their appropriate state agency or department to propose improvements necessary in state regulation and management of SAV habitats based on the standards developed in the above actions. Include elements such as dredging windows and conditions pertaining to harvesting shellfish or finfish in SAV beds by use of mechanical means.î**

Activities

1. Once standards have been identified and/or adopted by EPA, state marine fisheries agencies should ensure that the appropriate state agency and local municipalities are aware of this information, and encouraged to adopt the standards. States in which the adoption of water quality standards is overseen by an ASMFC Commissioner should ensure that the new standards are adopted. States should notify ASMFC of these activities. (long term)

Section III. Restoration of Submerged Aquatic Vegetation
Action:
***State*: ìASMFC members should encourage their appropriate state agency or department to set regional or state restoration goals for SAV acreage, abundance and species diversity considering historical records of abundance and distributions and estimates of potential habitat. Identify reasons for losses, and address any need for habitat improvement prior to restoration. Based on scientific protocols, identify areas currently suitable for SAV restoration, and consider them for protection and future use, or immediate use in restoration projects. Implement scientifically-based transplanting and planting protocols, and support their use by other organizations.î**

Activities:

1. States should identify whether state or regional restoration plans exist in activity under Section I.1. (short term)

2. If restoration goals or plans do not exist, states should identify the appropriate state agency and encourage them to develop restoration goals or plans. States should notify ASMFC of this activity. (short term)

3. ASMFC will develop minimum recommended components for any SAV restoration plan. These components may include historic distribution and abundance, potential causes of loss, viable restoration sites, and sites to be preserved. (medium term)

Section IV. Public Education and Involvement
Action:
***ASMFC and member States*: ìASMFC in coordination with member States, Federal agencies, and non-profits will promote and support the improvement of public understanding of the value, habitat requirements, status, significant threats, human impacts, and trends in abundance of SAV. States should include this information in their aquatic education programs.î**

Activities
1. Continue to distribute the Commissionís vessel related pollution brochure (ASMFC). (short term)

2. Seek funding for reprinting, and distribution of the brochure to recreational fishermen and boaters. (short term)

3. Advertise availability of SAV background document; distribute it to ASMFC participants and as requested. (short term)

4. Compile information on citizen involvement in SAV monitoring, protection and restoration programs, and publish as a document in ASMFCís Habitat Management Series. (medium to long term)

5. Request that USFWS Federal Aid offices require a habitat (SAV) component in all state aquatic education programs. (medium term)

6. Develop and implement an outreach program directed at the marine trade industry and various user groups which may impact SAVs. These groups would include marinas, boat builders, personal water craft, recreational shellfishermen, power boaters, etc. (long term)

7. Develop a generic video on SAVs, including information on their ecological importance and the results of human impacts, which could be shown to different user groups. The video could include suggested mitigation designs and methods to protect and preserve SAVs. (long term)

8. Compile a list of SAV protection and management references with contact names in addition to those included in the background document. (medium term)

9. Create an SAV specific brochure. (medium term)

***State*: ìASMFC members should encourage their appropriate state agency or department to promote the involvement of citizenís groups in activities such as groundtruthing of remotely sensed and mapped SAV locations; water quality monitoring programs; reporting of impacts, losses, or perturbations; and SAV restoration and protection activities.î**

Activities
1. State marine fisheries agencies should provide the ASMFC compilation of information on citizen participation projects to other appropriate state agencies or regional organizations, including ecosystem management teams, and encourage them to promote citizen involvement

in SAV restoration and protection activities. All citizen involvement should be encouraged to include the use of standard methodologies, with good QA/QC. ASMFC should be informed of these activities. (long term)

Section V. Scientific Research
Action:
***ASMFC and member States*: ìOn a coastwide basis, support research in the following areas:**
1) The relationship between SAV and the environmental quality of fish habitat on a coastwide basis, and the relative importance of SAV to other, high quality habitat types. This should include the development of specific habitat functions of SAV (e.g. spawning, feeding, growth, refuge), taking into consideration the benefits to managed fish species.

2) Improving methodologies for SAV transplanting; define specific habitat requirements of SAV; and determine the ecological functioning of transplanted vs. naturally vegetated areas.

3) Improving our understanding of the relationships between SAV and managed fish species, including patterns associated with different landscape or bed forms and sizes within the context of location within the system, as well as the influence of human disturbance and consequences of altering seagrass landscapes vis-‡-vis fragmentation and isolation.

4) The effects of eutrophication, sediment loading, toxics, disease, physical disturbance, and natural perturbations on growth and survival of SAV.

5) The effects of reduced genetic diversity on the ability of seagrass populations to survive habitat alterations.î

Activities:

1. Include research needs in ASMFCís research priorities document. (medium term)

2. Distribute the research priorities document broadly. (medium term)

3. Add following research priorities (short term):

    - potential seed harvesting and sowing methodologies and techniques

    - develop mitigation designs or methods to reduce the impact of existing docks, floats, boats, etc. on SAV beds, since many SAV beds are impacted by ìgrandfatheredî structures.

    - evaluate the effects of the designs or construction methods of new docks floats or moorings.

4. Encourage and foster partnerships between state management agencies, federal management and research agencies, and universities to design, seek funding for, conduct and disseminate the results of research which meet ASMFC management needs. (continuous)

Activities for Policy Implementation Section

1. Habitat Chair will notify fishery management board chairs and technical staff for the species with demonstrated reliance on SAV habitat (croaker, red drum, menhaden, spot, spotted seatrout, eel, black sea bass, tautog, bluefish, summer flounder, lobster, striped bass, and weakfish) of the importance of SAV to the managed species. (short term)

2. Habitat Chair will request that the policy be incorporated into plans or amendments for these species (short term), and that action items in the policy or activities designated by this implementation plan be incorporated into the plans as recommendations or compliance criteria. (short to long term)

Options for Reviewing Policy Effectiveness

1. Determine the net gain in states adopting and implementing standards and adopting and implementing restoration programs.

2. Determine the increase in monitoring or citizen involvement programs or restoration programs.

3. Determine the net gain in the number of entities that are:
    a. mapping
    b. protecting SAV through use of policy or criteria resulting from policy guidance,
    c. initiating restoration projects or new initiatives,
    d. implementing new research initiatives.

4. Review the implementation of specific activities designated in policy or implementation plan by way of surveys or state reporting.

Atlantic States Marine Fisheries Commission
Submerged Aquatic Vegetation Policy

Introduction

Background
Submerged aquatic vegetation or SAV systems, which include both true seagrasses in saline regions and freshwater angiosperms that have colonized lower salinity regions of estuaries, are among the most productive ecosystems in the world. They perform a number of irreplaceable ecological functions, which range from chemical cycling and physical modification of the water column and sediments, to providing food and shelter for commercial, recreational, as well as ecologically important organisms (Thayer et al., 1997). Many ASMFC managed species are directly dependent upon SAV for refuge, attachment, spawning, food, or prey location (Laney, 1997). Since all species managed by the Atlantic States Marine Fisheries Commission (ASMFC) are dependent upon coastal habitats for which SAV often serves vital functions; in essence, all ASMFC managed species are influenced by SAV to some degree.

ASMFC is establishing this policy on submerged aquatic vegetation, emphasizing both the true seagrasses and freshwater species, because of the important role SAV plays in the habitat of ASMFC managed species, and because some of these species utilize both seagrass and freshwater SAV habitats during their ontogenetic development. Diverse regional management strategies (Ernst and Stephan, 1997) and human activities (Goldsborough, 1997) can reduce local and regional SAV abundance, and result in impacts to fisheries. Recent declines have been reported in most Atlantic coastal states (Ernst and Stephan, 1997). Some regions have experienced severe declines, such as Chesapeake Bay, where SAV communities underwent an unprecedented decline in the late 1960s and early 1970s that affected all species in all areas of the bay (Orth and Moore, 1983). Although this region has experienced recent gains over the last decade (Orth et al., 1996), overall abundance undoubtedly remains low compared to historic levels. In order to protect and enhance its trust resources, ASMFC adopts this policy, and encourages its implementation by state, federal, local, and cooperative programs which influence and regulate fish habitat and areas impacting fish habitat; specifically SAV.

The development of this policy was overseen by the ASMFC Habitat Committee, with scientific guidance from experts in the field of SAV ecology. Literature and policy reviews were compiled to serve as background information, and are included in the document "Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State

Regulation, and Value to Atlantic Coastal Fish Stocks." The policy relies on these reviews; for more extensive background information, please refer to these reviews and their cited references.

ASMFC Trust Resources
Twenty-four finfish species are managed by ASMFC and its member states for which 20 management plans are either implemented, under preparation, or being amended. Species for which plans are in the implementation phase include:

Spanish mackerel (*Scomberomorous maculatus*)
Atlantic menhaden (*Brevoortia tyrannus*)
red drum (*Scianops ocellatus*)
tautog (*Tautoga onitis*)
spot (*Leiostomus xanthurus*)
spotted seatrout (*Cynoscion nebulosus*)
Atlantic striped bass (*Morone saxatilis*)
Atlantic croaker (*Micropogonius undulatus*)
weakfish (*Cynoscion regalis*)
winter flounder (*Pleuronectes americanus*)
scup (*Stenotomus chrysops*)

Plans for the following species are currently undergoing amendment:

American lobster (*Homarus americanus*)
Atlantic herring (*Clupea harengus*)
Atlantic sturgeon (*Acipenser oxyrinchus*)
black sea bass (*Centropristis striata*)
bluefish (*Pomatomus saltatrix*)
northern shrimp (*Pandalus borealis*)
summer flounder (*Paralichthys dentatus*)
shad/river herring (includes American shad, *Alosa sapidissima*, hickory shad, *A. mediocris*, alewife, *A. pseudoharengus*, and blueback herring, *A. aestivalis*).

Species for which plans are under preparation include:

American eel (*Anguilla rostrata*) and horseshoe crab (*Limulus polyphemus*).

Additional species of interest to the ASMFC and its member states include:

blue crab (*Callinectes sapidus*)
rainbow smelt (*Osmerus mordax*)
black drum (*Pogonias cromis*)
bay scallop (*Argopecten irradians*)
gulf and southern flounders (*Paralichthys albigutta, P. lethostigma*)
white and striped mullet (*Mugil curema, M. cephalus*)
brown, pink and white shrimp (*Penaeus aztecus P. duorarum, P. setiferus*)

Definition of Submerged Aquatic Vegetation

As considered in this policy, submerged aquatic vegetation refers to rooted, vascular, flowering plants that, except for some flowering structures, live and grow below the water surface. Because of their requirements for sufficient sunlight, seagrasses are found in shallow coastal areas of all Atlantic coast states, with the exception of Georgia and South Carolina, where freshwater inflow, high turbidity and tidal amplitude combine to inhibit their growth.

There are a minimum of 13 species of seagrasses common in US waters to which this policy may apply. In the New England and northern mid-Atlantic regions, eelgrass (*Zostera marina*) dominates, with two other species also occurring - Cuban shoalgrass (*Halodule wrightii*) in North Carolina and the more cosmopolitan widgeon grass (*Ruppia maritima*). In Florida, turtlegrass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) become dominants along with cuban shoalgrass and several species of *Halophila*, one of which (*H. johnsonnii*) has been proposed for listing by NMFS as an endangered plant species.

Approximately 20-30 species of freshwater macrophytes may be found in the tidal freshwater and low salinity areas of the estuaries of the eastern United States. These lower salinity communities can be quite diverse, with as many as 10 species co-occurring at a single location. Wild celery (*Vallisneria americana*), redhead grass (*Potamogeton perfoliatus*), sago pondweed (*Potamogeton pectinatus*), horned pondweed (*Zannichellia palustris*), common elodea (*Elodea canidensis*), coontail (*Ceratophyllum demersum*), and southern naiad (*Najas quadalupensis*) are a few of the native species that will dominate these areas while two non-native (exotic) species, milfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*), will also be found in many areas. Widgeongrass (*Ruppia maritima*) which can tolerate both fresh and saltwater, has the broadest range of all species. (Orth, 1997) This policy acknowledges that there will be cases, such as with exotics, where it may be appropriate to undertake management control measures.

This policy acknowledges that where native species have been eliminated, exotic species are of functional value; however, restoration of native species should be undertaken as appropriate.

Implications for Atlantic Coastal States and Other Organizations

The Atlantic States Marine Fisheries Commission was formed by the Atlantic coastal states in 1942 to assist in managing and conserving their shared fishery resources. The Atlantic member States of the Commission typically carry out these responsibilities through state marine fisheries agencies. Frequently state agencies regulating habitat protection are not involved with, nor even aware of, the activities of the Commission.

Many of the suggested state actions outlined in this policy will apply to agencies other than state marine fisheries agencies. The intent of this policy is not to hold marine fisheries agencies accountable for the suggested state activities, but rather to provide for the transmission of this policy and its objectives to the agencies or organizations that can best carry out the prescribed activities, and encourage the participation of these agencies in achieving policy goals.

States have taken diverse approaches in SAV management (Ernst and Stephan, 1997), and may already have some or all of the prescribed activities in place. Collateral purposes of this policy are to encourage states in the early stages of SAV management to implement these activities, and, by implication, to congratulate and provide additional encouragement to those states that are leading the way towards achieving policy goals. ASMFC also recognizes that non-governmental organizations in some states or regions may have implemented some of the prescribed state activities, such as SAV mapping or research. In these instances, the state activity recommended in this policy may be amended to support the activities already underway, in order to promote cooperation and avoid duplicative programs. Further information on implementation of this policy can be found under Policy Implementation on page 7.

Policy Statement

Goal

The goal of this policy is to preserve, conserve, and restore where scientifically possible, in order to achieve a net gain in SAV distribution and abundance along the Atlantic coast and tidal tributaries, and to prevent any further losses of SAV in individual states by encouraging them to:

1. Protect existing SAV beds from further losses due to degradation of water quality, physical damage to the plants, or disruption to the local benthic environment;

2. Set and achieve state or regional water and habitat quality objectives that will result in restoration of SAV through natural re-vegetation;

3. Develop and attain state SAV restoration goals in terms of acreage, abundance, and species diversity, considering historical distribution records and estimates of potential habitat.

There are six key components to achieving the goal of this policy: 1) Assessment of historical, current and potential distribution and abundance of SAV; 2) Protection of existing SAV; 3) SAV Restoration; 4) Public Education and Involvement; 5) Research; and 6) Implementation.

I. Assessing the Resource

Determining current status and identifying trends in health and abundance are key factors in management of SAV resources. In an effort to develop consistent monitoring techniques among regions, SAV mapping protocols have been identified by NOAA's Coastal Change Analysis Program (C-CAP; Dobson et.al., 1995). Applicability of the C-CAP protocols should be evaluated.

Policy:
At a minimum, each member state should ensure the implementation of a SAV resource assessment and monitoring strategy which will provide for a continuing quantitative evaluation of SAV distribution and abundance and the quality of supporting environmental parameters. The optimum coastwide situation would be a monitoring system which would establish consistent monitoring techniques among regions so that the data are comparable.

Action:
ASMFC: Support and promote adoption of a protocol for mapping of SAV which all member states can use to provide for data consistency and development of a centralized database.

State: ASMFC members should encourage their appropriate state agency or department to implement regular statewide or regional SAV monitoring programs which will identify changes in SAV health and abundance cumulatively on a coastwide basis. Surveys should optimally be on a five year basis at a minimum, and preferably annually, for areas considered to be especially at risk of severe declines from anthropogenic activities, disease, or other factors.

II. Protection of Existing Submerged Aquatic Vegetation
Before a net gain in SAV distribution and abundance can be realized, a concerted effort should be made to protect those areas where SAV currently exists. Impacts which result in losses of SAV such as direct alterations to a vegetated area or indirect actions within a watershed should be curtailed. While there have been numerous documented restoration successes, protection and conservation are a much more assured and cost effective approach to perpetuation of SAV. Because SAV habitat requirements are more stringent than those of many coastal marine living resources, controlling the type, extent, intensity and duration of impacts which damage SAV will further other efforts to restore and protect coastal fish habitat.

Policy:
Member states should use existing regulatory, proprietary, and resource management programs, and develop new programs, to limit permanent and irreversible, direct, and indirect impacts to SAV and their habitats.

Action:
ASMFC and member States: Review and evaluate the effectiveness of existing administrative procedures, regulatory, proprietary and resource management programs to protect existing SAV and their habitats (including mitigation, dredging, water quality standards, dock placement, marina expansion and vessel impacts such as elevated wakes, suspended sediments, placement and maintenance of moorings, and direct impacts from hulls, propellers, and personal watercraft).

ASMFC: 1)Support and promote the development of water quality standards by the Environmental Protection Agency that member states can implement to protect SAV habitat (i.e.

light attenuation, total suspended solids, chlorophyll a, dissolved inorganic nitrogen, dissolved inorganic phosphorus, critical life period).

2) In partnership with National Marine Fisheries Service and Fish and Wildlife Service, develop technical guidelines and standards to objectively determine gear impacts, and develop standard mitigation strategies.

State: ASMFC members should encourage their appropriate state agency or department to propose improvements necessary in state regulation and management of SAV habitats based on the standards developed in the above actions. Include elements such as dredging windows and conditions pertaining to harvesting shellfish or finfish in SAV beds by use of mechanical means.

III. Restoration of Submerged Aquatic Vegetation

In addition to protecting existing SAV habitat, restoration of former habitat is an important part of achieving an overall net gain. Planning will induce maximum restoration program effectiveness. Habitat quality which is necessary for SAV perpetuation and will provide for natural revegetation must be attained before restoration can occur. The use of scientifically-based restoration protocols will help ensure success where environmental conditions warrant.

Policy:

Restoration programs should be based on goals, and include establishment of habitat quality necessary for SAV prior to restoration. Restoration through planting or seed dispersal should incorporate scientifically based protocols, and may be used to augment natural re-vegetation.

Action:

State: ASMFC members should encourage their appropriate state agency or department to set regional or state restoration goals for SAV acreage, abundance and species diversity considering historical records of abundance and distributions and estimates of potential habitat. Identify reasons for losses, and address any need for habitat improvement prior to restoration. Based on scientific protocols, identify areas currently suitable for SAV restoration, and consider them for protection and future use, or immediate use in restoration projects. Implement scientifically-based transplanting and planting protocols, and support their use by other organizations.

IV. Public Education and Involvement

An informed and involved public will provide a firm foundation of support for SAV protection and restoration efforts. Education and involvement is an important facet of increasing public awareness and stewardship.

Policy:

ASMFC and member states should promote and support public education and stewardship programs that will increase the public's knowledge of SAV, its importance as fish habitat, and commitment to SAV conservation.

Action:
ASMFC and member States: ASMFC in coordination with member States, Federal agencies, and non-profits will promote and support the improvement of public understanding of the value, habitat requirements, status, significant threats, human impacts, and trends in abundance of SAV. States should include this information in their aquatic education programs.

State: ASMFC members should encourage their appropriate state agency or department to promote the involvement of citizen's groups in activities such as groundtruthing of remotely sensed and mapped SAV locations; water quality monitoring programs; reporting of impacts, losses, or perturbations; and SAV restoration and protection activities.

V. Scientific Research

Through scientific research, we will improve our knowledge and understanding of SAV to ensure that efforts to protect and restore the resource will be effective. Further information on growth, physiology, reproduction, life cycles, disease, transplanting, environmental requirements, and anthropogenic impacts is needed to protect and restore SAV.

Policy:
ASMFC and member states should promote and support those research projects which will improve our knowledge of SAV and its benefits as fish habitat.

Action:
ASMFC and member States: On a coastwide basis, support research in the following areas:
1) The relationship between SAV and the environmental quality of fish habitat on a coastwide basis, and the relative importance of SAV to other, high quality habitat types. This should include the development of specific habitat functions of SAV (e.g. spawning, feeding, growth, refuge), taking into consideration the benefits to managed fish species.

2) Improving methodologies for SAV transplanting and restoration techniques; define specific habitat requirements of SAV; and determine the ecological functioning of transplanted vs. naturally vegetated areas.

3) Improving our understanding of the relationships between SAV and managed fish species, including patterns associated with different landscape or bed forms and sizes within the context of location within the system, as well as the influence of human disturbance and consequences of altering seagrass landscapes vis-à-vis fragmentation and isolation.

4) The effects of eutrophication, sediment loading, toxics, disease, physical disturbance, and natural perturbations on growth and survival of SAV.

5) The effects of reduced genetic diversity on the ability of seagrass populations to survive habitat alterations.

Policy Implementation

Habitat Program
This policy will be distributed to all ASMFC Commissioners and other interested persons for use in promoting local and regional protection of SAV. Implementation of the policy will be reviewed on a regular basis to evaluate policy effectiveness and recommend revisions as necessary.

ASMFC federal partners, including the US Fish and Wildlife Service and National Marine Fisheries Service, are encouraged to adopt and implement this policy. Other federal agencies, such as the US Army Corps of Engineers and the Environmental Protection Agency, will be briefed on the policy, and encouraged to adopt it as well.

ASMFC will continue to progress in its commitment to facilitate communication between State and Federal fishery and habitat managers. The Commission will assist marine fisheries agencies in transmitting this policy to habitat protection agencies.

Fishery Management Planning
Under the Atlantic Coastal Fisheries Cooperative Management Act, the ASMFC may require that states implement certain facets of fishery management plans, termed "compliance criteria." As discussed in the introduction, most state marine fishery agencies do not have the necessary jurisdiction for implementation of many of the activities prescribed in this policy. As a result, ASMFC may choose not to adopt these specific actions as compliance criteria in fishery management plans. However, compliance criteria relative to the policy which can be implemented by state fisheries agencies may be adopted. The following is a list of compliance criteria which ASMFC will consider for adoption in fishery management plans (FMP) for species with demonstrated reliance on SAV habitat (Laney, 1997; croaker, red drum, menhaden, spot, spotted seatrout, eel, black sea bass, tautog, bluefish, summer flounder, lobster, striped bass and weakfish):

1) Preparation of an annual status report by each state on implementation of each aspect of the policy.

2) Transmission of the policy by each state to all agencies with habitat regulatory and management authority or organizations which can have a significant positive or negative impact on SAV.

3) Preparation of state plans to identify fishing gear and practices employed by any state regulated fishery which may negatively impact SAV; and development and implementation of strategies to eliminate negative impacts identifies pursuant to Section II where appropriate to achieve SAV objectives.

In addition, the policy should be incorporated by reference into FMPs for species with demonstrated reliance on SAV habitat. These FMPs should include background information on the importance of SAVs, and recommendations which parallel the prescribed activities of the policy.

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Appendix J. Habitat laws (Source: EPA 1994).

The Clean Water Act (CWA) 33 U.S.C. s/s 121 et seq. (1977):

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regu-lating discharges of pollutants to waters of the United States. This law gave EPA the authority to set effluent standards on an industry-by-industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in sur-face waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (NPDES) is obtained under the Act. The 1977 amendments focused on toxic pol-lutants. In 1987, the CWA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (POTWs) under the Construction Grants Program. The CWA provides for the delegation by EPA of many permitting, administrative, and enforcement aspects of the law to state gov-ernments. In states with the authority to implement CWA programs, EPA still retains oversight responsibilities.

The comprehensive environmental response, compensation, and liability act (CERCLA or Superfund) 42 U.S.C. s/s 9601 et seq. (1980)

CERCLA (pronounced SERK-la) provides a federal "Superfund" to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. Through the Act, EPA was given power to seek out those parties responsi-ble for any release and assure their cooperation in the cleanup. EPA cleans up orphan sites when potentially responsible parties (PRPs) cannot be identified or located, or when they fail to act. Through various enforcement tools, EPA obtains private party cleanup through orders, consent decrees, and other small par-ty settlements. EPA also recovers costs from financially viable individuals and companies once a response action has been completed. EPA is authorized to implement the Act in all 50 states and U.S. territories. Superfund site identification, monitoring, and response activ-ities in states are coordinated through the state environmental protection or waste man-agement agencies.

The emergency planning & community right-to-know act (EPCRA) 42 U.S.C. 11011 et seq. (1986):

Also known as Title III of SARA, EPCRA was enacted by Congress as the national legislation on community safety. This law was designed to help local communities protect public health, safety, and the environment from chemical hazards. To implement EPCRA, Congress required each state to appoint a State Emergency Response Commission (SERC). The SERCs were required to divide their states into Emergency Planning Districts and to name a Local Emergency Planning Committee (LEPC) for each district. Broad representa-tion by fire fighters, health officials, govern-ment and media representatives, community groups, industrial facilities, and emergency managers ensures that all necessary elements of the planning process are represented.

The endangered species act 7 U.S.C. 136; 16 U.S.C. 460 et seq. (1973):

The Endangered Species Act provides a pro-gram for the conservation of threatened and endangered plants and animals and the habi-tats in which they are found. The U.S. Fish and Wildlife Service (FWS) of the Department of Interior maintains the list of 632 endangered species (326 are plants) and 190 threatened species (78 are plants). Species include birds, insects, fish, reptiles, mam-mals, crustaceans, flowers, grasses, and trees. Anyone can petition FWS to include a species on this list or to prevent some activity, such as logging, mining, or dam building. The law prohibits any action, administrative or real, that results in a "taking" of a listed species, or adversely affects habitat. Likewise, import, export, interstate, and foreign commerce of listed species are all prohibited. EPA's decision to register a pesticide is based in part on the risk of adverse effects on endangered species as well as environmental fate (how a pesticide will effect habitat). Under FIFRA, EPA can issue emergency sus-pensions of certain pesticides to cancel or restrict their use if an endangered species will be adversely affected. Under a new program, EPA, FWS, and USDA are distributing hun-dreds of county bulletins which include habi-tat maps, pesticide use limitations, and other actions required to protect listed species. In addition, we are enforcing regulations under various treaties, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The U.S. and 70 other nations have established procedures to regulate the import and export of imperiled species and their habitat. The Fish and Wildlife Service works with U.S. Customs agents to stop the illegal trade of species, including the Black Rhino, African elephants, tropical birds and fish, orchids, and various corals.

The federal insecticide, fungicide and rodenticide act (FIFRA) 7 U.S.C. s/s 135 et seq. (1972):

The primary focus of FIFRA was to provide federal control of pesticide distribution, sale, and use. EPA was given authority under FIFRA not only to study the consequences of pesticide usage but also to require users (farmers, utility companies, and others) to register when purchasing pesticides. Through later amendments to the law, users also must take exams for certification as applicators of pesticides. All pesticides used in the U.S. must be registered (licensed) by EPA. Registration assures that pesticides will be properly labeled and that, if used in accordance with specifica-tions, will not cause unreasonable harm to the environment.

The (federal) freedom of information act (FOIA) U.S.C. s/s 552 (1966):

The Freedom of Information Act provides specifically that "any person" can make requests for government information. Citizens who make requests are not required to identify themselves or explain why they want the infor-mation they have requested. The position of Congress in passing FOIA was that the work-ings of government are "for and by the people" and that the benefits of government informa-tion should be made available to everyone. All branches of the federal government must adhere to the provisions of FOIA with certain restrictions for work in progress (early drafts), enforcement confidential information, classified documents, and national security information.

The national environmental policy act (NEPA) 42 U.S.C. s/s 4321 et seq. (1969):

The National Environmental Policy Act was one of the first laws ever written that estab-lishes the broad national framework for pro-tecting our environment. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action which significantly affects the environment. NEPA requirements are invoked when airports, build-ings, military complexes, highways, parkland purchases, and other such federal activities are proposed. Environmental Assessments (EAs) and Environmental Impact Statements (EISs), which are assessments of the likelihood of impacts from alternative courses of action, are required from all federal agencies and are the most visible NEPA requirements.

The occupational safety and health act 29 U.S.C. 61 et seq. (1970):

Congress passed the Occupational and Safety Health Act to ensure worker and workplace safety. Their goal was to make sure employers provide their workers a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress, or unsanitary conditions. In order to establish standards for workplace health and safety, the Act also created the National Institute for Occupational Safety and Health (NIOSH) as the research institution for the Occupational Safety and Health Administration (OSHA). OSHA is a division of the U.S. Department of Labor which over-sees the administration of the Act and enforces federal standards in all 50 states.

The pollution prevention act 42 U.S.C. 13101 and 13102, s/s 6602 et seq. (1990):

The Pollution Prevention Act focused indus-try, government, and public attention on reducing the amount of pollution produced through cost-effective changes in production, operation, and raw materials use. Opportuni-ties for source reduction are often not realized because existing regulations, and the industri-al resources required for compliance, focus on treatment and disposal. Source reduction is fundamentally different and more desirable than waste management or pollution control. Pollution prevention also includes other prac-tices that increase efficiency in the use of energy, water, or other natural resources, and protect our resource base through conservation. Practices include recycling, source reduction, and sustainable agriculture.

The resource conservation and recovery act (RCRA) 42 U.S.C. s/s 321 et seq. (1976)

RCRA (pronounced "rick-rah") gave EPA the authority to control hazardous waste from "cradle-to-grave." This includes the genera-tion, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous solid wastes. The 1986 amendments to RCRA enabled EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances. RCRA focuses only on active and future facili-ties and does not address abandoned or his-torical sites (see CERCLA). HSWA (pronounced "hiss-wa") - The federal Hazardous and Solid Waste Amendments. The 1984 amendments to RCRA which required phasing out land disposal of haz-ardous waste. Some of the other mandates of this strict law include increased enforcement authority for EPA, more stringent hazardous waste management standards, and a compre-hensive underground storage tank program.

The safe drinking water act (SDWA) 43 U.S.C. s/s 300f et seq. (1974):

The Safe Drinking Water Act was established to protect the quality of drinking water in the U.S. This law focuses on all waters actually or potentially designated for drinking use, whether from above ground or underground sources. The Act authorized EPA to establish safe standards of purity and required all own-ers or operators of public water systems to comply with primary (health-related) stan-dards. State governments, which assume this power from EPA, also encourage attainment of secondary standards (nuisance-related).

The superfund amendments and reauthorization act (SARA) 42 U.S.C. 9601 et seq. (1986)

The Superfund Amendments and Reautho-rization Act of 1986 reauthorized CERCLA to continue cleanup activities around the country. Several site-specific amendments, definitions, clarifications, and technical requirements were added to the legislation, including additional enforcement authorities. Title III of SARA also authorized the Emergency Planning and Community Right-to-Know Act (EPCRA). the toxic substances control act (TSCA) 15 U.S.C. s/s 2601 et seq. (1976) The Toxic Substances Control Act of 1976 was enacted by Congress to test, regulate, and screen all chemicals produced or imported into the U.S. Many thousands of chemicals and their compounds are developed each year with unknown toxic or dangerous characteris-tics. To prevent tragic consequences, TSCA requires that any chemical that reaches the consumer market place be tested for possible toxic effects prior to commercial manufacture. Any existing chemical that poses health and environmental hazards is tracked and report-ed under TSCA. Procedures also are autho-rized for corrective action under TSCA in cas-es of cleanup of toxic materials contamina-tion. TSCA supplements other federal statutes, including the Clean Air Act and the Toxic Release Inventory under EPCRA.

Appendix K. EPA Region 4 Ocean Dumping Program Summary (Source: EPA 1997).

Introduction

Under the Marine Protection Research and Sanctuaries Act (MPRSA), the U.S. Environmental Protection Agency (EPA) and the Corps of Engineers (COE) share a number of responsibilities with regard to the ocean disposal of dredged material. This involves: designating ocean sites for disposal of dredged material; issuing permits for the transportation and disposal of the dredged material; regulating times, rates, and methods of disposal and the quantity and type of dredged material that may be disposed of; developing and implementing effective monitoring programs for the sites; and evaluating the effect of dredged material disposed at the sites.

Site Selection and Designation

The principal authority and responsibility for designating ocean sites for the disposal of dredged material is vested with the Regional Administrators of the EPA Regions in which the sites are located. The Regions are responsible for developing and publishing Environmental Impact Statements (EIS) and the rulemaking paperwork associated with ocean disposal site designations. The COE Districts provide the EPA Region with the necessary information to prepare the EIS and identify any significant issues which should be addressed in the site designation process generally through a scoping process. Information required from the Districts includes: zone of siting feasibility (ZSF) data, justification for the need for ocean disposal, and alternatives to ocean disposal of the dredged material. The purpose of the EPA site designation process is to establish sites that minimize impacts to the environment, economize disposal site management and monitoring activities, and support multiple users.

Development of Site Management and Monitoring Plans (SMMPs)

The COE District and EPA brings together those people identified as having an interest in the SMMP for a given site. The usual participants are EPA Site Manager, COE Planning, COE Regulatory, COE Operation, State resource individuals, and major permittees (site users). Depending upon the particular issues, US. Fish and Wildlife, National Marine Fisheries Service, South Atlantic Fisheries Management Council, commercial fishermen, and others may be invited to participate in the process. The SMMP team works to identify the specific management goals for each site, based upon several factors (nearby resources, dredged material types, dredging frequencies, etc) . Once the management objectives are agreed upon, specific monitoring goals and objectives are identified to insure those management objectives can be achieved. If deemed necessary, specific monitoring is planned and scheduled. SMMPs are developed as part of the site designation process or separately for sites designated prior to 1992 and are required to undergo public review.

Permitting Procedures

Ocean dumping cannot occur unless a permit is issued under the MPRSA. In the case of dredged material, the decision to issue a permit is made by the U.S. Army Corps of Engineers, using EPA's environmental criteria and subject to EPA's concurrence. EPA's environmental criteria under the MPRSA basically provide that no ocean dumping will be allowed if: the dumping would cause significant harmful effects; or the material proposed to be dumped is not adequately characterized -- in other words, there is not enough information to make the above determination.

In February 1991, EPA and the Corps issued a comprehensive revision to the 1977 manual for testing dredged material proposed for ocean dumping (Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual, Report Number EPA-503/B-91/001). This manual, commonly known as the Green Book, sets out a framework containing the procedures approved by EPA and the Corps for evaluating the dredged material. The framework provides that the intensity of evaluation increases with the risk of contaminants and/or absence of existing information. If an evaluation in one level (tier) is not adequate to determine the material's suitability for ocean disposal, the evaluation proceeds to the next tier(s), and the protocols of the next tier(s) must be followed.

The following is a general summary of the testing and evaluation procedures included in each tier:

Tier I - Evaluation of Existing Information

Tier I specifies when and how existing information, such as results from previous tests on the material, can be used to evaluate the material. If the existing information is inadequate, the evaluation must go to the next tier(s).

Tier II - Conservative Screening Tools

Tier II specifies when and how sediment chemistry can be used in evaluating material by using worst case water column modeling and Theoretical Bioaccumulation Potential (TBP) calculations for the dredged material. (Because there is no model for evaluating toxicity, all sediments entering Tier II must also be tested for toxicity in Tier III.)

The 1991 manual includes updated scientific models for evaluating compliance with water quality criteria issued by EPA to help protect marine species. The dumping must meet the applicable water quality criteria.

The 1991 manual includes use of TBP, which is a scientifically valid approach for evaluating the potential bioaccumulation of certain specific, non-ionic compounds (such as PCBs and dioxin). There is no counterpart model available for metals or polar compounds so if their presence is a concern, actual bioaccumulation testing in Tier III is still necessary.

Tier III - Laboratory Bioassays

Tier III specifies approved testing procedures for toxicity and bioaccumulation. The acute toxicity tests employ 10 day exposures. The 1991 manual stresses the use of amphipods, which are sensitive bottom-dwelling organisms, and describes standardized test methods that were not available when the 1977 manual was developed.

The bioaccumulation tests employ 28 day exposures if contaminants with the potential to bioaccumulate are present in the material. The 1977 manual specified 10 day exposures for all compounds. Use of 28 day exposures to assess bioaccumulation of contaminants was found to be more appropriate.

Tier IV - Advanced Biological Evaluations

Tier IV consists of laboratory and field tests and other evaluations to reduce specific uncertainties about the potential impacts of proposed projects. Tests conducted under this tier are not considered routine in the regulatory program, and can require significant time and expense.

The Green Book includes evaluation methods which can be tailored to the material and location. This is intended to ensure that material is adequately evaluated to make a scientifically sound decision regarding the potential environmental impacts of the proposed ocean dumping, without requiring unnecessary or inappropriate tests in any given case.

Corps Districts and EPA Regional offices work together to develop Regional Implementation Manuals providing supplemental site-specific refinements to the national guidance, such as: identifying the contaminants of concern for the harbors within the region; and

identifying the specific species of organisms to be tested (from the list of organisms in the national manual).

Testing procedures used to evaluate ocean dumping must be approved by EPA and the Corps. No permit is issued unless the agencies have enough information to determine that the ocean dumping will not cause significant harmful effects.

Site Specific Concerns

Concerns regarding use of the Ocean Dredged Material Disposal Sites (ODMDS) are identified during the designation process, during development of the SMMPs or as a result of site monitoring or new public concerns. ODMDSs within EPA Region 4 where site specific concerns have been identified are listed in Table 1.

Table 1

Ocean Dredged Material Disposal Site	Site Specific Concerns
Charleston, SC ODMDS	Live bottom areas proximal to the site subject to possible impact.
Tampa, FL ODMDS	Disposal berm within the site has created unique habitat to be protected.
Miami, FL ODMDS	Effect of disposal plumes on nearshore coral reefs are under investigation.
Fort Pierce, FL ODMDS	Offsite transport of disposed dredged material and subsequent burial of nearby hard bottom communities is of concern to local community.
Jacksonville, FL ODMDS	Lies within Northern Right Whale Critical Habitat and site may be undersized.
Fernandina, FL ODMDS	Lies within Northern Right Whale Critical Habitat.
Brunswick, GA ODMDS	Lies within Northern Right Whale Critical Habitat.
Wilmington, NC ODMDS	Wood debris in dredged material suspected of migrating off site into shrimping grounds.

Proposed New Sites

The COE Districts have identified the following areas in need of new ODMDSs: Port Everglades, FL; Palm Beach, FL; Charlotte Harbor, FL; Port Royal, SC; and Wilmington, NC. Ocean site designations for these areas are in the various stages of the site designation process.

Appendix L. Marpol Annex V- Garbage Disposal Restrictions (Source: DOC 1988c.)

GARBAGE TYPE	ALL VESSELS EXCEPT PLATFORMS AND ASSOCIATED VESSELS		OFFSHORE PLATFORMS AND ASSOCIATED VESSELS
	Outside Special Areas[a]	In Special Areas[b]	
Plastics- including synthetic ropes, fishing nets, and plastic bags	Disposal prohibited	Disposal prohibited	Disposal prohibited
Floating dunnage, lining, and packing materials	Disposal prohibited less than 25 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, metal bottles, crockery, and similar refuse	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., comminuted or ground[c]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited	Disposal prohibited
Food waste not comminuted or ground	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited
Food waste comminuted or ground[c]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited
Mixed Refuse	Varies by component[d]	Varies by component[d]	Varies by component[d]

a Includes all fixed or floating platforms engaged in exploration or exploitation and associated offshore processing of seabed mineral resources, and all vessels alongside or within 500 m (1/3 mile) of such platforms.
b The Mediterranean, Baltic, Red and Black seas, and Persian Gulf.
c Must be able to pass through a screen with a mesh size no larger than 25 mm.
d When substances having different disposal or discharge requirements are mixed, the more stringent disposal requirement

Appendix M. The Effects of Fishing on Fish Habitat (Source: Auster and Langton 1998).

The Effects of Fishing on Fish Habitat

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ABSTRACT

The Sustainable Fisheries Act of 1996 mandates that regional fishery management Councils designate essential fish habitat (EFH) for each of the species which are managed, assess the effects of fishing on EFH, and develop conservation measures for EFH where needed. This synthesis of effects of fishing on fish habitat was produced to aid the fishery management councils in assessing the impacts of fishing activities. A wide range of studies were reviewed that reported effects of fishing on habitat (i.e., structural habitat components, community structure, and ecosystem processes) for a diversity of habitats and fishing gear types. Commonalities of all studies included immediate effects on species composition and diversity and a reduction in habitat complexity. Studies of acute effects were found to be a good predictor of chronic effects. Recovery after fishing was more variable, depending on habitat type, life history strategy of component species, and the natural disturbance regime. The ultimate goal of gear impact studies should not be to retrospectively analyze environmental impacts but ultimately to develop the ability to predict outcomes of particular management regimes. Synthesizing the results of these studies into predictive numerical models is not currently possible. However, conceptual models are presented which coalesce the patterns found over the range of observations. Conceptual models can be used to predict effects of gear impacts within the framework of current ecological theory. Initially, it is useful to consider fishes' use of habitats along a gradient of habitat complexity and environmental variability. A model is presented of gear impacts on a range of seafloor types and is based on changes in the structural habitat values. Disturbance theory provides the framework for predicting effects of habitat change based on spatial patterns of disturbance. Alternative community state models, and type 1-type 2 disturbance patterns, may be used to predict the general outcome of habitat management. Primary data are lacking on the spatial extent of fishing induced disturbance, the effects of specific gear types along a gradient of fishing effort, and the linkages between habitat characteristics and the population dynamics of fishes. Adaptive and precautionary management practices will therefore be required until empirical data becomes available for validating model predictions.

"Habitat alteration by the fishing activities themselves is perhaps the least understood of the important environmental effects of fishing."

Committee on Fisheries, Ocean Studies Board, National Research Council (1994)

INTRODUCTION

Stationary fishing gear (e.g., traps, gillnets, and longlines) and small scale mobile gear (i.e., beam trawls and shellfish dredges) towed from sailing vessels were used in the nineteenth century to harvest living marine resources. The widespread use of mobile fishing gear beyond near shore regions, and the use of larger vessels for all gear types, became possible only after the development of motorized propulsion and the steam capstan and winch. This widespread and critical change in fishing technology began in England with the launch of the steam trawler BERTA in the late 1800s. Fishing effort, and the range of technologies which support the industry, has increased greatly during the last century. For a wide number of harvested species, catch per unit effort has greatly decreased, and the populations of those species have also declined (FAO 1997). Many species are targeted throughout their geographic range and the wide array of harvesting systems (e.g., traps, gillnets, longlines, trawls, scallop dredges, hydraulic clam dredges) allow fishing to occur over the widest range of habitat types.

A lack of understanding the ecological consequences of the effects of removals of fish, and the direct effects of fishing and fishing gear on community and ecosystem functions, has produced questions about the sustainability of current levels of fishing. The number of reviews on this topic which have been produced during the past decade is perhaps the best indicator of this concern (Dayton et al. 1995; Hutchings 1990; ICES 1988, 1992, 1996; Jasperse 1992; Jennings and Kaiser 1998; Jones 1992; Langton 1994; Messieh et al. 1991; National Research Council 1994, 1995; Roberts 1995). In the United States, the need for information leading to predictive capabilities and precautionary approaches on this topic will only increase as a result of the legal requirement to manage essential fish habitat (Auster et al. 1997a; Langton et al. 1996).

The Sustainable Fisheries Act of 1996 requires the regional Fishery Management Councils and the National Marine Fisheries Service (NMFS) to identify and designate essential fish habitat (EFH) for each managed species, identify adverse impacts to EFH (including those caused by fishing activities), and develop actions to conserve and enhance EFH. The Act defines EFH as _those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity_. For the purpose of interpreting the definition (and for defining the scope of this report) _waters_ is interpreted by NMFS as _aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate_ and _substrate_ is defined to include sediment, hard bottom, structures, and associated biological communities. These definitions provide substantial flexibility in defining EFH based on our knowledge of the different species, but also allows EFH to be interpreted within a broader ecosystem perspective. Disturbance has been defined as _any discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment_ (Pickett and White 1985). Disturbance can be caused by many natural processes such as currents, predation, and iceberg scour (Hall, 1994). Human caused disturbance can result from activities such as harbor dredging and fishing with fixed and mobile gear. Disturbance can be gauged by both intensity (as a measure of the force of disturbance) and severity (as a measure of impact on the biotic community). Table 1 summarizes the relative effects of the range of agents which produce disturbances in marine communities. From an ecological perspective, fishing is the most widespread form of direct disturbance in marine systems below depths which are affected by storms (Watling and Norse MS1997).

One of the most difficult aspects of estimating the extent of fishing impacts on habitat is the lack of high resolution data on the distribution of fishing effort. Fishers are often resistant to reporting effort based on locations of individual tows or sets (for the obvious reason of divulging productive locations to competitors and regulators). Effort data in many fisheries are therefore apportioned to particular statistical areas for monitoring purposes. Using this type of data it has been possible to obtain averages of effort, and subsequent extrapolations of area impacted, for larger regions. For eight of the most heavily fished areas in the southern North Sea, for example, Rijnsdorp et al. (1996) estimated that between 1993 and 1996 a mean of 51% of the area was trawled 1-5 times per year, 33% was trawled less than once per year, and 4% was trawled 10-50 times per year. Trawling effort in the Middle Atlantic Bight off the northeast U.S. was summarized by Churchill (1989). Trawled area estimates were extrapolated from fishing effort data in 30' latitude x 30' longitude blocks. The range of effort was quite variable but the percent area impacted in some blocks off southern New England was over 200% with one block reaching 413%. Estimating the spatial impact of fixed gears is even more problematic. For example, during 1996 there were 2,690,856 lobster traps fished in the State of Maine (Maine Department of Marine Resources, unpublished data). These traps were hauled on average every 4.5 d, or 81.4 times $year^{-1}$. Assuming a 1 m^2 footprint for each trap, the area impacted was 219 km^2. If each trap was dragged across an area three times the footprint during set and recovery, the area impacted was 657 km^2. A lack of data on the extent of the area actually disturbed makes analysis of the impacts of fishing on habitat in those fisheries difficult.

The overall impact of fishing on the North American continental shelf is unknown despite research efforts in the United States spanning nearly 80 years. Alexander et al. (1914) reported that the effect of trawling on the bottom was negligible and stated that "otter trawls do not seriously disturb the bottom over which they are fished nor materially denude it of organisms which directly or indirectly serve as food for commercial fishes". Their conclusion was based on data from the catches, discounting the lack of data on organisms that passed through the trawl meshes. They also attributed shifts in species composition and abundance only to harvesting by the fishery with no connection to changes in habitat structure or the benthic community. This conclusion is not surprising given the state of ecological knowledge at the time (Auster 1988). Many more studies, using a wide range of gear types, have been conducted since that time at locations around the world.

Herein we summarize and interpret the current scientific literature on fishing impacts as they relate to fish habitat. We discuss these studies within three broad subject areas: effects on structural components of habitat, effects on benthic community structure, and effects on ecosystem level processes. The interpretation is based on commonalities and differences between studies. Fishing gear types are discussed as general categories (e.g., trawls, dredges, fixed gear). The necessity for these generalizations is based on two over-riding issues: (1) many studies do not specify the exact type and configuration of fishing gear used, and (2) each study reports on a limited range of habitat types. We recognize that individual units of fishing effort with different gears will produce a gradient of results (e.g., a scallop dredge or beam trawl will produce a greater force on the seafloor than a small whiting trawl, tickler chains will produce a different effect than rock-hopper or "street-sweeper" gear on the groundline of a trawl, king crab pots are larger and heavier than pots used for American lobster). However, our interpretation of the wide range of studies is based on the type and direction of impacts, not absolute levels of impacts. We do not address the issues of bycatch (Alverson et al. 1994), mortality of gear escapees (Chopin and Arimoto 1995), or ghost fishing gear (Jennings and Kaiser 1998, p. 11-12 and references therein) as these issues do not directly relate to fish habitat and recent reviews have been published which address these subjects.

EFFECTS ON STRUCTURAL COMPONENTS OF HABITAT

Interpretation of Results

The environmental characteristics which define species distributions can be found at a variety of spatial and temporal scales (e.g., Langton et al. 1995). At regional scales, the seasonal variations in seawater temperature can explain annual variations in the distribution of fishes (e.g., Murawski 1993). Within regions, temporally stable associations of species have been found and tend to follow isotherms and isobaths (Colvocoresses & Musick 1984, Overholtz & Tyler 1985, Phoel 1986, Gabriel 1992, Gabriel and Tyler 1980). Species groups are sometimes seasonal and may split or show changes in composition that correlate with temperature patterns. Nested within regional scale patterns are small-scale variations in abundance and distribution of demersal fishes which can be partially attributed to variation in topographic structure. In contrast, habitat associations for coral reef fishes, kelp bed fishes, seagrass fishes, and rock reef fishes are relatively clear (e.g., Ebeling and Hixon 1991, Heck and Orth 1980, Sale 1991). The entire demersal stage of the life history of many species associated with these unique habitats have obligate habitat requirements or demonstrate recruitment bottlenecks. Without the specific structural components of habitat, the populations of fishes with these habitat requirements would not persist. However, a gradient of habitat dependence can be found in the range of demersal fish species globally. For example, early benthic phase Atlantic cod require cobble or similar complex bottom for survival but have a refuge in size, and habitat associations are more facultative as size increases (Gotceitas and Brown 1993, Lough et al. 1989, Tupper and Boutilier 1995). Other species, however, have facultative habitat associations throughout their life (e.g., Able et al. 1995, Auster et al. 1991, 1995, 1997b, Langton et al. 1995, Sogard and Able 1991, Szedlmayer and Howe 1997). These associations may increase survivorship of individuals, and may contribute to wide variations in recruitment, but they are not obligate for the survival of populations (e.g., Lindholm et al. 1998).

Habitat has been defined as "the structural component of the environment that attracts organisms and serves as a center of biological activity" (Peters & Cross 1992). Habitat in this case includes the range of sediment types (i.e., mud through boulders), bed forms (e.g., sand waves and ripples, flat mud) as well as the co-occurring biological structures (e.g., shell, burrows, sponges, seagrass, macroalgae, coral). A review of 22 studies (Table 2) all show measurable impacts of mobile gear on the structural components of habitat (e.g., sand waves, emergent epifauna, sponges, coral), when defining habitat at this spatial scale. Results of each of the studies show similar classes of impacts despite the wide geographic range of the studies (i.e., tropical to boreal). In summary, mobile fishing gear reduced habitat complexity by: (1) directly removing epifauna or damaging epifauna leading to mortality, (2) smoothing sedimentary bedforms and reducing bottom roughness, and (3) removing taxa which produce structure (i.e., taxa which produce burrows and pits). Studies which have addressed both acute and chronic impacts have shown the same types of effects.

Little has been written about the recovery of seafloor habitat from fishing gear effects. Recovery of storm caused sedimentary features depends primarily on grain sizes of sediment and depth to which storm generated surge and currents occur. Some features can be reformed after seasonal or annual storm events while others will depend on larger meteorological events which occur on decadal time scales or longer. Recovery of biogenic features will depend on recruitment or immigration, depending on the spatial extent of impacts. Recovery will also depend on whether impacts are short term or chronic. For example, on coral-sponge hard bottom off the coast of Georgia, Van Dolah et al. (1987) found no long-term effects of trawling on the benthic community. After one year the sponge and octocorals that were experimentally trawled recovered with densities reaching or exceeding pretrawling levels at the study site. However, it is important to note that this study did not address chronic effects but a single tow of a roller-rigged trawl.

Few published accounts of the impacts of fixed gears on habitat have been written. Eno et al. (1996) studied the effects of crustacean traps in British and Irish waters. One experiment assessed the effects of setting and hauling pots on emergent epifaunal species (i.e., sea pens) on soft bottom. Both impacts from dragging pots across the bottom, and pots resting for extended periods on sea pens, showed the group was able to mostly recover from such disturbances. Limited qualitative observations of fish traps, longlines, and gillnets dragged across the seafloor during set and recovery showed results similar to mobile gear such that some types of epibenthos was dislodged; especially emergent species such as erect sponge and coral (High 1992, SAFMC 1991). While the area impacted per unit of effort is smaller for fixed gear than with mobile fishing gear, the types of damage to emergent benthos appear to be similar (but not necessarily equivalent per unit effort). Quantitative studies of fixed gear effects, based on acute and chronic impacts, have not been conducted.

The issue of defining pelagic habitats and elucidating effects of fishing is difficult because these habitats are poorly described at the scales that allow for measurements of change based on gear use. While pelagic habitat can be defined based on temperature, light intensity, turbidity, oxygen concentration, currents, frontal boundaries, and a host of other oceanographic parameters and patterns, there are few published data that attempt to measure change in any of these types of parameters or conditions concurrently with fishing activity and associations of fishes. Kroger and Guthrie (1972) showed that menhaden (*Brevortia patronus* and *B. tyrannus*) were subjected to greater predation pressure, at least from visual predators, in clear versus turbid water, suggesting that turbid habitats were a greater refuge from predation. This same type of pattern was found for menhaden in both naturally turbid waters and in the turbid plumes generated by oyster shell dredging activities (Harper and Hopkins 1976). However, no work has been published that addresses the effects of variation in time and space of the plumes or the effects using turbid water refugia on feeding and growth. There are also examples of small scale aggregations of fishes with biologic structures in the water column and at the surface. Aggregations of fishes may have two effects on predation patterns by: (1) reducing the probability of predation on individuals within the aggregation, and (2) providing a focal point for the activities of predators (a cue that fishermen use to set gear). For example, small fishes aggregate under mats of *Sargassum* (e.g., Moser et al. 1998) where high density vessel traffic may dis-aggregate mats. Also, fishes have been observed to co-occur with aggregations of gelatinous zooplankton and pelagic crustaceans (Auster et al. 1992, Brodeur in press). Gelatinous zooplankton are greatly impacted as they pass through the mesh of either mobile or stationary gear (unpublished observations), which may reduce the size and number of aggregations and disperse associated fishes. These changes could reduce the value of aggregating, resulting in increased mortality or reduced feeding efficiency.

Implications for Management

Commonalties in gear impact studies on habitat structure allow for the production of a conceptual model to visualize the patterns in gear impacts across a gradient of habitat types. Auster et al. (1998) developed a hierarchical, categorical, approach for classifying habitats on the cold temperate/boreal continental shelf of the northwest Atlantic. This type of classification scheme has proven very useful in habitat management for freshwater fisheries. The range of habitat types were condensed into eight habitat categories increasing from simple to complex (Table 3). For example, currents form sand wave fields which provide shelter for fish from high current speeds. This reduces the energy needed to maintain position on the bottom and permits ambush predation of drifting demersal zooplankton. Storm currents sort loose sediments and deposit shells and cobbles in the troughs of sand waves; the small crevices providing an ephemeral habitat for small fishes and crustaceans. Cobble bottoms provide interstices for shelter sites but also provide a hard surface for epibenthic organisms such as sponges and bryozoans to attach. These emergent epifauna provide additional cover value. Scattered boulders also provide shelter from currents but boulder piles provide deep crevices for shelter required by some species such as redfish (*Sebastes* spp.).

Habitat value for each habitat type does not increase linearly. Each category was assigned a numerical score based on its level of physical complexity (note that this model does not include effects of fishing on biodiversity per se). Categories 1 through 5 increase linearly. Staring at category 6, the score of 10 is based on a score of 5 (i.e., the score for cobble) from the previous category plus 5 for dense emergent epifauna which was assumed to double the cover value of small interstices alone. Category 7 is scored for cobble and emergent epifauna (i.e., 10) plus 2 more points for shallow boulder crevices and refuges from current. Finally, category 8 is scored as 15 because of the presence of shallow crevices and current refuges, previously scored as 12, plus deep crevices scored as 3. These scores are therefore the starting points representing unimpacted habitats.

A pictorial representation of the model, shown in Figure 1, indicates the response of the range of seafloor habitat types to increases in fishing effort (Auster MS1997). The range of fishing effort increases from left to right along the x axis with 0 indicating no gear impacts and 4 indicating the maximum effort required to produce the greatest possible change in habitat complexity. The numbers at present are dimensionless because better data are needed on the effects of various gear types, at various levels of effort, over specific habitats. The y axis is a comparative index of habitat complexity. Each habitat type starts at the value of the habitat in an unimpacted condition. The habitat categories are representative of the common types found across the northeast U.S. continental shelf and are likely to be found on most other continental shelf areas of the world. The responses to different types of bottom contact fishing gear are assumed to be similar.

This model shows a range of changes in habitat complexity based on gear impacts. It predicts reductions in the complexity provided by bedforms from direct smoothing by the gear. Biogenic structures are reduced by a number of mechanisms such as direct gear impacts as well as removal of organisms which produce structures (eg. crabs that produce burrows). There are some habitats where the model shows no significant reductions, such as gravel areas with very little epifaunal settlement. While mobile gear would overturn pebbles and cobbles, the actual structural integrity of the habitat would not be reduced (although organisms on the undersides of cobbles are exposed to predation). However, the value of cobble pavements are greatly reduced when epifauna are removed, as biogenic structures provides additional cover. Gear can move boulders and still provide some measure of hydraulic complexity to the bottom by providing shelter from currents. On the other hand, piles of boulders can be dispersed by large trawls and this reduces the cover value for crevice dwellers. The model should be widely applicable as the habitat types are widely distributed worldwide and the impacts are consistent with those described in the literature.

This conceptual model serves two purposes. First, it provides a holistic summary of the range of gear impacts across a range of habitat types. The end points in the model are based on empirical data and observations and should be useful for considering management actions for the conservation of fish habitat. The second purpose for developing the model is to provide a basis for future research. While it is possible to ascribe the endpoints of habitat complexity at both unimpacted and fully impacted states, the slope of the line remains unknown and the level of fishing effort required to produce specific rates of change is also unknown for all gear types. Responses may be linear or non-linear (e.g., logarithmic). Perhaps there are thresholds of disturbance beyond which some habitat types exhibit a response. Regardless, responses will most likely be habitat specific.

The impact model does not have an explicit time component. Here we add such a conceptual framework to the discussion. Cushing's match-mismatch hypothesis (Cushing 1975) has served as one of several hypotheses which explain annual variation in larval recruitment dynamics and has been the focus of large amounts of research effort for several decades. Here we propose a similar type of match-mismatch paradigm for linking variation in the survivorship of early benthic phase fishes with the abundance epibenthic organisms, particularly those with annual life histories, which may serve as habitat. Figure 2 shows the pattern in percent cover for an idealized benthic species which produces emergent structure (e.g., hydroid stalk, amphipod tube, mussel). This type of species has widespread settlement and occurs at high densities. At the time of settlement, large areas of the seafloor are occupied by this species. Over the course of time, predation and senesence reduce the cover provided by such taxa. The timing of settlement of early benthic phase fish will greatly effect the cover value provided by the benthic taxa. In addition to natural processes, fishing gear impacts further reduce the cover value over time and can narrow the window in which particular patches of epibenthos serve as effective cover for newly settled fishes. The time scale (x-axis) and patterns in the figure were developed to show an annual pattern representative of many taxa with such life history strategies, but this pattern can also be extended in time for longer-lived organisms. Like the conceptual impact model above, the timing and changes in slope of these lines is critical for understanding the dynamics of this interaction.

Ultimately, it will be necessary to develop models which include sensitivity indices for specific habitats, communities, and key taxa based on the effects of specific gear types, levels of effort, and life history patterns (of both fish and taxa which serve a habitat function). MacDonald et al. (1996) has developed such a sensitivity index to quantify the impact of fishing on particular epifaunal taxa in the North Sea region. The index is a function of recovery time after damage, fragility of the animal and intensity of the impact.

Lack of information on the small scale distribution and timing of fishing make it difficult to ascribe the patterns of impacts observed in field studies to specific levels of fishing effort. Auster et al. (1996) estimated that between 1976 and 1991, Georges Bank was impacted by mobile gear (i.e., otter trawl, roller-rigged trawl, scallop dredge) on average between 200-400% of its area on an annual basis and the Gulf of Maine was impacted 100% annually. Fishing effort was however not homogeneous. Sea sampling data from NMFS observer coverage demonstrated that the distribution of tows was nonrandom (Fig. 3). While these data represent less than 5% of overall fishing effort, they illustrated that the distribution of fishing gear impacts is quite variable.

Recovery of the habitat following trawling is difficult to predict as well. Timing, severity, and frequency of the impacts all interact to mediate processes which lead to recovery (Watling and Norse MS1997). For example, sand waves may not be reformed until storm energy is sufficient to produce bedform transport of coarse sand grains (Valentine and Schmuck 1995) and storms may not be common until a particular time of year or may infrequently reach a particular depth, perhaps only on decadal time scales. Sponges are particularly sensitive to disturbance because they recruit aperiodically and are slow growing in deeper waters (Reiswig 1973, Witman and Sebens 1985, Witman et al. 1993). However, many species such as hydroids and ampelescid amphipods reproduce once or twice annually and their stalks and tubes provide cover for the early benthic phases of many fish species and their prey (e.g., Auster et al. 1996, 1997b). Where fishing effort is constrained within particular fishing grounds, and where data on fishing effort is available, studies which compare similar sites along a gradient of effort, have produced the types of information on effort-impact that will be required for effective habitat management (e.g., Collie et al. 1996, 1997; Thrush et al. in press).

The role these impacts on habitat have on harvested populations is unknown in most cases. However, a growing body of empirical observations and modeling demonstrate that effects can be seen in population responses at particular population levels. For example, Lindholm et al. (1998) have modeled the effects of habitat alteration on the survival of 0-year cohorts of Atlantic cod. The model results indicate that a reduction in habitat complexity has measurable effects on population dynamics when the adult stock is at low levels (i.e., when spawning and larval survivorship does not produce sufficient recruits to saturate available habitats). At high adult population levels, when larval abundance may be high and settling juveniles would greatly exceed habitat availability, predation effects would not be mediated by habitat and no effect in the response of the adult population to habitat change was found.

Empirical studies that most directly link changes due to gear impacts on habitat structure to population responses are being carried out in Australia. Sainsbury (1987,1988, 1991) and Sainsbury et al. (in press) have shown a very tight coupling between a loss of emergent epifauna and fish productivity along the north west continental shelf. In these studies there was a documented decline in the bycatch of invertebrate epifauna in trawl catches, from 500 kg hr^{-1} to only a few kg hr^{-1}, and replacement of the most commercially desirable fish associated with the epifaunal communities by less valuable species associated with more open habitat. By restricting fishing the decline in the fish population was reversed. This corresponded to an observed recovery in the epifaunal community, albeit the recovery for the larger epifaunal invertebrates showed a considerable lag time after trawling ceased. This work is based on a management framework which was developed to test hypotheses regarding the habitat dependence of harvested species. The hypotheses, described in Sainsbury (1988, 1991), assessed whether population responses were the result of: (1) independent single-species (intraspecific) responses to fishing and natural variation, (2) interspecific interactions such that as specific populations are reduced by fishing, non-harvested populations experienced a competitive release, (3) interspecific interactions such that as non-harvested species increase from some external process, their population inhibits the population growth rate of the harvested species, and (4) habitat mediation of the carrying capacity for each species, such that gear induced habitat changes alter the carrying capacity of the area. This is a primary example of adaptive management in which regulations were developed to test hypotheses and were the basis for modifying subsequent management measures. This type of management process exemplifies management of fisheries based primarily on an understanding of ecological relationships.

EFFECTS ON COMMUNITY STRUCTURE

Interpretation of Results

Studies on the effects of fishing on benthic communities have often produced variable results regarding the impact on community structure. The reasons for these differences may include sampling strategies, use of different metrics, different methods of fishing, different functional groups of species which compose the community, and subtle differences in habitat type. Furthermore, studies have often been conducted in areas that have a history of fishing activity and therefore may not have truly undisturbed reference areas for comparison, despite the efforts of the investigator (see Hall et al. 1993, Kaiser MS1997). Changes in benthic community structure also have to be understood against a background of natural disturbance and variability (Thrush et al., in press). Bearing in mind these caveats, the literature on fishing gear impacts can be divided into short term and long term studies that reveal some common characteristics and patterns resulting from fishing on the seafloor.

An immediate reduction in the density of non-target species is often reported following impacts from mobile gear (Table 4). In assessing this effect it is common to compare numbers and densities for each species before and after fishing and/or with an undisturbed reference site. Kaiser and Spencer (1996a), for example, found a reduction in diversity and abundance of some taxa at one location in the Irish Sea where sediments were relatively stable. They reported a 58% decrease in mean abundance and 50% reduction in the mean number of species per sample. In contrast, at a location where the sediments were more mobile the impact of beam trawling was not as substantial. In other European studies, Bergman and Hup (1992) and Santbrink and Bergman (1994) have documented species and size specific differences in macrofaunal abundance and mortality, with densities decreasing for some species, and mortality increasing, after trawling but in other cases there were no observable effects. In a scallop dredging study in New Zealand two experimentally fished sites showed an immediate decrease in macrofaunal densities in comparison to corresponding reference sites (Thrush et al. 1995). In another study of scallop dredging in Australia, Currie and Parry (1994) found that the number of individuals at the dredged sites was always lower than the reference sites despite an overall increase in animal numbers, over the 88 day study, because of amphipod recruitment to both the experimental and reference areas.

Time series data sets that allow for a direct long term comparison of before and after fishing are essentially nonexistent, primarily because the extent to which the worlds oceans are currently fished was not foreseen, or because time series data collection focused on the fish themselves rather than the impact of fishing on the environment. Nevertheless, there are several benthic data sets that allow for an examination of observational or correlative comparisons before and after fishing (Table 5). Perhaps the longest time series comparisons of long-term impact of fishing on benthic community structure are the studies of Reise (1982) and Riesen and Reise (1982) in the Wadden Sea. In reviewing change for 101 species in the benthic community over 100 years Reise (1982) noted no long-term trends in abundance for 42 common species but found 11 of these species showed considerable variation. Sponges, coelenterates and bivalves suffered the greatest losses while polychaetes showed the biggest gains. Subtidally there was a decrease in the most common species from 53 to 44 while intertidally the opposite was observed, an increase from 24 to 38. Riesen and Reise (1982) examined a 55 year data set and documented increases in mussel beds and the associated fauna. They noted a loss of oysters, due to overexploitation, and *Sabellaria* reefs, because they were systematically targeted by trawlers, as well as the loss of seagrass from disease. In another European study, Pearson et al. (1985) compared changes in the Kattegatt following a 73 year hiatus in sampling. In this case, community composition had changed to the extent that there was only a 30% similarity between stations over time, with the primary shift being a decrease in sea urchins and an increase in brittle stars. They observed a general decline in deposit feeders and an increase in suspension feeders and carnivores as well as a decline in animal size. Holme (1983) also made some comparisons from data collected over an 85 year time span in the English Channel and noted changes in the benthic community which he speculated might relate to the queen scallop fishery. The results of these long term studies are consistent with the patterns found in short term studies of habitat and community structure.

Data sets on the order of months to a few years are more typical of the longer term studies on fishing impacts on benthic community structure. The impact of experimental trawling has been monitored over a series of months, for example, in the Bay of Fundy at a high energy sandy site (Brylinsky et al. 1994, Watling et al. MS1997). Trawl door marks were visible for 2 to 7 months but no sustained significant impact on the benthic community was noted. However, Watling et al. (MS1997) measured community level changes caused by scallop dredging at a lower energy muddy sand location in the Gulf of Maine. There was a loss in surficial sediments and lowered food quality of the sediments. The subsequent variable recovery of the benthic community over the following six months correlated with the sedimentary food quality which was measured as microbial populations, abundance of chlorophyll *a* and enzyme hydrolizable amino acid concentrations. While some taxa recolonized the impacted areas quickly, the abundances of some taxa (i.e., cumaceans, phoxocephalid and photid amphipods, nephtyid polychaetes) did not recover until food quality also recovered.

The most consistent pattern in fishing impact studies at shallow depths is the resilience of the benthic community to fishing. Two studies in the intertidal, harvesting worms and clams using suction and mechanical harvesting gear, demonstrated a substantial immediate effect on the macrofaunal community but from seven months to two years later the study sites had recovered to pre-fished conditions (Beukema 1995, Kaiser and Spencer 1996a). At nearshore subtidal depths, harvesting bay scallops in a North Carolina seagrass bed and razor clams in a Scottish sea loch, Peterson et al. (1987) and Hall et al. (1990) found little long term impact on the benthic community structure except at the most intense level of fishing. After 40 days, the loch showed no effect of fishing and in the lightly harvested seagrass bed, with <25% seagrass biomass removal, recovery occurred within a year. In the seagrass bed where harvesting was most extensive, with 65% of the seagrass biomass removed, recovery was delayed for two years and after four years preharvesting biomass levels were still not obtained. In a South Carolina estuary, Van Dolah et al. (1991) found no long term effects of trawling on the benthic community. The study site was assessed prior to and after the commercial shrimp season and demonstrated variation over time but no trawling effects *per se*. Other studies of pre and post impacts from mobile gear on sandy to hard bottoms have generally shown similar results (Currie and Parry 1996, Gibbs et al. 1980, MacKenzie 1982) with either no or minimal long term impact detectable.

Other benthic communities show clear effects which can be related to fishng. Collie et al. (1997) has, for example, characterized disturbed and undisturbed sites on Georges Bank, based on fishing records, and found more individuals, a greater biomass and greater species richness and diversity in the undisturbed areas. Engel and Kvitek (MS 1997) also found more fish and epifaunal invertebrates in a lightly trawled area compared to a more heavily trawled site over a three year period off Monterey, California. Perhaps the most convincing cases of fishing related impacts on the benthic community are from studies in Northern Ireland, Australia, and New Zealand. Brown (1989) has reported the demise of the horse mussel community in Strangford Loch with the development of the queen scallop fishery. The horse mussel beds were essentially unchanged from 1857 until 1980 when the trawl fishery for scallops was initiated. Along the northwest Australian shelf Bradstock and Gordon (1983) and Sainsbury (1987, 1988, 1991) and Sainsbury et al. (in press) describe a habitat dependent fishery with fish biomass being related to the coral-like byrozoan community. With the demise of this epifaunal community there was a shift in fish species composition to less commercially desirable species. In experimentally closed areas there has been a recovery of fish and an increase in the small benthos but, based on settlement and growth of larger epifaunal animals, it may take 15 years for the system to recover. Finally, sampling of fishing grounds along a gradient of fishing effort in the Hauraki Gulf of New Zealand has shown that 15-20% of the variability in the macrofauna community could be attributed to fishing (Thrush et al. in press). As fishing effort decreased there were increases in the density of large epifauna, long-lived surface dwellers (with a decrease in deposit feeders and small opportunistic species), and in the Shannon-Weiner diversity index. These results validated most predictions made from small scale studies, suggesting that there is value in continuing such work. However, where data are available to determine patterns of fishing effort at the scale of fishing grounds, large scale studies such as this are beneficial for validating predictions from limited experimental work and, most importantly, establishing the range of ecological effects along a gradient of disturbance (i.e., produced by resource extraction and variable intensity of impacts from particular harvesting methods. Ultimately, such data can be used to develop strategies for the sustainable harvest of target species while maintaining ecosystem integrity.

Implications for Management

Clearly the long term effects of fishing on benthic community structure are not easily characterized. The pattern that does appear to be emerging from the available literature is that communities that are subject to variable environments and are dominated by short-lived species are fairly resilient. Depending on the intensity and frequency of fishing, the impact of such activity may well fall within the range of natural perturbations. In communities which are dominated by long-lived species in more stable environments the impact of fishing can be substantial and longer term. In cases such as described for Strangford Loch and the Australian shelf, recovery from trawling will be on the order of decades. In many areas, these patterns correlate with shallow and deep environments. However, water depth is not the single variable that can be used to characterize fishing impacts. There are few studies that describe fishing impacts on shallow mud bottom communities or deep areas at the edge of the continental shelf. Such sites would be expected to be relatively low energy zones, similar to areas in Strangford Loch, and might not recover rapidly from fishing disturbances. Studies in these relatively stable environments are required to pattern fishing impacts over the entire environmental range but, in anticipation of such results, it is suggested here that one should expect a tighter coupling between fish production and benthic community structure in the more stable marine environments.

EFFECTS ON ECOSYSTEM PROCESSES

Interpretation of Results

A number of studies indicate that fishing has measurable effects on ecosystem processes, but it is important to compare these with natural process rates at appropriate scales. Both primary production and nutrient regeneration have been shown to be effected by fishing gear. These studies are small in scope and it is difficult to apply small-scale studies at the level of entire ecosystems. Understanding that processes are affected confirms the need to understand the relative changes in vital rates caused by fishing and the spatial extent of the disturbances.

Disturbance by fishing gear in relatively shallow depths (i.e., 30-40 m depth) can reduce primary production by benthic microalgae. Recent studies in several shallow continental shelf habitats have shown that primary production by a distinct benthic microflora can be a significant portion of overall primary production (i.e., water column plus benthic primary production; Cahoon and Cooke, 1992; Cahoon et al., 1990; 1993). Benthic microalgal production supports a variety of consumers, including demersal zooplankton (animals that spend part of each day on or in the sediment and migrate regularly into the water; Cahoon and Tronzo, 1992). Demersal zooplankton include harpacticoid copepods, amphipods, mysids, cumaceans, and other animals that are eaten by planktivorous fishes and soft bottom foragers (Thomas and Cahoon, 1993).

The effects of fishing were elucidated at Stellwagen Bank in the northwest Atlantic during 1991 and 1994. Measurements showed that a productive benthic microflora exists on the crest of the Bank (Cahoon et al., 1993; Cahoon et al., unpubl. data) but demersal zooplankton was low in comparison to the other shelf habitats and lower than would be expected given the available food supply (Cahoon et al.1995). Several explanations can be advanced for this anomalously low abundance. These include competitive or predatory interactions with meiofauna or the holozooplankton, disturbance by macrobenthos, intense predation by planktivorous fishes, and physical disturbance by mobile fishing gear. Many demersal zooplankters appear to construct and/or inhabit small burrows or capsules made of accreted or agglutinated sand. These formations provide shelter for demersal zooplankters in a habitat otherwise devoid of structure. Many small biogenic structures were observed on the sediment surface and even gentle handling by divers destroyed them easily. Movement by divers and an ROV caused demersal zooplankters to exhibit escape responses. Events that disturb the bottom, particularly such relatively powerful events as storms and towing mobile fishing gear along the sediment surface, must destroy these delicate habitat features. Disturbance of demersal zooplankters may result in increased predation which reduces local populations of zooplankters. Juvenile fish that feed on these taxa may require greater times and longer distances away from benthic shelter sites to forage in the water column in order to capture prey, exposing themselves to greater predation risk (Walters and Juanes 1993).

Recovery rates of populations of benthic primary producers are not well known. Brylinski et al. (1994) showed that trawling had significant effects on benthic diatoms, but recovery occurred at all stations after about 30 days. The experimental sites which were trawled were in the intertidal in the Bay of Fundy. Trawling occurred during high tides and sampling at low tide. It is important to note that light intensity (and spectral composition) in this experiment are much greater than at sites where trawling normally occurs; where seawater constantly overlays the substrate.

Experimental measurements from scallop dredge and otter trawl impacts off coastal Maine showed that dragging can both resuspend and bury labile organic matter (Mayer et al. 1991). Burial shifts the decomposition and availability from aerobic eucaryotic-microbial pathways to anerobic pathways. Short term effects may include shifts from metazoan communities which support harvested species (e.g., meiofauna-polychaetes-flounders) toward anerobic microbial respiration. Studies by Watling et al. (MS1997) empirically demonstrate these short term trends. Longer term effects of chronic dragging and burial are difficult to predict.

Reimann and Hoffmann (1991) measured the short term effects of mussel dredging and bottom trawling off Denmark in a shallow coastal marine system. Dredging and trawling increased suspended particulates immediately to 1361% and 960-1000% respectively, above background. Oxygen decreased and nutrients such as amminia and silicate increased. Dyekjaer et al. (1995) calculated the annual effects of mussel dredging in the same region. The total annual release of suspended particles during dredging is relatively minor when compared with total wind-induced resuspension. Similarly, the release of nutrients is minor when compared with the nutrient loading from land runoff. However, local effects may be significant when near bottom dissolved oxygen concentrations are low and reduced substances are resuspended, depending upon the depth of stratification, water flow rates, and the number of dredges operating simultaneously.

Direct movement of fishing gear over and through the sediment surface can change sediment grain size characteristics, change suspended load, and change the magnitude of sediment transport processes. Churchill (1989) showed that trawling could resuspend sediments on the same magnitude as storms and can be the primary factor regulating sediment transport over the outer continental shelf in areas where storm related currents and bottom stresses are weak. Gear induced resuspension of sediments can potentially have important impacts on nutrient cycling (Pilskaln et al. MS1997). Open continental shelf environments typically receive approximately half of their nutrients for primary production from sediment resuspension and pore water exchange. The nutrients are produced from the microbial based decay of organic matter and remineralization within sediments. Changes in rates of resuspension from periodic to steady pulses of nutrients (e.g., nitrate fluxes), caused by gear disturbance to the seafloor, can shift phytoplankton populations from picoplankton towards diatoms which may ultimately be beneficial for production of harvested species, while changes in nutrient ratios may stimulate harmful algal blooms.

Implications for Management

The disturbances caused by fishing to benthic primary production and organic matter dynamics are difficult to predict. Semi-closed systems such as bays, estuaries, and fjords are subject to such effects at relatively small spatial scales. Open coastal and outer continental shelf systems can also experience perturbations in these processes. However, the relative rates of other processes may minimize the effects of such disturbances depending upon the level of fishing effort.

Mayer et al. (1991) discuss the implications of organic matter burial patterns in sediments versus soils. Their results are similar to organic matter patterns found in terrestrial soils. Sediments are essentially part of a burial system while soils are erosional. While gear disturbance can enhance remineralization rates by shifting from surficial fungal dominated communities to subsurface communities with dominant bacterial decomposition processes, burial caused by gear disturbance might also enhance preservation if material is sequestered in anaerobic systems. Given the importance of the carbon cycling in estuaries and on continental shelves to the global carbon budget, understanding the magnitude of effects caused by human disturbances on primary production and organic matter decomposition will require long term studies as have been conducted on land.

DISCUSSION

Direct Alteration of Food Webs

In heavily fished areas of the world it is undebatable that there are ecosystem level effects (Gislason, 1994; Fogarty and Murawski 1998) and that shifts in benthic community structure have occurred. The data to confirm that such shifts have taken place is limited at best (Riesen and Reise, 1982) but the fact that it has been documented at all is highly significant. If the benthic communities change, what are the ecological processes that might bring about such change?

One of these is an enhanced food supply, resulting from trawl damaged animals and discarding both nonharvested species and the offal from fish gutted at sea. The availability of this food source might affect animal behavior and this energy source could influence survival and reproductive success. There are numerous reports of predatory fishes and invertebrate scavengers foraging in trawl tracks after a trawl passes through the area (Medcof and Caddy 1971, Caddy 1973, Kaiser and Spencer 1994, Ramsey et al. 1997a, b). The prey available to scavengers is a function of the ability of animals to survive the capture process, either being discarded as unwanted by-catch or having been passed through or over by the gear (Meyer et al. 1981, Fonds 1994, Rumhor et al. 1994, Santbrink and Bergman 1994, Kaiser and Spencer 1995). Studies in both the Irish and North Sea on the reaction of scavengers to a trawling event, usually involving beam trawling, are the most comprehensive. In the Irish Sea studies focused on the movement of animals over time into an experimentally trawled areas, at locations that range in sediment type from mud to gravel. Results were found to be habitat dependent (Ramsay et al. 1997a,b) and not always consistent (Kaiser and Ramsay 1997) although the general trends are that the rate of movement of scavengers into a trawled area reflects the mobility of the animals, their sensory abilities and their behavior (Kaiser and Spencer 1996b). Fish were usually the first to arrive and slower moving invertebrates like whelks and starfish, which were also attracted to the area, required a longer time to respond to the availability of damaged or dead prey. That the scavengers are feeding has been documented both by direct diver observations and analysis of stomach contents (see Caddy 1973, Rumhor et al. 1994). Stomach contents data demonstrate that fish not only feed on discarded or damaged animals, and often eat more than their conspecifics at control sites, but they also consume animals that were not damaged but simply displaced by the trawling activity, or even those invertebrates that have themselves responded as scavengers (Kaiser and Spencer 1994, Santbrink and Bergman 1994). Hence the biomass available for consumption from discards and offal are not effecting the community equally but selectively providing additional food resources for those taxa which differentially react to the disturbance created by fishing.

It is of interest to note that Kaiser and Spencer (1994) make the comment, as others have before them, that it is common practice for fishermen to re-fish recently fished areas to take advantage of the aggregations of animals attracted to the disturbed benthic community. The long term effect of opportunistic feeding following fishing disturbances is an area of speculation. In the North Sea, for example, the availability of "extra" food, either from discarded bycatch or as a more direct result of trawling induced mortality, has been suggested as one reason why the population of dab, *Limanda limanda*, has increased. Kaiser and Ramsay (1997) argue that the combination of predator and competitor removal by fishing together with an increased food supply has resulted in the increase in the dab population. Obviously the negative effects on the prey organisms themselves are also important and may have an equal but opposite effect on their density. Faunal changes in the North Sea have been noted with major shifts in the composition of the benthic community that can be correlated with trawling. The general decline in populations of hard bodied animals, such as bivalves and heart urchins, has been suggested to be the direct result of trawl damage with, one might speculate, this food becoming available to scavengers.

Another process that can indirectly alter food webs is alteration of the predator community by removing keystone predators. Removal of herbivorous fishes and invertebrates produced a shift in coral reef communities from coral-invertebrate dominated systems to filamentous and fleshy algae dominated (Roberts 1995 provides a synoptic review). The removal of sea otters from kelp bed communities in the western Pacific has also had cascading effects on urchin populations and the dynamics of kelp (Duggins 1980, Estes 1996). In the northwest Atlantic, Witman and Sebens (1992) showed that onshore-offshore differences in cod and wolffish populations reduced predation pressure on cancrid crabs and other megafauna in deep coastal communities. They suggest that this regional difference in predation pressure is the result of intense harvesting of cod, a keystone predator, with cascading effects on populations of epibenthos (e.g., mussels, barnacles, urchins) which are prey of crabs. American lobsters were also considered a keystone predator by controlling urchin populations, which controlled the distribution of kelp (e.g., Mann and Breen 1972, Mann 1982). Communities shifted from kelp dominated to coralline algae dominated under the influence of intense urchin predation, with concomitant shifts in the mobile species which use such habitats. A hypothesis about this shift in communities focused on the role of lobster removals by fishing, where urchins which are a primary prey of lobsters, had large population increases resulting in greater herbivory on kelp. However, Elner and Vadas (1990) brought the keystone predation hypothesis into question as urchins did not react to lobster predation by forming defensive aggregations and lobster diets were not dominated by urchins. Understanding the ultimate control of such shifts remains elusive but recent harvesting of urchins has coincided with a return of kelp dominated habitats. Other processes (e.g., annual variation in physical processes effecting survivorship of recruits, climate change, El Nino, recruitment variability of component species caused by predator induced mortality) can also result in food web changes and, while it is important to understand the underlying causes of such shifts, precautionary approaches should be considered given the strong inference of human caused effects in the many cases where studies were focused on identifying causes.

Predicting the Effects of Disturbance

This review of the literature indicates that fishing, using a wide range of gear, produces measurable impacts. However, most studies were conducted at small spatial scales and it is difficult to apply such information at a regional levels where predictive capabilities would allow us to manage at an ecosystem scale (Jennings and Kaiser 1998). Studies can be divided into those focused on acute impacts, of a single or a small number of tows, or those which focus on chronic effects. While the former type of study is most common and amenable to experimental manipulation, the latter is the type most directly applicable in the arena of habitat management. Unfortunately, few long term monitoring programs allow for an analysis of all of the appropriate metrics needed to ascertain the effects of fishing on EFH. Additionally, while there are clear effects on local and regional patterns of biodiversity, an obvious metric needed to monitor the effects of ecosystem level management, we do not have a good understanding of how communities respond to large scale disturbances. This level of knowledge is needed to separate the responses of natural versus anthropogenic caused variability.

Our current understanding of ecological processes related to the chronc disurbances caused by fishing make results difficult to predict. Disturbance has been widely demonstrated as a mechanism which shifts communities (Dayton 1971, Pickett and White 1985, Witman 1985, Suchanek 1985). While a full discussion of this area of ecology is beyond the scope of this review, general models produced from such work are useful for understanding fishing as an agent of disturbance in an ecological perspective. Assumptions regarding the role of fishing on the dynamics of marine communities generally assert that the cessation or reduction of fishing will allow populations and communities to recover. That is, recover to a climax community state as is the case in long-lived terrestrial plant communties. Succession of communities implies a predictable progression in species composition and abundance (Connell 1989, Bell et al. 1991). Such knowledge of successional patterns would allow managers to predict future community states and directly manage EFH. While direct successional linkages have been found in some communities, others are less predictable.

Two types of patterns in shifts in communiy states due to disturbance are illustrated in Figure 4. The first model is the traditional successional model where communties change from type A to B to C and so forth. There are empirical examples of this type of succession in soft substrate benthic communties (e.g., Rhoads et al. 1978). Succession is based on one community of organisms producing a set of local environmental conditions (e.g., enriching the sediments with organic material) which make the environment unsuitable for continued survival and recruitment but are favorable for another community of organisms. Disturbance can move the succession back in single or multiple steps, depending on the type of conditions which prevail after the disturbance. The successional stages are predictable based on the conditons which result from the organisms themselves or from conditions after a perturbation. The second type of model is disturbance mediated and lottery based (based on Horn 1976). Empirical studies of such relationships are generally found in hard substrate communities (e.g., Dayton 1971, Horn 1976, Sebens 1986, Witman 1987). Shifts in community type are produced by competition and disturbance (e.g., predation, grazing, storms, fishing gear) that can result in shifts toward community types which are often unpredictable because they are based on the pool of recruits available in the water column at the time that niche space is available.

The spatial extent of disturbed and undisturbed communities is a concern in designing and interpreting studies (Pickett and White 1985, Barry and Dayton 1991, Thrush et al. 1994). Single, widely spaced disturbances may have little overall effect on habitat integrity and benthic communities, and may show reduced recovery times as a result of immigration of mobile taxa (e.g., polychaetes, gastropods). In the ecological literature, this is a type 1 disturbance, where a small patch is disturbed but surrounded by a large unimpacted area. In contrast, type 2 disturbances are those in which small patches of undisturbed communities are surrounded by large areas of disturbed communities. Immigration into such patches requires large scale transport of propagules from outside source patches, or significant reproductive output (and high planktonic survival and larval retention) from the small undisturbed patches. Making predictions about the outcome of disturbances even where spatial extent is known is difficult since transport of colonizers (i.e., larvae, juveniles, and adults) depends on oceanographic conditions, larval period, movement rates of juveniles and adults, time of year, and distance from source. However, as an example of disturbance effects given specific sets of conditions, it is possible to illustrate general trends in the response of biogenic habitat structure to type 1 and 2 disturbances and the population responses based on characteristics of obligate and facultative habitat users (Fig. 5). Type 1 disturbances have recovery rates that are generally faster because they are subject to immigration dominated recovery versus the dependence of larval recruitment for recovery of type 2 disturbances. Population responses to such disturbances are also variable. Obligate habitat users have a much greater response to habitat disturbance such that type 1 disturbances would produce substantial small scale effects but overall population responses would be small. Comparatively, it would be difficult to detect responses from populations of facultative habitat users because of large areas of undisturbed habitat. However, type 2 disturbances would produce large responses in obligate habitat users such that a large percentage of required habitat would be effected. Facultative habitat users would have a measurable response at population levels where habitat mediated processes are important.

The dependence of fish communities on particular habitat features is well represented in the literature on coral reef, kelp forest, and seagrass fish communities (e.g., Sale 1991, Ebeling and Hixon 1991, Heck and Orth 1980). Studies at this particular scale are generally lacking for most harvested taxa on outer continental shelves. One problem in interpreting existing studies is that we tend to compartmentalize the processes which structure these communities and not apply our general knowledge of habitat mediated processes to other fish assemblages using other habitats. In reality, fish assemblages occur in a continuum along two gradients; one of habitat complexity and the other of environmental variation (Fig. 6). Only limited numbers of species, and communities, have hard (limited) linkages between parts of the food web where gear impacts on prey communities would have obvious and easily measurable effects. Large temperate and boreal marine ecosystems are characterized by soft (flexible) linkages with most species having flexible prey requirements. Measuring effects which can be linked to changes in prey availability, and ultimately back to effects of fishing gear will be challenging in these situations. New molecular and stable isotope techniques offer the possibility for better tracking of trophic transfer of carbon and labeling of the role of particular prey taxa in secondary and tertiary production. The same can be said for effects of structural habitat change. It is difficult to detect signal changes because variability in populations are the cumulative result of many factors. Small scale field studies producing information on the patterns of survivorship and predator-prey interactions in particular habitats, laboratory tests to determine relative differences in habitat mediated survivorship under constant predator-prey densities, and numerical modeling to link the small scale approaches with population level responses provides the bridge to link small scale studies to large scale patterns.

Further Considerations for Management

Fishing is one of the most widespread human impacts to the marine environment. The removal of fish for human consumption from the world_s oceans has effects not only on the target species but also on associated communities. The size specific, and species specific, removal of fish can change the system structure but, fortunately, the regions of the continental shelf which are normally fished appear to be fairly resilient. The difficulty for managers is defining the level of resilience, in the practical sense of time/area closures or mesh regulations or overall effort limits, that will allow for the harvest of selected species without causing human induced alterations of ecosystem structure to the point that recovery is unduly retarded or community and ecosystem support services are shifted to an alternate state (Steele 1996). Natural variability forms a backdrop against which managers must make such decisions and, unfortunately, natural variability can be both substantial and unpredictable. The above discussion on the impact of fishing on marine communities does not address the role of natural variability directly but it is apparent that in many of the systems studied there is an inherent resistance to biological change. In the very long term one can expect natural variability to generate regime shifts but the challenge for natural resource managers is not to precipitate these shifts prematurely or in unintended directions.

Much of the research described herein is not at a scale that directly relates to effects on fish populations and therefore does not link directly to fishery management decisions. The research on fishing gear impacts does offer an indication of the types and direction of changes in benthic communities over large spatial scales as well as confirmation that benthic communities are dynamic and will ultimately compensate for perturbations. However, as observations show, shifts in communities are not necessarily beneficial to the harvested species. The scale of fishing is a confounding factor in management because systems are being fished to the point where recovery is delayed so long that the economic consequences are devastating. We are currently seeing this pattern in many U.S. fisheries (and many other fisheries worldwide for that matter). Because our knowledge of ecosystem dynamics is still rather rudimentary managers bear the responsibility of adopting a precautionary approach when considering the environmental consequences of fishing rather than assuming that the extraction of fish has no ecological price and therefore no feedback loop to our non-ecologically based economic system.

This review has revealed that primary information is lacking for us to strategically manage fishing impacts on EFH without invoking precautionary measures. A number of areas where primary data are lacking, which would allow better monitoring and improved experimentation ultimately leading to improved predictive capabilities, are:

1. **The spatial extent of fishing induced disturbance.** While many observer programs collect data at the scale of single tows or sets, fisheries reporting systems often lack this level of spatial resolution. The available data makes it difficult to make observations, along a gradient of fishing effort, in order to assess the effects of fishing effort on habitat, community, and ecosystem level processes.

2. **The effects of specific gear types, along a gradient of effort, on specific habitat types.** These data are the first order needs to allow an assessment of how much effort produces a measurable level of change in structural habitat components and associated communities. Second order data should assess the effects of fishing disturbance in a gradient of type 1 and type 2 disturbance treatments.

3. **The role of seafloor habitats on the population dynamics of fishes.** While there is often good time series data on late-juvenile and adult populations, and larval abundance, there is a general lack of empirical information (except perhaps in coral reef, kelp bed, and seagrass fishes) on linkages between habitat and survival, which would allow modeling and experimentation to predict outcomes of various levels of disturbance.

These data and research results should allow managers to better strategically regulate where, when, and how much fishing will be sustainable in regards to EFH. Conservation engineering should play a large role in developing fishing gears which are both economical to operate and minimize impacts to environmental support functions.

The ultimate goal of research on fishing impacts is not to retrospectively evaluate what fishing does to the environment but to predict cause and effect given a particular management protocol. This requires the application of the conceptual models introduced in this discussion to actual management decisions and, at the same time, increasing our understanding of ecological mechanisms and processes at the level of the fish populations and associated communities. This demands, in particular, an appreciation of the importance of both the intensity and frequency of fishing impacts. Fishing should be conducted with an intensity that does not create isolated patches of communities whose progeny are required to recolonize an impacted area, if the objective is maintenance of habitat integrity. Similarly the habitat requirements of the harvested species must be taken into account to insure that harvesting strategies do not disturb habitats more frequently than is required to balance economic as well as ecological sustainability.

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Table 1. Comparisons of intensity and severity of various sources of physical disturbance to the seafloor (based on Hall 1994, Watling and Norse MS1997). Intensity is a measure of the force of physical disturbance and severity is the impact on the benthic community.

Source	Intensity	Severity
ABIOTIC Waves	Low during long temporal periods but high during storm events (to 70-80 m depth)	Low over long temporal periods since taxa adapted to these events but high locally depending on storm behavior
Currents	Low since bed shear normally lower than critical velocities for large volume and rapid sediment movement	Low since benthic stages rarely lost due to currents
Iceberg Scour	High locally since scouring results in significant sediment movement but low regionally	High locally due to high mortality of animals but low regionally
BIOTIC Bioturbation	Low since sediment movement rates are small	Low since infauna have time to repair tubes and burrows
Predation	Low on a regional scale but high locally due to patchy foraging	Low on a regional scale but high locally due to small spatial scales of high mortality
HUMAN Dredging	Low on a regional scale but high locally due to large volumes of sediment removal	Low on a regional scale but high locally due to high mortality of animals
Land Alteration (Causing silt laden runoff)	Low since sediment laden runoff per se does not exert a strong physical force	Low on a regional scale but high locally where siltation over coarser sediments causes shifts in associated communities
Fishing	High due to region wide fishing effort	High due to region wide disturbance of most types of habitat

Table 2. Studies of the impacts of fishing gear on the structural components of fish habitat.

Habitat	Gear Type	Location	Results	Reference(s)
Eelgrass	Scallop dredge	North Carolina	Comparison of reference quadrats with treatments of 15 and 30 dredgings in hard sand and soft mud substrates within eelgrass meadows. Eelgrass biomass was significantly greater in hard sand than soft mud sites. Increased dredging resulted in significant reductions in eelgrass biomass and number of shoots.	Fonesca et al. (1984)
Eelgrass and shoalgrass	Clam rake and "clam kicking"	North Carolina	Comparison of effect of two fishing methods. Raking and "light" clam kicking treatments, biomass of seagrass was reduced approximately 25% below reference sites but recovered within one year. In "intense" clam kicking treatments, biomass of seagrass declined approximately 65% below reference sites. Recovery did not begin until more than 2 years after impact and biomass was still 35% below the level predicted from controls to show no effect.	Peterson et al. (1987)
Eelgrass and shoalgrass	Clam rakes (pea digger and bull rake)	North Carolina	Compared impacts of two clam rake types on removal of seagrass biomass. The bull rake removed 89% of shoots and 83% of roots and rhizomes in a completely raked 1 m2 area. The pea digger removed 55% of shoots and 37% of roots and rhizomes.	Peterson et al. (1983)
Seagrass	Trawl	western Mediter-ranean	Noted loss of *Posidonia* meadows due to trawling; 45% of study area. Monitored recovery of the meadows after installing artificial reefs to stop trawling. After 3 years plant density has increased by a factor of 6.	Guillen et al. (1994)
Sponge-coral hard-bottom	Roller-rigged trawl	off Georgia coast	Assessed effect of single tow. Damage to all species of sponge and coral observed; 31.7% of sponges, 30.4% of stony corals, and 3.9% of octocorals. Only density of barrel sponges (*Cliona* spp.) significantly reduced. Percent of stony coral damage high because of low abundance. Damage to other sponges, octocorals, and hard corals varied but chnages in density not significantly different. No significant differences between trawled and reference sites after 12 months.	Van Dolah et al. (1987)
Sponge-coral hard-	roller-frame shrimp	Biscayne Bay, Florida	Damage to approximately 50% of sponges, 80% of stony corals, and 38% of soft corals.	Tilmant (1979) (cited in Van Dolah

bottom	trawl			et al. 1987)

Habitat	**Gear Type**	**Location**	**Results**	**Reference(s)**
Various tropical emergent benthos	Trawl	North West Shelf, Australia	Catch rates of all fish and large and small benthos show that in closed areas fish and small benthos abundance increased over 5 years while large benthos (>25 cm) stayed the same or increased slightly. In trawled areas all groups of animals declined. Found that settlement rate and growth to 25 cm was on the order of 15 years for the benthos.	Sainsbury et al. (In press)
Gravel pavement	Scallop dredge	Georges Bank	Assessed cumulative impact of fishing. Undredged sites had significantly higher percent cover of the tube-dwelling polychaete *Filograna implexa* and other emergent epifauna than dredged sites. Undredged sites had higher numbers of organisms, biomass, species richness, and species diversity than dredged sites. Undredged sites were characterized by bushy epifauna (bryozoans, hydroids, worm tubes) while dredged sites were dominated by hard-shelled molluscs, crabs, and echinoderms.	Collie et al. (1996, 1997)
Gravel-boulder	Assumed roller-rigged trawl	Gulf of Maine	Comparison of site surveyed in 1987 and revisited in 1993. Initially mud draped boulders and high density patches of diverse sponge fauna. In 1993, evidence of moved boulders, reduced densities of epifauna and extreme trucation of high density patches.	Auster et al. (1996)
Cobble-shell	Assumed trawl and scallop dredge	Gulf of Maine	Comparison of fished site and adjacent closed area. Satistically significant reduction in cover provided by emergent epifauna (e.g., hydroids, bryozoans, sponges, serpulid worms) and sea cucumbers.	Auster et al. (1996)
Gravel	Beam trawl	Irish Sea	An experimental area was towed 10 times. Density of epifauna (e.g., hydroids; soft corals, *Alcyonium digitatum*) was decreased	Kaiser and Spencer

			approximately 50%.	(1996a)
Boulder-Gravel	Roller-rigged trawl	Gulf of Alaska	Comparisons of single tow trawled lane with adjacent reference lane. Significant reductions in density of structural components of habitat (two types of large sponges and anthozoans). No significant differences in densities of a small sponge and mobile invertebrate fauna. 20.1% boulders moved or dragged. 25% of ophiuroids (*Amphiophiura ponderosa*) in trawled lanes were crushed or damaged compared to 2% in reference lanes.	Freese et al. (In prep.)
Gravel over sand	Scallop dredge	Gulf of St. Lawrence	Assessed effects of single tows. Suspended fine sediments and buried gravel below the sediment-water interface. Overturns boulders.	Caddy (1973)
Habitat	**Gear Type**	**Location**	**Results**	**Reference(s)**
Bryozoan beds (on sand and cobble)	Otter trawl and roller-rigged trawl	New Zealand	Qualitative comparison of closed and open areas. Two bryozoans produce "coral-like" forms and provide shelter for fishes and their prey. Comparisons of fished site with reference sites and prior observations from fishers show reduced density and size of colonies.	Bradstock and Gordon (1983)
Mussel bed	Otter trawl	Strangford Lough, Northern Ireland	Comparison of characteristics of trawled and untrawled *Modiolus modiolus* beds as pre and post impacts of a trawl. Trawled areas, confirmed with sidescan sonar, showed mussel beds disconnected with reductions in attached epibenthos. The most impacted sites were characterized by few or no intact clumps, mostly shell debris, and sparse epifauna. Trawling resulted in a gradient of complexity with flattened regions at the extreme. Immigration of *Nephrops* into areas previously dominated by *Modiolus* may result in burial of new recruits due to burrowing activites; precluding a return to a functional mussel bed habitat.	Magorrian (1995)
Sand-mud	Trawl and scallop	Hauraki Gulf, New	Comparisons of 18 sites along a gradient of fishing effort (i.e., heavily fished sites through unfished reference sites). A gradient of increasing large epifaunal cover correlated with decreasing fishing	Thrush et al. (In press)

	dredge	Zealand	effort.	
Soft sediment	Scallop dredge	Port Phillip Bay, Australia	Compared reference and experimentally towed sites in BACI designed experiment. Bedforms consisted of cone shaped callianasid mounds and depressions prior to impact. Depressions often contained detached seagrasses and macroalgae. Only dredged plot changed after dredging. Eight days after dredging the area was flattened; mounds were removed and depressions filled. Most callianasids survived and density did not change in 3 mo following dredging. One month post impact, seafloor remained flat and dredge tracks distinguishable. Six months post impact mounds and depressions were present but only at 11 months did the impacted plot return to control plot conditions.	Currie and Parry (1996)
Sand	Beam trawl	North Sea	Observations of effects of gear. As pertains to habitat, trawl removed high numbers of the hydroid *Tubularia*.	DeGroot (1984)
Gravel-sand-mud	Trawl	Montere y Bay	Comparison of heavily trawled (HT) and lightly trawled (LT) sites. The seafloor in the HT area had significantly higher densities of trawl tracks while the LT area had significantly greater densities of rocks >5 cm and mounds. The HT area had shell debris on the surface while the LT area had a cover of flocculent material. Emergent epifauna density was significantly higher for all taxa (anenomes, sea pens, sea whips) in the LT area.	Engel and Kvitek (MS1997)
Habitat	**Gear Type**	**Locatio n**	**Results**	**Reference(s)**
Sand	Otter trawl	North Sea	Observations of direct effects of gear. Well buried boulders removed and displaced from sediment. Trawl doors smoothed sand waves. Penetrated seabed 0-40 mm (sand and mud).	Bridger (1970, 1972)
Sand-shell	Assum ed trawl and scallop dredge	Gulf of Maine	Comparison of fished site and adjacent closed area. Statically significant reduction of habitat complexity based on reduced cover provided by biogenic depressions and sea cucumbers. Observations at another site showed multiple scallop dredge paths resulting in smoothed bedforms. Scallop dredge paths removed cover provided by hydrozoans which reduced local densities of associated shrimp species. Evidence of shell aggregates dispersed by scallop dredge.	Auster et al. (1996)
Sand-silt to mud	Otter trawl with	Long Island Sound	Diver observations showed doors produced continuous furrows. Chain gear in wing areas disrupted amphipod tube mats and bounced on bottom around mouth of net, leaving small scoured depressions.	Smith et al. 1985

	chain sweep and roller gear		In areas with drifting macroalgae, the algae drapped over groundgear of net during tows and buffered effects on the seafloor. Roller gear also created scoured depressions. Spacers between discs lessened impacts.	

Table 3. Hierarchical classification of fish habitat types (from Auster et al. MS1997, 1998) on the outer continental shelf of the cold temperate and boreal northwest Atlantic. Categories are based on Auster et al. 1995, Langton et al. 1995, Auster et al. 1996, and unpublished observations).

Category	Description	Rationale	Complexity Score
1	flat sand and mud	areas with no vertical structure such as depressions, ripples, or epifauna	1
2	sand waves	troughs provide shelter from current; previous observations indicate species such as silver hake station keep on the downcurrent sides of sand waves and ambush drifting demersal zooplankton and shrimp	2
3	biogenic structures	burrows, depressions, cerianthid anenomes, hydroid patches; features which are created and/or used by mobile fauna for shelter	3
4	shell aggregates	provide complex interstitial spaces for shelter; as an aside shell aggregates also provide a complex high contrast background which may confuse visual predators	4
5	pebble-cobble	also provides small interstitial spaces and may be equivalent in shelter value to shell aggregate, however shell is a more ephemeral habitat	5
6	pebble-cobble with sponge cover	attached fauna such as sponges provide additional spatial complexity for a wider range of size classes of mobile organisms	10
7	partially buried or dispersed boulders	while not providing small interstitial spaces or deep crevices, partially buried boulders do exhibit high vertical relief; dispersed boulders on cobble pavement provide simple crevices; the shelter value of this type of habitat may be less or greater than previous types based on the size class and behavior of associated species	12
8	piled boulders	provides deep interstitial spaces of variable sizes	15

Table 4. Studies of short-term impacts of fishing on benthic communities.

Taxa	Gear and Sediment Type	Region	Results	Reference(s)
Infauna	beam trawl; megaripples and flat substrate	Irish Sea, U.K.	Assessed at the immediate effects of beam trawling and found a reduction in diversity and abundance of some taxa in the more stable sediments of the northeast sector of their experimental site but could not find similar effects in the more mobile sediments. Out of the top 20 species 19 had lower abundance levels at the fished site and nine showed a statistically significant decrease. Coefficient of variation for numbers and abundance was higher in the fished area of the NW sector supporting the hypothesis that heterogeneity increases with physical disturbance. Measured a 58% decrease in mean abundance and a 50% reduction in the mean number of species per sample in the sector resulting from removal of the most common species. Less dramatic change in the sector where sediments are more mobile.	Kaiser and Spencer (1996a)
Starfish	beam trawl; coarse sand, gravel and shell, muddy sand, mud	Irish Sea, U.K.	Evaluated damage to starfish at three sites in the Irish sea that experienced different degrees of trawling intensity. Used ICES data to select sites and used side scan to confirm trawling intensity. Found a significant correlation between starfish damage (arm regeneration) and trawling intensity.	Kaiser (1996)
Horse mussels	otter trawl; horse mussel beds,	Strangeford Lough; N. Ireland	Used video/rov, side scan and benthic grabs to characterize the effect of otter trawling and scallop dredging on the benthic community. There was special concern over the impact on *Modiolus* beds in the Lough. Plotted the known fishing areas and graded impacts based on a subjective 6 point scale; found significant trawl impacts. Side scan supported video observations and showed areas of greatest impact. Found that in otter trawl areas that the otter boards did the most damage. Side scan suggested that sediment characteristics had changed in heavily trawled areas.	Industrial Science Division. (1990)
Benthic fauna	beam trawl;	Irish Sea, U.K.	Sampled trawled areas 24 hours after trawling and 6 months later. On stable sediment found siginificant difference immediately after	Kaiser et al MS 1997

	mobile megaripple structure and stable uniform sediment		trawling. Reduction in polychaetes but increase in hermit crabs. After six months there was no detectable impact. On megaripple substrate no significant differences were observed immediately after trawling or 6 months later.	
Taxa	**Gear and Sediment Type**	**Region**	**Results**	**Reference(s)**
Bivalves, sea scallop, surf clams, ocean quahog	scallop dredge, hydraulic clam dredge; various substrate types	Mid-Atlantic Bight, USA	Submersible study of bivalve harvest operations. Scallops harvested on soft sediment (sand or mud) had low dredge induced mortality for uncaught animals (<5%). Culling mortality (discarded bycatch) was low, approx. 10%. Over 90% of the quahogs that were discarded reburrowed and survived whereas 50% of the surf clams died. Predatorsy crabs, starfish, fish and skates, moved in on the quahogs and clams ithe predator density 10 tiems control area levels within 8 hours post dredging. Noted numerous "minute" predators feeding in trawl tracks. Non-harvested animals, snd dollars, crustaceans and worms significantly disrupted but sand dollars suffered little apparent mortality.	Murawski and Serchuck (1989)
Ocean quahog	hydraulic clam dredge;	Long Island, N.Y., USA	Evaluated clam dredge efficiency over a transect and changed up to 24 hours later. After dredge fills it creates a "windrow of clams". Dredge penetrates up to 30 cm and pushes sediment into track shoulders. After 24 hours track looks like a shallow depression. Clams can be cut or crushed by dredge with mortality ranging from 7 to 92 %, being dependent on size and location along dredge path. Smaller clams survive better and are capable of reburrowing in a few minutes.Predators, crabs, starfish and snails, move in rapidly and depart within 24 hours.	Meyer et al. (1981)
Macro-benthos	scallop dredge; coarse sand	Mercury Bay, New Zealan d	Benthic community composed of small short-lived animals at two experimental and adjacent control sites. Sampling before and after dredging and three months later. Dredging caused an immediate decrease in density of common macrofauna. Three months later some populations had not recovered. Immediate post-trawling	Thrush et al. (1995)

			snails, hermit crabs and starfish were feeding on damaged and exposed animals	
Scallops and associated fauna	scallop dredge; "soft sediment"	Port Phillip Bay, Australia	Sampled twice before dredging and three times afterwards, up to 88 days later. The mean difference in species number increased from 3 to 18 after trawling. The total number of individuals increased over the sampling time on both experimental and control primarily as a result of amphipod recruitment, but the number of individuals at the dredged sites were always lower than the control. Dissimilarity increased significantly, as a result of dredging, because of a decrease in species numbers and abundance.	Currie and Parry (1994)
Sea Scallops and associated fauna	otter trawl and scallop dredge; gravel and sand	Gulf of St. Lawrence, Canada	Observed physical change to sea floor from otter doors and scallop dredge and lethal and nonlethal damage to the scallops. Noted an increase in the most active predators within the trawl tracks compared to outside; winter flounder, sculpins and rock crabs. No increase in starfish or other sedentary forms within in an hour of dredging.	Caddy (1973)
Taxa	**Gear and Sediment Type**	**Region**	**Results**	**Reference(s)**
Macrofauna	beam trawl; hard-sandy substrate	North Sea, coast of Holland	Sampling before and after beam trawling (*hrs, 16 hrs and 2 weeks) showed species specific changes in macrofaunal abundance. Decreasing density ranged from 10 to 65% for species of echinoderms (starfish and sea urchins but not brittle stars), tube dwelling polychaetes and molluscs at the two week sampling period. Density of some animals did not change others increased but these were not significant after 2 weeks.	Bergman and Hup (1992)
Benthic fauna	beam trawl and shrimp trawl; hard sandy bottom, shell debris and sandy-mud	North Sea, German coast	Preliminary report using video and photographs comparing trawled and untrawled areas. Presence and density of brittle stars, hermit crabs, other "large" crustaceans and flatfish was higher in the controls than the beam trawl site. Difference in sand ripple formation in trawled areas was also noted, looking disturbed not round and well developed. Found a positive correlation with damage to benthic animals and individual animal size. Found less impact with the shrimp trawl, diver observations confirmed low level of impact although the net was "festooned" with worms. Noted large megafauna, mainly crabs, in trawl tracks.	Rumhor et al. (1994)

Soft bottom macrofauna	beam trawl; very fine sand	North Sea, Dutch Sector	Compared animal densities before and after trawling and looked at fish stomach contents. Found that total mortality due to trawling varied between species and size class of fish, ranging from 4 to 139% of pretrawling values. (values> 100% indicate animals moving into the trawled area). Mortality for echinoderms was low, 3 to 19%, undetectable for some molluscs, esp. solid shells or small animals, while larger molluscs had a 12 to 85% mortality. Burrowing crustaceans had low mortality but epifaunal crustaceans approximated 30 % but ranged as high as 74%. Annelids were generally unaffected except for Pectinaria, a tube building animal. Generally mortality increased with number of times the area was trawled (once or twice). Dab were found to be the major scavanger, immigrating into the area and eating damaged animals.	Santbrink and Bergman (1994)
Hemit Crabs	beam trawl	Irish Sea, U.K.	Compared the catch and diet of two species of hermit crab on trawled and control sites. Found significant increases in abundance on the trawl lines two to four days after trawling for both species but also no change for one species on one of two dates. Found a general size shift towards larger animals after trawling. Stomach contents weight was higher post-trawling for one species. Diets of the crabs were similar but proportions differed.	Ramsey et al. (1996)
Taxa	**Gear and Sediment Type**	**Region**	**Results**	**Reference(s)**
Sand macrofauna and infauna	scallop dredge	Irish Sea	Compared experimental treatments based frequency of tows (i.e., 2,4,12,25). Bottom topography changes did not change grain size distribution, organic carbon, or chlorophyll content. Bivalve molluscs and peracarid crustaceans did not show signficant changes in abundance or biomass. Polychaetes and urchins showed significant declines. Large molluscs, crustaceans and sand sand eels were also damaged. In general, there was selective elimination of fragile and sedentary components of the infauna as well as large epifaunal taxa.	Eleftheriou and Robertson (1992)

Table 5. Studies of long-term impacts of fishing on benthic communities.

Habitat Type and Taxa Present	Time Period	Location	Effect	Reference
Sand; macrobenthos and meiofauna	2-7 months	Bay of Fundy	Experimental trawling in high energy area. Otter trawl doors dug up to 5 cm deep and marks were visible for 2 to 7 months. Initial significant effects on benthic diatoms and nematodes but no significant impact on macrofauna. No significant longterm effects.	Brylinsky et al. (1994)
Quartz sand; benthic infauna	5months	South Carolina Estuary	Compared benthic community in two areas, one open to trawling one closed, before and after shrimp season. Found variation with time but no relationship between variations and trawling per se.	Van Dolah et al. (1991)
Sandy; ocean quahogs	----	Western Baltic	Observed otter board damage to bivalves, especially ocean quahogs, and found an inverse relation between shell thickness and damage and a positive correlation between shell length and damage.	Rumhor and Krost (1991)
Subtidal shallows and channel; macrobenthos	100 years	Wadden Sea	Reviewed changes in benthic community documented over 100 years. Considered 101species. No long term trends in changing abundance for 42 common species, with 11 showing considerable variation. Sponges, coelenterates and bivalves suffered greatest losses while polychaetes showed the largest gains. Decrease subtidally for common species from 53 to 44 and increase intertidally from 24to38.	Reise (1982)
Intertidal sand; lug worms	4 years	Wadden Sea	Studied impact of lugworm harvesting versus control site. Machine digs 40 cm gullies. Immediate impact is a reduction in several benthic species and slow recovery for some the the larger long-lived species like soft shelled clams. With one exception, a polychaete, the shorter-lived macrobenthic animals showed no decline. It took several years for the area to recover to prefishing conditions.	Beukema (1995)
Various habitat types; all species	---	North Sea	Review of fishing effects on the North Sea based primarly on ICES North Sea Task Force reports. Starfish, sea urchins and several polychaetes showed a 40 to 60 % reduction in density after beam trawling but some less abundant animals showed no change and one polychaete increased. At the scale of the North Sea the effect of trawling on the benthos is unclear.	Gislason (1994)

Habitat Type and Taxa Present	Time Period	Location	Effect	Reference
Sand; macrofauna	73 years	Kattegatt	Compared benthic surveys form 1911-1912 with 1984. Community composition has changed with only approximately 30% similarity between years at most stations. Primary change was a decrease in sea urchins and increase in brittle stars. Animals were also smaller in 1984. Deposit feeders have decreased while suspension feeders and carnivores have increased.	Pearson et al. (1985)
Subtidal shallows and channels; Macrofauna	55 years	Wadden Sea, German y	Documented increase in mussel beds and associated species such as polychaetes and barnacles when comparing benthic survey data. Noted loss of oyster banks, *Sabellaria* reefs and subtidal sea grass beds. Oysters were overexploited and replaced by mussels; *Zostera* lost to disease. Conclude that major habitat shifts are the result of human influence.	Riesen and Reise (1982)
146 stations; Ocean Quahogs	---	Southern North Sea, Europe	Arctica valves were collected from 146 stations in 1991 and the scars on the valve surface were dated, using internal growth bands, as an indicator of the frequency of beam trawl damage between 1959 and 1991. Numbers of scars varied regionally and temporally and correlated with fishing.	Witbaard and Klein (1994)
Various habitats; Macrofauna	85 years	Western English Channel, UK	Discusses change and causes of change observed in benthic community based on historic records and collections. Discusses effects of fishing gear on dislodging hydroid and bryozoan colonies, and speculates that effects reduce settlement sites for queen scallops.	Holme (1983)
Gravel/sand; Macrofauna	3 years	Central California, USA	Compared heavily trawled area with lightly trawled (closed) area using Smith MacIntyre grab samples and video transect data collected over three years. Trawl tracks and shell debris were more numerous in heavily trawled area, as were amphinomid polychaetes and oligochaetes in most years. Rocks, mounds and flocculent material were more numerous at the lightly trawled station. Commercial fish were more common in the lightly trawled area as were epifaunal invertebrates. No significant differences were found between stations in term of biomass of most other invertebrates.	Engel and Kvitek (MS 1997)

Fine sand; razor clam		Barrinha, Southern Portugal	Evaluated disturbance lines in shell matrix of the razor clam and found an increase in number of disturbance lines with length and age of the clams. Sand grains were often incorporated into the shell suggestive of a major disturbance , such as trawling damage, and subsequent recovery and repair of the shell.	Gaspar et al. (1994)
Fine to medium sand; ocean quahogs	----	Southern New Jersey, USA	Compared areas unfished, recently fished and currently fished for ocean quahogs using hydraulic dredges. Sampled invertebrates with a Smith MacIntyre grab. Few significant differences in numbers of individuals or species were noted, no pattern suggesting any relationship to dredging.	MacKenzie (1982)
Habitat Type and Taxa Present	**Time Period**	**Location**	**Effect**	**Reference**
Gravel, shell debris and fine mud; Horse mussel community	8 years	Strangford Lough, Northern Ireland	Review paper of effects of queen scallop fishery on the horse mussel community. Compared benthic survey from the 1975-80 period with work in 1988. Scallop fishery began in 1980. *Modiolus* community has remained unchanged essentially from 1857 to 1980. The scallop fishery has a large benthic faunal bycatch, including horse mussels. Changes in the horse mussel community are directly related to the initiation of the scallop fishery and there is concern about the extended period it will take for this community to recover.	Brown (1989)
Shallow muddy sand; scallops	6 months	Maine, USA	Sampled site before, immediately after and up to 6 months after trawling. Loss of surficial sediments and lowered food quality of sediments, measured as microbial populations, enzyme hydrolyzable amino acids and chlorophyll *a*, was observed. Variable recovery by benthic community. Correlation with returning fauna and food quality of sediment.	Watling et al. (MS 1997)
Sand and seagrass; hard shelled clams and bay scallops	4 years	North Carolina, USA	Evaluated effects of clam raking and mechanical harvesting on hard clams, bay scallops, macroinvertebrates and seagrass biomass. In sand, harvesting adults showed no clear pattern of effect. With light harvesting seagrass biomass dropped 25% immediately but recovered in a year. In heavy harvesting seagrass biomass fell 65% and	Peterson et al. (1987)

			recovery did not start for >2 years and did not recover up to 4 years later. Clam harvesting showed no effect on macroinvertebrates. Scallop densities correlated with seagrass biomass.	
Gravel pavement; benthic magafauna	Not known	Northern Georges Bank, USA	Used side scan, video and naturalist dredge sampling to characterize disturbed and undisturbed sites based on fishing activity records. Documented a gradient of community structure from deep, undisturbed to shallow disturbed sites. Undisturbed sites had more individual organisms, greater biomass, greater species richness and diversity and were characterized by an abundant bushy epifauna. Disturbed sites were dominated by hard-shelled molluscs, crabs and echinoderms.	Collie et al. (1997)
Sand; epifauna	3 year	Grand Banks, Canada	Experimentally trawled site 12 times each year within 31 to 34 hours for three years. Total invertebrate bycatch biomass declined over the three year study in trawls. Epibenthic sled samples showed lower biomass, averaging 25%, in trawled areas than reference sites. Scavanging crabs were observed in trawl tracks after first 6 hours and trawl damage to brittle stars and sea urchins was noted. No significant effects of trawling were found for four dominant species of mollusc.	Prena et al. (MS 1997)
Sand, shrimp and macrobenthos	7 months	New South Wales, Australia	Sampled macrofauna, pretrawling, after trawling and after commercial shrimp season using Smith McIntyre grab at experimental and control sites. Under water observation of trawl gear were also made. No detectable changes in macrobenthos was found or observed.	Gibbs et al. (1980)
Habitat Type and Taxa Present	**Time Period**	**Location**	**Effect**	**Reference**
Soft sediment; scallops and associated fauna	17 months	Port Phillip Bay, Australia	Sampled 3 months before trawling and 14 months after trawling. Most species showed a 20 to 30% decrease in abundance immediately after trawling. Dredging effects generally were not detectable following the next recruitment within 6 months but some animals had not returned to the trawling site 14 months post trawling.	Currie and Parry (1996)
Bryozoans; fish and assocaited fauna	----	Tasman Bay,	Review of ecology of the coral-like bryozoan community and changes in fishing gear and practices since the 1950s. Points out the interdependence of fish with this benthic	Bradstock and Gordon (1983)

		New Zealand	community and that the area was closed to fishing in 1980 because gear had developed which could fish in and destroy the benthic community thereby destroying the fishery.	
Various habitat types; diverse tropical fauna	5+years, ongoing	North West Shelf, Australia	Describes a habitat dependent fishery and an adaptive management approach to sustaining the fishery. Catch rates of all fish and large and small benthos show that in closed areas fish and small benthos abundance increased over 5 years while large benthos (>25 cm) stayed the same or increased slightly. In trawled areas all groups of animals declined. Found that settlement rate and growth to 25 cm was on the order of 15 years for the benthos.	Sainsbury et al. (In press)
Mudflat; commercial clam cultivation and benthos	7 months	South-east England	Sampled benthic community on a commercial clam culture site and control area at the end of a two year growing period, immediately after sampling, and again 7 months later. Infaunal abundance was greatest under the clam culture protective netting but species composition was similar to controls. Harvesting with a suction dredge changed the sediment characteristics and reduced the numbers of individual animals and species. Seven months later the site had essentially returned to the unharvested condition.	Kaiser et al. (1996a)
Sand; razor clam and benthos	40 days	Loch Gairloch, Scotland	Compared control and experimentally harvested areas using a hydraulic dredge at 1 day and 40 days after dredging. On day one a non-selective reduction in the total numbers of all infaunal species was apparent but no differences were observed after forty days.	Hall et al. (1990)
Sand and muddy areas; Macro-zoobenthos	3years; ongoing	German Bite, Germany	Investigated macrozoobenthos communities around a sunken ship that had been "closed" to fishing for three years. Compared this site with a heavily fished area. Preliminary results show an increase in polychaetes and the bivalve Tellina in the fished, sandy, area. The data does not yet allow for a firm conclusion regarding the unfished area but there is some (nonsignificant) increase in species numbers and some delicate, sensitive species occurred within the protected zone.	Arntz et al. (1994)

Figure Legends

Figure 1. Conceptual fishing gear impact model. The range of fishing effort increases from left to right along the x axis with 0 as a pristine condition and 4 as a maximally impacted state. The y and z axis are based on information in Table 3. The y axis is a comparative index of habitat complexity. The z axis shows the range of habitat categories from simple (bedforms) to complex (piled boulders).

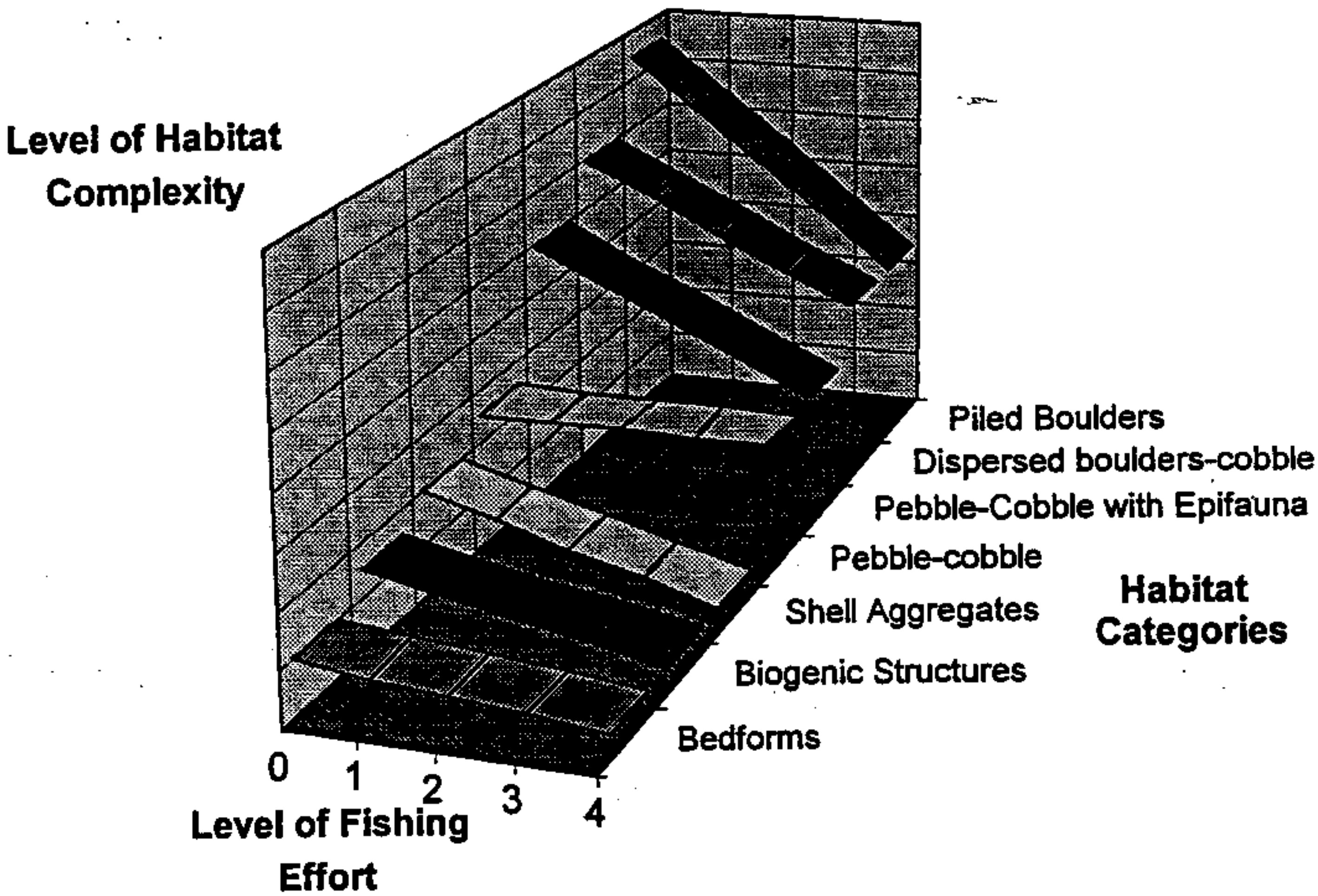
Figure 2. Habitat match-mismatch paradigm which links variation in the survivorship of early benthic phase fishes with abundance of epibenthic organisms. The illustration shows a temporal pattern in percent cover for an "idealized" benthic species with emergent structure (e.g., hydroid, amphipod tubes) under conditions of natural variation (solid line) and when impacted by fishing activities (dotted line). The habitat value of such areas is dependent on the timing of recruitment of fishes in relation to settlement and subsequent mortality of epibenthos from natural and human caused sources. For example, at the time period marked A, settlement into unimpacted benthos provides greater cover for fishes than an area impacted by fishing. However, at the settlement period marked B, recruitment of epibenthos has recently occurred and the cover provided under either state is nearly identical. The settlement period marked C is similar to A, and reflects the dichotomy of natural versus fishing enhanced changes in a dynamic habitat.

Figure 3. Spatial distribution of trawl and scallop dredge tows from NMFS Sea Sampling database for 1989-1994 (April). This illustration represents a total of 14,908 tows. Note that the spatial distribution of effort is not homogeneous but aggregated in productive fishing areas.

Figure 4. Models of alternative community states. Arrows indicate direction of community shifts. A. The successional model which has relatively predictable shifts in community type. B. A lottery based model which has more stochastic, non-linear responses to disturbance.

Figure 5. Comparison of biogenic habitat structure and population responses to type 1 and type 2 forms of habitat disturbance.

Figure 6. Habitat complexity and environmental variability domain of fish assemblages as it relates to obligate and facultative habitat users. Fish assemblages occur in a continuum along the two gradients.



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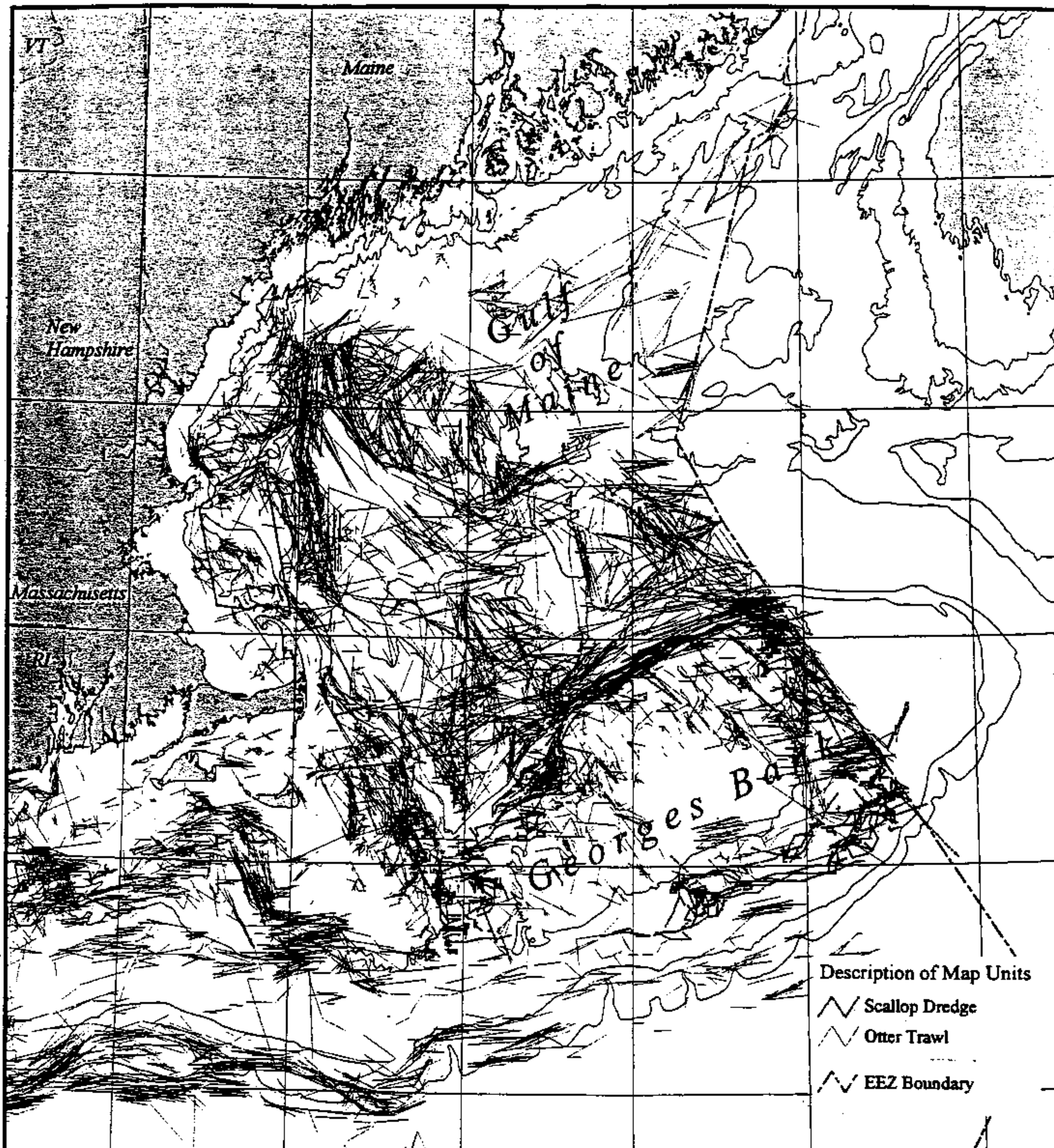

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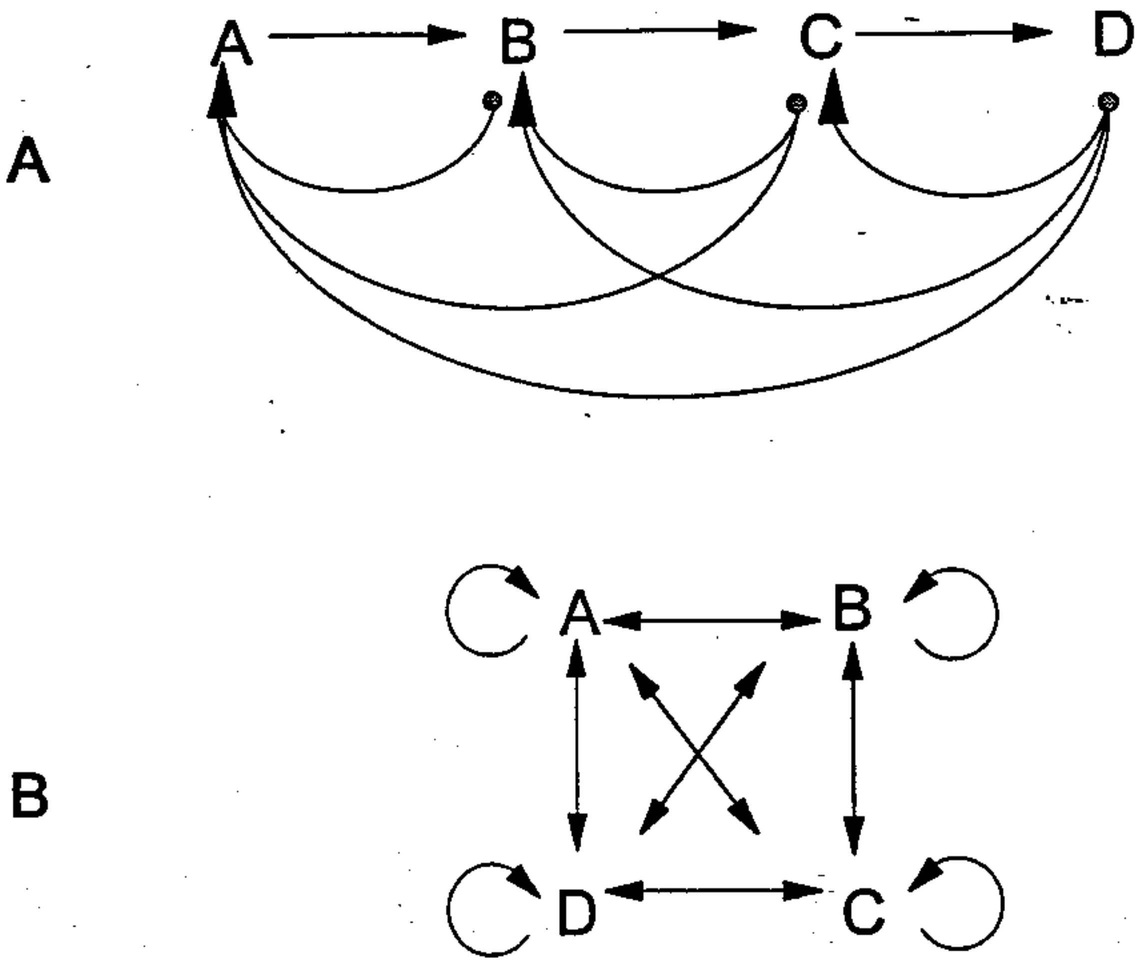

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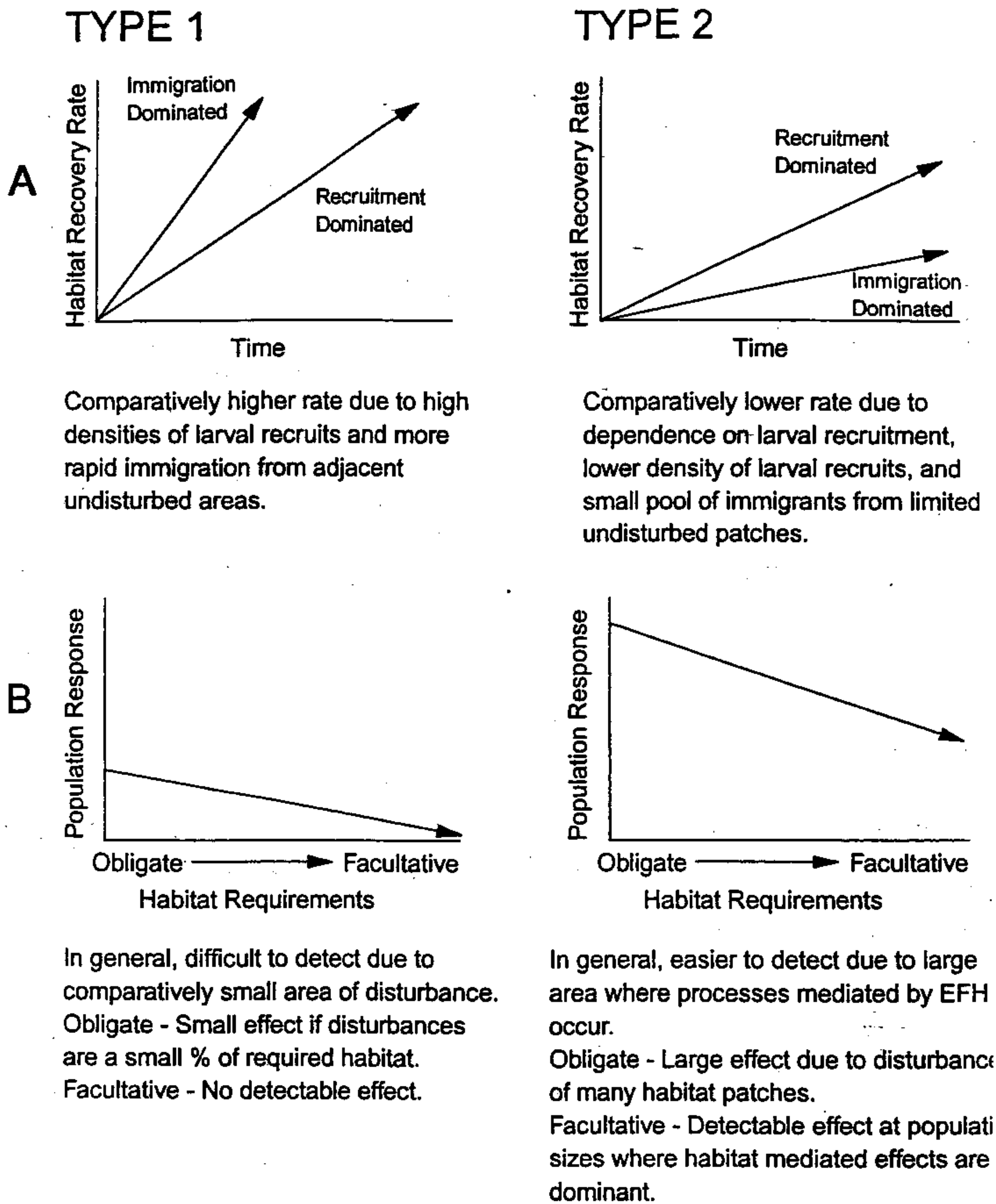

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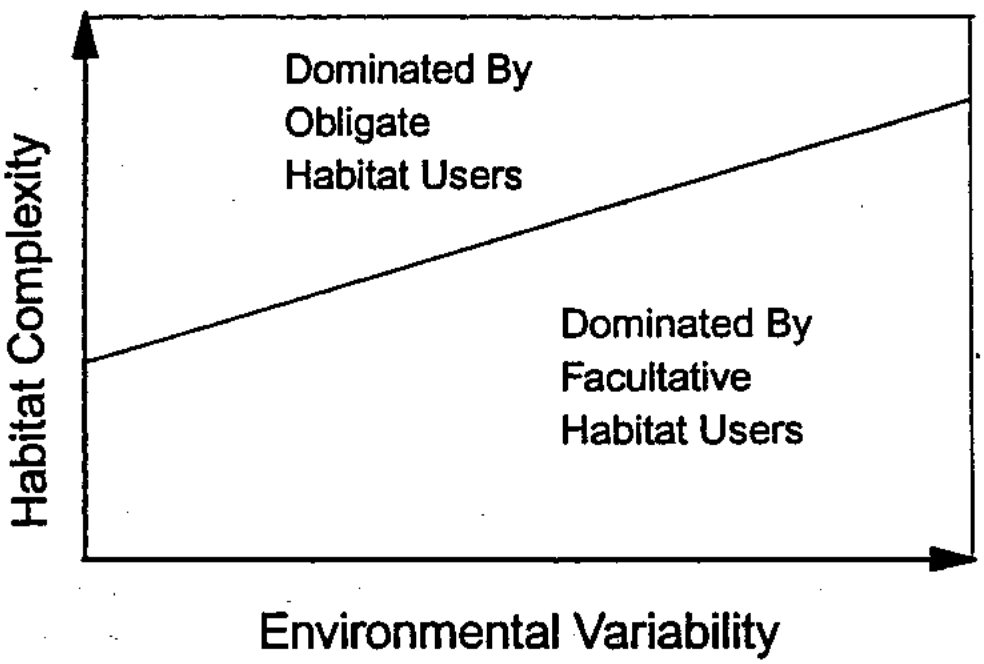

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Appendix N. SAFMC Project and Policy Review Process and NMFS 1997 Project Review and Habitat Activities Summary (Source: SAFMC 1992 and NMFS 1998).

SAFMC EFH Policy and Procedures:
(Approved 9/98)

SAFMC Responsibilities For Essential Fish Habitat and Environmental Protection:

On January 20, 1998, the Guidelines for implementing the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) became effective [50 CFR Part 600 (Docket No. 961030300-7238-04; I.D. 120996A)RIN 0648-AJ30]. The guidelines are intended to assist Fishery Management Councils (Councils) and the Secretary of Commerce (Secretary) in describing and identifying EFH in fishery management plans (FMPs), including identification of adverse impacts from both fishing and non-fishing activities on EFH, and identification of actions required to conserve and enhance EFH. The guidelines also detail procedures that the Secretary (acting through the NMFS), other Federal agencies, state agencies, and the Councils will use to coordinate, consult, or provide recommendations on Federal and state activities that may adversely affect EFH.

Established policies and procedures of the SAFMC provide the framework for coordination with NMFS, and other habitat partners in the south Atlantic region to conserve and enhance essential fish habitat. New and expanded responsibilities contained in the MSFCMA are being met by modifying the Council's established procedures for reviewing Federal or state actions that may adversely affect the EFH of a managed species. The Council actively comments on non-fishing projects or policies that may impact essential fish habitat. In response to an earlier amendment to the Magnuson Act, the Council adopted a habitat policy and procedure document that established a four state Habitat Advisory Panel and adopted a comment and policy development process. Pursuant to §600.930 of the final interim rule implementing the EFH provisions of the MSFCMA, the Council is modifying the existing review process to address the new EFH mandate. The Habitat Policy serves as the foundation of the Council's commitment to conserve, and manage our nations fishery resources and the essential fish habitat they depend upon.

SAFMC Essential Fish Habitat and Environmental Protection Policy:

In recognizing that managed species are dependent on the quantity and quality of their essential fish habitats, it is the policy of the SAFMC to protect, restore, and develop essential fish habitat upon which species fisheries depend; to increase the extent of their distribution and abundance; and to improve their productive capacity for the benefit of present and future generations. For purposes of this policy: **"essential fish habitat" is defined as those waters and substrate necessary to fish for spawning, breeding, or growth to maturity; "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; and "necessary" means the habitat required to support a sustainable fishery and a healthy ecosystem.**

The objectives of the SAFMC policy will be accomplished through the recommendation of no net loss or significant environmental degradation of existing essential fish habitat. A long-term objective is to support and promote a net-gain of essential fish habitat through the restoration and rehabilitation of the productive capacity of essential fish habitats that have been degraded, and the creation and development of productive essential fish habitats where increased fishery production is probable. The SAFMC will pursue these goals at state, Federal, and local levels. The Council shall assume an aggressive role in the protection and enhancement of habitats important to species, and shall actively enter Federal, decision-making processes where proposed actions may otherwise compromise the productivity of fishery resources of concern to the Council.

EFH in Fishery Management Plans:

The Council, pursuant to the MSFCMA Section 303(7)(a) Contents of Fishery Management Plans Required Provisions is mandated to "...describe and identify essential fish habitat based on the guidelines established by the Secretary under Section 305(b)(1)(A), minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat;"

To address this mandate, SAFMC staff, through consultation with a Species Plan Development Team, Species Committee, NMFS SERO Habitat Conservation Division and NMFS SEFSC, will insure that:

1. Essential fish habitat for a species to be managed, where information is readily available, is defined at the earliest possible stage of the fishery management plan development process. This information will be incorporated into the Habitat Plan which serves as a habitat source document for all Fishery Management Plans; and

2. Recommendations to the responsible agencies, are included in the plan which identify habitat improvements or changes in Federal policies, which are desirable to achieve the objectives of the plan (e.g. habitat policy statements for an essential fish habitat type or activity impacting essential fish habitat).

The SAFMC Habitat Plan, presents a detailed description of the southeast ecosystem by habitat type specifying EFH for managed species or species complexes. The Habitat Plan, pursuant to the guidelines, also considers designation of Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPCs) where identified for managed species. The following criteria are considered when determining whether a type, or area of EFH is an essential fish habitat-habitat area of particular concern: (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; and (3) whether, and to what extent, development activities are, or will be, stressing the habitat type. A coral HAPC process under the coral plan already exists and differs somewhat from the process recommended in the EFH guidelines. The Habitat Plan also includes information on anadromous and catadromous species and the habitat they depend upon to provide the Council with information on which to develop comments on projects impacting that habitat.

In addition to describing EFH, the Habitat Plan also identifies non-fishing related activities that have the potential to adversely affect EFH quantity or quality. The Habitat Plan presents available information describing the ecosystem and the dependence of managed species on the ecosystem as well as available information on how fishing and non-fishing activities influence habitat function. An assessment of the cumulative and synergistic effects of multiple threats, including the effects of natural stresses (such as storm damage or climate-based environmental shifts), and an assessment of the ecological risks resulting from the impact of those threats on the managed species habitat is included. General conservation and enhancement recommendations are included in the Habitat Plan to be used by the Council, NMFS, and other habitat partners in commenting on actions impacting EFH. These include but are not limited to recommending the enhancement of rivers, streams, and coastal areas, protection of water quality and quantity, recommendations to local and state organizations to minimize destruction/degradation of wetlands, restore and maintain the ecological health of watersheds, and replace lost or degraded EFH.

Project and Policy Review:

The SAFMC, through its Habitat and Environmental Protection Committee, may review, comment on or make recommendations on those proposed habitat alterations, policy or other human actions which may have an adverse impact on those fisheries addressed in the Council's plans and or under the authority of the MFCMA. The Magnuson-Stevens Fishery Conservation and Management Act, Public Law 104-208 reflects the new Secretary of Commerce and Fishery Management Council authority and responsibilities for the protection of essential fishery habitat. The Act specifies that each Federal agency shall consult with the Secretary with respect to any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by such agency that may adversely affect any essential fish habitat identified under this Act.

Additional provisions specify that the Council: may comment on and make recommendations to the Secretary and any Federal or State agency concerning any activity authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by any Federal or State agency that, in the view of the Council, may affect the habitat, including essential fish habitat, of a fishery resource under its authority; and shall comment on and make recommendations to the Secretary and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority. Within 30 days after receiving a recommendation, a Federal agency shall provide a detailed response in writing to the Council and the Secretary regarding the matter. The response shall include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on such habitat. In the case of a response that is inconsistent with the recommendations of the Secretary, the Federal agency shall explain its reasons for not following the recommendations.

Additional terms in the Act specify provisions for commenting on activities impacting essential fish habitat. If the Secretary receives information from the Council or Federal or State agency or determines from other sources that an action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by any State or Federal agency would adversely affect any essential fish habitat identified under this Act, the Secretary shall recommend to such agency measures that can be taken by such agency to conserve such habitat. Within 30 days after receiving a recommendation, a Federal agency shall provide a detailed response in writing to any Council commenting and the Secretary regarding the matter. The response shall include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on such habitat. In the case of a response that is inconsistent with the recommendations of the Secretary, the Federal agency shall explain its reasons for not following the recommendations.

SAFMC Project Review Process:

The following procedures are supplemented by the Council review procedures diagram which follows:

1. NMFS Habitat Conservation Division field personnel shall forward copies of public notices of permit requests for significant state or federally authorized or federally permitted projects immediately to Council staff followed by special briefings, as appropriate, or by NMFS position statements, as developed.

2. Significant projects may also be selected by the Habitat Committee or Council members, and Council staff or Habitat Advisory Panel members for consideration by the Council.

3. Council staff when deemed appropriate, request state and other federal assessments (position statement) of project impact for these projects as soon as developed and forward to the committee.

4. The SAFMC Habitat and Environmental Protection Advisory Panel shall, when called upon by the Council chairman, review proposed actions and provide expert testimony.

5. The Habitat Committee shall develop a position to be forwarded to the Council for consideration. The Committee, given time constraints, may also take action with concurrence of the Council chairman.

6. The Council shall file comments of concern or recommended project modifications to reduce environmental damage with the federal construction or regulatory agency (COE, FERC, etc.).

a. Committee members, Advisory Panel members and Council staff may testify at public hearings, at the request of the Council Chairman.

b. Request clarification from COE and regulatory agencies, as needed.

7. The Committee shall report on its actions, at Council meetings as needed.

Criteria Used to Define Significant Projects:

1. a. any activity that in the view of the Council may affect the essential fish habitat of a fish (any fishery, any stock of fish, any species of fish and any habitat of fish) under its jurisdiction (jurisdiction- geographical area of authority);

b. any activity that in the view of the Council is likely to substantially affect the essential fish habitat of an anadromous fishery resource under its jurisdiction.

2. Projects that may be precedent setting or in critical or unique habitat areas.

3. Projects that may, in the view of the NMFS SERO Habitat Conservation Division personnel, USFWS or EPA be elevated to Washington (pursuant to the Clean Water Act, National Environmental Policy Act, etc.) and require headquarters action. In addition, projects that may, in the view of the Council should be elevated to Washington and require NMFS, USFWS, or EPA headquarters action.

SAFMC Habitat and Environmental Protection Committee Assessment Guidelines for Proposed Actions:

The following will serve as guidance to the Committee in making its assessment of potential adverse impacts of proposed actions.

1. The extent to which precedent would be set in relation to existing or potential cumulative impacts of similar or other developments in the project area;

2. The extent to which the activity would directly affect the production of the fishery resources (e.g., alteration of hydrologic regimes, alteration of water circulation patterns, salinity regimes, detrital export, etc.);

3. The extent to which the activity would directly affect the essential fish habitat of fishery resources;

4. The Council follow mitigation guidelines as defined in the Federal guidance document for the establishment, use and operation of mitigation banks which is consistent with mitigation policies established under the Council on Environmental Quality Implementing Regulations (CEQ regulations) [40 CFR Part 1508.20], and the Section 404(b)(1) Guidelines (Guidelines) [40 CFR Part 230] which indicates the use of credits may only be authorized for purposes of complying with Section 10/404 when adverse impacts are unavoidable.

5. The extent of any adverse impact that can be avoided through project modification or other safeguards (e.g., piers in lieu of channel dredging, bridging in lieu of filling);

6. The existence of alternative sites available to reduce unavoidable project impacts, and;

7. The extent of which the activity is water dependent.

In addition, the Council will cooperatively work with NMFS and other State, Federal and regional habitat partners to apply the activity based conservation recommendations contained in Section 5.3 of the Habitat Plan. These are a generalized set of environmentally sound engineering and management practices that should be employed when an action might significantly and adversely affect EFH.

SAFMC Habitat and Environmental Protection Advisory Panel:

The SAFMC recognizing the importance of and dependence on habitat, by fishery stocks under its jurisdiction will establish a Habitat and Environmental Protection Advisory Panel to aid in the implementation of its habitat policy.

Habitat Advisory Panel Structure and Function:

The SAFMC Advisory Panel will consist of four sub-panels which will be the functional components that will, when requested by the Council Chairman, review proposed actions or policy affecting habitat.

The SAFMC shall establish, at its discretion, a Habitat Advisory Panel to advise the Habitat Committee concerning:

1. Proposed activities which may have adverse effects upon the fishery resources or the essential fish habitat for which the SAFMC has management responsibility; and

2. Habitat issues at the state, regional, or national level which may be of concern to the Council.

Habitat Advisory Panel members serve as the Council's habitat contacts and professionals in the field. The Advisory Panel is structured and functions differently than other panels. The Panel is made up of four state sub-panels each having representatives from the state marine fisheries agency, the U S Fish and Wildlife Service, state coastal zone management agency, conservationist, commercial fisherman, and recreational fishermen. In addition to the state representatives, at large members on the overall panel include representatives from EPA Region IV, NMFS Southeast Fisheries Center, NMFS SERO, Atlantic States Marine Fisheries Commission, and NMFS Habitat Conservation Division Headquarters. This body functions as a whole or as sub-panel depending on the scope of the issue. The Panel serves to provide the Council with both expert recommendations on activities being considered for permitting as well as guidance in development of Habitat policy statements. With guidance from the Panel, the Council, has developed and approved policies on; oil and gas exploration, development and transportation; dredging and dredge material disposal; submerged aquatic vegetation, and ocean dumping. These are included in Section 5 of the Habitat Plan under recommendations to protect EFH.

Coordination with State, Federal and Regional Habitat Partners:

In order to foster cooperation and efficient management of fishery resources and their habitats, the SAFMC will work closely and cooperatively with its member states, the Atlantic States Marine Fisheries Commission, other regional Councils, State fishery agencies, State coastal zone management agencies, USFWS, EPA, and recreational and commercial fisherman in identifying, describing and protecting EFH in the south Atlantic region through the development and application of the recommendations contained in the SAFMC Habitat Plan.

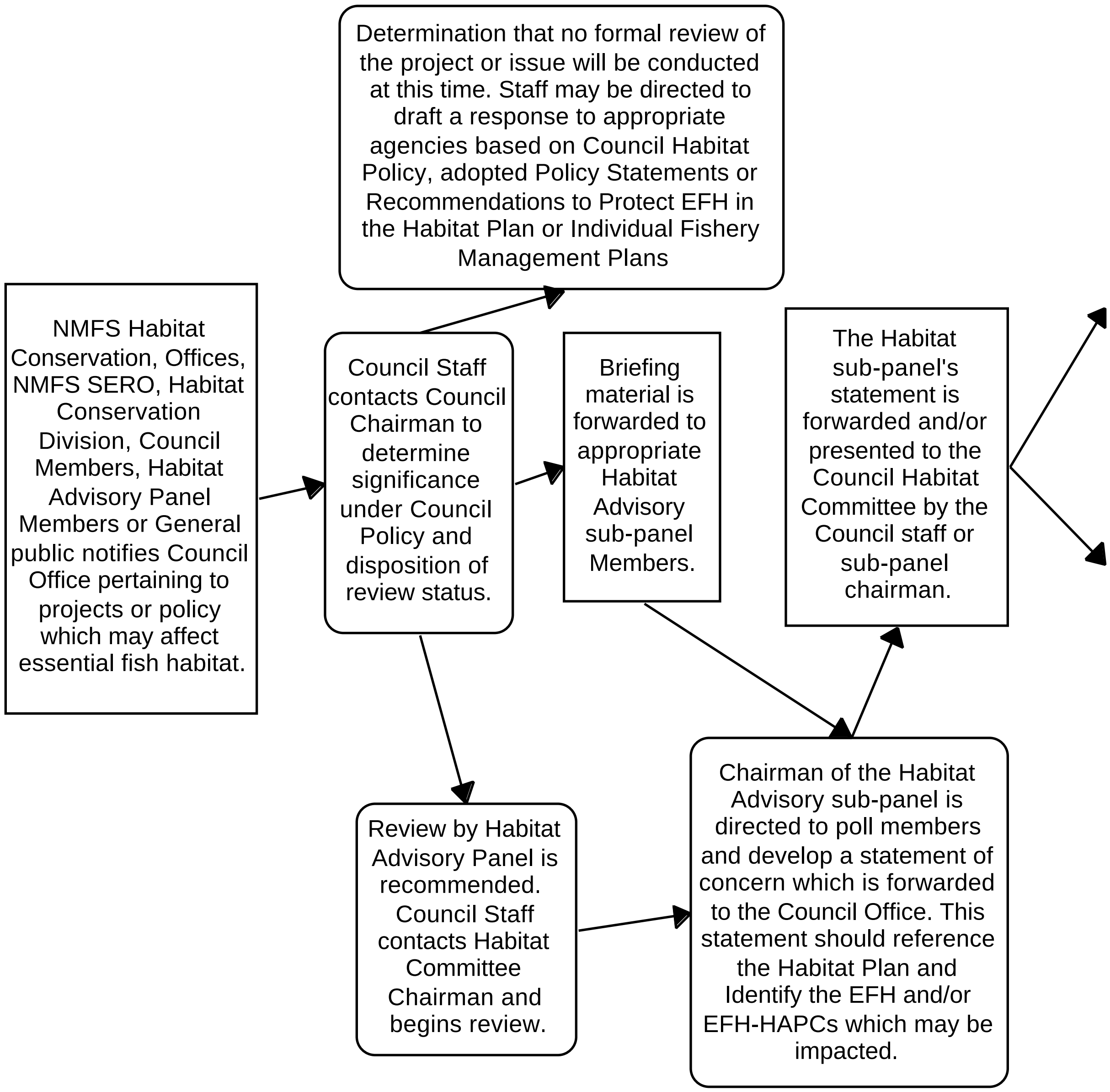
EFH Recommendations and Policy Statements:

The Council's habitat policy statements and recommendations to protect EFH are presented in the Habitat Plan to provide NMFS, State, other Federal and regional habitat partners guidance and additional rationale to conserve and protect EFH in the south Atlantic region. Additionally, as new information and methodologies become available, the Council will revise existing policies and recommendations or develop a new policy statement to address the issue.

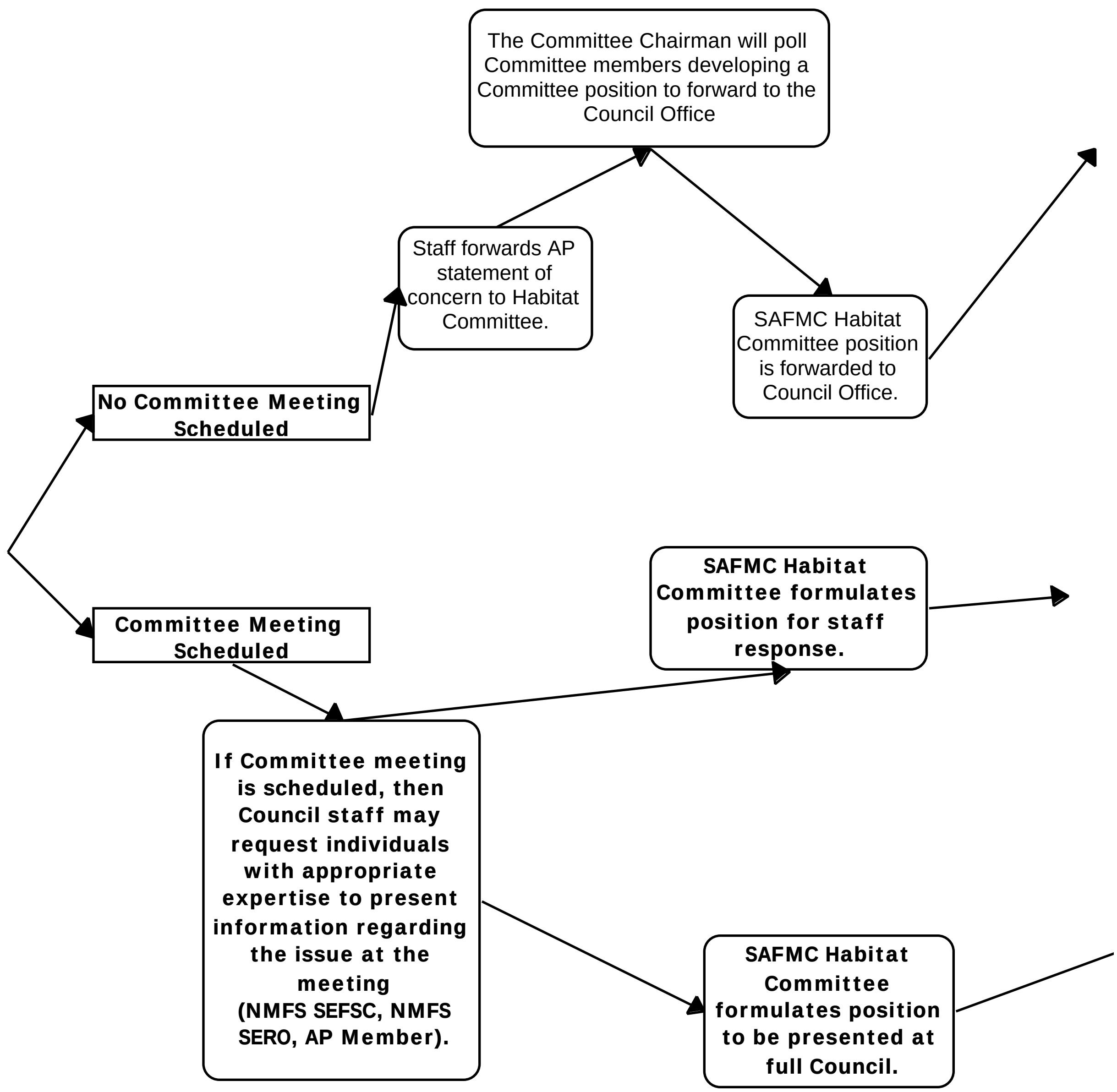
The Council has established a process for the development of habitat policy statements for specific habitats and activities. Given the abbreviated nature of many project comment periods, the Council uses the adopted Council habitat policies to be used when commenting to the permitting agency and a formal review of the project is not possible, or not necessary.

The SAFMC has developed specific guidance in the form of policy statements for activities occurring in submerged aquatic vegetation and for dredging and dredged material disposal (including use of Ocean Dredged Material Disposal Sites, offshore and nearshore underwater berm creation, maintenance dredging and sand mining for beach renourishment, and open water disposal); and oil and gas exploration, transportation, and development. The policies contain detail, including detailed descriptions of the resources involved, a discussion of potential impacts to those resources, and identification of provisions that should be implemented or considered to protect EFH. The Council encourages other parties commenting on projects to cite these recommendations when commenting on permits that impact EFH or EFH-(Habitat Areas of Particular Concern) HAPCs as defined in the Habitat Plan.

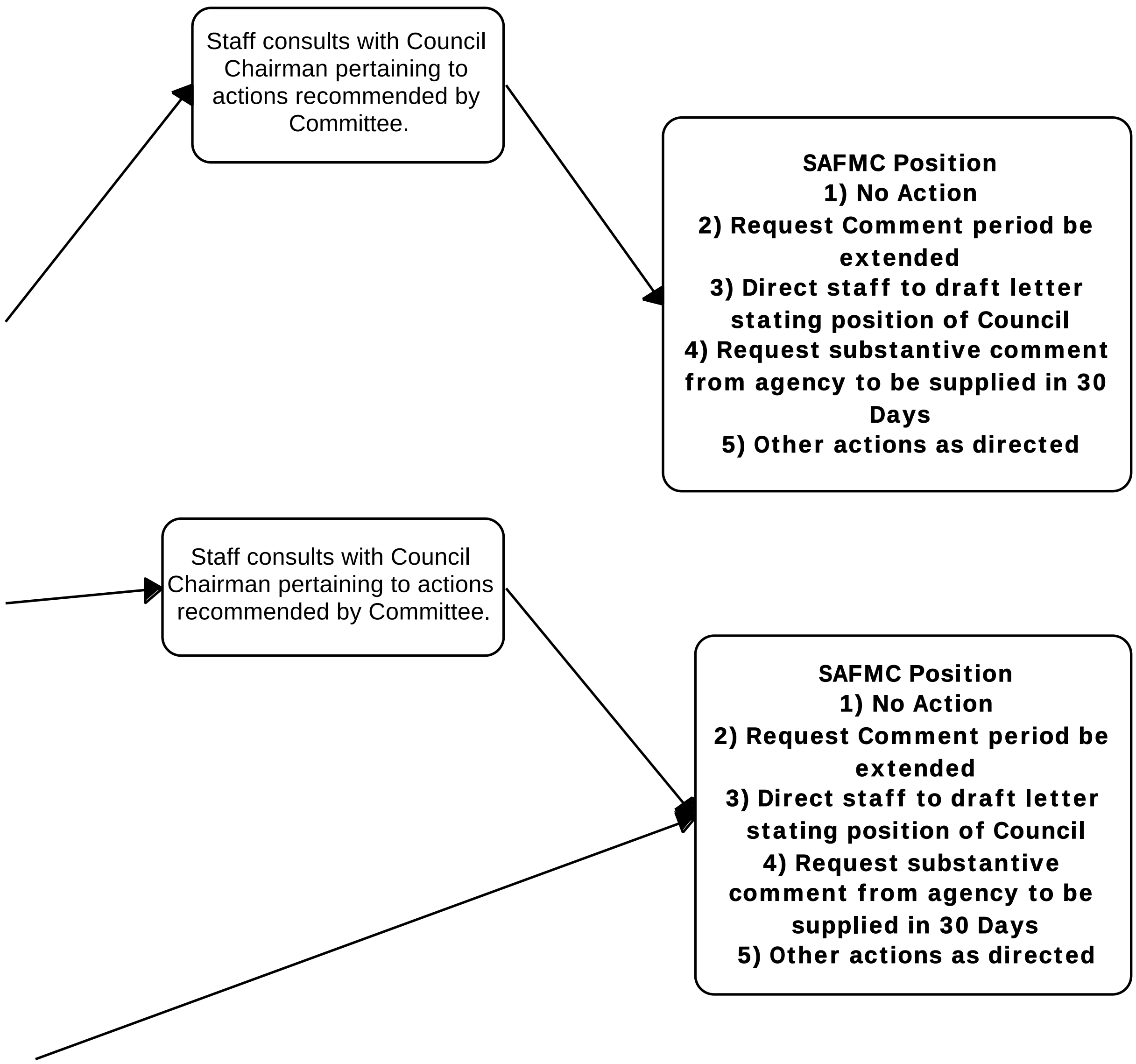
SAFMC Essential Fish Habitat and Environmental Protection: Page 1.
Project/Review Procedures (Approved 9/98)



SAFMC Essential Fish Habitat and Environmental Protection: Page2.
Project/Review Procedures (Approved 9/98)

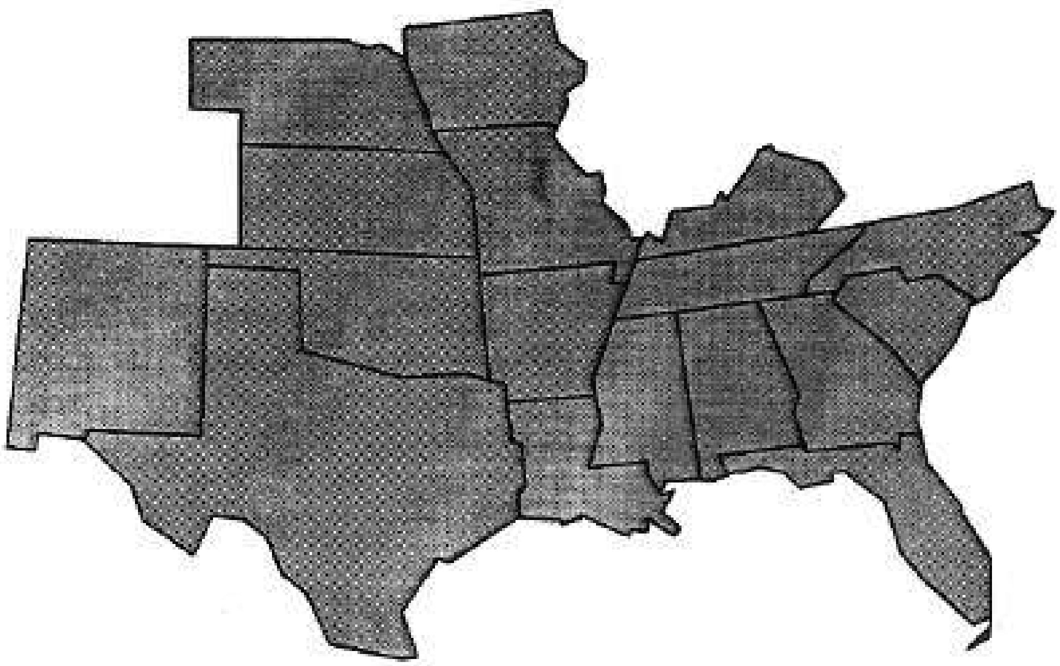


SAFMC Essential Fish Habitat and Environmental Protection: Page3.
Project/Review Procedures (Approved 9/98)



Habitat Protection Accomplishments

Fiscal Year 1997



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Habitat Conservation Division
Southeast Region

EXECUTIVE SUMMARY

The National Marine Fisheries Service's (NMFS) National Habitat Plan (NHP), Strategic Plan, and Habitat Conservation Policy call for improved protection of fisheries habitats. The Agency's mission is to protect, conserve, restore, and create habitats and ecosystems vital to self-sustaining populations of living marine resources under National Oceanic and Atmospheric Administration (NOAA)/NMFS stewardship. The NMFS commits to protect and conserve habitats from human-induced degradation; restore degraded habitats; and to create habitats with greater value than at present. Effort will also be expended to maintain current partners and to form new partnerships to help with program success; to provide the best possible science to guide the NMFS in its efforts; to inform constituents and the general public of accomplishments related to habitat conservation as well as the importance of healthy productive habitats to meet the ever-expanding recreational and commercial needs for fish and shellfish; and to develop realistic proposals that will allow the NMFS to carry out its mission.

Within the NMFS Southeast Region (SER), the Habitat Conservation Division (HCD) has the responsibility for conducting habitat protection programs. These programs are highlighted in this report along with the general and specific activities and accomplishments for fiscal year 1997 (FY97). This report further serves to provide information on our efforts to meet the objectives of the SER plan for implementing the NHP. The SER uses various statutory authorities found in Federal laws (see discussion under the section on Habitat Protection Accomplishments). Activities during FY97 focused on individual consultations involving Federal regulatory programs, pre- and post-application planning, Federal projects affecting habitat, National Environmental Policy Act (NEPA) consultations, watershed planning, partnerships and coordination with others (e.g., Fishery Management Councils), coordination between science and management, outreach efforts as possible, and a heightened involvement in habitat restoration, enhancement, creation, and preservation activities.

The front-line habitat conservation requirements are achieved principally through the efforts of HCD personnel stationed at five branch offices in various locations throughout the SER.. Acting under authority of various Federal laws and statutes, field personnel interact directly with Federal, state, and local officials, and with private citizens seeking to perform work in coastal waters of the southeast. Through consultative services involving field inspections, meetings, public hearings, and document review, biologists provide recommendations for sequentially avoiding, minimizing, and offsetting adverse impacts to habitat. During the year we accomplished the following.

- The NMFS conducted 291 preapplication consultations for proposed water development projects. We believe this process to be especially useful in protecting fisheries habitat because potential permit applicants usually have not invested heavily in project plans. They are therefore often more amenable to accepting recommendations from resource agencies aimed at reducing environmental impact. The process also allows the NMFS to deal with the regulated public in a forum that is less adversarial than when project plans have been developed and advertised for public review. The amount of habitat that can be involved in this process is substantial. During FY97, 63 of the 291 preapplication consultations we held involved more than 5,784 acres of fishery habitat.

- The NMFS reviewed 5,914 individual proposals to develop in wetlands. Most of these activities (about 64 percent and 2 percent, respectively) were found to either pose no significant threat to fishery resources or were deferred to other agencies. Many of the projects with minimal environmental impact resulted as a consequence of preapplication planning. About 12 percent were of concern because they involved substantial environmental impact. These projects required modification or denial of Federal authorization to protect fisheries resources. Over 22 percent of the review opportunities could not be accommodated because of manpower and funding constraints.

- Federal water development projects include construction and maintenance of Federal navigation channels, beach erosion and hurricane protection, flood control, port expansion and deepening, and other similar actions. The Corps of Engineers (COE) is the principal Federal agency in the coastal zone for the planning, design, and implementation of such projects. Environmental review is conducted by the COE, Fish and Wildlife Service (FWS), Environmental Protection Agency (EPA), NMFS, and state natural resource agencies. The NMFS's review of Federal projects is conducted largely in connection with provisions of the Fish and Wildlife Coordination Act (FWCA); however, other statutes such as the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and NEPA also apply. These laws encourage our review and input with respect to anticipated impacts and means by which adverse impacts can be avoided and offset. The HCD reviewed 104 Federally constructed or sponsored projects during the year.

- The NEPA requires preparation of an Environmental Impact Statement (EIS) for major Federal actions having significant affects on the human environment. The NMFS reviews these documents to ensure that they adequately address impacts to fishery resources and to provide recommendations on least damaging alternatives. The review process can be a powerful tool for the NMFS in its advocacy role on behalf of fishery resources and their habitat. The NMFS comments must be considered and addressed by the lead Federal agency. If NMFS views are not adequately considered, NEPA provides for an appeals process that allows the issue to be mediated at higher organizational levels. During FY97, 73 such consultations occurred.

- The NMFS participated in numerous activities associated with mitigation planning and habitat restoration that are unrelated to other habitat restoration programs and activities addressed in this report. The majority of these opportunities are related to Federal regulatory programs. The NMFS devoted considerable effort in planning for mitigation bank development, mitigation guideline development, and general mitigation planning. Activities related to the Coastal Wetland Planning Protection and Restoration Act (CWPPRA) continue to be a major habitat restoration activity in the Southeast. This year was extremely active in this arena of the habitat program and substantial accomplishments are evident in all parts of the habitat program. We conservatively estimate that we interacted on proposals this year that will preserve, enhance, restore, or create more than 157,796 acres of fisheries habitat. This includes 23,610 acres associated with mitigation banks and 65,000 acres of NMFS-sponsored restoration projects under the CWPPRA program.

- The National Estuary Program (NEP) is a comprehensive, multi-agency evaluation, planning, and action oriented initiative for preserving, protecting, and restoring the aquatic resources within entire estuarine ecosystems. The EPA is the lead Federal agency. The NMFS represented NOAA and provided technical assistance. Estuary programs in effect and requiring effort include: Galveston Bay and Corpus Christi Bay, Texas; Barataria-Terrebonne Bays Complex, Louisiana; Tampa Bay, Sarasota Bay, Indian River, and Charlotte Harbor, Florida; Mobile Bay, Alabama; and Albemarle-Pamlico Sound, North Carolina.

- Both the NOAA and NMFS have responsibilities related to habitat protection in the Southeast, and these responsibilities are often intertwined. The NMFS SER also performs actions directly for NOAA and NMFS Headquarters. Consequently, coordination and cooperation among these entities is essential and forms a large share of the habitat protection activities undertaken during the year.

- Outreach efforts included formal and informal presentations, production of reports and informational materials, and publication of research and management related material for peer and public use. Information requests by private, local, state, and Federal entities were answered. The NMFS disseminated habitat information through presentations at scientific and management meetings, journal publications, poster sessions, classroom and organization lectures, and interaction with environmental groups and the media.

Appendix O. Status and Availability of Essential Fish Habitat Information - Southeast Habitat Partners (Source: SAFMC EFH Workshop 1 & 2).

Summary: Essential Fish Habitat Workshops #1 & #2

GIS Presentation of EFH Information-

- **ArcView will be the Software Platform and Format for EFH Maps**

- **The Two Proposed Levels of Resolution for EFH maps are to the Estuary and to the State and / or Region.**

In Habitat Plan - maps fit the estuary (Use Estuarine Drainage Areas (EDA))

(e.g., ESI Maps, National Wetland Inventory Maps, Aids to Navigation NOAA/USCG)

In Comprehensive Habitat Amendment - Maps to the State and/ or Regional Level

- **EFH and Species Distribution and Environmental Parameters: [Use C-Cap Land Cover, Wetland, and Water and Submerged Land Classifications overlaid on NOAA Bathymetry]**

UPLAND

Developed High Intensity
Developed Low Intensity
Grassland
Cultivated Land
Evergreen Forest
Scrub/Shrub
Bare Land
Mixed Forest Deciduous Forest
Water

WATER AND SUBMERGED LAND

Submersed Rooted Vascular (SRV)
Coral & Live Bottom
Unconsolidated Shore
(Mud and Sand Flats)

WETLAND

Estuarine
Forest (>20ft)
Shrub/Scrub (Mangroves in FL)
Emergent (Salt & Brackish Marsh)
(Uses Juncus Break)

Palustrine
Forest (>20ft)
Shrub/Scrub
Emergent (Freshwater Marsh)

Use ESI Maps for NC, SC & GA
Terrestrial Emergents shoreward
*C-Cap gaps in GA and northern

Sources and Availability by State of Essential Fish Habitat Distribution Information

ESTUARINE:

Saltmarsh & Brackish Marsh/ Estuarine Emergent

Source	NC	SC	GA	FL
C-CAP		¦		
NWI	¦	¦(partial)	¦	¦
NCWI	¦	¦	¦	¦
CZM				

Fresh Marsh / Palustrine

Source	NC	SC	GA	FL
C-CAP		¦		
NWI	¦	¦(partial)	¦	¦
NCWI	¦	¦	¦	¦
CZM				

Mangroves

Source	FL
NWI	¦
FMRI Land Use	¦

Mud & Sand Flats / Unconsolidated Bottom

Source	NC	SC	GA	FL
ESI	¦	¦	¦	¦
FMRI				FKNMS & Biscayne Bay
C-CAP		¦		
OCRM		¦(riprap)		
NWI	¦	¦	¦	¦
Shellfish Map- State	¦			
APES	¦			
NOAA SEA	¦	¦	¦	¦

Submersed Rooted Vascular (SRV- Seagrass)

Source	NC	SC	GA	FL
ESI	¦	¦	¦	¦
C-CAP				FKNMS & Biscayne Bay
CGIA		¦		¦
INDIAN RIVER				
NOAA CSC				¦

Sources and Availability by State of Essential Fish Habitat Distribution Information- (cont.)

ESTUARINE

Oyster / Shell Habitat

Source	NC	SC	GA	FL
NC SHELLFISH	!			
NC CULTCH	!			
NC LEASES	!			
ESI	!	!	!	!
N. SHELLFISH REG.	!	!	!	!
SC MARINE DIVISION	DHEC Class.	!		
PAPER	Poly Water Quality			!
FMRI				
Water Quality				!
Closures				!
Leases				!

Environmental Parameters

PARAMETERS	NC	SC	GA	FL
AVHRR	CSC	CSC	CSC	CSC
TEMP	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
SALINITY	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
DEPTH	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
TURBIDITY	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
POLLUNTANT LOADS	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
NUTRIENTS	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA
DISOLVED OXYGEN	Div WQ	Eutr.	Eutr.	Eutr.
	Eutr.			
PESTICIDES	NOAA SEA	NOAA SEA	NOAA SEA	NOAA SEA

OFFSHORE

Coral, Coral Reefs, and Live/Hard Bottom Habitat

Source:

South East Area Monitoring and Assessment Program (SEAMAP) - Bottom Mapping Project
FMRI
NOAA Grays Reef
Florida Keys National marine Sanctuary

Artificial Reefs

State Inventories
National Artificial Reef Plan
SEAMAP

Sources and Availability by State of Essential Fish Habitat Distribution Information- (cont.)

Pelagic Habitat
Sargassum
NOAA NOS Dist. DB

Water Column
Currents NOAA NOS
Depth NOAA NOS
Temperature Dynamic Analysis
Salinity NOAA NOS

Sources and Availability of Information on Managed Species Distribution
by Life Stage and by State

Florida					
	Adult	Larvae	Juvenile	Eggs	
Penaeid Shrimp	¦		¦		
Rock Shrimp	¦				
Red Drum	¦	¦	¦		
Snapper/Grouper					
King Mackerel	¦ NOAA	¦ N FL	¦		
Spanish Mackerel	¦ NOAA	¦ N. FL			
Dolphin	¦				
Little Tunny	?				
Cobia	?				
Golden Crab	?				
Calico Scallops	¦	¦	¦	ESI Data	
Spiny Lobster	¦	¦	¦	ESI Data	
Coral & Live Bottom	¦			ESI Data	

Sources and Availability of Information on Managed Species Distribution
by Life Stage and by State (cont.)

Georgia					
	Adult	Larvae	Juvenile	Eggs	
Penaeid Shrimp	¦	¦	¦		
Rock Shrimp	¦				
Red Drum	¦	¦	¦		
Snapper/Grouper	¦	¦			
King Mackerel	¦	¦	¦		
Spanish Mackerel	¦	¦	¦		
Dolphin	¦	¦	¦		
Little Tunny	¦ (*)				
Cobia	¦ (*)				
Golden Crab	¦				
Calico Scallops	¦				
Spiny Lobster					
Coral & Live Bottom	¦				
	(* Fishery Dependant Data)				

South Carolina					
	Adult	Juvenile	Larvae	Eggs	
Penaeid Shrimp	¦	¦	¦		
Rock Shrimp	¦	¦			
Red Drum	¦	¦	¦		
Snapper/Grouper	¦	¦	¦		
King Mackerel	¦	¦	¦		
Spanish Mackerel	¦	¦	¦		
Dolphin					
Little Tunny			¦		
Cobia	¦	¦	¦		
Golden Crab	¦				
Calico Scallops	¦	¦			
Spiny Lobster	¦				
Coral & Live Bottom	¦				

Sources and Availability of Information on Managed Species Distribution
by Life Stage and by State (cont.)

North Carolina					
	Adult	Juvenile	Larvae	Eggs	
Penaeid Shrimp	¦	¦	¦		
Rock Shrimp	¦	¦			
Red Drum	¦	¦			
Snapper/Grouper	¦	¦	¦		
King Mackerel	¦	¦	¦		
Spanish Mackerel	¦	¦	¦		
Dolphin	¦	¦			
Little Tunny	¦		¦		
Cobia	¦	¦	¦		
Golden Crab	¦				
Calico Scallops	¦	¦			
Spiny Lobster	¦	¦			
Coral & Live Bottom	¦				

Appendix P. Level of Available EFH Information for Species Managed by the SAFMC.

North: North Carolina/Virgina Border to Cape Canaveral; South: Cape Canaveral to Dry Tortugas. Level 1 - geographic presense/absence data available; Level 2 - habitat-specific densities availiable; Level 3 - growth, reproduction, survival rates available; Level 4 - production rates available.

FMP/Common Name	Scientific Name	North	South
Shrimp FMP			
Brown shrimp	*Penaeus aztecus*	1	1
Pink shrimp	*Penaeus duorarum*	1	1,3
Rock shrimp	*Sicyonia brevirostris*	1	1
Royal red shrimp	*Pleoticus robustus*	1	1
Seabob shrimp	*Xiphopenaeus kroyeri*	1	1
White shrimp	*Penaeus setiferus*	1	1, 3
Red Drum FMP			
Red drum	*Sciaenops ocellatus*	1	1,2,3
Snapper Grouper FMP			
Triggerfishes	Balistidae		
Gray triggerfish	*Balistes capriscus*	1	1
Queen triggerfish	*Balistes vetula*	1	1
Ocean triggerfish	*Canthidermis sufflamen*	1	1
Jacks	Carangidae		
Yellow jack	*Caranx bartholomaei*	1	1
Blue runner	*Caranx crysos*	1	1
Crevalle jack	*Caranx hippos*	1	1
Bar jack	*Caranx ruber*	1	1
Greater amberjack	*Seriola dumerili*	1, 3	1, 3
Lesser amberjack	*Seriola fasciata*	1	1
Almaco jack	*Seriola rivoliana*	1	1
Banded rudderfish	*Seriola zonata*	1	1
Spadefish	*Ephippidae*		
Spadefish	*Chaetodipterus faber*	1	1
Grunts	Haemulidae		
Black margate	*Anisotremus surinamensis*	1	1,2,3
Porkfish	*Anisotremus virginicus*	1	1,2,3
Margate	*Haemulon album*	1	1
Tomtate	*Haemulon aurolineatum*	1	1
Smallmouth grunt	*Haemulon chrysargyreum*	1	1,3
French grunt	*Haemulon flavolineatum*	1	1
Spanish grunt	*Haemulon macrostomum*	1	1,3
Cottonwick	*Haemulon melanurum*	1	1
Sailors choice	*Haemulon parra*	1	1,3

White grunt	*Haemulon plumieri*	1,3	1,3
Blue stripe grunt	*Haemulon sciurus*	1	1,3
Wrasses	Labridae		
Hogfish	*Lachnolaimus maximus*	1	1
Puddingwife	*Halichoeres radiatus*	1	1
Snappers	Lutjanidae		
Black snapper	*Apsilus dentatus*	1	1
Queen snapper	*Etelis oculatus*	1	1
Mutton snapper	*Lutjanus analis*	1	1,3
Schoolmaster	*Lutjanus apodus*	1	1,3
Blackfin Snapper	*Lutjanus buccanella*	1	1
Red snapper	*Lutjanus campechanus*	1	1
Cubera snapper	*Lutjanus cyanopterus*	1	1
Gray snapper	*Lutjanus griseus*	1	1,3
Mahogany snapper	*Lutjanus mahogoni*	1	1,3
Dog snapper	*Lutjanus jocu*	1	1
Lane snapper	*Lutjanus synagris*	1	1
Silk snapper	*Lutjanus vivanus*	1	1
Yellowtail snapper	*Ocyurus chrysurus*	1,3	1,3
Vermillion snapper	*Rhomboplites aurorubens*	1,3	1
Tilefish	Malacanthidae		
Blueline tilefish	*Caulolatilus microps*	1	1
Golden tilefish	*Lopholatilus chamaeleonticeps*	1	1
Sand tilefish	*Malacanthus plumieri*	1	1
Temperate basses	Percichthyidae		
Wreckfish	*Polyprion americanus*	1	1
Groupers	Serranidae		
Bank sea bass	*Centropistis ocyurus*	1	1
Rock sea bass	*Centropistis philadelphica*	1	1
Black sea bass	*Centropristis striata*	1,2,3	1
Rock hind	*Epinephelus adscensionis*	1	1
Grasyby	*Epinephelus cruentatus*	1	1
Speckled hind	*Epinephelus drummondhayi*	1	1
Yellowedge grouper	*Epinephelus flavolimbatus*	1	1
Coney	*Epinephelus fulvus*	1	1
Red hind	*Epinephelus guttatus*	1	1
Jewfish	*Epinephelus itajara*	1	1,3
Red grouper	*Epinephelus morio*	1	1
Misty grouper	*Epinephelus mystacinus*	1	1
Warsaw grouper	*Epinephelus nigritus*	1	1
Snowy grouper	*Epinephelus niveatus*	1	1
Nassau grouper	*Epinephelus striatus*	1	1
Black grouper	*Mycteroperca bonaci*	1	1
Yellowmouth grouper	*Mycteroperca interstitialis*	1	1
Gag	*Mycteroperca microepis*	1,2,3	1
Scamp	*Mycteroperca phenax*	1,3	1
Tiger grouper	*Mycterpoperca tigris*	1	1
Yellowfin grouper	*Mycteroperca venenosa*	1	1
Porgies	Sparidae		
Sheepshead	*Archosargus probatocephalus*	1	1
Grass porgy	*Calamus arctifrons*	1	1

Jolthead porgy	*Calamus bajonado*	1	1
Saucereye porgy	*Calamus calamus*	1	1
Whitebone porgy	*Calmus leucosteus*	1	1
Knobbed porgy	*Calamus nodosus*	1	1
Red porgy	*Pagrus pagrus*	1,2,3	1
Longspine porgy	*Stenotomus caprinus*	1	1
Scup	*Stenotomus chrysops*	1	1
Coastal Migratory Pelagics FMP			
Mackerel	Scombridae		
Cero	*Scomberomorus regalis*	1	1
King mackerel	*Scomberomorus cavalla*	1,3	1,3
Spanish mackerel	*Scomberomorus maculatus*	1,3	1,3
Dolphin	*Coryphaena hippurus*	1	1,3
Little tunny	*Euthynnus alletteratus*	1	1
Golden Crab FMP			
Golden crab	*Chaeceon fenneri*	1	1,2,3
Spiny Lobster FMP			
Spiny lobster	*Panulirus argus*	1	1,3
Coral, Coral Reefs, and Live Hard Bottom Habitat FMP			
Scleractinia	stony coral	1	1,2,3
Antipatharia	black coral	1	1
Calico Scallop FMP			
Calico Scallop	*Agopecten gibbus*	1	1
Sargassum Habitat FMP			
Sargassum	*Sargassum natans &*		
	Sargassum fluitans	1	1, 3

SOUTH CAROLINA OFFSHORE FISHING REEFS: LOCATION, BEARINGS, AND DESCRIPTION

Little River Reef
LORAN C-45424.0/59409.0
1 buoy marks reef, bearing 125°/2.7 nm from south jetty at Little River Inlet.
Consists of 25,000 auto tires and eight Army "BK" barges, 60 tire/concrete structures.
Water depth 20-30'.

Little River Offshore Reef
LORAN C-45386.5/59418.5
1 buoy marks reef, bearing 156°/10.5 nm from Little River Inlet.
Consists of three 55' boats and miscellaneous concrete.
Water depth 50-60'.

Springmaid Pier Reef
Located adjacent to the Springmaid Pier
Fishing Pier in Myrtle Beach.
Consists of 100 tire/concrete reef units placed 50 to 150 feet south of the pier.

BP-25 Reef
LORAN C-45306.0/59551.4
Reef is unmarked, ship bears 173°/29.5 nm from buoy "2LR" at Little River Inlet and
113°/31.5 nm from
buoy "MI" at Murrells Inlet.
Consists of a 160' ship.
Water depth 90-95'.

Bill Perry Reef
LORAN C-45350.9/59582.0
1 buoy marks reef, bearing 100°/25 nm from Murrells Inlet buoy "MI."
Consists of two 56' LCM's, two 115' LCU's, one 45' steel-hulled shrimp trawler, one 65'
tugboat and 75
steel reef units.
Water depth 65'.

Paradise Reef
LORAN C-45465.2/59761.9
2 buoys mark reef, bearing 105°/3.2 nm from south jetty at Murrells Inlet.
Consists of 60,000 tires, various barges, other vessels and 200 concrete reef balls.
Water depth 30-35'.

Ten Mile Reef
LORAN C-45418.1/59736.9
2 buoys mark reef, bearing 130°/9.5 nm from south jetty at Murrells Inlet.
Consists of 14,000 tires, various vessels, a 200' barge and an A7 airplane.
Water depth 34-45'.

Pawley's Island Reef
LORAN C-45456.9/59815.0
1 buoy marks reef, bearing 177°/5.5 nm from south jetty at Murrells Inlet.
Consists of 31,000 tires and various landing craft.
Water depth 23-35'.

North Inlet Reef
LORAN C-45437.5/59849.7
1 buoy marks reef, bearing 020°/9.6 nm from Winyah Bay channel buoy "2WB."
Consists of 175 steel reef units and 200 concrete reef balls.
Water depth 45'.

Georgetown Reef
LORAN C-45411.3/59882.9
1 buoy marks reef, bearing 074°/7.6 nm from end of Winyah Bay jetty.
Consists of a 90' shipwreck, trolling alley, two barges, eleven scaffolds and a 55' LCM.
Water depth 35-39'.

Georgetown Nearshore Reef
LORAN C-45425.7/59937.8
1 buoy marks reef, bearing 065°/2.7 nm from Winyah Bay south jetty mound.
Consists of miscellaneous steel and metal structures, one 130' barge and one 62' barge.
Water depth 30'.

C J Davidson Jr Reef
LORAN C-45381.4/59942.5
1 buoy marks reef, bearing 147°/6.5 nm from channel buoy "2WB."
Consists of a 150' barge and several steel and concrete reef units.
Water depth 53'.

Vermilion Reef
LORAN C-45265.8/59835.5
Unmarked ship, bearing 117°/27.5 nm from the south jetty at Winyah Bay.
Consists of a 460' Victory ship.
Water depth 110'.

Greenville Reef
LORAN C-45319.6/59954.0
Reef is unmarked, bearing 149°/17.5 nm SE of Winyah Bay channel buoy "2WB."
Consists of 40 drydock platforms, two submarine sonar domes, and two barges.
Water depth 85'.

Cape Romain Reef
LORAN C-45363.2/59996.4
1 buoy marks reef, bearing 173°/12.0 nm from Winyah Bay channel buoy "2WB."
Consists of a 100' barge, a 90' tugboat, a 55' LCM and a 65' tugboat
Water depth 55-65'.

Hector Reef
LORAN C-45380.3/60027.1
Marked by Coast Guard buoy "WR-4" bearing 176°/11.7 nm from channel buoy "2WB."
Consists of a broken-up steel-hulled freighter, four Army "BK" barges, a 55' LCM and a 130' barge.
Water depth 12-30'.

Capers Reef (R-8)
LORAN C-45438.2/60370.4
1 state buoy and Coast Guard buoy "R-8" mark reef, bearing 090°/12.2 nm from offshore end of Charleston
jetties
Consists of various-sized ship and boat hulls, 30,000 auto tires and 200 concrete reef balls.
Water depth 20-45'.

Charleston Nearshore Reef
LORAN C-45480.9/60479.9
1 buoy marks reef, bearing 120°/2.5 nm from Charleston Harbor north jetty.
Consists of miscellaneous concrete material, five "BK" barges and two 150' deck barges.
Water depth 30'.

Y-73 Reef
LORAN C-45317.4/60316.1
Consists of a 180' ex-US Army coastal tanker, three 90' tugboats and 225 steel reef units.
Water depth 95'.

Charleston Sixty Reef
LORAN C-45415.8/60490.8
1 buoy marks reef bearing 145°/12.5 nm from Charleston Harbor south jetty.
Consists of 160 steel reef units, miscellaneous steel structures, one deck barge and one 220' hopper barge.
Water depth 60'.

Folly Beach Fishing Pier Reef
Located adjacent to Folly Beach Fishing Pier
Consists of 200 concrete reef balls placed on the south side of the pier.

Comanche Reef
LORAN C-45295.1/60350.4
Unmarked ship bearing 135°/22.5 nm from Charleston Harbor channel buoy "C."
Consists of a 165' steel-hulled ship.
Water depth 105'.

Kiawah Reef (4KI)
LORAN C-45493.1/60693.6
2 buoys mark reef, bearing 115°/6.5 nm from N. Edisto Inlet buoy "2NE."
Consists of large drydock, L.C.U., barge, pontoons, 30,00 tires and various vessels.
Water depth 20-40'.

North Edisto Nearshore
LORAN C-45530.0/60730.0
1 buoy marks reef, bearing 090°/1.5 nm from North Edisto channel buoy "2NE."
Consists of two 150' deck barges and miscellaneous concrete.
Water depth 30'.

Edisto Offshore Reef
LORAN C-45382.7/60692.2
Unmarked reef, bearing 158°/23.5 nm from Stono Inlet.
Consists of two sunken ships, one large steel deckhouse and one shrimp boat.
Water depth 65-70'.

Edisto Forty Reef
LORAN C-45534.3/60815.2
1 buoy marks reef, bearing 209°/6.5 nm from North Edisto channel buoy "2NE."
Consists of 1200 tons of miscellaneous concrete.
Water depth 45'.

Edisto Sixty Reef
LORAN C-45483.8/60780.0
1 buoy marks reef, bearing 167°/10.5 nm from North Edisto channel buoy "2NE."
Consists of three 50' swing bridge sections, a 338' steel-hulled ship and miscellaneous concrete.
Water depth 65'.

Paradise Pier Reef
Located adjacent to Paradise Fishing Pier on the southern end of Hunting Island in Fripp Inlet.
Consists of several hundred pieces of concrete culvert pipe and 2,000 bushels of oyster shells.

Fripp Island Reef
LORAN C-45546.1/60968.8
1 buoy marks reef, bearing 140°/5.8 nm from Fripp Inlet.
Consists of 50,000 auto tires, a 100' barge, numerous steel structures and 200 concrete reef balls.
Water depth 30-35'.

Hunting Island Reef
LORAN C-45525.2/60965.1
1 buoy marks reef, bearing 144°/8.5 nm from Fripp Inlet.
Consists of barges and 30,000 tires.
Water depth 35-50'.

Parris Island Reef
LORAN C-45669.2/61130.5
1 buoy marks reef, located in Broad River between Parris Island and Daws Island.
Consists of several concrete bridge sections.
Water depth 15-40'.

Fish America Reef
LORAN C-45617.8/61179.28
2 buoys mark reef, bearing 279°/5.0 nm from Port Royal Sound channel buoy "9".
Consists of concrete bridge railings and 400 tons of concrete pipe placed in rows between the buoys.
Water depth 5-9'.

Betsy Ross Reef
LORAN C-45504.1/61061.9
Unmarked single ship, bearing 105°/8.4 nm from Port Royal channel entrance buoy "2PR." A 430' liberty ship and five steel swing bridge sections. Water depth 90'.

North Carolina Artificial Reefs

AR-140

Reef Buoy coordinate 35°56'45"/075°31'47"

Reef Specifications

Range 001° Magnetic 8.9 nm from Oregon Inlet sea buoy.
Buoy 26975.0/40690.0
Avg. Depth57 ft.

Reef Material	Deployed	Location
Box cars	1986	26975.0/40690.5
		26975.0/40690.0
130 ft barge	1989	26975.1/40689.1
130 ft barge	1989	26975.0/40690.0

AR-145

Reef Buoy coordinate 35°54'01"/075°23'53"

Reef Specifications

Range 049° Magnetic 8.1 nm from Oregon Inlet sea buoy.
Buoy 26941.4/40685.7
Avg. Depth65 ft.

Reef Material	Deployed	Location
115 ft. Landing craft	1987	26941.4/40685.5-.6
Concrete bridge rubble	1991	26941.9/40684.7
		26941.9/40684.3
		26941.8/40684.2
		26941.6/40684.5
		26941.4/40684.7
		26941.5/40684.0
185 ft vessel	1994	26941.2/40685.3
Advance II		26941.5/40685.0

AR-160

Oregon Inlet Reef

Map Available:Please note that all maps consist of a JPEG file of approximately 175K.

Reef Buoy coordinate 35°43'54"/075°26'47"

Reef Specifications

Range 150° Magnetic 4.0 nm from Oregon Inlet sea buoy.
Buoy 26940.7/40574.1
Avg. Depth 66 ft. (Deeper around vessels)

Reef Material	Deployed	Location
440 ft liberty ship ZANE GRAY	1974	26940.7/40574.1
440 ft liberty ship DIONYSUS	1978	26940.9/40576.3
		26940.8/40576.8

AR-220

Reef Buoy coordinate 35°08'07"/075°40'38"

Reef Specifications

Range 111° Magnetic 4.9 nm from Hatteras Inlet sea buoy.
Buoy 26951.0/40182.0
Avg. Depth 64 ft.

Reef Material	Deployed	Location
Box Cars	1986	26951.3/40181.3
		26951.3/40181.0
		26951.0/40181.4
		26951.8/40181.3
		26951.7/40181.5
		26951.7/40181.3
		26951.6/40181.3
Concrete pieces	1993	26951.3/40181.7
		26951.2/40181.3

AR-225

Reef Buoy coordinate 35°06'45"/075°39'14"

Reef Specifications

Range 120° Magnetic 6.2 nm from Hatteras Inlet sea buoy.

Buoy 26945.0/40175.0

Avg. Depth 69 ft.

Reef Material	Deployed	Location
Train Cars and concrete	1986	26945.9/40175.7
		26945.6/40175.3
		26945.5/40175.3

During inspection of this site, a rock ledge was found at 26945.2/40173.0.

This ledge is about 250 yards long, 1-3' of profile and is oriented NE-SW.

AR-230: MR. J.C. REEF

Reef Buoy coordinate Buoy is Missing

Reef Specifications

Range 148° Magnetic 3.7 nm from Hatteras Inlet sea buoy.

Buoy 26957.0/40155.0

Avg. Depth72 ft.

Reef Material	Deployed	Location
105 ft tug	1987	26957.0/40155.0
MR. J. C.		26957.3/40154.9
130 ft yard freighter	1991	26957.3/40155.1-.3
75 ft landing craft	1991	26957.4/40155.6

AR-250

Reef Buoy coordinate 34°56'54"/075°54'52"

Reef Specifications

Range 156° Magnetic 5.1 nm from Ocracoke Inlet sea buoy.
Buoy 26987.3/40024.0
Avg. Depth83 ft.

Reef Material	Deployed	Location
Box cars	1986	26986.9/40023.5
Concrete and steel rubble	1990-1992	26987.2/40024.2
		26987.3/40024.3
		26987.0/40023.6
		26987.4/40023.6
		26987.3/40024.1

AR-255

Reef Buoy coordinate 34°55'29"/075°57'55"

Reef Specifications

Range 184° Magnetic 6.1 nm from Ocracoke Inlet sea buoy.
Buoy 26995.9/39998.0
Avg. Depth84 ft.

Reef Material	Deployed	Location
Box cars	1986	26995.7/39997.9
		26995.7/39998.0
		26995.9/39998.1
		26995.8/39997.7
Concrete and steel rubble	1993	26995.9/39998.5

AR-285: GEORGE SUMMERLIN REEF

Reef Buoy coordinate 34°33'23"/076°26'21"

Reef Specifications

Range 125° Magnetic 3.5 nm from the east Cape Lookout Shoals Slough buoy (RW "E")

Buoy 27062.2/39682.7
Avg. Depth 65 ft.

Reef Material	Deployed	Location
130' steel vessel	1989	27062.2/39683.3
500 pieces 5' x 8' concrete pipe	1991	27062.2/39683.1
		27062.6/39682.7
50 pieces of large concrete pipe	1993	27062.3/39682.0
		27062.3/39681.8
		27062.3/39682.3

ESTUARINE REEFS

AR-191 Black Walnut Point Reef

Location 140* magnetic from Marker 2 at entrance to Edenton Channel. 1.0 nm due north of Black Walnut Point

Material 220 tires, 12 boat molds, 10 trash boxes

AR-291 Bayview Reef - Pamlico River

Location 100 ft offshore Town of Bayview, near the mouth of Bath Creek

Material 28,000 tires

AR-292 Quilley Point - Pungo River

Location 90* magnetic - 0.75 nm from ICW marker #5

Material 19,200 tires

AR-296 Hatteras Island Business Association Reef

Location 1.0 nm north of Frisco Channel marker #6

Material 16,280 tires, fossil rock (marl)

AR-298 Ocracoke

Location 035* magnetic - 1.5 nm from Big Foot Slough Channel entrance

Material 104 ft barge on buoy at 27019.4/40132.4
130 ft barge 100' NE of buoy at 27019.4/40133.0
75 tons concrete rubble at buoy, 60 ft tug

AR-392 New Bern

Location 140* magnetic - 2.6 nm from Union Point Park, Neuse River

Material 105,000 tires

AR-396 Oriental

Location 900 yd SE of Whitehurst Point near Oriental

Material Scrap metal, 22,000 tires, fossil rock (marl)

North Carolina Estuarine Reefs

AR-191 Black Walnut Point Reef

Location 140* magnetic from Marker 2 at entrance to Edenton Channel. 1.0 nm due north of Black Walnut Point

Material 220 tires, 12 boat molds, 10 trash boxes

AR-291 Bayview Reef - Pamlico River

Location 100 ft offshore Town of Bayview, near the mouth of Bath Creek

Material 28,000 tires

AR-292 Quilley Point - Pungo River

Location 90* magnetic - 0.75 nm from ICW marker #5

Material 19,200 tires

AR-296 Hatteras Island Business Association Reef

Location 1.0 nm north of Frisco Channel marker #6

Material 16,280 tires, fossil rock (marl)

AR-298 Ocracoke

Location 035* magnetic - 1.5 nm from Big Foot Slough Channel entrance

Material 104 ft barge on buoy at 27019.4/40132.4
130 ft barge 100' NE of buoy at 27019.4/40133.0
75 tons concrete rubble at buoy, 60 ft tug

AR-392 New Bern

Location 140* magnetic - 2.6 nm from Union Point Park, Neuse River Material 105,000 tires

AR-396 Oriental

Location 900 yd SE of Whitehurst Point near Oriental

Material Scrap metal, 22,000 tires, fossil rock (marl)

Appendix R. Ecology of neonate loggerhead turtles inhabiting pelagic fronts near Florida Current (Source: Witherington 1997).

ECOLOGY OF NEONATE LOGGERHEAD TURTLES INHABITING PELAGIC FRONTS NEAR THE FLORIDA CURRENT

Interim Report to the National Marine Fisheries Service

for FO602-96-11

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December 1997

INTRODUCTION

Although the pelagic phase of sea turtle life history is poorly known, two principal assumptions persist in guiding biological thought and conservation decisions pertaining to pelagic sea turtle ecology. The first of these working hypotheses is that neonate/juvenile sea turtles are passive drifters that inhabit frontal boundaries near major currents in the open ocean and a second is that these young sea turtles forage upon the surface biota within these fronts. Unfortunately, there have been no detailed ecological studies that would support of refute these hypotheses. Study of pelagic turtles has been difficult, largely due to the inaccessibility of the areas they inhabit.

The present study seeks to test these and other hypotheses on the ecology of neonate loggerhead turtles. Capture of neonate loggerheads, behavioral observations, and sample collections from turtles and from their habitat were conducted within a region of the Atlantic Ocean off Florida where young loggerhead turtles are regularly found. These post-hatchlings (estimated to be 5-60 days old) are found within debris lines 20-40 NM from shore near the western boundary of the Florida Current. On days of acceptable weather, an average of 12 post-hatchling loggerheads have been observed for each hour spent searching (Witherington, 1994). This area provides a unique opportunity to study the ecology of pelagic turtles.

A pilot study of post-hatchling loggerheads at the edge of the Florida Current found an alarming frequency of debris ingestion (Witherington, 1994). Tar or plastics were found in the lavaged stomach contents of 56% of sampled loggerheads and 63% of these turtles had tar adhering to their jaws.

This study has the following objectives.

1. Characterize the behavior of pelagic post-hatchling loggerheads. Address the questions: Are pelagic loggerheads passive drifters? Do they favor areas within fronts that have a specific current speed and direction? Do post-hatchling loggerheads have an affinity for specific types of objects (e.g., sargassum, woody debris, plastics)?

2. Characterize the habitat where post-hatchling loggerheads are found. Address the questions: Are the areas where post-hatchlings are found true oceanic fronts (shear boundaries between two water masses)? How accurately do the occurrence of sargassum and the presence of true frontal boundaries predict the presence of post-hatchlings?

3. Characterize food choice of post-hatchling loggerheads. Address the questions: What are post-hatchling loggerheads eating? What potential food items and ingestion hazards are present in their foraging areas? What are the preferences for

ingested items based upon frequency of ingestion and availability in the water? What are the origins of plastics and tar found in the stomachs of turtles and in the waters they inhabit?

WORK ACCOMPLISHED, 10-1-96 TO 11-30-97

Eighteen trips were made to a region of the Atlantic, east of Cape Canaveral, Florida, near the 40 fathom contour at approximately 28.5 N and 80.0 W. Trips were made during the period of hatchling emergence activity on nearby nesting beaches and spanned the period of 22 July through 1 October 1997. The vessel used on these trips was a 6.5 m cuddy cabin with a 150 hp outboard motor.

Within the target region, visible lines of sargassum, grass, foam, or debris, were sought as areas where neonate turtles could be found. Measurements of position (latitude and longitude), water surface temperature, conductivity, and current speed and direction, were made within each line encountered and at points located 0.1 NM on either side of the line. Temperature and conductivity were measured with a YSI model 30 meter and current measurements were made by tracking a current drogue with a Garman global positioning receiver. Additional notes describing the surveyed habitat were made such as extent of sargassum, width of the debris line, and weather and sea conditions.

Following these initial measurements, timed searches were made as the vessel moved at idle speed (approximately 2.5 kts) through the center of the debris line. As turtles were observed, notes were made on the time of the observation, position, and species of turtle. Observed turtles fell into four categories:

1. Turtles observed but not captured. These data will be used with data from captured turtles to calculate a catch-per-unit-effort and a species frequency index.

2. Turtles captured by dip net only and released. In addition to time, position, and species data, these turtles were weighed, measured for straight-line carapace length and width, and given an oral exam for the presence of tar.

3. Turtles captured with a debris sampler and released. This capture technique (described below) was used to collect nearby floating debris with each turtle. In addition to the information collected for turtles described above, gastric/esophageal lavages were conducted to sample recently ingested items.

4. Turtles found dead and collected. These turtles were given necropsies and a quantified examination of gut contents.

Debris Sampling/Turtle Capture

The device used for capturing turtles and nearby debris was a modified dip net. The mesh of the net was replaced with a funnel of 500 micron stainless steel mesh which connected to a 300 micron mesh removable sample bag. The opening of the net was circular and 70 cm in diameter.

As turtles were observed ahead of the moving vessel, the sampler was placed into the water, left in for a count of two seconds, and withdrawn in such a way that the turtle and debris in the immediate area were collected. Turtles were removed from the sample bag, processed, and released, and the remaining contents of the bag were sealed in an airtight plastic bag and placed on ice for later examination. In the laboratory, the debris sample was weighed and the biomass of constituent items was approximated using the technique described below.

Gastric and Esophageal Lavage

Turtles chosen for gastric/esophageal samples were inverted, and their mouth opened to receive a 3-mm outside-diameter flexible vinyl tube. A reference point on the tube aided in its insertion into the stomach. Filtered sea water was introduced into the stomach and esophagus by hand-pumping a rubber ear-wash bulb connected to the tube. Items flushed from the turtle were caught in a 500 micron-mesh sieve. There were no detectable adverse effects from the procedure. Lavage samples were washed with seawater into glass vials and stored on ice for later examination.

Biomass Approximation for Debris Samples, Lavage Samples, and Gut Contents

After weighing, large samples (such as most of the debris samples) were first reduced in size by randomly dividing them and discarding portions selected by coin toss. Samples were cut until they fit easily onto a 8.4 cm^2 grid (6x6) of filter paper. After samples were drained on the filter paper, a clear acrylic plate with a 6x6 grid etched into it, was placed over the sample on the filter paper. One centimeter posts supporting the acrylic plate kept the plate from crushing the sample.

The sample was then placed on the stage of a binocular dissecting microscope with a 10x10 square graticule in one eyepiece. The sample was surveyed by matching the outer margin of the graticule grid to each of the 36 squares of the etched acrylic plate overlying the sample. Descriptions of items to the lowest possible taxon were made for four graticule intercept-points at each of the 36 overlying grid squares. In smaller samples (such as in all of the lavage and gut samples) the entire contents of the sample was surveyed and all graticule intercept points were examined.

Turtles Captured and Samples Collected

A total of 293 posthatchling loggerheads were observed. Of these, 241 were captured. Sixty-five of the captured loggerheads have associated debris samples and gastric/esophageal samples. Forty-nine loggerheads were observed but not captured and three were found dead and were collected.

Gas chromatograms were generated at the petroleum chemistry laboratory, University of South Florida, for 20 tar samples from 19 loggerheads. Most of these samples came from jaw scrapings. Analysis is pending on the age, origin, and refinement of the samples. Determinations of tar in other lavage and jaw samples were made by observations of solubility in dichloromethane.

No green turtle posthatchlings were observed. In the 1997 season approximately one in 66 hatchlings leaving East Florida nesting beaches was a green turtle (FDEP/FMRI Index Nesting Beach Survey unpublished data). That no green turtles were observed in 293 observations of posthatchling turtles may reveal something of the disparate distributions of these two species.

Necropsies were performed and gut contents were sampled for the three posthatchling loggerheads found dead in debris lines in addition to one green turtle and six loggerhead posthatchlings that washed onto East-central Florida beaches. Analyses are pending.

STUDY PERIOD AND DELIVERABLES

The study period for the project is October 1996 through March 1998. Analysis will be complete by February 1998 and a final project report to NMFS will be completed by March 1998. Manuscripts describing the findings of this study will be submitted to peer reviewed journals and reprints of ensuing publications will be forwarded to NMFS.

LITERATURE CITED

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Appendix S. Acoustic sampling to identify red drum, spotted seatrout, and black drum spawning locations in South Carolina and Georgia.

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Over the past few years, we have used underwater microphones to investigate spawning activities of the spotted seatrout (*Cynoscion nebulosus*), the red drum (*Sciaenops ocellatus*) and the black drum (*Pogonias cromis*). All of these species are members of the family Sciaenidae (the drums); these species in particular have been found to make species-specific sounds positively correlated with active spawning aggregations.

Since these species have seasonally distinct spawning seasons, our yearly efforts have begun as early as late March (black drum spawning occurs throughout April), and continued through late September (spotted seatrout spawn from May through August; red drum from August through September). Of special interest is the fact that even though spotted seatrout and black drum spawn in many locations distinct from those of red drum, all three species are found to utilize the few documented areas where red drum spawn (see chronology below). Our only plans for 1998 are to further investigate red drum spawning activity in Port Royal Sound. If red drum are found in this area, we will have confirmed only three locations in the coastal regions of South Carolina; all along the southern part of our coast.

We believe that red drum must spawn in more than the three locations found within the confines of our estuaries and coastal inlets, especially since no spawning locations have been identified north of the Charleston Harbor entrance. We believe that spawning activity must be occurring in offshore waters (possibly in the nearshore shoals near Cape Romain) but presently do not have the resources to effectively investigate such a phenomenon.

Listed below is a brief history of our fish sound detection.

Chronologically:
South Carolina waters:

1990 -surveyed for red drum and found only spotted seatrout aggregations (verified by capturing spawning females in noisy fish group) in Charleston Harbor and all coastal inlets to and including Bulls Narrows at the north end of Bulls Island. 1991 surveyed Charleston Harbor and found Black Drum sounds in the harbor entrance during the spring, spotted seatrout noises in many discrete spots within the estuary (including the harbor entrance), and one incidence of red drum spawning, once again in the harbor entrance.

1992 - surveyed for black drum in Harbor area, paid little attention to spotted seatrout, focused on red drum near Ft. Sumter. All three of these species were found in spawning aggregations in the Charleston Harbor entrance.

1993 -conducted extensive surveys throughout the local region, beginning in the Charleston Harbor entrance for each, and ending well away from the ocean up major rivers and along the Intercoastal Waterway north of Charleston. Found incidence of all three species: - Black drum restricted to lower estuary in deep holes - Spotted seatrout all over, in every system investigated - Red drum ONLY in the one spot at the entrance to Charleston Harbor. No effort was made to venture past the end of the Charleston Harbor jetties.

1994 - delays in remote hydrophone construction, plus design problems, caused little extended remote sampling, primarily in preplanned areas offshore of inlets and near artificial reefs.

We have made efforts to survey inlets along the SC coast from Winyah Bay to Calibogue Sound. During the time of day during which we knew red drum activity was occurring in the Charleston Harbor entrance, we listened in:

Winyah Bay
Santee River mouth
Cape Romain
Capers Inlet
Dewees Inlet
Breach Inlet
Charleston Harbor Inlet
Stono Inlet
North Edisto Inlet
South Edisto Inlet
St. Helena Sound and inlet Port Royal Sound Inlet
Calibogue Sound Inlet

The only places in which red drum activity was detected, other than the Charleston Harbor entrance, was inside St. Helena Sound in about 35 - 50 feet of water. The inlet area of St. Helena produced no red drum noise.

1996, 1997 Efforts to expand into the lower part of South Carolina to investigate red and black drum spawning sound production was spotty. An additional potential red/black drum spawning location requiring future investigation is in the Port Royal Sound immediately north of Hilton Head Island. Black drum were found in this spot, but technical difficulties precluded the establishment of red drum utilizing this location.

Georgia waters:

1995, 1996, 1997 - Drs. Louiz and Susan Barbieri of the Sapelo Marine Institute investigated red drum spawning locations in Georgia coastal waters. Their only positive identification of red drum spawning activity was in Cumberland Inlet near the Florida state border. Additional information from the Georgia research is pending.