Chapter 6: HMS FISH HABITAT PROVISIONS

October 20, 1998

6.1 Introduction

This chapter identifies and describes habitats, including essential fish habitat (EFH) for highly migratory species (HMS) covered by this FMP on behalf of the Secretary of Commerce in accordance with the Magnuson-Stevens Act. It considers threats to EFH from fishing activities and potential threats to EFH from non-fishing activities. It identifies options for the conservation and enhancement of EFH that should be considered in the planning of projects that might adversely affect HMS EFH. These measures are representative of the conservation and enhancement measures that may be recommended by NMFS during consultation with Federal action agencies, as required by section 305(b) of the Magnuson-Stevens Act, on projects that may potentially impact HMS EFH, although specific conservation measures will be developed on a case-by-case basis. NMFS authority includes the direct management of activities associated with fishing for marine, estuarine and anadromous resources; NMFS' role in Federal interagency consultations with regard to non-fishing threats is advisory. This document assumes no new authority or regulatory role for NMFS in the control of non-fishing activities beyond the statutory requirements to recommend measures to conserve living marine resources, including their habitats.

Section 303(a)(7) of the Magnuson Stevens Act, 16 U.S.C. §§ 1801 *et seq*., as amended by the Sustainable Fisheries Act in 1996, requires that FMPs describe and identify EFH, 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.

The Magnuson-Stevens Act provides the following definition: **"Essential fish habitat means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity."** (16 U.S.C. § 1801 (10)) The EFH interim final rule [62 FR 66551] (EFH regulations), provides additional interpretation of the definition of essential fish habitat: "***Waters* include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; *substrate* includes sediment, hard bottom, structures underlying the waters, and associated biological communities; *necessary* means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."**

This chapter contains all of the required provisions as specified in the EFH regulations covering all managed species (all life stages) under this FMP for which information is available. An initial review of available literature and information was undertaken to assess habitat use and ecological roles of the species in the HMS fishery management unit. Published and unpublished scientific reports, fishery independent and fishery dependent data, and expert and anecdotal information were synthesized, after appropriate evaluation, for inclusion in this chapter, detailing the habitat use by the managed species (section 6.3). Habitats that satisfy the criteria from the Magnuson-Stevens Act and EFH regulations have been identified and described as EFH; some additional habitats that have been identified as necessary for a sustainable fishery, but that lie outside the U.S. EEZ and therefore cannot be identified as EFH under the Magnuson-Stevens Act (e.g., the Gulf of Guinea off the African coast) have been highlighted as particularly important habitats to the HMS, as suggested in the EFH regulations.

Impacts of HMS and non-HMS fishing gear and practices were analyzed by examining published literature and anecdotal evidence of potential impacts or comparable impacts from other fisheries (section 6.4). Based on this initial assessment, the fishing methods of the HMS fisheries probably have limited impact on HMS EFH. There is the possibility that other (non-HMS) fisheries may adversely impact HMS EFH. This should be more closely examined and addressed through coordination with other fishery management authorities. No true management measures and therefore no regulations are proposed in this chapter, although the evaluation of fishing impacts to EFH does provide additional support for the implementation of time-area closures as a precautionary measure to maintain the biological characteristics of HMS (swordfish) EFH . At this time there is no evidence that HMS fishing practices are causing adverse impacts, although conservation recommendations are included to mediate the possible effects of fishing practices listed in section 6.4.

Information presented under the Habitat Provisions is consistent with the goals of habitat conservation. The chapter further proposes the following guidance for future NMFS actions regarding management of HMS fishery resources:

> Recognizing that all species are dependent on the quantity and quality of their essential habitats, it is the goal of the Highly Migratory Species Management Division to:
>
> > Conserve, restore and improve habitats upon which commercial and recreational marine fisheries depend, to increase their extent and to improve their productive capacity for the benefit of present and future generations.
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> This policy is supported by two general objectives:
>
> > a. Maintain the current quantity and productive capacity of habitats supporting important commercial and recreational fisheries, through development of better understanding of the dynamics of habitat that influence biological productivity, and the pursuit of a hierarchical policy of avoidance, minimization and compensatory mitigation for actions that cause adverse effects to essential fish habitats.
> >
> > b. Restore, rehabilitate or enhance the productive capacity of habitats which have already been degraded to increased fishery productivity for the benefit of the resource and the Nation.

6.1.1 List of Preparers

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6.1.2 List of Reviewers Consulted

The following reviewers were asked to provide independent reviews of the species information for accuracy, clarity and completeness:

Tunas and Swordfish:	E.D. Houde D.P. de Sylva B. B. Collette HMS Advisory Panel
Sharks:	Grant Gilmore Robert Hueter Jack Musick HMS Advisory Panel
National Marine Fisheries Service:	Northeast Fisheries Science Center - H.L. Pratt,Jr., Narragansett Southeast Fisheries Science Center - J. K. Carlson, Panama City

6.2 Habitat Types and Distributions

The highly migratory species (HMS) included in this FMP - tunas, swordfish, and sharks - traverse large expanses of the world's oceans, straddling jurisdictional boundaries. Although many of the species frequent other oceans of the world, the management jurisdiction covered by this FMP covers Federal waters seaward of state or territorial waters, including the U.S. Caribbean, the Gulf of Mexico and the Atlantic coast of the United States to the seaward limit of the U.S. Exclusive Economic Zone (EEZ). These areas are connected by currents and water patterns that influence the occurrence of the managed species at particular times of the year. On the largest scale, the North and South Equatorial currents bathe the U.S. Caribbean islands. The North Equatorial Current continues through the Caribbean Basin to enter the Gulf of Mexico through the Yucatan Straits. The current continues through the Florida Straits to join the other water masses (including the Antilles Current) to form the Gulf Stream along the eastern coast of the U.S. Variations in flow capacities of the Florida Straits and the Yucatan Straits produce the Loop Current, the major hydrographic feature of the Gulf of Mexico. These water movements in large part influence the distributions of the pelagic life stages of HMS.

Analysis of the distributions of HMS species led to the identification of various habitats, essential to the species. Tuna and swordfish distributions are most frequently associated with hydrographic features such as density fronts between different water masses. The scales of these features vary. For example, the river plume of the Mississippi River extends for miles into the Gulf of Mexico and is a fairly predictable feature, depending on the season. Fronts that set up over the De Soto Canyon in the Gulf of Mexico, or over the Charleston Bump or the Baltimore Canyon in the mid-Atlantic, may be of a much smaller scale. The locations of many fronts or frontal features are statistically consistent within broad geographic boundaries. These locations are influenced by riverine inputs, movement of water masses, and the presence of topographic structures underlying the water column, thereby influencing the habitat of HMS.

In determining EFH for HMS, consideration has been given to habitat associations for all life stages. Although they typically range throughout open ocean waters, HMS also move inshore, including to coastal estuaries, at some time during their life cycles. For example, Atlantic sharks are broadly distributed as adults but have been found to utilize specific estuaries and shallow coastal areas during pupping. Typically, the pups (neonates) remain in these same estuaries throughout their early life stages, which may vary from a few to many months. Many of these estuaries and shallow coastal areas used for pupping have been characterized only in general terms (e.g., salinity, temperature and/or season). Associations with particular bottom types are undefined, and this lack of information has been identified as an important research need (Section 6.5).

Because of the seasonal use of these habitats, in addition to open ocean habitats, inshore areas and estuaries are described in terms of distribution, size, depth, freshwater inflows and habitat types (e.g., bottom types) available. As additional information is accumulated, this section will be expanded to more fully characterize the links between the managed species and specific habitat characteristics. The following sections describe the distribution of the habitats that are utilized by these species, including those that are considered to be EFH. They include descriptions of the features of the continental shelf/slope and the dominant current patterns in-so-far as they may influence the existence and persistence of hydrographic fronts. Much of the information originally appeared in previous documents and references and sources appear there (Appeldoorn and Meyers, 1993; MMS, 1992; 1996, NOAA, 1991; 1992; 1996; 1997a; 1997b; and 1997c).

6.2.1 Atlantic

For management of the HMS, the Atlantic region of U.S. Federal jurisdiction spans the area between the Canadian border in the north and the Dry Tortugas in the south. It includes a diverse spectrum of aquatic species of commercial, recreational, and ecological importance. The distribution of marine species along the Atlantic seaboard is strongly affected by the cold Labrador Current in the northern part, the warm Gulf Stream in the middle and southern portions of the region, and the combination of high summer and low winter temperatures.

For many species, Cape Hatteras forms a strong zoogeographic boundary between the mid- and south Atlantic areas. The Cape Cod/Nantucket Island area is a somewhat weaker zoogeographic boundary in the north. Considering the region as a whole, it is clear that there are four fairly distinct biological regimes:

1. **Arcadian/Scotian Province** - from the Canadian border (jurisdictionally) to just south of Cape Cod (north Atlantic);

2. **Virginian Transition Province** - from Cape Cod to Cape Hatteras;

3. **Carolinian Province** - Cape Hatteras to just south of Cape Canaveral; and

4. **Floridian/Caribbean Province** - just north of Miami to the Dry Tortugas.

For the purposes of this chapter, we will divide the Atlantic region into three zones - North Atlantic, Mid-Atlantic and South Atlantic - for general descriptions of habitats, combining regimes 3 and 4 above; however, species distributions and ecological roles are influenced by the larger scale environments (province). The boundaries between these zones are fluid and do not limit either the movement of the HMS or the water masses that flow through the region. All of these provinces have resident and migratory species that make up the complex fish assemblages. The mid-Atlantic area from Cape Cod to Cape Hatteras represents a transition zone between northern cold-temperate waters of the north and the warm-temperate waters to the south. Water temperatures in the mid-Atlantic vary greatly by season. Consequently, many of the fish species, including HMS, of importance in the mid-Atlantic area are seasonal migrants, whereas the major species in the other three areas are typically resident (MMS, 1992; 1996).

Continental Shelf/Slope Features: (Material in this section is largely a summary of information in MMS, 1992; 1996. Sources of original information are referenced in those documents)

North Atlantic Shelf Features: The circulation patterns of the Gulf of Maine and Georges Bank dominate the oceanographic regime of the northeastern Atlantic shelf. The Gulf of Maine is a deep indentation in the continental shelf with irregular bottom topography. Its bottom consists of three major basins and many smaller ones separated by numerous ridges and ledges. It is a semi-enclosed sea with Nova Scotia as its northern and eastern boundary and the northeastern U.S. coast as its western boundary. Georges and Browns Banks significantly separate the Gulf of Maine from the Atlantic Ocean.

Georges Bank is a large, relatively shallow topographic high that lies southeast of the Gulf of Maine. The bank's seaward edge comprises part of the shelf break in the north Atlantic. Georges Bank is consistently one of the most productive habitats for plankton in the world. The tidal and oceanographic current regimes in the area and Georges Bank's proximity to deep slope water allow upwelling events to occur that transport nutrient rich deep water to the shallow, euphotic areas of the bank. This provides increased primary productivity that benefits higher trophic level fish and shellfish species. On the seaward side, Georges Bank is incised by numerous submarine canyons. The outcroppings and hardened sediments of the canyons provide increased attachment substrate for deeper-water epifaunal organisms (animals attached to the substrate) and allow complex faunal communities to form.

From the Scotian Shelf in the north, past Georges Bank and through the Mid-Atlantic Bight, a shelf-slope front exists. This hydrographic boundary separates the fresher, colder, and more homogeneous waters of the shelf and the horizontally stratified, warmer, and more saline waters of the continental slope. The shelf-slope front may act as a barrier to shelf-slope transfer of water mass and momentum.

From Nova Scotia to Cape Hatteras, 26 large valleys which head (originate) on the shelf cut into the seafloor downward across the continental slope and rise. The current regimes in these submarine canyons promote significant biological productivity and diversity. Tidal oscillations on the shelf combined with the intermittent influence of Gulf Stream warm core rings on the slope dominate currents and influence sediment transport in the canyons. The canyon topography directs the mean shelf current below 100 m (328 ft) into the canyon rather than along the shelf break. Peak currents occur near the canyon heads and flow down the canyon while currents at intermediate depths flow up the canyon. These patterns suggest a circulation that may trap sediments in the canyon heads and produce conditions conducive to front development. HMS are known to aggregate in the areas where these fronts form, most likely as productive feeding grounds.

On the north and mid-Atlantic continental slope and rise the epifauna is controlled by a combination of depth and topography (canyon versus slope gradient). Whereas on the south Atlantic slope and rise, the epifauna appears to be controlled by a more complex oceanographic system dominated by a current regime which includes the Gulf Stream and Western Boundary Undercurrent and by a greater diversity of substrate.

Mid-Atlantic Shelf Features: The mid-Atlantic region is between the colder, arctically influenced environments to the north and the warm, sub-tropical systems to the south. This area reflects a transition zone between the glacial till, rocky shores and steep gradients of the New England states and the wide, gently sloping geology of the coastal plains of the southeastern U.S. The mid-Atlantic is a highly diverse, often seasonally-utilized zone for many aquatic and terrestrial species. A major biogeographic boundary for marine organisms on the continental shelf occurs at Cape Hatteras where the Gulf Stream turns eastward, separating the temperate and tropical provinces. A sharp faunal break is less obvious on the slope, although this area does appear to be a region of rapid faunal change.

The mid-Atlantic shelf is relatively flat, but there is a ridge-and-swale (hill-and-valley) topography that may be a result of present oceanographic conditions or remnant barrier beaches. The shelf typically is composed of a thin surface layer of poorly-sorted shell and medium-to-coarse grained sand that overlays clay sediments. In general, the surface sediments grade from medium-grained sands inshore to finer sediments at the shelf break. Coarse-grained sediments generally support large quantities of animals, including many sessile forms. Fine-grained sediments usually contain a depauperate fauna, and attached organisms are uncommon. Within the Mid-Atlantic Bight, the quantity of fauna decreases markedly from north to south and from shallow to deep water.

Offshore of the eastern U.S, the six major submarine canyons - Block, Hudson, Wilmington, Baltimore, Washington, and Norfolk Canyons - occur within 150 km of shore. They begin in waters of little more than 100 to 200 m (325-650 ft) and descend to 2,000 m (6500 ft). Numerous smaller submarine canyons, V-shaped valleys that resemble land canyons of fluvial origin, cut into the continental slope along the Atlantic coast. Canyons become less rugged and numerous to the south with the last significant one, Norfolk Canyon, occurring off Chesapeake Bay.

Canyon topography tends to be rugged and diverse, with numerous outcrops providing a greater amount of substrate for faunal attachment than is typically found along the rest of the continental margin. Submarine canyons also appear to act like terrestrial watersheds, concentrating water, sediments, and dissolved and particulate nutrients which flow off the shelf. This characteristic can tend to increase the zone of influence of estuarine and coastal activities into shallow or deep shelf waters, potentially affecting the quality of HMS EFH. The heterogeneity of canyon environments results in communities that are generally richer biologically than those on the adjacent shelf and slope. Additionally, the species assemblages inhabiting the head, axis, and lower walls of large submarine canyons are frequently different from those found on the continental slope. Canyon assemblages are often dominated by large populations of sessile filter feeders, but slope assemblages usually consist of sparse mobile carnivore/scavenger populations.

South Atlantic Shelf: The south Atlantic continental shelf area can be divided into five types of habitat: coastal, open shelf, live-bottom, shelf-edge, and upper continental slope. Each of these types has its own distinctive characteristics and species assemblages.

The coastal habitat has a smooth sandy-mud bottom and is usually shallower than 20 m (66 ft). The open shelf habitat is found between about 20 and 55 meters (66 and 180 ft) and has a smooth sandy substrate. This habitat predominates between the occasional live-bottom areas on the outer shelf. Typically, these are areas of relatively low productivity.

Live-bottom habitats, although sporadically distributed, are areas of high productivity and are usually found in water depths of approximately 20 to 55 m (66 to 180 ft). In shallower water, live-bottom areas are usually dynamic because water currents can transport the surface sand layer and cover existing communities or expose new hard bottoms for colonization. The deeper water live-bottom areas tend to be more stable. Thus the complexity and average vertical relief of these live-bottom areas typically increase seaward. The exposed hard substrate in these areas has allowed colonization by many attached species, such as soft corals, and provides three dimensional space for many species, some of which are prey for HMS. These live-bottom areas provide habitat for the warm water snapper-grouper assemblage of fishes. In addition to these live-bottom communities, extensive banks of coral occur on the Blake Plateau at depths between 650 and 850 m (~2,100-2,800 ft). Along the shelf-edge, water depths average between 40 and 100 m (130-325 ft). The bottom topography varies from smooth mud to areas of high relief with associated corals and sponges. The lower-shelf habitat has smooth mud bottoms in water depths between 100 and 200 m (~330 and 660 ft).

The shelf-edge habitat may range in water depth between 40 and 100 m (131 and 328 ft). The bottom topography varies from smooth sand to mud to areas of high relief with associated corals and sponges. The fish species found in this area include parrotfish (Scaridae) and the deepwater species of the snapper-grouper assemblage. Many juveniles of certain species of fish are found in *Sargassum* overlying this habitat, but the fate of these juveniles is unknown. The last category in the south Atlantic, the upper continental slope habitat, has smooth mud bottoms in water depths of 100 to 200 m (328 to 656 ft). Many of the species in this zone are representatives of cold water northern species exhibiting tropical submergence (i.e., being located in deeper, cooler water as latitude decreases).

This pattern, hard and soft bottom habitats interspersed, also occurs in the southern part of the Atlantic shelf (Miami to the Dry Tortugas). The Florida shelf is a limestone platform which is exposed in some areas and covered with quartz and carbonate sands in others. Off-shore hard bottom habitats usually consist of rock covered by a thin, mobile, sand veneer. These areas are usually colonized by a diverse biota of tropical and temperate species, including macroalgae, stony corals, soft corals, sponges, and bivalves. Overall, about 30 percent of the southwest Florida shelf consists of live bottom areas. In addition, this area contains most of the true coral reefs, and their associated fauna, found in North America. The coral reef areas are highly diverse habitats with complex three-dimensional space and relatively high biological productivity.

A topographic irregularity southeast of Charleston, South Carolina, known as the Charleston Bump, is an area of productive sea floor which rises abruptly from 700 m (2,300 ft) to 300 m (980 ft) within a distance of about 20 km, and at an angle which is approximately transverse to both the general isobath pattern and the Gulf Stream currents. The Charleston Gyre is a persistent oceanographic feature that forms in the lee of the Charleston Bump. It is a location from which larval swordfish have been commonly found and may serve as nursery habitat.

Deepwater banks occur 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 in the western south Atlantic region, especially within Bahamian national waters, and have been reported in the Straits of Florida off Little Bahama Bank. Although most of them are outside U.S. waters, some do occur near the outer edge of the EEZ. The banks are composed of lithified sandy carbonate sediments supporting a regionally diverse array of benthic fauna, with ahermatypic branching corals as the chief contributors to structure and habitats.

Physical Oceanography (Water Movements and Marine Habitats): (Material in this section is largely a summary of information found in MMS, 1992; 1996. Sources of original information are referenced in those documents.)

The shelf area of the Mid-Atlantic Bight averages about 100 km (~60 mi) in width, reaching a maximum of 150 km (~90 mi) near Georges Bank and a minimum of 50 km (~30 mi) offshore of Cape Hatteras. The mean current flow is along-shelf and to the southwest, interspersed with localized areas where outflow from major estuaries (i.e., Connecticut River, Lower New York Bay, Delaware Bay, and Chesapeake Bay) interrupts the flow field. Current speeds are strongest at the narrowest part of the shelf where wind-driven current variability is highest. The slope area is influenced by the presence of the western Slope Sea Gyre, which is present 85 percent of the time with a relatively strong net southeastward flow along the New Jersey coast.

In the high northern latitudes, North Atlantic Deep Water (NADW) flows southward out of the Norwegian Sea and into the Labrador Sea forming the Deep Western Boundary Current (DWBC) (also known as the Western Boundary Undercurrent). After taking a counterclockwise course through the Labrador Sea, the DWBC flows around the Grand Banks of Newfoundland and then follows the topography of the U.S. Atlantic slope. It passes under the Gulf Stream near Cape Hatteras and continues into the South Atlantic. Meanders of the DWBC core account for variations in velocity and volume transport according to measurements in the Blake Plateau region.

The continental shelf in the South Atlantic Bight varies in width from 50 km (32 mi) off Cape Canaveral, Florida to a maximum of 120 km (75 mi) off Savannah, Georgia and a minimum of 30 km (19 mi) off Cape Hatteras. The shelf is divided into three cross-shelf zones. Waters on the inner shelf (0 to 20 m [0 to 66 ft]) interact extensively with rivers, coastal sounds, and estuaries. This interaction tends to form a band of low-salinity, stratified water near the coast that responds quickly to local wind-forcing and seasonal atmospheric changes. Mid-shelf (20 to 40 m [66 to 132 ft]) current flow is strongly influenced by local wind events with frequencies of 2 days to 2 weeks. In this region, vertically well mixed conditions in fall and winter contrast with vertically stratified conditions in the spring and summer. Gulf Stream frontal disturbances (e.g., meanders and cyclonic cold core rings) that occur on time scales of 2 days to 2 weeks dominate currents on the outer shelf (40 to 60 m [132 to 197 ft]).

The Gulf Stream produces periodic meanders, filaments, and warm and cold core rings that significantly affect the physical oceanography of the continental shelf and slope. This western boundary current has its origins in the tropical Atlantic Ocean (i.e., the Caribbean Sea). The Gulf Stream system is made up of the Yucatan Current that enters the Gulf of Mexico through the Yucatan Straits; the Loop Current which is the Yucatan Current after it separates from Campeche Bank and penetrates the Gulf of Mexico in a clockwise flowing loop; the Florida Current, as it travels through the Straits of Florida and along the continental slope into the South Atlantic Bight; and the Antilles Current as it follows the continental slope (Bahamian Bank) northeast to Cape Hatteras. From Cape Hatteras it leaves the slope environment and flows into the deeper waters of the Atlantic Ocean.

The flow of the Gulf Stream as it leaves the Straits of Florida is jet-like with maximum speeds at the surface that are usually about 200 cm/s. During strong events, maximum current speeds greater than 250 cm/s have been recorded offshore of Cape Hatteras. The width of the Gulf Stream at the ocean surface ranges from 80 to 100 km (50 to 63 mi) and extends to depths of between 800 and 1,200 m (2,624-3,937 ft).

Meandering events of the Gulf Stream are caused by atmospheric forcing or bathymetric features (e.g., the Charleston Bump). Meanders are lateral oscillations of the mean current stream (flow field) produced by migrating waves. They may affect the location of the Gulf Stream's western boundary and have amplitudes (east-west displacement) of up to 25 km (15.5 mi) off the coast of Florida and Georgia. However, north of the Charleston Bump, the amplitude may increase to about 100 km (63 mi). Meanders occur periodically in the 2- to 15-day range.

As a meander passes, the Gulf Stream boundary oscillates sequentially onshore (crest) and offshore (trough). A meander can cause the Gulf Stream to shift slightly shoreward or well offshore into deeper waters. The Gulf Stream behaves in two distinct meander modes (small and large), with the size of the meanders decreasing as they move northward along the coast. During the large meander mode, the Gulf Stream front is seaward of the shelf break, with its meanders having large amplitudes. Additionally, frontal eddies and accompanying warm-water filaments are larger and closer to shore. During the small meander mode, the Gulf Stream front is at the shelf break. Frontal eddies and warm-water filaments associated with small amplitude meanders are smaller and farther from shore. Since HMS tend to follow the edge of the Gulf Stream, their distance from shore can be greatly influenced by the patterns of meanders and eddies.

Meanders have definite circulation patterns and conditions superimposed on the statistical mean (average) condition. As a meander trough migrates in the direction of the Gulf Stream's flow, it upwells cool nutrient-rich water, which at times may move onto the shelf and may evolve into an eddy. These boundary features move south-southwest. As warm-water filaments, they transfer momentum, mass, heat, and nutrients to the waters of the shelf break.

Gulf Stream filaments are mesoscale events which occur regularly offshore the southeastern United States. The filament is a tongue of water extending from the Gulf Stream pointing to the south. They form when meanders cause the extrusion of a warm-surface filament of Gulf Stream water onto the outer shelf. The cul-de-sac formed by this extrusion contains a cold core that consists of a mix of outer-shelf water and nutrient-rich water. This water mix is a result of upwelling as the filament/meander passes along the slope. The period from genesis to decay typically is about 2 to 3 weeks.

The Charleston Gyre is a permanent oceanographic feature of the South Atlantic Bight, caused by the interaction of the Gulf Stream waters with the topographically irregular Charleston Bump. The gyre produces an upwelling of nutrients, which contributes significantly to primary and secondary productivity of the Bight, and is thus important to some ichthyoplankton, including swordfish larvae (Govoni *et al.*, in prep). The degree of upwelling varies with seasonal position and velocity of the Gulf Stream currents.

In the warm waters between the western edge of the Florida Current/Gulf Stream and 20° N and 40° N latitude, pelagic brown algae, *Sargassum natans* and *S. fluitans*, form a dynamic structural habitat. 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 U.S. 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 irregular mats or simply be scattered in small clumps. Oceanographic features such as 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, sea turtles, numerous marine birds, at least 145 species of invertebrates, and over 100 species of fishes. The fishes associated with pelagic *Sargassum* include juveniles as well as adults, including large pelagic adult fishes. Swordfish are among the fishes that can be found associated with *Sargassum*. The

Sargassum community, consisting of the floating *Sargassum* (associated with other algae, sessile and free-moving invertebrates, and finfish) is important to some epipelagic predators such as wahoo and dolphin. The *Sargassum* community provides food and shelter from predation for juvenile and adult fish, and may have other functions such as habitat for fish eggs and larvae.

Offshore water quality in the Atlantic is controlled by oceanic circulation. Oceanic circulation is dominated by the Gulf Stream and by oceanic gyres in the mid-Atlantic. A shoreward, tidal and wind-driven circulation dominates as the major cause of pollutant transport between estuaries and the nearshore. Water quality in nearshore water masses adjacent to estuarine plumes and in water masses within estuaries is also influenced by density-driven circulation. Suspended sediment concentration can be used as an indication of water quality. For the Atlantic coastal areas, suspended sediment concentration varies with respect to depth and distance from shore. The variability is greatest in the mid-Atlantic and south Atlantic. Resuspended bottom sediment is the principal source of suspended sediments in offshore waters.

Coastal and Estuarine Habitats: (Material in this section is largely a summary of information found in NOAA, 1991; 1996; 1997a; and 1997b. Sources of original information are referenced in those documents.)

Although HMS move primarily through open ocean waters, they do periodically utilize inshore habitats. This is especially true for several species of sharks that move inshore, often into shallow coastal waters and estuaries, to give birth; these areas then become nursery areas as the young develop. Coastal habitats that may be encountered by HMS are described in this section. Those areas that are known nursery or spawning grounds, or areas of HMS aggregation for feeding or other reasons, are considered to be EFH for those species. It should be noted that characteristics of coastal and offshore habitats may be affected by activities and conditions occurring outside of those areas (farther up-current) due to water flow or current patterns that may transport materials that could cause negative impacts.

Coastal Environments: A great diversity of shoreline types is found along the Atlantic coast. Pocket beaches (small sheltered areas between rocky headlands) are the dominant shoreline type in Massachusetts, Rhode Island, Connecticut, and along Long Island Sound. Much of the ocean frontage along Cape Cod and from Long Island to southern Florida consists of sandy beach-dune and/or barrier beach areas. At the southern tip of Florida and along the Florida Keys, swamps and mangroves are the dominant shoreline features. Mudflats exist along the shores of many of the bays and sounds, the most extensive found along the shores of Delaware and Chesapeake Bays and along the coast of Georgia. In addition, there are localized sections of dense shoreline development.

Beaches are particularly important for providing protection from storms, high tides, and wave action for the lagoons, sounds, wetlands, and low ground located landward of them. Natural dune areas found landward of sandy beaches often support seabirds, shorebirds, waterfowl, and a dune grass or shrub community. The ecologically fragile dune grass or shrub communities are important for maintaining beach and dune stability and are particularly intolerant of pollution or beach development. Mudflats, swamps, and mangroves occur in areas of low wave energy. These areas tend to act as sediment sinks, trapping nutrients that support a variety of plants, fish, birds, and mammals; they also trap and sequester pollutants.

The coastline of the mid-Atlantic states is typified by elongated barrier spit-barrier island complexes which separate the Atlantic Ocean from shallow, and usually narrow, lagoonal bays. The exceptions to this rule are the mouths of large drowned-river valley type estuaries (e.g., Chesapeake Bay, Delaware Bay and the Hudson-Raritan Estuary) and the unique back barrier lagoons of the Albermarle-Pamlico Sound system. Where large river valley estuarine embayments are absent, the mainland is generally protected from the wave-dominated coastal ocean by coastal barriers, which are commonly wide enough to support extensive development and thriving seasonal resorts. The Eastern Shore of Virginia is the lone exception. In this area, a nearshore meso-tidal hydrodynamic regime keeps the barrier islands from elongating, effectively disconnecting them from the mainland and isolating them from development pressures.

The coastal ocean is a shallow, nutrient-rich, and productive environment. Longshore currents advect sediments and nutrients parallel to the typically north-south running shoreline and are a primary cause of the elongate barrier islands and narrow inlets common in this region. The numerous inlets and other passageways for exchange between the estuarine and oceanic waters provide an important conduit between systems for a diverse suite of living marine resources, many of which spend significant portions of their lives in either medium, or require a specific habitat type for growth and development during a specific life stage. The opportunity for movement between two very different systems contributes greatly to the biological productivity and, thus, the commercial importance of the mid-Atlantic coast.

Sediments in the coastal zone are often coarse-grained compared with estuarine and outer continental shelf sediments. Wave action nearshore tends to segregate size fractions within the coastal zone such that a seaward fining of particles occurs from the beach face to the offshore areas. Deviation from this pattern often occurs at the mouths of major river valley estuaries where the outflow plume often deposits fine grained silts and clays in the nearshore zone. Typical sediments are a mixture of quartz particles and those of biogenic origin (i.e. shell fragments) until finer grains are encountered offshore.

The coastal zone is generally a high energy environment. As offshore swells and waves "feel" the bottom, they crest and break at the beach face. Storm energy is often concentrated in this zone as waves generated far offshore finally release their large amounts of latent power. This energy is often converted to strong currents which can carry large sediment loads and can erode shorelines and destroy man-made structures rapidly. Without hard structure for attachment, as is common in the mid-Atlantic, many sessile organisms cannot live in this environment. However, a number of attached animals find suitable substrate on man-made objects such as pilings and revetments, and many benthic filter-feeding organisms thrive in the rapid transfer of nutrients.

Estuaries and Coastal Wetlands: The Gulf of Maine, a deep cold water basin, is nearly sealed off from the open Atlantic by Georges and Browns Banks, which fall off sharply into the continental shelf. Vineyard and Nantucket Sounds and Cape Cod are other major features of this region. The mid-Atlantic area is fairly uniform physically and is influenced by many large coastal rivers and estuarine areas, including Chesapeake Bay, the nation's largest estuary, Narragansett Bay, Long Island Sound, the Hudson River, Delaware Bay, and the nearly continuous band of estuaries behind the barrier beaches from southern Long Island to Virginia. The southern edge of the region includes the estuarine complex of Currituck, Albemarle, and Pamlico Sounds, a 2,500 square mile system of large interconnecting sounds behind the Outer banks of North Carolina.

The south Atlantic is characterized by three long crescent shaped embayments, roughly separated by four prominent points of land: Cape Hatteras, Cape Lookout, and Cape Fear in North Carolina; and Cape Romain in South Carolina. Low barrier islands occur along the coast south of Cape Hatteras, with concomitant sounds that are only a mile or two wide. These barriers become a series of large, irregularly shaped islands along the coast of Georgia and South Carolina, separated from the mainland by one of the largest coastal salt-marsh areas in the world. Similarly, a series of islands borders the Atlantic coast of Florida. These barriers are separated in the north by broad estuaries and in the south by narrow, shallow lagoons.

Estuaries are highly productive, yet fragile, environments that support a great diversity of fish and wildlife species. Many commercially valuable fish and shellfish stocks are dependent on these areas during some stage of their development. In the vicinity of North Carolina, Virginia, and Maryland, approximately 90 percent of the commercially valuable fish species are dependent on the estuaries for at least some part of their life cycle. Waterfowl, shorebirds, wading birds, and raptors use coastal wetlands for breeding, feeding, migrating, and wintering. A variety of reptilian, amphibian, and mammalian species are also common residents of coastal wetlands.

Estuaries contain a number of important habitats which thrive in the mixture of salt and fresh water, and provide a number of functions for aquatic and terrestrial organisms. Coastal wetlands such as salt marshes, tidal freshwater marshes and forested and non-forested non-tidal wetlands are common in mid-Atlantic estuaries. Submerged aquatic vegetation (SAV) is a diverse group of rooted vascular plants that range from saline (true seagrasses) to fresh water. Their distributions are indicative of water quality, as they require a delicate balance of sediments, nutrients, and light to survive. Tidal flats, which are exposed to the air during low tides, are nondescript habitats that often are important in nutrient cycling and to seabirds as forage grounds.

Along the Atlantic seaboard coastal wetlands are located predominantly south of New York because these coastal areas have not been glaciated. Nearly 75 percent of the Atlantic coast salt marshes are found in the states of North Carolina, South Carolina, and Georgia. These three states contain approximately 9 million acres of salt marsh.

Wetland vegetation provides stability to coastal habitats by preventing the erosion of sediments and by absorbing the energy of storms. The dominant salt marsh vegetation along much of the Atlantic coast includes the cordgrasses *(Spartina* sp.), salt grass (*Distichlis spicata*), needle rushes (*Juncus roemerianus*) and other salt tolerant species. Because of the unique adaptations necessary for plants to survive in salt water environments, species diversity is much lower than in freshwater environments.

There is a total of 13,900 mi^2 of estuarine habitat along the Atlantic coast. Approximately 68 percent (9,400 mi^2) of this habitat occurs north of the Virginia/North Carolina border, with Chesapeake Bay contributing significantly to the total. The dominant SAVs in these estuaries are eelgrass *(Zostera marina)* and widgeongrass *(Ruppia maritima).* South of the Gulf of Maine, where there is a wider coastal plain and greater agriculture activity, estuaries carry higher sediment and nutrient loads. The increased fertility and generally higher water temperatures resulting from these nutrient loads allow these estuaries to support greater numbers of fish and other aquatic organisms.

South of the Virginia/North Carolina border, there are approximately 4,500 mi^2 of estuarine habitat. The Currituck, Albemarle, and Pamlico Sounds, which together constitute the largest estuarine system along the entire Atlantic coast, make up a large portion of these southern estuaries. A unique feature of these sounds is that they are partially enclosed and protected by a chain of fringing islands, Outer Banks, located 32 to 48 km from the mainland. Dominant SAVs in most of the southern estuaries are eelgrass, widgeongrass, and shoalgrass (*Halodule wrightii*).

Estuaries are more susceptible to pollution from land than other coastal water bodies. This susceptibility of an estuary to water quality problems varies depending on the extent of tidal flushing. An indication of the potential efficiency of tidal flushing is tidal range. With the exception of estuaries along the coasts of North Carolina and south Florida, most estuaries along the Atlantic coast are mesotidal, having tidal ranges from 2 to 4m. Estuaries along the coasts of North Carolina and southern Florida are classified as microtidal, having tidal ranges less than 2m. Since microtidal estuaries exhibit poor tidal flushing capacity, North Carolina and south Florida estuaries are more susceptible to water pollution than other estuaries along the Atlantic coast.

In Maryland and Virginia, the primary problems reported are excessive nutrients (nitrates and phosphates), particularly in the Chesapeake Bay and adjoining estuarine areas (State of Maryland, 1990; Commonwealth of Virginia, 1990). Other problems included elevated bacterial and suspended sediment levels. Non-point sources were described as the main causes of pollution. Elevated bacterial levels were also listed as a local coastal pollution problem in Maryland.

In North Carolina, the primary problems listed for estuarine areas were enrichment in organics and nutrients, fecal coliform bacteria, and low dissolved oxygen (DO). Insufficient sewage treatment and agricultural runoff are indicated as major causes of these pollution problems. Oil spills from vessel collisions and groundings, as well as illegal dumping of waste oil are a common cause of local, short-term water quality problems especially in estuaries along the north and mid-Atlantic coasts.

North Atlantic Estuaries: The high energy coast of the North Atlantic region is characterized by a rocky shoreline with numerous islands and small embayments. The region can be divided into two physiographic subregions, the Northern Gulf of Maine and the Southern Gulf of Maine. As HMS (e.g., bluefin tuna) are seasonally common in inshore areas within the Southern Gulf of Maine region, the estuaries that occur there are described in this section.

Southern Gulf of Maine Estuaries: In the Southern Gulf of Maine, the dominant coastal features include Cape Cod, Massachusetts Bay, and Cape Ann. The coastline consists mainly of high-energy sand, cobble or gravel beaches and rocky shores. Estuarine surface water in this region covers approximately 961 square miles, with freshwater inflow to the area dominated by discharge from the Merrimack River and several smaller river systems. Following are descriptions of the major estuaries occurring in the Southern Gulf of Maine region. The sources of these descriptions are NOAA, 1991 and NOAA,1997a.

Great Bay: The Great Bay estuarine system consists of Great Bay, Little Bay, the Piscataqua River and several smaller streams and rivers. The upper section of the estuary is shallow, while the lower region can reach depths up to 80 ft; the average depth for the estuary is 11.4 ft. Great Bay is generally a well mixed estuary, although moderate stratification can occur during periods of high flow. The tidal range near Portsmouth is 9 ft. Turbidity occurs periodically with tides, and episodically with winds at any time of the year. Chlorophyll *a* concentration, an indication of primary productivity, ranges from low to high. Nuisance algal blooms in the mixing and seawater zones occur mainly from July through September, and have been known to affect biological resources. However, nitrogen and phosphorus concentrations are considered to be moderate. Although there are no reported observations of anoxia (oxygen depletion), hypoxia (extremely low oxygen conditions) has been reported in a small subarea of the mixing zone in July and August. Pelagic and benthic communities in Great Bay are considered to be diverse, with SAV coverage ranging from low to high densities, increasing in abundance in the mixing and seawater zones. In addition, the system includes approximately 2,700 acres of salt marsh.

Merrimack River: The Merrimack River, which is the major freshwater inflow to the region, is a shallow salt-wedge estuary (average depth 11.8 ft) where salinities tend to be moderately to highly stratified throughout the year. The tidal range is 8.2 ft near the mouth of the estuary. Spatial coverage for SAV is considered to be medium in the mixing zone; however it has dramatically decreased in abundance since 1970. Approximately 2,300 acres of salt marsh are found within the estuary's drainage area.

Massachusetts Bay: Massachusetts Bay, a large coastal bay with smaller coastal embayments, has a circulation that is strongly influenced by tides and nontidal surface currents. The average depth of the estuary is approximately 89.5 ft; the tidal range is approximately 9 ft near Beverly Harbor. Salinities within the main bay are similar to those of the Gulf of Maine. Chlorophyll *a* concentrations are moderate, and nitrogen and phosphorus concentrations are considered to be within medium ranges throughout the year. However, nuisance and toxic algal blooms occur, the latter having an impact on biological resources. Occurrences of anoxia or hypoxia have not been noted. The planktonic and benthic communities are considered to be diverse, except in urban areas where the benthic community is dominated by annelids. SAV has been on the decline, a situation that has been attributed to increased point sources and physical alterations to the watershed.

Boston Harbor: This estuarine system consists of Boston Harbor and several smaller coastal embayments. The average depth of the estuary is 25.8 ft. Within the main harbor, salinity is similar to that found in the Gulf of Maine, and is vertically homogeneous throughout the bay. Freshwater inflow is dominated by the Neponset River. Turbidity is considered to be medium, with highest levels occurring periodically between late spring and late summer. Circulation in the bay is strongly affected by tidal influences and non-tidal surface currents. The tidal range is approximately 9 ft near the mouth of Boston Harbor. Chlorophyll *a* concentrations are medium, with highs occurring periodically in summer. Nitrogen and phosphorus concentrations are considered to be moderate. Although nuisance and toxic algal blooms occur within the bay, they are not believed to be a problem to biological resources. While anoxic conditions have not been found, bottom hypoxia has been observed in the bay, in the Inner Harbor area, periodically from July through September, resulting in extensive biological stress within the area. Water column stratification is believed to be a contributing factor to the hypoxic conditions. The planktonic community in the bay is diverse; the benthic community is dominated by crustaceans in Boston Harbor and annelids in Boston Inner Harbor. SAV has been on the decrease in the Boston Harbor seawater zone, this being attributed to epiphytes and disease.

Cape Cod Bay: Cape Cod Bay, the largest in the region, consists of a large coastal bay that is partially enclosed by Cape Cod, a ridge on the Coastal Plain consisting of glacial deposits, and four smaller bays and harbors. The average depth of the estuary is 77.1 ft. Circulation in the bay is strongly influenced by tides and non-tidal surface currents; tidal range is approximately 9 ft near Wellfleet harbor. Turbidity concentrations are considered to be low, while chlorophyll *a* concentrations range from medium to high. While nitrogen concentrations range from medium to high, due to point sources, phosphorus is considered to be moderate. In the spring, nuisance algal blooms occur that do not appear to impact biological resources. However, toxic blooms that occur episodically in June do have an effect on biological resources. Although there are no observations of anoxia, hypoxia occurs in bottom waters periodically from July through September, causing biological stress conditions. Bottom dissolved oxygen in the embayments has decreased since 1970. Although the benthic community of the bay consists mainly of annelids near Plymouth, elsewhere it is diverse. There has been a decrease in SAV that is believed to be attributed to increases in non-point sources. Approximately 10,600 acres of salt marsh are known to occur within the Bay's drainage area.

***Mid-Atlantic Estuaries*:** The estuarine systems in the Mid-Atlantic region from southern New England to the Virginia/North Carolina border include more than 7,790 square miles of surface water area. The shoreline along this region is irregular, with wide sandy beaches and extensive coastal and barrier island formations. The estuaries within this region can be divided into four major physiographic subregions: Southern New England Coast, New York Bight, Delmarva Shore/Delaware Bay, and the Chesapeake Bay. The sources of the information presented in this section are NOAA, 1991; 1997b.

Southern New England Coast Estuaries: This region extends from Cape Cod to Montauk Point, Long Island, and includes Long Island Sound. Within this area there are five major estuarine systems that encompass approximately 1,895 square miles of water surface area. The major coastal features include Buzzards Bay, Gardiners Bay and Long Island Sound, estuaries that are generally open to the Atlantic Ocean and subject to significant tidal mixing, resulting in high salinities . Freshwater inflow is dominated by groundwater, and, to a lesser extent, discharge from the Connecticut, Housatonic, and Blackstone rivers.

Buzzards Bay: Buzzards bay is a glacial outwash dominated system consisting of the main bay and smaller coastal embayments, with the Elizabeth Islands breaching the main bay from Vinyard Sound to the south. Average depth of the estuary is 33.8 ft, and the tidal range is approximately four (4) ft throughout the bay. Freshwater inflow from surficial sources is minimal, with groundwater seepage the major source of freshwater input to the bay. Salinity structure in the main bay is vertically homogeneous, and is essentially the same as seawater for the majority of the year. Chlorophyll *a* concentrations are generally moderate to high, showing maximum concentrations periodically in late spring to summer in the seawater zone. Nitrogen and phosphorus concentrations are considered to be moderate, although nitrogen is believed to have increased since 1970. Nuisance and toxic algal blooms do not appear to threaten biological resources. Maximum turbidity throughout the year occurs in the embayment subareas. Although anoxia has not been observed, episodic occurrences of hypoxia in the seawater embayments have been observed in bottom waters during the summer. The planktonic community is considered to be diverse, and the embayment benthic community dominated by mollusks. SAV has decreased due to changes in point sources. Salt marshes within the drainage area total about 4,100 acres.

Narragansett Bay: This estuarine system consists of Narragansett Bay and several smaller embayments. The average depth of the estuary is 30.2 ft. The tidal range is 3 ft at the mouth of the bay to approximately 5 ft near Warwick, RI. Circulation in the bay is affected largely by tidal mixing and wind currents, and the major freshwater inflow is from the Blackstone and Taunton rivers. Salinity structure in the bay is fairly homogeneous. Chlorophyll *a* concentrations are moderate to high, with maximum concentrations occurring in late spring to summer, light being the limiting factor in the tidal fresh and mixing zones, and nitrogen in the seawater zone. Nitrogen and phosphorus concentrations are high in the tidal fresh zone, and moderate to high in the mixing and seawater zones, with elevated nutrient conditions occurring from November to January. Nuisance algal blooms occur in all salinity zones periodically during the summer and have an impact on biological resources. Except in the seawater zone, where anoxia is not observed, periodic anoxia and hypoxia occur in bottom waters throughout the estuary from June to September, with water column stratification playing a moderate role in the development of these conditions. However, due to changes in point discharges, duration, frequency, and spatial coverages all have been on the decline. The planktonic community in the tidal fresh and seawater zones is dominated by diatoms, while in the mixing zone it is dominated by flagellates. The benthic community is a diverse mixture of organisms in the tidal fresh zone, and is dominated by annelids in the mixing and seawater zones. SAV disappeared in the tidal fresh and mixing zones between 1938 and 1951. Salt marsh within the estuary covers approximately 3,800 acres.

Gardiners Bay: This system consists of Gardiners Bay and several smaller embayments. The average depth of the estuary is 20.2 ft; the tidal range is 2 ft near the entrance to Block Island Sound. Freshwater input is supplied primarily be groundwater sources, with minimal inflow contributed by the Peconic River. The salinity structure is essentially vertically homogenous with tidal mixing and wind being the significant forcing mechanisms. Both turbidity and chlorophyll *a* concentrations are high in the mixing zone and moderate to high in the seawater zone. Maximum chlorophyll *a* occurs episodically in the summer, with light being the limiting factor in the mixing zone and nitrogen in the seawater zone. Nitrogen and phosphorus concentrations are considered to be moderate. Episodic nuisance and toxic algal blooms occur in spring, summer and fall, in both the mixing and seawater zones where they have impacted biological resources. There are no observations of anoxia or hypoxia. The planktonic community is considered to be diverse; SAV coverage has increased in recent years due to recovery from the effects of brown tides. The drainage area of the bay contains approximately 3,300 acres of salt marsh.

Long Island Sound: Long Island Sound is an expansive glacial outwash dominated estuarine system. The average depth of the estuary is 62.2 ft. The major freshwater input is from the Connecticut, Housatonic and Thames rivers. Turbidity is moderate to high. The tidal range is approximately 4.2 ft in the southern sound to nearly six ft in the northern sound. In the western sound, a stratified salinity structure is influenced by the East River, while in the eastern sound the salinities are higher and the variability less distinct. Chlorophyll *a* concentrations in the sound are high in the tidal fresh water and mixing zones, and there is a gradient of medium to hyper-eutrophic concentrations from the eastern to western seawater zone. Maximum Chlorophyll *a* occurs periodically in late spring/summer in the tidal fresh zone and in early spring/summer in the seawater zones. For the tidal fresh and mixing zones, the limiting factor is nitrogen, while in the seawater zone it is nitrogen, silica and light. Overall nitrogen and phosphorus are reported to be moderate to high. In all zones, nuisance algal blooms impact biological resources; toxic blooms affect resources in the seawater zone. Periodic bottom water hypoxia events occur from June to September in the mixing and seawater zones, and anoxia has been observed in the seawater zone. Duration, frequency, and spatial extent of these events have been on the increase due to changes in point and non-point sources, and an increased occurrence of stratification. The planktonic community is dominated primarily by diatoms and flagellates, and the benthic community by annelids. Decreases in SAV are attributed to point and non-point sources and disease. However, there are approximately 16,100 acres of salt marsh within the drainage basin of the Sound.

Connecticut River: This estuary is a riverine subsystem to Long Island Sound, displaying a salt wedge salinity structure near the mouth. It is the major source of freshwater inflow to the middle and eastern sound, tending to cause lower spring salinities in that region due to the high freshwater discharge during spring runoff. Moderate stratification occurs during mean river stages. The average depth of the estuary is 12.5 ft, and the tidal range approximately 3 ft near the mouth. Concentrations of chlorophyll *a* are high, with maxima occurring during the late summer; turbidity is considered to be moderate. Nitrogen concentrations are moderate, while phosphorus is low. Nuisance algal blooms occur in the tidal fresh zone during the summer and are reported to impact biological resources. Episodic hypoxic events occur in the tidal fresh zone, the duration and spatial coverage of these events being on the decline due to changes in point sources. Annelids dominate the benthic community in the mixing zone; salt marshes cover approximately 3,100 acres.

New York Bight Estuaries: The New York Bight subregion contains four major estuarine systems along the Long Island and New Jersey coastline, encompassing a total water surface area of 640 square miles. This region is dominated by wide sandy beach complexes and extensive barrier islands. Extensive salt marshes are also predominant throughout the area. Freshwater inflow sources include the Hudson River and smaller coastal-plain derived rivers, as well as groundwater. The Hudson River is hydrographically distinct because of its dominant riverine influence.

Great South Bay: Great South Bay is a narrow, bar-built estuary containing a series of interconnected embayments and inlets with the freshwater inflow dominated by groundwater sources and small coastal streams. The average depth if the estuary is 8.9 ft and the tidal range approximately 2.5 ft near the inlets. Salinity structure is vertically homogeneous throughout the estuary. Chlorophyll *a* concentrations are moderate, while turbidity is considered to be high, maximums occurring periodically in early summer. Nitrogen and phosphorus concentrations are moderate throughout the year, but nuisance algal blooms occur during the summer, and are reported to have an impact on biological resources. From July to September, periodic anoxic and hypoxic conditions occur throughout the water column in the mixing zone. Both the planktonic and benthic communities are diverse. SAV coverage is low, having decreased due to brown tides. However, salt marshes within the drainage basin cover approximately 18,300 acres.

Hudson River/Raritan Bay: This estuarine system consists of a series of interconnected bays, rivers and tidal straits, with Raritan and Sandy Hook bays the two main bay systems. Responses of these areas to specific estuarine circulation forces are complex, and significant mixing occurs from the East River south to the lower bay area. Both saltwater intrusion and freshwater discharge from the Hudson River greatly reduce residence time within the estuary, where the average depth 20.8 ft. The tidal range varies considerably throughout the system, but at the mouth of the East River is approximately 4.5 ft. Within the system, chlorophyll *a* concentrations range from moderate to hyper-eutrophic, particularly in Jamaica Bay, with maximum conditions occurring in the summer in all zones and also in the early spring in the mixing and seawater zones. Except for nitrogen in the lower bay, light is the limiting factor in all areas. Elevated nitrogen concentrations occur in March and from July to September in the mixing zone, while elevated phosphorus has been observed in the mixing zone in July and August and in the seawater zone in May, July and August. Nuisance diatom blooms, which are reported to affect biological resources, and highest turbidity occur in early spring and summer in the mixing and seawater zones. Anoxic events occur from June to August throughout the water column in Jamaica Bay, and hypoxic events from June to August in bottom waters of the seawater zone and throughout the water column in the mixing zone. Water column stratification is a significant factor in these developments. However, although increases in these events have been observed in the seawater zone due to point sources, decreases are occurring in the mixing zone. The planktonic community is dominated by diatoms in the tidal fresh zone, but is more diverse in the mixing and seawater zones. The benthic community is dominated by mollusks in the tidal fresh zone, annelids in the mixing zone, and annelids and crustaceans in the seawater zone. SAV disappeared in the 1930's due to disease, and eutrophic conditions have prevented its re-establishment.

Barnegat Bay: Barnegat Bay is a fairly shallow -- the average depth of the estuary is 4.6 ft -- bar-built estuary containing a series of interconnected embayments and inlets. Freshwater inflow is dominated by small coastal plain derived sources such as the Toms and Metedeconk rivers. Currents within the bay are driven mostly by winds, with significant circulation occurring near dredged channels. However, the salinity structure tends to be vertically homogeneous throughout the estuary. The mean tidal range is 3.1 ft near Barnegat Inlet, but within the main bay area is dampened considerably. Chlorophyll *a* within the bay is considered to be high, with maximums occurring periodically in late winter and late summer, nitrogen being the limiting factor. High turbidity events, which are wind driven, occur episodically during the summer. While phosphorus concentrations are generally low, nitrogen is reported to be moderate, with elevated concentrations evident from December to February. Biological resources are impacted by nuisance algal blooms that occur periodically during the summer. No occurrences of hypoxia or anoxia have been reported. Both the planktonic and benthic communities are considered to be diverse. SAV coverage is moderate, and there are approximately 41,600 acres of salt marshes within the estuary drainage area.

New Jersey Inland Bays: This system consists of a narrow, bar-built estuary containing a series of interconnected embayments, small sounds and inlets. Freshwater inflow to the system is dominated by small coastal plain derived streams such as the Mullica and Harbor rivers. The salinity structure tends to be vertically homogeneous throughout the estuary, with significant circulation occurring near dredged channels. The average depth of the estuary is 6.2 ft and the tidal range is approximately 3.7 ft near the Little Egg Inlet and 4.1 ft near Wildwood, New Jersey. Chlorophyll *a* concentrations are high, maximums occurring in late summer with nitrogen the limiting factor. Observed trends are associated with changes in point and non-point sources and alterations to the basin. Turbidity concentrations are considered to be high, with the highest occurring periodically during the early summer. Nitrogen is moderate, while phosphorus is considered to be low. Nuisance algal blooms that are reported to affect biological resources occur episodically during the summer in the seawater zone. There are no reported events of hypoxia or anoxia. In the seawater zone, the benthic community is a diverse mixture of organisms, and the planktonic community is dominated by chlorophytes. SAV coverage is unknown in the mixing zone and high in the seawater zone.

> *Delmarva Shore/Delmarva Bay Estuaries*: The coastline of the Delmarva shore contains four major estuarine systems, having a total water surface area of approximately 990 square miles. It is dominated by a series of barrier islands, dune complexes, and wide, sandy beaches. Extensive salt marshes are also found throughout the area. Tides are a dominant influence on water column mixing, primarily near estuarine inlets, while wind plays a major role in the short term salinity structure and circulation. With the exception of Delaware Bay, which is hydrographically distinct due to the dominance of the Delaware River, freshwater inflow is minimal, and a vertically homogeneous salinity pattern persists throughout much of the year.

Delaware Bay: Delaware Bay is a large riverine system with circulation dominated by discharge from the Delaware River. The bay is classified as a partially mixed or moderately stratified estuary. The average depth of the estuary is 20.8 ft. Tides range from approximately 1 ft near the mouth of the bay to approximately 6 ft near the Cohansey River. Salinity is highly variable due to flow changes from the Delaware River and freshwater runoff from coastal plain derived sources, with stratification more pronounced in the spring months. Turbidity levels are moderate to high. Chlorophyll *a* concentrations have been found to be high to hyper-eutrophic, and nitrogen and phosphorus concentrations are moderate to high, with elevated nitrogen occurring from December to February and phosphorus from October to December, associated with point sources. However, although the bay is an extremely nutrient-enriched system, it does not exhibit the classic symptoms of eutrophication that are observed in other estuaries. Nuisance algal blooms in the tidal fresh zone are reported to have an impact on biological resources. Low oxygen levels have historically been a problem in the estuary, and remain a concern. The planktonic community in the tidal fresh zone is considered to be diverse, while in the mixing and seawater zones it is dominated by diatoms. The benthic community is diverse in the tidal fresh and mixing zones, and is dominated by a combination of annelids and crustaceans in the seawater zone. A continuum of tidal marshes borders the shores of the Delaware estuary, ranging from salt marshes to brackish -water marshes further up the estuary, to freshwater tidal marshes in the upper estuary. However, only about four percent of the tidal wetlands have been subject to permanent alteration. Salt marsh coverage within the drainage area is approximately 147,200 acres. There are no published accounts of recent occurrence of SAV. The relatively high natural turbidity in the estuary is presumed to prevent the establishment of these grasses.

Delaware Inland Bays: This is a shallow, back-barrier lagoonal system - average depth of the estuary is 4.2 ft - comprised of Rehoboth and Indian River Bays. Although considered a partially mixed estuary, salinity stratification occurs, especially during the spring months. The tidal range may be as much as 3 ft near the Indian River Inlet; however, wind, shallow depths and tidal forcing combine to produce water column mixing such that the high nutrient and phytoplankton conditions do not usually produce anoxic or hypoxic conditions. Turbidity is considered to be high, with maximum levels occurring in January and in the summer. Elevated nitrogen and phosphorus concentrations occur from March to May for the former, and in July and August for the latter. Chlorophyll *a* concentrations are considered to be high, with maximums occurring periodically in the summer, phosphorus being the limiting factor in the mixing zone, co-limiting with nitrogen in the seawater zone. Nuisance algal blooms occur in the summer, and have been reported to impact biological resources. While the planktonic community is diverse in the mixing zone, it is dominated by diatoms in the seawater zone. The benthic community is dominated by annelids in the mixing zone and crustaceans in the seawater zone. SAV has not been noted in this system, although palustrine and estuarine emergent wetlands can be found.

Maryland Inland bays: This is a shallow lagoonal bay system that includes Ilse of Wight, Assawoman, and Little Assawoman Bays. Circulation is dominated by tidal influences, and, although considered a partially mixed estuary, salinity stratification occurs in the summer months, when freshwater input is minimal. The St. Martin River is the only significant freshwater inflow into system. Tidal range is approximately 3 ft near Ocean City, Maryland. Nitrogen concentrations are reported to be medium to high and phosphorus to be high, with elevated nutrients occurring from June to August, associated with point sources. The estuary has been noted to have hyper-eutrophic conditions - chlorophyll *a* concentrations range from high to hyper-eutrophic - a situation that seems to be improving. Turbidity is high in the summer, and episodically high throughout the rest of the year. However, low dissolved oxygen conditions have not been reported. In the seawater zone, nuisance algal blooms have been reported that have caused impacts on biological resources. The planktonic community is dominated by flagellates, and the benthic community dominated by mollusks in the mixing zone and crustaceans in the seawater zone. SAV is not present in the mixing zone, but can be found in the more saline portions near the Assateague Inlet. Salt marshes are the dominant type of coastal wetland in this ecosystem.

Chincoteague Bay: This bay, which is bounded on the seaward side by Assateague Island, a thin barrier island, is a fairly shallow bar-built estuary containing a series of interconnected embayments, small sounds and inlets. Average depth is 5.9 ft. Within the bay, tidal influence is dampened quickly with distance from Chincoteague Inlet; therefore, winds often drive water level and circulation. Tidal range is approximately 3.6 ft near Chincoteague inlet, and considerably less within Chincoteague Bay. Freshwater input is from several small streams that drain a very small area of the Delmarva Peninsula. Chlorophyll *a*, nitrogen, and phosphorus are all considered to be moderate, while turbidity in the bay is high, maximum concentrations occurring periodically in the summer, associated with point sources. SAV coverage is low, but on the increase. Salt marshes dominate the coastal wetland habitat, totaling 24,900 acres.

Chesapeake Bay: The Chesapeake Bay is the largest estuary in North America and acts as the catchment basin for parts of seven states. As such, it can best be described as a combination of several estuaries, all of which are drowned river valleys. The Chesapeake Bay proper extends from its mouth at Cape Charles and Cape Henry, Virginia, to the head-of-tide of the Susquehanna River in Maryland, and includes the estuarine areas of the James, York, Rappahannock, Potomac, Patuxent, Chester and Choptank Rivers, as well as many other small rivers, and several large embayments. The bay is described as a very complex and diversified ecosystem. Seawater enters the bay mouth and underlies the less dense freshwater flowing out. The seawater becomes diluted as it travels up the bay, yet its influence affects all the living resources within the estuary. In the freshwater-dominated western side of the bay, salinities are generally lower and more stratified than for the eastern side. The Chesapeake is generally very shallow; however, several relict channels from ancestral rivers remain as deep trenches, 60 ft or more, down the mainstem of the bay and the axes of the larger rivers. The Chesapeake exhibits the largest annual range of temperatures of any estuary in the world; in the cold winters, upper portions of the bay may freeze, and in a typical summer, subtropical water temperatures may exist. Extensive (~50,000 acres) and diverse (15 species) seagrasses and other submersed rooted vegetation colonize fertile shallows. These grasses have been declining overall, although there are localized instances of regrowth. Relicts of once plentiful oyster beds still remain within the bay; overharvesting and disease have reduced a once-thriving fishery to essentially a historic remnant. On the shoreline, large and small fringing salt marshes provide habitats and conduits of nutrient exchange between the terrestrial and aquatic habitats. Approximately 27,790 acres of salt marsh line the shores of the Chesapeake Bay, providing numerous functions and values. The Bay is also one of the most highly impacted estuaries in the world, and one of the best studied and modeled. However, it is difficult to generalize about a water body that extends for over 200 hundred linear miles. Therefore, it is more instructive to divide the bay into discrete sections. The descriptions that follow utilize the boundaries set forth by NOAA's Estuarine Eutrophication Survey (NOAA, 1997b).

Chesapeake Bay Mainstem: The Susquehanna River provides the primary source of freshwater to the upper Chesapeake Bay. This large drowned river valley is quite deep in places and has exhibited hypoxia and anoxia in these areas. The main stem of the bay covers 2700 square miles of water, with 2275 billion cubic feet of water filling the generally shallow basin. While the tidal range can be large in places, significant wind events can drive circulation, especially towards the head of the bay. A two-layer density structure is apparent during all seasons of the year, with salinity variability more apparent near the head of the bay. The nutrient load from the estuarine drainage area (24,730 square miles) is significant, and hyper-eutrophic conditions can be locally important. In the tidal fresh zone, elevated concentrations of nutrients occur all year; in the mixing and seawater zones elevated nitrogen occurs in the spring and elevated phosphorus in the summer, these trends associated with point and non-point sources. Chlorophyll *a* concentrations range from moderate to hyper-eutrophic, with maximum levels in the tidal zone occurring in the winter and summer, and in the mixing and seawater zones in the spring, with additional highs in the mixing zone in the summer. Turbidity ranges from low to high, with maximum levels occurring during the spring in the tidal fresh and upper mixing zones, and throughout the year in the lower mixing zone. Low dissolved oxygen conditions occur periodically in bottom waters during the summer, with water column stratification a significant factor. The planktonic community is generally dominated by diatoms in the spring and flagellates in the summer. The benthic community is dominated by annelids. SAV coverage ranges from low to medium, and since 1980 has increased in the mixing and seawater zones.

Chester River: The Chester River estuary is a small tributary that drains 520 square miles of mostly agricultural lands on Maryland's eastern shore. Non-point sources of nutrients from these lands contribute to high total nitrogen and moderate total phosphorous throughout the estuary. Wind conditions commonly drive the circulation in this semi-enclosed basin. Bottom waters seasonally become hypoxic under appropriate conditions. The lack of tidal mixing results in a stratified water column which facilitates anoxic conditions. SAV can be found in low abundance in the mixed salinity areas.

Choptank River: The Choptank River, adjacent Trippe Bay, and several small creeks make up this segment of the Chesapeake Bay. Freshwater inflow from the upland is minimal, yet nutrient input from the lands within the drainage basin (1339 square miles) is significant. Tidal mixing may be overcome by wind events. The nutrient load and low tidal flushing provide a good environment for eutrophication, and, accordingly, phytoplankton concentrations are high. Low dissolved oxygen conditions have been noted in bottom waters in the summer months. SAV maintains comparatively low coverage, but may be on the increase.

Patuxent River: The Patuxent River estuarine drainage area encompasses 932 square miles of moderately developed upland. Both the tidal fresh and mixing portions have shown large chlorophyll *a* concentrations seasonally, and nutrient concentrations remain high although they have been gradually decreasing. SAV typically has exhibited low coverage in both salinity zones, with regrowth noted in the tidal fresh water areas.

Potomac River: Several small rivers discharge into the estuarine portion of the Potomac River. In addition, the Potomac River itself drains parts of four states. The result is a large inflow of fresh water (15,900 cfs from the estuarine drainage alone) into the estuary and a large tidal fresh water zone (75 square miles). The drainage area is highly developed urban, residential and agricultural land, which results in significant non-point source run-off as well as point source pollution. The nutrient load is high for all reaches for nitrogen, and moderate for phosphorous. Eutrophic conditions may form in the summer, and anoxia and hypoxia may occur in deeper waters from May to September. SAV has exhibited rapid regrowth from earlier declines in the upper mixing zone.

Tangier/Pocomoke Sounds: This subsystem incorporates the drainage for the Nanticoke, Wicomico, Manokin and Pocomoke Rivers and the shallow embayments their mouths form with the several low elevation islands that run down the axis of the lower Bay. This estuary drains around 3200 square miles of land, and covers an actual area of 460 square miles. The drainage for this basin is significantly smaller than for those on the western side of the bay; that, coupled with tidal dynamics, maintains a higher salinity regime, on average. Nutrient inputs from the western half of the Delmarva Peninsula (which is highly utilized for agriculture) are significant, but dissolved oxygen conditions do not reach hypoxic levels, probably due to tidal flushing. This area supports significant SAV. SAV is decreasing in the mesohaline areas of this region.

Rappahannock River: A relatively undeveloped estuarine drainage area of 1169 square miles feeds into the Rappahannock River estuary. This drowned river valley system has low freshwater inflow and a small tidal fresh water segment. Nutrient inputs have been classified as moderate, and chlorophyll *a* concentrations are high throughout the estuary in late spring and summer. The lower portions may become stratified in the summer, and anoxic and hypoxic conditions may form in the deeper areas. SAV coverage is very low to low, and has increased moderately in the mixing zone.

York River: The Mattaponi and Pamunkey rivers converge to form the York River in a relatively underdeveloped estuarine drainage basin covering 2654 square miles. The freshwater inflows from these rivers are significant and the tidal regime and basin hydrography are such that large portions of each are tidal fresh water systems with tide ranges nearing 4 feet. Stratification is common in this system, and hypoxia may form in the mixed salinity zone under such conditions. Some SAV beds may be found in the tidal fresh water and mixed salinity zones, and extensive emergent fresh water wetlands are located within each tributary.

James River: The James River provides much of the fresh water input into the lower Chesapeake Bay. Tidal freshwater portions of this major estuary reach up towards the fall line in Richmond, Virginia. This estuary drains a significant portion of southern Virginia (4,447 square miles), which contains a mixture of land-uses from heavy industrial, to agricultural, to forests and forested wetlands. Upper portions of the James may exhibit hyper-eutrophic conditions; all portions exhibit significant nutrient loadings and high chlorophyll *a* concentrations. Dissolved oxygen concentrations do not reach critical biological levels, probably due to the large tidal and freshwater inflow influences. Vertical stratification and bi-directional estuarine currents may develop in the summer months. SAV can be found in the lower James River estuary, although turbidity is typically high in all seasons.

Eastern Shore of Virginia Bays: Water quality information for this small stretch of mesotidal bays along the southeastern tip of the Delmarva is not available; some studies indicate that adjacent land use (primarily agriculture) influences water quality. The barrier islands which provide protection from the open ocean here are very dynamic, migrating with the longshore current, disintegrating and reforming as conditions dictate. This area is suitable for emergent wetlands, salt tolerant seagrasses and oyster beds and is protected from development by virtue of its naturally dynamic nature.

***South Atlantic Estuaries*:** South Atlantic estuaries encompass more than 4,440 square miles of water surface area. The region is characterized by extensive coastal and barrier features, and can be divided into three distinct subregions: Carolina Capes, Sea Island Coast, and the Florida Coast. The sources of the following information are NOAA, 1971; 1996.

Carolina Capes Estuaries: The major coastal features in this region are the extensive shoal structures and the series of barrier islands off North Carolina and South Carolina. Extensive salt marshes also predominate throughout the area. Due to the proximity of the western edge of the Gulf Stream off the Outer Banks, salinities in this area tend to be higher than for other Atlantic estuaries. Otherwise, wind plays a major role in short-term salinity structure and circulation within the estuaries. Near the inlets, tides are a dominant influence on water column mixing.

Albemarle/Pamlico Sounds: The Albermarle and Pamlico Sound system the is largest back-barrier lagoonal system in North America, and is second only to the Chesapeake Bay in surface area, covering 27,686 square miles. The average depth of the estuary is 13.5 ft. The tidal range is 2 ft near the inlets, but is dampened to 0.6 ft within Pamlico Sound. Freshwater inflow into the Albemarle/Pamlico Sounds is dominated by discharge from the Roanoke, Chowan, Neuse-Trent and Tar-Pamlico river systems. This estuary drains 12,781 square miles of land within its basin, and is essentially enclosed, with only three small inlets providing its connection with the coastal ocean to the east. Tidal mixing is significantly reduced with distance from these inlets, and water level and circulation are primarily wind driven. Chlorophyll *a* levels are moderate to hyper-eutrophic, and turbidity levels moderate to high. Nitrogen and phosphorus levels are considered to be moderate to high. Periodic occurrences of nuisance and toxic algae have been recorded seasonally within the estuary. Current trends in water quality are unknown for the most part, although anoxia and hypoxia are reported for limited bottom areas. The planktonic community is dominated by blue-green algae in the Chowan River, and diatoms in Pamlico Sound and the seawater zone. Polychaetes and molluscs dominate the benthic community in the mixing and seawater zones. Fringing wetlands are found along the undeveloped portions of the shoreline, and extensive brackish marshes extend upstream. A total of 157,600 acres of salt marsh are estimated to occur with the drainage basin. SAV can be found within the saline and mixing portions of the estuaries; an unexplained decline in the coverage of SAV has been reported.

Pamlico and Pungo Rivers: The Pamlico and Pungo Rivers comprise 170.6 square miles of water surface area that drain into Pamlico Sound to the east. Tides range from 2 ft near the inlets of the Outer Banks to 1 ft at the mouth of the Pamlico and Pungo Rivers. The estuary has an average depth of 9.4 ft, holding 44.7 billion cubic feet of water. It can be significantly influenced by local wind conditions, which often drive circulation and override astronomical tidal forcing. Periodically high levels of chlorophyll *a* occur in winter and summer, while turbidity levels are considered to be moderate. Nitrogen and phosphorus concentrations are also considered to be moderate, although elevated levels are seen from January to March. Low dissolved oxygen levels have been noted in the deeper portions of the estuary, probably a result of moderate nutrient inputs providing exploitable resources for algal blooms, some of which can be toxic (e.g., *Pfisteria piscicida*). The planktonic community is dominated by flagellates, and the benthic community by annelids and crustaceans. Limited amounts of SAV are reported in the mixing salinity zone, coupled with low amounts of fringing emergent wetlands (~80 acres of 1000 acres total coastal wetlands) allows the planktonic communities to dominate primary production within the estuary.

Neuse River: The Neuse River is one of the many rivers that eventually drain into the Pamlico/Albermarle Sound back barrier lagoonal system. The estuarine portion includes areas of the Trent River to the south. The average depth of the estuary is 11.5 ft; the drainage area is 2,221 square miles. Salinity stratification often occurs near the mouth of the Neuse River, but is more common upstream. Chlorophyll *a* concentrations are considered to be moderate to hyper-eutrophic. In the tidal fresh zone elevated nitrogen and phosphorus are known to occur from February to June, while in the mixing zone they are elevated from January to April and June to August, respectively. Although overall concentrations are considered to be moderate, their combination with a low flow and mixing have contributed to occasional seasonal hypoxic and anoxic conditions from June to October. Also, toxic or nuisance algal blooms have been reported to impact biological resources from early summer to early fall. The planktonic community is diverse; the benthic community is dominated by annelids. SAV coverage is low, and has been identified as generally decreasing in areal coverage. In keeping with the land cover characteristics of coastal North Carolina, most of the wetlands are of the forested non-tidal variety known locally as pocosins.

Bogue Sound: The Bogue Sound system is a typical back-barrier lagoonal system, and is therefore very saline and shallow - the average depth of the estuary is 4.6 ft. A drainage area of 691 square miles feeds into the 12.9 billion cubic feet of the sound system, which receives freshwater inputs from the White Oak, Newport and North Rivers, all of which become vertically stratified in late winter and spring. Within the lagoonal system, however, tidal and wind driven mixing promote a vertically homogeneous salinity regime. The system is considered to have moderate levels of chlorophyll *a*, with maximums occurring in the spring in the mixing zone and in the summer in the seawater zone, nitrogen being the limiting factor in both. Nitrogen is moderate, while phosphorus concentrations are low. Toxic algal events are rare, although nuisance algal blooms occur on occasion. Diatoms are known to dominate the planktonic community; the benthic community is dominated by annelids. In addition, the Bougue estuarine system includes 21,100 acres of salt marshes. There are limited SAV resources within the sound and up into the more mixed salinity reaches.

New River: The New River estuary is classified as a drowned river valley estuary. Three large bays - Morgan, Farnell and Stones - comprise the upper reaches of the estuarine portion of the New River, which drains 470 square miles of land in its drainage basin. The estuary is relatively small (32.8 square miles in surface area, 5.2 billion cubic feet in volume) with a stable salinity structure and nearly vertical mixing in the tidally dominated reaches. The estuary averages 5.8 feet in depth and is deepest in the mixed salinity zones. Tidal influence is generally restricted to the lower estuary where increases in vertical mixing cause relatively stable salinities to persist. Moderate stratification is common in the upper portion of the New River, especially during high inflow conditions. Chlorophyll *a* concentrations are moderate to hyper-eutrophic, and moderate to high levels of turbidity have been found. Both reach maximum levels periodically in the mixing zone in the summer and winter, nitrogen and silica being the limiting factors. Nitrogen and phosphorus are moderate to high at differing times of the year, and both episodic nuisance and toxic algal blooms occur in summer and winter months, causing impacts to biological resources.   Bottom water hypoxia occurs in the mixing zone from June to September, water column stratification playing a role in these conditions. The planktonic community is dominated by a mixture of diatoms and flagellates; the benthic community in the seawater zone is dominated by annelids. Some SAV is present in very limited amounts in the seawater zone, and 4,100 acres of salt marshes have been identified within the estuarine drainage basin.

Cape Fear River: The Cape Fear River estuary averages 11.5 ft in depth over a total surface area of approximately 38.3 square miles. It is a relative small estuary, holding 11.3 billion cubic feet of water, receiving freshwater input from the Cape Fear, Black and Northeast Cape Fear rivers. Although tides, ranging to about 4 ft at the estuary mouth, are the dominant influence on the salinity structure of the estuary, seasonal variability in the riverine inputs also has major effects on the seasonal salinity structure. Nutrient levels within the estuary are reported to be high on average, compared with other estuaries. Chlorophyll *a* concentrations are moderate to high, with maximum concentrations occurring periodically from April to September; the limiting factors being light, phosphorus, and nitrogen, depending on location. High turbidity occurs in winter in all zones, especially with heavy rainfall and dredging activities. No hypoxia or anoxia have been observed. The planktonic community is dominated by a mixture of diatoms and flagellates; the benthic community is dominated by annelids. Very low amounts of SAV are present in all salinity zones. Also, 9,000 acres of salt marsh are estimated to occur within the Cape Fear drainage basin.

Winyah Bay: This estuary, with an average depth of 11.0 ft, receives the majority of its freshwater inflow from the Pee Dee and Little Pee Dee rivers. Seasonal variation in this inflow serves to alter salinities approximately 10 ppt throughout most of the estuary. Moderately stratified conditions are most common within the mixing zone and navigation channels in the spring, shifting northward in the fall. The tidal range is 4.5 ft at North Inlet, where the vertical salinity structure is generally homogeneous. Chlorophyll *a* concen-trations in the bay are moderate to high, maximums occurring periodically from late spring to fall. In the tidal fresh and mixing zones, phosphorus and light are generally the limiting factors for chlorophyll *a*, while in the North Inlet mixing zone and in the seawater zone, nitrogen and light are limiting. Turbidity is high throughout the year. Nitrogen and phosphorus are reported to have moderate to high levels, positive trends generally associated with watershed management practices. Bottom water anoxia and hypoxia periodically occur in the mixing zone of Winyah Bay from May to September, and in the seawater zone of North Inlet in August and September. The planktonic community of the Winyah Bay system is dominated by diatoms, and the benthic community by insects in the tidal fresh zone and annelids in the mixing zone, while the seawater zones are diverse. Salt marsh coverage within the drainage basin is approximately 12,400 acres; the distribution and trends of SAV are generally unknown.

North and South Santee Rivers: This is a drowned river valley system with highly variable freshwater and salinity structures. Although horizontal salinity gradients exist, mainly in the lower estuary, stratification is generally weak. In the lower rivers, salinities vary significantly between successive high and low tides, which range 4.2 ft near the estuary mouth. Nitrogen and phosphorus concentrations are reported to be moderate during the late summer months. No occurrences of nuisance algal blooms have been reported, and anoxia and hypoxia are unknown throughout the estuary. Trends for turbidity, nitrogen and phosphorus are reported as decreasing significantly due to rediversion of water in the estuary. Diatoms dominate the plankton community. Insect dominate the benthic community in the tidal fresh zone; crustaceans dominate in the mixing zone. Salt marsh covers approximately 12,900 acres within the drainage basin; current distribution and trends for SAV are unknown.

Sea Island Coast Estuaries: This coastal region consists of low-lying sea islands bordered by marshes, and relatively gently periodically inundated, sloping marsh islands bound by tidal creeks. Deltaic structures within the Sea Island Coast resemble sediment filled drowned river valleys. Estuarine mixing here is primarily influenced by tidal fluxes, tidal ranges being higher in this region than in any other portion of the South Atlantic - as much as 7.2 ft near Savannah, Georgia. The major source of freshwater inflows in this region are from rivers originating in the coastal plain, and the Appalachian Mountains and the Piedmont.

Charleston Harbor: Charleston Harbor is formed by the confluence of the Cooper, Ashley, and Wando rivers. The average depth of the estuary is 18.3 ft. Tides range approximately 5.2 ft near the harbor mouth, and have a dominant influence on salinity variability in the upper portions of the Ashley and Cooper rivers, the latter having more pronounced vertical stratification than other parts of the estuary. The harbor is characterized as having moderate to high levels of chlorophyll *a*, and high levels of turbidity, maximums for both occurring periodically in the summer in all zones. Biomass is limited by phosphorus and light in the tidal fresh and mixing zones, and by nitrogen and light in the seawater zone. Nitrogen and phosphorus are generally considered to be moderate, except for high concentrations in the Ashley River, and nuisance and toxic algal blooms are not known to have affected biological resources. Anoxia and hypoxia occur periodically during the late spring and summer in the mixing and seawater zones. The planktonic community is dominated by diatoms; the benthic community by insects in the tidal fresh zone, and a mixture of annelids and mollusks in the mixing and seawater zones. Salt marsh coverage within the drainage basin is approximately 26,800 acres; SAV, although on the increase, is reported as low in coverage.

St. Helena Sound: St. Helena Sound is a drowned river valley/bar-built system with numerous tributaries and island formations. Average depth of the estuary is 12.8 ft. The major freshwater source for the system is the South Edisto River. The dominant forcing mechanism affecting salinity structure is the semi-diurnal tides, which exhibit a range of 6.9 ft near the estuary mouth. Within the system, salinity structure varies, being weak and seasonally variable in the lower Combahee and South Edisto rivers, and vertically homogeneous in St. Helena Sound. The Sound is characterized as having low levels of chlorophyll *a* and high turbidity in the seawater zone. Nutrient levels are considered to be moderate, and biological impacts from nuisance and toxic algal blooms are unknown. Periodic occurrences of anoxia in bottom waters and hypoxia throughout the water column are observed in the mixing zone from June to September. The planktonic community is dominated by diatoms and the benthic community by a mixture of annelids and crustaceans. Distribution and trends for SAV are unknown; there are approximately 91,600 acres of salt marsh within the drainage area.

Broad River: This is a drowned river valley system with intricate tidal creeks and marsh islands. The average depth of the estuary is 24.0 ft; tides range an average of 6.9 ft near the estuary mouth. The major freshwater inflow to the system is from the Coosawhatchee River, with little seasonal variability. Chlorophyll *a* levels are considered to be moderate and turbidity low. Nitrogen and phosphorus are moderate to high, elevated nitrogen occurring in the mixing zone in February and again from August to October, and phosphorus elevated in the mixing zone in July, August and November, and in the seawater zone from June to August. Anoxia in bottom waters and hypoxia throughout the water column occur periodically in the mixing and seawater zones from June to September. The planktonic community is dominated by diatoms; the benthic community by a mixture of annelids and crustaceans; distribution and trends for SAV are unknown. Salt marshes within the drainage area cover approximately 88,300 acres.

Savannah River: The Savannah River is part of a drowned river valley system; it is the major source of freshwater inflow. The average depth of the estuary is 15.2 ft. The tidal range is 6.5 ft at the mouth, with tides the dominant forcing mechanism to the overall salinity structure, which is considered to be moderately stratified. Chlorophyll *a* levels within the river are considered to be moderate, maximum concentrations occurring periodically from June to August, with the limiting factors being light in the mixing zone, and silica in the seawater zone. Biological impacts from nuisance and toxic algal blooms are not reported. Turbidity levels are high throughout the year. Nitrogen and phosphorus are reported as moderate to relatively high, elevated concentrations occur primarily from May to August in the tidal fresh and mixing zones. Anoxia occurs periodically from June to August, and hypoxia from May to September, both in bottom waters, due to water column stratification. Fluctuations are associated with non-point source trends. The planktonic community in the Savannah River is diverse, while the benthic community is dominated by crustaceans in the tidal fresh zone and annelids in the mixing zone. The status of SAV in the tidal fresh zone is unknown, however, SAV is not present in the remainder of the estuary. There are approximately 32,200 acres of salt marsh within the drainage area.

Ossabaw Sound: This is a small coastal plain system that receives its freshwater inflow from the Ogeechee and Canoochee rivers. Seasonal variability in rainfall can alter salinity concentrations as much as 10 ppt in most of the estuary. Throughout the sound, which has an average depth of 14.3 ft, the tidal range is approximately 6.9 ft. The sound is characterized as having high to moderate levels of chlorophyll *a*, with maximum concentrations occurring episodically in the mixing zone and periodically in the seawater zone in April and May. Turbidity is considered to be moderate to high, while nitrogen and phosphorus are reported to be low to moderate, with maximum concentrations occurring from May to September. Anoxia and hypoxia do not occur. SAV is not present in the estuary; salt marsh coverage totals 24,500 acres.

St. Catherines/Sapelo Sounds: This is a drowned river valley-barrier island system comprised of small tidal creeks. It receives minimal freshwater from mainland runoff, groundwater, and lateral flow from nearby rivers. The average depth of the estuary is 14.5 ft. Tides range from 6.5 to 9 ft, and are the dominant forcing mechanism for salinity structure, which is generally homogeneous throughout most of the estuary. The system is characterized as having moderate levels of chlorophyll *a*, with maximum concentrations occurring periodically in the summer, light being the limiting factor in the mixing zone and silica in the seawater zone. Turbidity levels are high throughout the year. Nitrogen and phosphorus levels are generally low, although significant increases are known to occur in the mixing zone, associated with non-point sources. No anoxic or hypoxic conditions have been reported. The plankton community is diverse. Although SAV is not known to be present, salt marshes within the drainage basin total approximately 35,200 acres.

Altamaha River: This is a coastal plain system consisting of the Altamaha River and several tidal creeks. The average depth of the estuary is 10.2 ft. Seasonal freshwater inflow in the major forcing mechanism influencing salinity variability. Moderately to highly stratified conditions exist in the central and lower estuary; however, during high inflow vertically homogeneous conditions occur in the river above Onemile Cut. The semi-diurnal tide range averages 6.5 ft near the mouth of the estuary. Chlorophyll *a* levels are considered to be moderate to high, with maximum concentrations occurring episodically in the mixing zone, which represents approximately 80 percent of the estuary, and periodically in the seawater zone in the summer, light being the limiting factor for the former and silica for the latter. Turbidity levels are reported to be high throughout the year. Nitrogen and phosphorus are low in the seawater zone and moderate elsewhere in the estuary; no anoxic or hypoxic conditions have been reported. Both the planktonic and benthic communities are dominated by a diverse mixture of organisms. SAV is not present in the estuary; salt marshes cover approximately 7,900 acres.

St. Andrew/St. Simons Sounds: This is a drowned river valley system surrounded by barrier islands. The majority of the freshwater inflow is from the Satilla River. Salinity is weakly stratified, and, although it is dominated primarily by tidal mixing and the Satilla River, it is also influenced by the Altamaha River to the north. The tide ranges from 6.5 ft at the estuary mouth to 7.8 ft near Hermitage Point. The average depth of the system is 14.3 ft. Chlorophyll *a* for this system is considered to have moderate concentrations, with maximums occurring episodically in the mixing zone and periodically in the seawater zone in the summer, light being the limiting factor in the former, and silica in the latter. No impacts to biological resources due to nuisance or toxic algal blooms have been reported, neither have anoxic nor hypoxic conditions. Nitrogen levels have been reported to be moderate to high, and phosphorus moderate, elevated levels of both occurring in the tidal fresh zone from March to May, and in the mixing zone from May to August. Both the planktonic and benthic communities are considered to be diverse. SAV is not present; however, salt marsh coverage within the drainage basin is approximately 113,400 acres.

St. Marys River/Cumberland Sound: This is a bar-built estuarine system receiving the majority of its freshwater inflow from the St. Marys River. The salinity structure is determined primarily by seasonal pulses from the river, with discharges the highest in the late winter and spring. The salinity structure is vertically homogeneous throughout most of the lower river and within Cumberland Sound, due to tidal mixing. The average depth of the estuary is19.7 ft; tides average 6 ft near the mouth of the river. The system is characterized as having moderate chlorophyll *a* concentrations that reach maximums periodically from June to August, in the mixing zone the limiting factor being light, while in the seawater zone it is silica. No impacts to biological resources from nuisance or toxic algal blooms have been reported. Although nutrients are generally considered to be low, elevated concentrations occur from April to September in the seawater zone. No anoxic or hypoxic conditions have been reported. Both the planktonic and benthic communities are considered to be diverse. SAV is not present.

Florida Coast Estuaries: The shallow lagoonal estuaries of Florida's Atlantic coast are semi-enclosed by extensive barrier island features. Horizontal density gradients can occur in these estuaries as a result of freshwater inflow from drainage canals on the western side, and tidal exchange through inlets on the eastern side.

St. Johns River: St. Johns River is an elongated estuarine system comprised of large lakes along most of the river's main stem. The average depth of the estuary is 12.0 ft. Tidal influences are most pronounced at the mouth of the river, where the tidal range is approximately 4 ft. The vertical salinity structure of the estuary is moderately stratified, this being influenced by tidal action, winds, and precipitation. The estuary is characterized as having high to moderate chlorophyll *a* levels, maximums occurring periodically from April to early fall, with light being the limiting factor in the tidal fresh and mixing zones and residence time in the seawater zone. Turbidity is high to moderate, with highest levels occurring from April to July in the tidal fresh zone and from July to December in the mixing and seawater zones. Nutrient concentrations are relatively moderate, except for high phosphorus levels in the seawater zone. There are periodic occurrences of nuisance algal blooms in June and July, and toxic dinoflagellates occur episodically. No anoxia or hypoxia has been observed. Diatoms dominate the planktonic community; the benthic community is dominated by annelids in the seawater zone and mollusks in the tidal fresh and mixing zones. There have been minor declines in SAV in the tidal fresh and mixing zones. However, there are approximately 16,800 acres of salt marsh within the estuarine drainage basin.

Indian River: This estuary is a narrow, lagoonal system that is influenced by winds, storm events, freshwater runoff, and evaporation. Although saltwater intrusion creates vertical stratification within the estuary, and freshwater runoff influences lateral salinity, wind and storm events are the dominant forces affecting the overall salinity structure of the system. The average depth of the estuary is 6.6 ft; the tidal range is 1ft near Ft. Pierce Inlet. High to hyper-eutrophic chlorophyll *a* levels and high turbidity are found in the estuary. Maximum levels of the former occur from spring to fall, with light the limiting factor in all zones, while highest turbidity is seen all year in the mixing zone, and at various times of the year elsewhere. Nuisance and toxic algal blooms occur periodically from June to August, and result in impacts to biological resources. Elevated nutrient concentrations occur from April to September, as do anoxic and hypoxic conditions in bottom waters, this due to water column stratification. Flagellates are the dominant plankton, and the benthic community is dominated by annelids and crustaceans. SAV is reported to be present in low to moderate amounts, and has been declining due to non-point sources. There are approximately 2,400 acres of salt marsh within the system.

Biscayne Bay: Biscayne Bay is a shallow - the average depth is 7.7 ft - lagoonal estuary that is influenced by flood control structures on canals and tributaries, and upstream intrusion of saltwater, both of these factors affecting salinity patterns. Circulation is tidally driven, with wind also having an influence, this generally maintaining a vertically mixed water column throughout the estuary. The system is characterized as having generally low levels of chlorophyll *a*, with maximums occurring periodically in September and October, light being the limiting factor. Turbidity levels are considered to be low to moderate, reaching highest levels in the northern mixing zone and seawater zones. Although nutrient concentrations are generally low to medium, elevated levels occur from September to January in the mixing and seawater zones. Anoxia and hypoxia, which are rare in the south mixing zone, occur in the north mixing zone from June to

September, primarily in dredged areas and at the water surface in or near canals. High oxygen levels are found in the seawater zones, probably due to the unstratified nature of the water column. Diatoms dominate the planktonic community. The benthic community is dominated by SAV, which is widely distributed and on the slight increase in the northern end of the seawater zone. Also, there are some hard-bottom areas that are dominated by soft corals and sponges. Salt marsh coverage within the drainage basin is approximately 10,400 acres.

6.2.2 Gulf of Mexico

The Gulf of Mexico supports a great diversity of fish resources that are related to variable ecological factors, such as salinity, primary productivity, bottom type, etc. These factors differ widely across the Gulf of Mexico and between inshore and offshore waters. Characteristic fish resources are not randomly distributed; high densities of fish resources are associated with particular habitat types (e.g., east Mississippi Delta area, Florida Big Bend seagrass beds, Florida Middle Grounds, mid-outer shelf, and the De Soto Canyon area). The highest values of surface primary production are found in the upwelling area north of the Yucatan Channel and in the De Soto Canyon region. In terms of general biological productivity, the western Gulf is considered to be more productive in the oceanic region than is the eastern Gulf. Productivity of areas where HMS are known to occur varies between the eastern and western Gulf, depending on the influence of the Loop Current (section 6.2.2.2).

Continental Shelf/Slope Features: (Material in this section is largely a summary of information in MMS, 1992; 1996. Sources of original information are referenced in those documents.)

The Gulf of Mexico is a semi-enclosed, subtropical sea with a surface area of approximately 1.6 million km^2. The main physiographic regions of the Gulf basin are the continental shelf (including the Campeche, Mexican, and U.S. shelves), continental slope and associated canyons, the Yucatan and Florida Straits, and the abyssal plains. The continental shelf width along the U.S. coastline is narrowest, at only 9.9 mi (16 km) wide, off the Mississippi River. Evidence suggests that the river outflow effectively splits the shelf into the Texas-Louisiana western province and the Mississippi-Alabama-Florida eastern province. The continental shelf width varies significantly from about 217 mi (350 km) offshore west Florida, 97 mi (156 km) off Galveston, Texas, decreasing to 55 mi (88 km) off Port Isabel near the Mexican border. The depth of the central abyss ranges to 13,000 ft (4,000 m). The Gulf is unique among mediterranean seas because it has two entrances: the Yucatan Strait and the Straits of Florida. The Gulf's general circulation is dominated by the Loop Current and its associated eddies. The Loop current is caused by differences between the sill depths of the two straits. Coastal and shelf circulation on the other hand is driven by several forcing mechanisms: wind stress, freshwater input, buoyancy and mass fluxes, and transfer of momentum and energy through the seaward boundary.

The physiographic provinces in the Gulf of Mexico -- shelf, slope, rise, and abyssal plain-- reflect the underlying geology. In the Gulf, the continental shelf extends seaward from the shoreline to about the 200-m water depth and is characterized by a gentle slope of less than one degree. The continental slope extends from the shelf edge to the continental rise, usually at about the 6500 ft (2,000 m) water depth. The topography of the slope in the Gulf is uneven and is broken by canyons, troughs, and escarpments. The gradient on the slope is characteristically 1-6 degrees, but may exceed 20 degrees in some places, particularly along escarpments. The continental rise is the apron of sediment accumulated at the base of the slope. The incline is gentle with slopes of less than one degree. The abyssal plain is the basin floor at the base of the continental rise.

Texas/Louisiana Shelf Features: The shelf and shelf edge of the central and western Gulf are characterized by topographic features that are inhabited by hard-bottom benthic communities. The habitats created by the topographic features is important in several respects: they support hard-bottom communities of high biomass, high diversity, and high numbers of plant and animal species; they support, as shelter and/or food, large numbers of recreational and commercially important fishes; and, they are unique to the extent that they are small, isolated areas within vast areas of much lower diversity; they are relatively pristine areas (especially the East and West Flower Garden Banks); and they have an aesthetically attractive intrinsic value. Benthic organisms (primarily corals) that contribute to the relief of these features are mainly limited by temperature and light. Although corals will grow or survive under low light level conditions, they will do best while submerged in clear, nutrient-poor waters. Light penetration in the Gulf is limited by several factors including depth and events of prolonged turbidity. Hard substrate favorable to colonization by coral communities in the northern Gulf is found on outer shelf, high relief features.

Because midshelf banks experience less light penetration and colder temperatures, the biota differs significantly from outer shelf banks. Instead of the high diversity coral reef zone found at the Flower Gardens (outer shelf), the midshelf banks tend to be dominated by zones of minor relief building activity, e.g., Sonnier Bank, Stetson Bank, and Claypile Bank. Claypile Bank, with only 10 m of relief, is considered a low-relief bank and is often enveloped by the nepheloid layer. Thus, the level of biological community development is lowest at Claypile Bank. Two other midshelf banks, 32 Fathom Bank and Coffee Lump, have reliefs less than 10 m and are also considered to be low-relief banks. Geyer Bank, which crests at 37 m (within the depth that the high-diversity coral reef zone would be expected), does not contain a coral reef; only minor reef building has occurred.

The south Texas banks are geologically distinct from the shelf edge banks. Several of the south Texas banks are low-relief banks, have few hard-substrate outcrops, exhibit a reduced biota, and have a thicker sediment cover than the other banks. Sebree Bank is a low-profile feature located in 36.5 m (120 ft) of water. The highest area of the bank is about 31 m (102 ft) deep. The bank appears composed of large boulders mostly veneered by fine sediments. The low relief of the bank and the fine sediments covering the bank indicate that Sebree Bank frequently exists in turbid conditions. The biota of the bank appears sparse due to these conditions. The bank attracts abundant nektonic species that utilize the overlying water column.

Eastern Gulf Shelf Features: Although the Gulf off Florida does not contain any of the topographic features common to the offshore areas off Texas and Louisiana, the Florida offshore waters do contain several offshore habitats of particular note which fall under the general definition of live bottom.

The "pinnacle trend" can be found in the waters south-southwest of Mobile Bay between 67 and 110m (220 and 360 ft). The pinnacles appear to be carbonate reef structures in an intermediate stage between growth and fossilization. These features may have been built during lower stands of sea level and during the rise in sea level following the most recent ice age. The hard structure of the pinnacles provides a surprising amount of surface area for the growth of sessile invertebrates and attracts large numbers of fish. The pinnacles are found at the outer edge of the Mississippi/Alabama shelf between the Mississippi River and the De Soto Canyon. The bases of the pinnacles rise from the sea floor between 50 and 100 m with vertical relief of 20 m. These pinnacles may provide structural habitat for a variety of pelagic fishes and their prey.

The northwest Florida shelf is dominated by sand-bottom assemblages with low-relief, low-diversity communities widely interspersed with carbonate outcroppings. These outcroppings occasionally serve as attractors for hard-bottom biota and large aggregations of small fishes.

Live bottoms are regions of high productivity characterized by a firm substrate with high diversity of epibiota. These communities are scattered across the west Florida shelf in shallow waters with depth zonation apparent, and within restricted regions off Louisiana, Mississippi, and Alabama. The density of the epibiotal communities varies from sparse to 100 percent coverage of the bottom and largely depends on bottom type, current regimes, suspended sediments, habitat availability, and anthropogenic perturbations. Sessile epibiota include seagrasses, algae, sponges, anemones, encrusting bryozoans, and associated communities. For the purposes of this document, live bottoms also include rocky formations with rough, broken, or smooth topography.

The Florida Middle Ground is probably the best known and most biologically developed of the eastern Gulf live bottoms, with extensive inhabitation by hermatypic (reef building) corals and related communities. This area is 160 km (99 mi) west-northwest of Tampa and has been designated as a Habitat Area of Particular Concern (HAPC) by the Gulf of Mexico Fishery Management Council (50 CFR 638). Bottom longlines, traps and pots, and bottom trawls are prohibited within the HAPC. The taking of any coral is prohibited except as authorized by permit from the NMFS.

The Florida Middle Ground represents the northernmost extent of coral reefs and their associated assemblages in the eastern Gulf. The Middle Ground is similar to the

Flower Garden Banks off Texas (typical Caribbean reef communities), although with a reduced number of species present, probably because it is nearer the northern limit of viable existence for these types of coral communities. In the Caribbean, reefs may grow as deep as 80 m (260 ft), while in the Gulf they seem to be limited to a depth of about 40 m (130 ft). The Middle Ground reefs rise essentially from a depth of 35 m (115 ft), and the shallowest portions are about 25 m (80 ft) deep. The Florida Middle Ground supports numerous Caribbean fishes, coral, and other invertebrate species. This is probably due to the intrusion of the Loop Current, short periods of low temperatures, and high biological productivity.

The southwest Florida shelf, in water depths between 10 and 200 m (33-660 ft), has been characterized into several biological assemblages that are associated with particular substrates and depths. Although depth is probably not the decisive factor in determining the distribution of the biotic assemblages, three major biotic depth zones are evident. There appears to be an innershelf zone between 10 and 60 m (33-197 ft) water depths, a transitional zone between 60 and 90 m (197-297 ft), and an outer-shelf zone from 90 to 200 m (297-660 ft). A brief description of each assemblage can be found in the Gulf of Mexico Council's EFH amendment (GMFMC, 1998).

The Florida Keys comprise an important shallow-water, tropical, coral-reef ecosystem that is unique on the continental shelf of North America. The coral reefs of the Keys are vital to the economy of Florida. Commercial and recreational fishing, as well as non-consumptive uses such as boating, scuba diving, snorkeling, and educational and natural history activities are economically important. The Florida reef tract is the only shallow-water tropical coral reef ecosystem found on the continental shelf of North America. The Florida Keys archipelago, extending from Soldier Key to the Dry Tortugas, exhibits a diverse array of hard-grounds, patch reefs, and bank reefs from nearshore to 13 km (8 mi) offshore.

Patch reefs are the principal reef form between Elliott Key and Key Largo, where approximately 5,000 patch reefs are found. Patch reefs typically occur in water depths of about 2 to 9 m (6.6-30 ft). Bank reefs occur 7.4 to 13 km (4.6-8 mi) seaward of the Keys, paralleling the coast. Most occur off Key Largo and from Big Pine Key to Key West where major islands protect the reefs from the detrimental influence of Florida Bay waters. A reef flat is located on the inshore side of bank reefs. The deepest portions of Florida bank reefs are in 37- 40m (121-132 ft) depths and occur as isolated outcrops surrounded by sediments. The Dry Tortugas is composed of islands, shoals, and reefs located about 117 km (73 mi) west of Key West.

Physical Oceanography (Water movements and Marine Habitats): (Material in this section is largely a summary of information in MMS, 1992; 1996 and original sources of information are available in those documents.)

The Gulf receives large amounts of freshwater runoff from the Mississippi River as well as from a host of other drainage systems. This runoff mixes with the surface water of the Gulf, making the nearshore water chemistry quite different from that of the open ocean. Sea surface salinities along the northern Gulf vary seasonally. During months of low freshwater input, salinities near the coastline range between 29 to 32 parts per thousand (ppt). High freshwater input conditions during the spring and summer months result in strong horizontal gradients and inner shelf salinities less than 20 ppt. The mixed layer in the open Gulf, from the surface to a depth of approximately 100 to 150 m (330 - 495 ft), is characterized by salinities between 36.0 and 36.5 ppt.

Sharp discontinuities of temperature and/or salinity at the sea surface, such as the Loop Current front or fronts associated with eddies or river plumes, are dynamic features that may act to concentrate buoyant material such as detritus, plankton, or eggs and larvae. These materials are transported, not by the front's movements or motion across the front, but mainly by lateral movement along the front. In addition to open ocean fronts, a coastal front, which separates turbid, lower salinity water from the open-shelf regime, is probably a permanent feature of the northern Gulf shelf. This front lies about 30 to 50 km offshore. In the Gulf, these fronts are the most commonly utilized habitat of the pelagic billfish species.

The Loop Current is a highly variable current entering the Gulf through the Yucatan Straits and exiting through the Straits of Florida (as a component of the Gulf Stream) after tracing an arc that may intrude as far north as the Mississippi-Alabama shelf. The current has been detected down to about 1000 m below the surface. Below that level there is evidence of a countercurrent. The "location" of the Loop Current is definable only in statistical terms, due to its great variability. Location probabilities during March, the month of greatest apparent intrusion, range from 100 percent in the core location at 25° N latitude, down to small probabilities (10 percent) near midshelf. Analysis has indicated an average northern intrusion to 26.6° N latitude, within a wide envelope.

When the Loop Current extends into or near shelf areas, instabilities, such as eddies, may develop that can push warm water onto the shelf or entrain cold water from the shelf. These eddies consist of warm water rotating in a clockwise fashion. Major Loop Current eddies have diameters on the order of 300 to 400 km (186-249 mi) and may extend to a depth of about 1000 m. Once these eddies are free from the Loop, they travel into the western Gulf along various paths to a region between 25° N to 28° N latitude and 93° W to 96° W longitude. As eddies travel westward, a decrease in size occurs due to mixing with resident waters, and friction with the slope and shelf bottoms. The life of an individual eddy to its eventual assimilation by regional circulation in the western Gulf is about one year. Along the Louisiana/Texas slope, eddies are frequently observed to affect local current patterns hydrographic properties, and possibly the biota of fixed platforms or hard bottoms. Once an eddy is shed, the Loop Current undergoes major dimensional adjustment and reorganization.

Small anticyclonic (clockwise) eddies are also generated by the Loop Current. They have diameters on the order of 100 km (62 mi), and the few data available indicate a shallow vertical extent (ca. 200 m or 660 ft). These smaller eddies have a tendency to move westward along the Louisiana/Texas slope. Also, cyclonic (counterclockwise) eddies associated with the larger-scale eddy process have been observed in the eastern Gulf and the Louisiana/Texas slope. Their origin and role in the overall circulation are presently not well understood. A major eddy seems to be resident in the southwestern Gulf; however, recent evidence points toward a more complex, and less homogeneous structure.

Shelf circulation is complicated because of the large number of forces and their variable seasonality. A northward current driven by prevailing winds and the semipermanent anticyclonic eddy exist offshore of south Texas. A strong east-northeasterly current along the remaining Texas and Louisiana slope has been explained partly by the effects of the semi-permanent anticyclonic eddy and a partner cyclonic eddy. West of Cameron, Louisiana (93° W longitude), current measurements clearly show a strong response of coastal current to the winds, setting up a large-scale anticyclonic gyre. The inshore limb of the gyre is the westward or southwestward (downcoast) component that prevails along much of the coast, except in July-August. Because the coast is concave, the shoreward prevailing wind results in a convergence of coastal currents. A prevailing countercurrent toward the northeast along the shelf edge constitutes the outer limb of the gyre. The convergence at the southwestern end of the gyre migrates seasonally with the direction of the prevailing wind, ranging from a point south of the Rio Grande in the fall to the Cameron area by July. The gyre is normally absent in July but reappears in August/ September when a downcoast wind component develops.

The Mississippi/Alabama shelf circulation pattern is not well understood at present. There appears to be divergent flow near the delta region. Offshore Panama City, Florida, the prevailing flow is eastward, but reversals occur at the time of maximum westward wind components. Offshore Mobile, Alabama, currents are eastward on the average, and flow reversals coincide with eastward winds. Most current reversals occur during summer or during Loop Current intrusion events. The inner shelf general circulation is a two-season event. During winter the water column is homogeneous and surface circulation is mainly alongshore and westward. The cross-shelf component is weaker and directed onshore. During spring-summer conditions, the surface flow is mostly eastward. Under winds with easterly components, the water tends to flow shoreward and accumulate against the shoreline creating a pressure gradient that drives bottom water alongshore in the direction of the winds. However, Loop Current intrusions, when present, will completely dominate the shelf circulation.

The west Florida shelf circulation is dominated by tides, winds, eddy-like perturbations, and the Loop Current. The flow consists of three regimes: the outer shelf, the mid-shelf, and the coastal boundary layer. Also, the Loop Current and eddy-like perturbations are stronger in this region. During Loop Current intrusion events, upwelling of colder, nutrient-rich waters has been observed. In waters less than 30 m (98 ft) the wind-driven flow is mostly alongshore and parallel to the isobaths. A weak mean flow is directed southward in the surface layer. In the coastal boundary layer, longshore currents driven by winds, tides, and density gradients predominate over the cross-shelf component. Common flow ranges from moderate to strong, and the tidal components are moderate. Longshore currents due to winter northerlies, tropical storms, and hurricanes may range much higher, depending on local topography, fetch, and duration. Longshore currents, consisting of tidal, wind-driven, and density-gradient components, predominate over across-shelf components within a narrow band (10-20 km) close to the coast, referred to as the coastal boundary layer.

Sea-surface temperatures in the Gulf range from nearly constant throughout (isothermal) (29-30° C) in August to a sharp horizontal gradient in January, (25° C in the Loop core to 14-15° C along the northern shelves). Surface salinities along the northern Gulf are seasonal. During months of low freshwater input, salinities near the coastline range between 29-32 ppt. High freshwater inputs (spring-summer months) are characterized by strong horizontal salinity gradients and inner shelf values of less than 20 ppt. The vertical distribution of temperature reveals that in January, the thermocline depth is about 30 to 61m (98-200 ft) in the northeastern Gulf and 91 to 107m (298-350 ft) in the northwestern Gulf. In May, the thermocline depth is about 46 m (150 ft) throughout the entire Gulf.

Dissolved oxygen varies seasonally, with a slight lowering during the summer months. Very low oxygen levels (hypoxia) have been found in some areas of open Gulf bottom waters. A zone of hypoxia affecting up to 16,500 square kilometers of bottom waters during mid-summer on the inner continental shelf from the Mississippi River delta to the upper Texas coast has been identified, most likely the result of high summer temperatures combined with freshwater runoff carrying large nutrient loads from the Mississippi River.

Coastal and Estuarine Habitats: (Material in this section is largely a summary of information in MMS, 1996; Field *et al.*, 1991; and NOAA 1997c. Sources of original information are referenced in those documents.)

Beaches and Barrier Islands: Coastal barrier land forms in the Gulf of Mexico consist of islands, spits, and beaches that stretch in an irregular chain from Texas to Florida. These elongated, narrow land forms are composed of sand and other unconsolidated, predominantly coarse sediments that have been transported and deposited by waves, currents, storm surges, and winds.

The barrier islands of the Gulf of Mexico occur in five settings: the continuous barrier chain of the Texas coast, the barriers of the Chenier Plain along the northwest Texas and western Louisiana coasts, the Mississippi River Deltaic Plain barrier islands, the barrier islands of Mississippi Sound, and the barrier chain along the Florida coast.

A nearly continuous barrier shoreline extends along the Texas coast from south Texas to Rollover Pass, Texas. The barrier islands and spits were formed from sediments supplied from three deltaic headlands: the Trinity delta in Jefferson County immediately west of the Sabine River; the Brazos Colorado Rivers delta complex in Brazoria and Matagorda Counties; and the Rio Grande delta in southernmost Cameron County.

The Texas barriers are arranged symmetrically around these erosional deltaic headlands. Erosional and accretionary barriers are about evenly split. Erosional barriers have developed along the deltaic headlands, and tend to be narrow, sparsely vegetated, and have a low profile and numerous washover channels. Accretionary barriers occur on either side of retreating deltaic headlands and tend to be wide, to have prominent vegetated dunes, and contain few, if any, washover channels. Accretionary barriers grade into erosional barriers within interdeltaic embayments.

The Chenier Plain extends from west of the Texas barrier coast into the western part of coastal Louisiana. Here the coast is fronted by sand beaches and coastal mudflats. The source of the mud is the sediment discharge of the Mississippi and Atchafalaya Rivers, which tends to drift westward along with the prevailing winds and associated nearshore currents. Fluid mud extends from the seaward edge of the marsh grasses to a few hundred yards offshore. The mud is an extremely effective wave-energy absorber. Consequently, the mainland shore is rarely exposed to effective wave action except during storms. The sand beaches that occur along the Chenier Plain rest against the mainland marshes. Although the beaches consist of only a thin accumulation of sand and although some parts of the coast are experiencing erosion, some of the Louisiana Chenier beaches are advancing seaward. The Texas Chenier beaches are essentially erosive. Here, thin accumulations of sand, shell, and caliche nodules make up beaches that are migrating landward over tidal marshes. These beaches are narrow and have numerous overwash features and local, poorly developed sand dunes.

The Mississippi Sound barrier islands are relatively young, having formed some 3,000 to 4,000 years ago as a result of shoal bar aggradation; the positions of the islands have not changed significantly since that time. The islands are well vegetated by a southern maritime climax forest of pine and palmetto. The islands generally are stable with high beach ridges and prominent sand dunes. Although overwash channels do not commonly occur, the islands may be overwashed during strong storms. The islands in general are stable, with no trend toward erosion or thinning of the island, but with a trend toward westward migration in response to the predominantly westward-moving longshore currents. An exception to this general rule is Dauphin Island, Alabama, which is essentially a low-profile erosive barrier island, except for a small Pleistocene core at its eastern end. The Mississippi Sound islands are separated from each other by tidal inlets with deep, wide channels. These channels have associated ebb and flood tidal deltas. Shoals are adjacent to all the barriers. The barriers are separated from the mainland by the Mississippi Sound.

Along the panhandle coast of Florida to Cape San Blas, the barrier islands and beaches fringing the coast are characteristically stable features with broad, high-profile beaches backed by dunes that are 3 to 4.5 m high. To the south and east of the Destin area, the beaches tend to become narrower. Washover channels and fans occur locally and are generally the result of tropical storm impacts. Many of the beaches along the coast are backed by a series of beach ridges with each ridge truncating the previous one. These ridges indicate that in the past the coastline experienced alternating periods of erosion and deposition and changes in predominant littoral current directions.

The predominantly east-west trend of the barrier features along the panhandle coast terminates in the Cape San Blas area. Cape San Blas is the most prominent cuspate foreland in the Gulf of Mexico. Barrier islands and spits extend for as much as 50 km on either side of the Cape. The Cape and its associated islands have been accretionary or stable during the past several decades. Beyond Cape San Blas to just north of Tampa Bay, the Florida coast takes on a concave-inward arcuate trend that is generally devoid of barrier features.

Barrier features appear again just north of Tampa Bay and continue to Cape Romano located just north of the Everglades National Park. The barriers along this stretch of the Florida coast occur in three successive barrier sequences consisting of eroding headlands, flanking spits, and adjacent barrier islands. The spit and island features are symmetrically distributed on either side of the eroding headland. Most of the barriers in southwest Florida are short, narrow, and of low topographic profile. In spite of this low profile, they do not have many washover features because of the low wave energy conditions that prevail here.

Although no true barrier land forms occur south of Cape Romano, the Florida Keys, consisting of linear, cemented limestone islands, provide habitats for unique local flora and fauna and for the quiet-water environment of Florida Bay. Functionally, therefore, they are acting as barriers.

Estuaries and Coastal Wetlands: There are 5.62 million hectares (ha) of estuarine habitat among the five states bordering the Gulf. This includes 3.2 million ha of open water, 2.43 million ha of emergent tidal vegetation (including about 162,000 ha of mangroves), and 324,000 ha of submerged vegetation. Estuaries are found from east Texas through Louisiana, Mississippi, Alabama, and northwestern Florida. Estuaries of the Gulf of Mexico export considerable quantities of organic material, thereby enriching the adjacent continental shelf areas.

The importance of wetlands to the coastal environment has been well documented. Coastal wetlands are characterized by high organic productivity, high detritus production, and efficient nutrient recycling. Wetlands provide habitat for a great number and wide diversity of invertebrates, fish, reptiles, birds, and mammals. Inshore and estuarine areas bordered by wetlands are particularly important as pupping and nursery grounds for juvenile stages of many important invertebrate and fish species including many species of Atlantic sharks.

Coastal wetland habitat types that occur along the Gulf Coast include mangroves, nonforested wetlands (fresh, brackish, and saline marshes), and forested wetlands. Marshes and mangroves form an interface between marine and terrestrial habitats, while forested wetlands occur inland from marsh areas. Wetland habitats may occupy narrow bands or vast expanses, and can consist of sharply delineated zones of different species, monospecific stands of a single species, or mixed plant species communities.

In Texas, coastal marshes occur along the inshore side of barrier islands and bays and on river deltas. Sparse bands of black mangroves are also found in this region. Broad expanses of emergent wetland vegetation do not commonly occur south of Baffin Bay at the northern edge of Kennedy County because of the climate and hypersaline waters to the south.

Louisiana contains most of the Gulf coastal wetlands. These wetlands occur in two physiographic settings: the Mississippi River Deltaic Plain and the Chenier Plain. The present wetlands on the deltaic plain formed on top of a series of overlapping riverine deltas that have extended onto the continental shelf during the past 6,000 or so years. These wetlands are established on a substrate of alluvial and organic-rich sediment that is subject to high, natural-subsidence rates. The effects of subsidence are compounded by sea level rise. Under natural conditions, sedimentation encourages vertical accretion of wetland areas and may offset the submergence and inundation that result from subsidence and sea level rise. Areas of the deltaic plain that are located near an active channel of the Mississippi River tend to build outward and marsh areas tend to expand. At the same time, areas located near inactive, abandoned channels tend to deteriorate and erode as a result of the lack of sediment.

The Chenier Plain, located to the west of the Atchafalaya Bay in the western part of coastal Louisiana, is a series of separate ridges of shell and sand, oriented parallel or oblique to the coast, that are separated by progradational mudflats that are now marshes or open water. The mudflats are built during times when the Mississippi River channel is located on the western side of the deltaic plain or when minor changes in localized hydrologic and sedimentation patterns favor deposition in the Chenier area.

In Mississippi and Alabama, the mainland marshes behind Mississippi Sound occur as discontinuous wetlands associated with estuarine environments. The most extensive wetland areas in Mississippi occur east of the Pearl River delta near the western border of the state and in the Pascagoula River delta area near the eastern border of the state. The wetlands of Mississippi are more stable than those in Louisiana, reflecting the more stable substrate and more active sedimentation per unit of wetland area. Also, there have been only minor amounts of canal dredging in the Mississippi wetlands.

Most of the wetlands in Alabama occur on the Mobile River delta or along the northern Mississippi Sound. Between 1955 and 1979, fresh marshes and estuarine marshes declined by 69 percent and 29 percent, respectively, in these areas. On a percentage basis, wetlands loss has occurred more rapidly in Alabama during these years than it did in Louisiana. Major causes of non-fresh wetland losses were industrial development and navigation, residential and commercial development, natural succession, and erosion-subsidence. Loss of fresh marsh was mainly attributable to commercial and residential development and silviculture.

Coastal marsh habitat in Florida occurs for the most part north of Tampa Bay. To the south, because of milder winter temperatures, mangrove swamp predominates. In the northern part of the state, emergent wetlands have very little distribution in the Florida panhandle. The limited areas of wetlands that do occur occupy narrow, often discontinuous bands in saline and brackish zones behind barrier islands and spits, near river mouths, and along some embayments. The most extensive and continuous expanse of coastal marshland in the eastern Gulf occurs along the Big Bend coastline between Cape San Blas and Pasco County, just north of Tampa Bay. This stretch of the coast, which is important shark habitat, is exposed to very low wave energy because of the broad and very shallow offshore bank. This low energy environment allows the marsh edge to grow out directly into Gulf waters.

About 189,945 hectares (ha) of mangroves are estimated to occur within Florida. About 90 percent of Florida's mangrove area occurs along the Gulf coast from the Caloosahatchee River to the southernmost part of the peninsula. Red, black, and white mangroves dominate the coastal swamps of Florida. The mangrove community may vary from a narrow fringe less than 10 m wide to extensive basin and riverine forests extending several kilometers inland. Extensive destruction of mangrove forests in Florida has occurred in various ways including outright destruction and land filling, diking, and pollution damage.

Along the 24,800-km Gulf coastline, 21 major estuaries are found on the U.S. coast. The amount of freshwater input to the Gulf basin from precipitation and a number of rivers--dominated by the Mississippi and Atchafalaya Rivers--is enough to influence the hydrography of most of the northern shelf. The basin's freshwater budget shows a net deficit, however, due to the high rate of evaporation.

Gulf of Mexico Estuaries**:** Estuaries in the Gulf of Mexico encompass more than 23,938 square miles of water surface area. Historical periods of coastal flooding and intense sediment deposition have sculpted the Gulf shoreline into a gently sloping, lowland environment. The region can be divided in top four subregions: Western Florida Coast, Big Bend/Panhandle Coast, Mississippi Delta/Louisiana Coast, and the Texas Coast. The sources of information included in this section are Field *et al.*, 1991, NOAA 1997c, and GMFMC, 1998.

Western Florida Coast Estuaries: The estuarine systems within the southern-most portion of this region are dominated by mangrove islands, tidal channels, and extensive wetlands found along the coastal fringe of the Everglades. The area is extremely complex and affected by tidal action, weather-related events and canal structures. From Cape Romano northward, the coastline consists of sandy beaches, some rocky areas, swamps, and tidal marshes. Freshwater inflow to the region is primarily from the Hillsboro, Alafia, Peace, Caloosahatchee river systems. Tidal range is approximately 2 to 3 ft throughout the region.

Florida Bay: Florida Bay is a shallow - average depth 7.3 ft - lagoonal estuary featuring innumerable mangrove islands, and mangrove forests fronting expansive marshes on the mainland The systems are interconnected by extensive series of tidal creeks and natural passes. Approximately two thirds of the tidal marsh and more than 60 percent of the mangroves are in the area north of Cape Sable. A vertically mixed water column persists, and salinities are generally high to hypersaline, salinity variability being dominated by wind-driven circulation and weather events. The tidal range is approximately 2 ft near Cape Sable. Because most of this complex lies within the boundaries of the Everglades National Park, it has not been subjected to the extensive filling for housing and other purposes that estuarine areas farther to the north have experienced The estuary is characterized as having low to high chlorophyll *a* concentrations and high turbidity. Nitrogen concentrations are medium to high, while phosphorus is low. Low dissolved oxygen contrations occur throughout the water column periodically between June and October. Nuisance and toxic algal blooms occur only in the seawater zone. The planktonic community varies throughout the bay, and is either dominated by blue-green algae and diatoms, or is a diverse mix of organisms; the benthic community is dominated by annelids in some areas, while in others it is considered to be diverse. SAV coverage is medium.

South and North Ten Thousand Islands: South Ten Thousand Islands is a shallow - average depth 6.5 ft - lagoonal estuary consisting of Whitewater Bay, and a number of features similar to the North Ten Thousand Islands system - small tidal rivers, small mangrove islands and tidal marshes. The average depth of the latter estuary is 5.7 ft. The majority of freshwater inflow to these systems is from overland sheet flow and regulated canal structures connected to Lake Okeechobee. Circulation in these systems is wind driven, and a vertically mixed water column exists. The tidal range is approximately 3.5-3.6 ft. Chlorphyll *a* concentrations are considered to be medium, with phosphorus and nitrogen the limiting factors, and turbidity levels high. Nutrient levels vary from low to high. Both hypoxia and anoxia occur from July to September, causing impacts to biological resources. Nuisance and toxic algal blooms have not been observed. The planktonic community in both systems is dominated by diatoms; the benthic community is considered to be diverse. SAV coverage ranges from low to meduim; total salt marsh coverage for both systems is approximately 54,800 acres.

Charlotte Harbor/Caloosahatchee River: This system consists of Charlotte Harbor proper, Pine Island Sound, San Carlos Bay, Matlacha Pass, and the tidal areas of the Peace, Myakka, and Caloosahatchee rivers. The Caloosahatchee estuary is fed primarily by the artificially controlled flow of the Caloosahatchee River that traverses some 101 km (63 miles) from Lake Okeechobee. To the north is Charlotte Harbor (including Pine Island Sound), fed also by the Peace and Myakka Rivers. Charlotte Harbor is fronted by many islands and has more than 322 km (200 miles) of shoreline consisting primarily of mangrove forests and salt marshes. The average depth of the estuarine system is 8.7 ft; the tidal range is 1.0-1.3 ft. Chlorophyll *a* concentrations are high in the Caloosahatchee River, and range from medium to hypereutrophic in Charlotte Harbor, maximums occurring periodically in the summer, with light, nitrogen and phosphorus being the limiting factors. Nutrients are high in the river, and range from low to high in the harbor, where nuisance and toxic algal blooms also occur episodically from April to June. Hypoxia occurs in bottom waters of both the river and harbor periodically during the summer months. Anoxic conditions in Charlotte Harbor have been observed in all zones. The planktonic community in the harbor is dominated by blue-green algae in the tidal fresh zone, flagellates and diatoms in the mixing zone, and diatoms in the seawater zone; the benthic community is dominated by annelids, except in the seawater zone where it is more diverse. SAV coverage is low both in the river and harbor areas. Total salt marsh for the harbor is approximately 6,800 acres.

Sarasota Bay: This is an elongated bar-built coastal lagoon with an average depth of 6.4 ft and a tidal range of 1.3 ft. The majority of the freshwater inflow is from several small tributaries and storm-water drains. The salinity structure is determined by seasonal patterns of precipitation and evaporation, while wind and tides influence the bay's circulation. Turbidity levels are moderate, while chlorophyll *a* concentrations are considered to be high, particularly in the summer, nitrogen being the limiting factor. Nutrients are moderate to high, and nuisance and toxic algal blooms have been observed, the latter particularly in the seawater zone. Anoxia and hypoxia in bottom waters occur periodically from June to September. The planktonic community is dominated by diatoms and flagellates, and the benthic community by annelids. SAV coverage is medium, and has been on the increase, probably due to changes in non-point sources.

Tampa Bay: Tampa Bay is a large Y-shaped estuary consisting of Tampa Bay proper, and Old Tampa and Hillsborough bays. Major rivers discharging into the bay are the Little Manatee, Alafia, Manatee, Palm and Hillsborough, with flows from the latter three artificially controlled. Widely spaced barrier islands front the Tampa Bay system. The average depth of the estuary is 12.8 ft, and the tidal range is 2.2 ft at Egmont Key. A well-defined salinity gradient is established by the free exchange and circulation of Gulf water. However, circulation of the bay has been altered by dredged channels, disposal sites, major causeways and shoreline landfills. Chlorophyll *a* ranges from medium to hypereutrophic, with maximums occurring periodically from June to October, nitrogen and light being the limiting factors. Nuisance blooms of blue-green algae and dinoflagellates occur in the summer in the seawater zone, as do toxic blooms of *Gymnodinium breve*. The planktonic community is dominated by diatoms; the benthic community is diverse in some areas, and dominated by annelids in others. Lower Tampa Bay contains some SAV, which is on the increase, and about half of its eastern shore is dominated by mangrove forests.

Mangroves and salt marshes also are found in portions of Old Tampa Bay, while much of the remaining shoreline has been developed.

Big Bend/Panhandle Coast Estuaries: This region encompasses approximately 1,588 square miles of water surface area. The Big Bend area of this region has a rugged shoreline with wide, shallow pools and expansive areas of freshwater and tidal marshes. Freshwater inflow is dominated by the Suwannee River. The tidal range in the Big Bend area is approximately 3.5 ft. Estuaries of the Florida Panhandle consist mainly of smooth, sandy beaches and well developed dune systems, with the coastline partially enclosed by barrier islands. Protected bays located here have high discharge rates from freshwater sources. The tidal range along the Panhandle is 1.5 to 2.0 ft.

Suwannee River: This system consists of Suwannee Sound, the Suwannee River delta, and extensive wetland areas. The average depth of the estuary is 4.6 ft. Salinity variability is most pronounced in Suwannee Sound where tides are a dominant influence and range approximately 3 ft. This system is characterized as having chlorophyll *a* concentrations from low to meduim, with maximum concentrations occurring periodically from May to September, the limiting factor being nitrogen. Turbidity levels in the seawater zone are moderate; nutrients levels are moderate to high. Although there are no nuisance algal blooms, toxic blooms are known to occur episodically. Anoxia and hypoxia are not a problem in the estuary. The planktonic community is dominated by diatoms; the benthic community is dominated by aquatic insects in the tidal fresh zone, but is considered to be diverse in other areas. SAV coverage ranges from low to medium, while salt marsh cover is approximately 20,900 acres

Apalachee Bay to Anclote Key: The estuary system between Apalachicola Bay and Anclote Key (just above Tampa Bay) contrasts sharply with the panhandle estuaries to the west. The estuarine system along this stretch of the coast does not conform to the classic definition of an estuary - it is an open water system, not semi-enclosed, nor is it separated from a major water body by barrier islands. There are no upland hills and valleys creating inland bays and, as there are no barrier islands, there is nothing to impede stream flow to form drowned valleys. Instead, there is an extremely broad zone of fresh and salt water mixing over the continental shelf with a gentle gradient of about 0.4 m per 12.6 km (1.5 feet per mile) offshore. Salinity ranges from near 0 to about 32 ppt. The periphery of Apalachee Bay is lined by many small estuaries, streams, lakes and freshwater marshes. Nevertheless, the near shore flora and fauna are characteristically estuarine. Freshwater discharge to this area is from several rivers that drain the region, with the salinity structure influenced primarily by the Econfina, Fenholloway, and Ochlockonee rivers. The tidal range is 2.1 ft near the entrances to these major rivers. Bottom sediments usually consist of mud and muddy sand. Chlorophyll *a* and nutrient concentrations within the system are generally low to medium, while turbidity is medium to high. Although nuisance algal blooms have not been observed, toxic blooms occur in the seawater zone. The phytoplankton community is dominated by diatoms; the benthic community is dominated by annelids in the tidal fresh zone, but is diverse elsewhere. SAV coverage ranges from very low to high, and is reported to be on the increase. Salt marshes within the Apalachee Bay drainage area total approximately 24,400 acres.

Apalachicola Bay: The Apalachicola Bay system is a broad, shallow lagoonal system consisting of the bay proper and several smaller embayments. It is separated from the Gulf of Mexico by three barrier islands. The primary source of freshwater inflow is the Apalachicola River, which determines the salinity structure in the bay. The annual cyclic flows of the Apalachicola River are inversely proportional to salinity in the bay, which ranges from near zero to about 32 ppt. The cyclic flow of the river is an important factor concerning primary productivity. Chlorophyll *a* concentrations range from low to medium, with maximums seen from December to April. Turbidity in the mixing and seawater zones is medium to high. Although nuisance algal blooms do not occur, toxic blooms occur in the seawater zone episodically from June to October. Low dissolved oxygen conditions occur in bottom waters periodically, also from June to October. Bottom sediments consist chiefly of clays transported by the Apalachicola Rive; the benthic community is dominated by annelids, except in the mixing zone where it is diverse. Some portions of the bay consist of hard muds that support large oyster reefs. The planktonic community is dominated by diatoms. SAV coverage is low; salt marshes total 17,000 acres.

St. Andrew Bay: The St. Andrew Bay system is a relatively deep - average depth is 11.9 ft - Y-shaped embayment that consists of four drowned stream basins: St. Andrew, East, North, and West bays, the depths of which are 5.2, 2.1, 1.7 and 2.0 m, respectively. Minimal freshwater is supplied by Econfina and Bear creeks, the former being the primary influence on the salinity structure of the bay. Like other north Florida estuaries, near shore areas are predominantly sand with silts and clays found in the center. Salinity in the system varies greatly, but is generally 18-33 ppt. The tidal range is1.3 ft near West Pass. Chlorophyll *a* concentrations are considered to be medium, with maximums occurring periodically during the summer, associated with point and non-point sources. Turbidity and nutrients are moderate, reaching highest concentrations in the spring and summer. Nuisance and toxic algal blooms occur episodically in the summer, as do hypoxia and anoxia in bottom waters. The planktonic community is dominated by diatoms; the benthic community by annelids in the mixing and seawater zones. SAV coverage is low, and salt marsh totals approximately 8,500 acres.

Choctawhatchee Bay: This is a relatively deep and narrow lagoon consisting of the Choctawhatchee Bay and river delta and several smaller embayments, separated from the Gulf of Mexico by a barrier spit along the southern shore. Average depth of the estuary is 14.2 ft. Salinity varies from zero near the Choctawhatchee River delta to about 30 ppt near Destin East Pass, the only outlet to the Gulf. Extreme stratification has been reported for the eastern portion of the Bay. The tidal range is about 0.6 ft near East Pass. Sediments around the Bay's periphery to about 800 m offshore, and in water no deeper than two meters, is medium-grade sand. The center of the bay is characterized by very fine, clay-size sediment transported to the Bay through the Choctawhatchee River, while in the western portion of the bay there is a lack of fine sediment cover over reworked sand sediment. Turbidity ranges from medium to high, while chlorophyll *a* concentrations are considered to be medium, phosphorus being the limiting factor. Elevated nutrient concentrations, which are attributed to non-point sources, occur throughout the year in the tidal fresh zone and from May to September in the mixing zone. Nuisance and toxic algal blooms occur periodically during the summer. Both hypoxia and anoxia are observed, especially in the tidal fresh and mixing zones, occurring mostly in bottom waters from June to October, and due primarily to water column stratification. The planktonic community is dominated by diatoms in the mixing and seawater zone, while the benthic community is diverse, except in the tidal fresh zone, where it is dominated by annelids. SAV are found in certain portions of this area, overall coverage being low. Salt marshes cover approximately 2,700 acres.

Pensacola Bay: The Pensacola Bay system is a drowned river estuary and lagoon, consisting of Pensacola, Escambia, East, and Blackwater bays and Santa Rosa Sound, separated from the Gulf of Mexico by Santa Rosa Island. The average depth of the estuary is 12.7 ft., and the tidal range 3.2 ft near the mouth of the bay. Low tidal amplitude and frequency, and relatively low river discharge are responsible for the low flushing rate (one complete turnover every 18 days). The salinity structure is determined by seasonal freshwater discharge, primarily from the Escambia River; salinity varies from zero near the headwaters to 30 ppt near the inlet. Fine to coarse sands, sometimes mixed with clays, are found in shallows near the shorelines, but fine alluvial clays cover most of the bay bottom. The system is characterized as having a wide range of chlorophyll *a* concentrations - from low to hypereutrophic - with increases over the last few years in the mixing zone being attributed to point and non-point sources. Nutrients range from low to high, with elevated concentrations occurring throughout the year in Bayou Texar and in March and April elsewhere. Nuisance and toxic algal blooms are not known to occur, and, although anoxic conditions have not been observed, hypoxia occurs periodically in the Escambia River and in the mixing zone. Although the planktonic community is generally diverse, the benthic community shows a diversity of organisms only in the seawater zone, and is dominated by aquatic insects in the tidal zone and by annelids in the mixing zone. SAV coverage is very low; salt marsh coverage within the drainage basin is approximately 6,700 acres.

Perdido Bay: This is a small system consisting of Perdido Bay and several small creeks. It is separated from the Gulf of Mexico by Perdido Key, Perdido Pass being the only area where direct exchange with the Gulf occurs. The vertical salinity structure is determined by seasonal discharge from the Perdido River, and also by deep areas that trap saline bottom waters. The average depth of the estuary is 6.9 ft; the tidal range within the bay is approximately 1.6 ft. Within the system, chlorophyll *a* and nutrient concentrations range from low to medium, higher levels occurring periodically in the spring and summer, with light the limiting factor in the tidal fresh zone and nutrients in the mixing and seawater zones. Elevated nitrogen and phosphorus concentrations are seen from April to October, and nuisance and toxic algal blooms occur during the summer. Anoxia and hypoxia are seen periodically from June to October in bottom waters, water column stratification being a significant factor for these conditions. Turbidity is medium to high throughout the year. Although the planktonic community is generally diverse, diversity of organisms in the benthic community is seen only in the seawater zone, with aquatic insects and annelids dominating the tidal fresh and mixing zones, respectively. SAV coverage ranges from none to low, while salt marsh covers approximately 1,900 acres.

Mobile Bay: Mobile bay is a drowned river valley estuary consisting of the main bay, Mobile River, Tensaw River and small embayments. The average depth of the estuary is 9.9 ft. The salinity structure of the bay is determined by the Mobile River, and is moderately stratified throughout the year. The tidal range is 1.3 ft near Main Pass. While turbidity is moderate to high, chlorophyll *a* concentrations in the bay are moderate, maximum concentrations occurring periodically from April to September in the mixing zone and from December to May in the seawater zone, limiting factors being nitrogen and phosphorus. Nutrients range from low to medium, with elevated concentrations seen throughout the year in the tidal fresh zone, and from January to May in the seawater zone. Although nuisance algal blooms do not occur, toxic blooms are reported from October to December. Hypoxic and anoxic conditions occur periodically from July to October in bottom waters. Tidal marshes are found in the north end of the bay and along Dog, Deer and Fowl Rivers, and along the shorelines of Weeks, Oyster and Bon Secour Bays and Little Point Clear. The total area of salt marshes is approximately 17,000 acres.

Mississippi Delta/Louisiana Coast Estuaries: Estuarine systems in this region encompass approximately 5,791 square miles of water surface area, plus the Mississippi/Atchafalaya River Plume, totaling 12,256 square miles. The entire Mississippi Delta area is greatly affected by the Mississippi River and indirectly by the Atchafalaya River, significant inflows from these and other small coastal rivers causing reduced salinities and density gradients near the estuary mouths. The coastal environment is characterized by shallow, turbid embayments and extensive marsh systems. The drainage patterns have been highly altered by man-made channels. Coastal Louisiana is predominately a broad marsh indented by shallow bays containing innumerable valuable nursery areas. These waters are generally shallow with over half between zero and 6.0 feet (1.8 m) in depth. Sediments consist of mud, sand and silt and are very similar across the coast, ranging from coarse near the Gulf and barrier islands to fine in the upper estuaries.

Mississippi Sound: Mississippi Sound is a system of estuaries adjoining a lagoon. The sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The circulation in the central Mississippi Sound is greatly influenced by tidal flux through Dog Keys and Ship Island Passes. The primary source of freshwater is Bay St. Louis. The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River, the Lake Borgne-Lake Pontchartrain complex, and Bay St. Louis. Silt clay is the dominant sediment in the sound. The salinity regime of eastern Mississippi Sound is determined largely by the influx of Gulf waters through Petit Bois, Horn, and Dog Keys Passes and the outflow of waters from Mobile Bay, the Pascagoula River and Biloxi Bay. Both north-south and east-west salinity gradients exist in addition to vertical gradients. Seasonally, salinities are lowest in the early spring, rise sporadically through the summer, and peak in the fall. Temporary oxygen depletion may occur in deep holes and behind sills in river channels. Anoxia, resulting from excessive biological oxygen demand, occurs periodically in waters near heavily populated areas and in waters subject to industrial outfalls. In some years, the presence of Yucatan Loop waters has been detected near the barrier islands. This water mass, which is characterized by high salinity, below average temperature and extremely low levels of dissolved oxygen, may remain in the area through the late summer months and at times penetrate into Mississippi Sound near the Island passes. Nutrients in the system are considered to be low to medium; nuisance algal blooms are also known to occur episodically in January and February, and toxic blooms are seen from July to September. SAV coverage is generally very low, while salt marshes cover approximately 170,600 acres.

Lake Borgne: Lake Borgne has an area of 272.1 square miles with an average depth of 9.5 ft and drains an area of 7790 sq miles. The average daily freshwater inflow is 25,100 cfs, mainly from the Pearl River. Salinity has been altered since construction of the Mississippi River-Gulf outlet and other channels connecting the lake with Breton and Mississippi Sounds. High turbidity and low coverage of SAV feature this system. The planktonic community is diverse; the benthic community is dominated by annelids. Anoxia or hypoxia have not been observed in this area.

Breton and Chandeleur Sounds: This area is located in the Mississippi deltaic plain, and consists of many small embayments and tidal marshes separated from the Gulf of Mexico by a chain of barrier islands (Chandeleur Islands). The average depth is 8.9 ft. The surface area is 1,662.4 sq miles with a little more than half being seawater (salinity > 25 ppt). The freshwater inflow is mainly from the Pearl River through Lake Borgne at an average daily rate of 10,300 cfs. While nitrogen is low, phosphorus concentrations are high in the nearshore areas. Turbidity is high or medium in most parts of the sounds. Anoxia and hypoxia occur in bottom waters of the seawater zone from July to September, causing biological stress to the benthic communities. SAV coverage is limited to some shallow areas and is declining.

Mississippi River: The Mississippi River has an extended estuarine system consisting of a delta area, small embayments and tidal marshes. The surface area is 378.3 square miles with a drainage area of 1,846 square miles. The average depth of the estuary is 23.1 ft. As the largest single freshwater source in the U.S., the Mississippi River provides freshwater inflow at an average daily rate of 464,400 cfs, as well as large quantities of nutrients to the estuaries throughout the entire Louisiana and Texas coast. The salinity in most areas ranges between 0.5 to 25 ppt, with the upper tidal areas being freshwater (< 0.5 ppt). Nitrogen and phosphorus concentrations are high throughout the estuary. Chlorophyll *a* concentrations are low in the tidal freshwater areas and medium in the saline water. High turbidity prevails in the whole area and occurs all year, which is the limiting factor of primary productivity. Anoxia and hypoxia have not been observed even though stratification occurs from July through September. The benthic community is dominated by annelids and crustaceans. SAV is virtually absent in this system. However, in the delta region there are approximately 1,042,900 acres of salt marsh.

Barataria Bay: Barataria Bay is an estuarine-wetland system located at the southwest side of Mississippi River deltaic plain, covering an area of 359.2 square miles with an average depth of 4.5 ft. The average daily inflow is 5,500 cfs. About 30 percent of the system has salinity below 0.5 ppt. The lower portion consists of Caminada and Barataria Bays with shallow, wide areas of open water interspersed with numerous marsh islands. The upper portion is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes. An extensive network of small navigation channels and drainage canals has significantly altered the hydrology of the bay. Seasonal advection from the Mississippi River and precipitation are the main sources of freshwater. This system is highly eutrophic, with turbidity also high. High concentrations of nitrogen, phosphorus and chlorophyll *a* occur throughout the year, and nuisance blue-green algae is persistent in the upper portion of the system. Anoxia and hypoxia occur from June to September. The planktonic community is dominated by blue-green algae; the benthic community is diverse with annelids dominant in the lower portion of the system. SAV coverage ranges from low to medium.

Terrebonne/Timbalier Bay: This system is located in the Mississippi River deltaic plain, covering an area of 515.2 square miles. The average depth is 4.7 ft. The upper portion of the system is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes, although historically, well developed salt marshes have declined due to watershed alterations. Seasonal advection from the Mississippi River and precipitation are the main sources of freshwater; the average daily inflow is 4,600 cfs. Salinity ranges from 0.5 to 25 ppt. High eutrophication is a feature of this system. Nitrogen concentration is medium, but is on the increase, while phosphorus and chlorophyll *a* concentrations are high, nitrogen, phosphorus and silica being the limiting factors. Nuisance and toxic algae occur episodically in this area. However, anoxia and hypoxia have not been observed. Both the planktonic and benthic communities are considered to be diverse. SAV coverage is low, and salt marshes have declined due to watershed alterations.

Atchafalaya/Vermillion Bays: This system consists of four major water bodies, numerous bayous, locks, and canals. The whole estuarine area is 832.6 square miles. The average depth is 6.5 ft. The primary sources of freshwater are from Atchafalaya and Vermilion Rivers with an average daily inflow rate of 223,800 cfs. Eutrophication prevails in this system. Nutrients, chlorophyll *a* concentrations and turbidity are all high, largely due to non-point source pollution. Nuisance and toxic algal species occur in the lower portion. Anoxia and hypoxia occur in the Atchafalaya River from June to October when the water column stratifies. Blue-green algae dominate the planktonic community; the benthic community is dominated by arthropods, molluscs, or annelids depending on the location. SAV coverage is high in the upper freshwater areas, but is decreasing due to the introduction of non-indigenous *Hydrila*. Salt marshes cover approximately 126,500 acres.

Mermentau River: The Mermentau River extends from the mouthof the estuary at the Gulf of Mexico to the head-of-tide at the Catfish Point Control Structure near Grand Lake. The estuarine surface area is 7.0 square miles, and the average depth of 3.9 ft. Freshwater inflow is mainly from Grand Lake, but the discharge is regulated, causing salinity to fluctuate in response to periodic control structure releases. The average daily inflow is 4393 cfs. Nitrogen concentration is moderate, while phosphorus and turbidity are high, the latter particularly high during the winter. Nuisance algal blooms, anoxia and hypoxia have not been observed. SAV is absent from this system.

Calcasieu Lake: The Calcasieu Lake estuary consists of Calcasieu Lake and several secondary embayments. The entire area is 99.7 square miles, with an average depth of 9.4 ft. This estuary receives the majority of its freshwater from the Calcasieu River at an average daily rate of 6300 cfs. In Calcasieu Lake, both nitrogen and phosphorus concentrations range from medium to high, with elevated conditions seen from March to May. High turbidity occurs in the summer. Chlorophyll *a* concentrations are high, with maximums occurring from February through April, with nitrogen being the limiting factor. Nuisance and toxic algal blooms occur periodically in the summer. Anoxia and hypoxia occur in the lake bottom, but this condition has improved in recent years due to point source pollution control. The planktonic and benthic communities are generally diverse. SAV coverage is low and on the decrease, primarily due to alterations to the watershed and to point sources. The extent of salt marsh is approximately 82,600 acres.

Sabine Lake: The Texas-Louisiana border divides Sabine Lake, a broad, shallow open bay with a narrow, deep channel on the western side. It is connected to the Gulf of Mexico by Sabine Pass. The average depth of the estuary is 8.2 ft, while the main navigation channel is 36 ft, significantly influencing circulation and salinity patterns. An average of 17,200 cfs of fresh water flows into the bay annually, primarily from the Sabine and Neches Rivers. Salinity ranges from 0-20 ppt in upper Sabine Lake and 20-30 ppt in Sabine Pass. The bay bottom consists primarily of mud and silt. The western portion of the bay is heavily industrialized, and most of the marsh vegetation is found on the eastern side. A few small oyster reefs are found in the southern portion. Chlorophyll *a* and nutrients levels are moderate, while turbidity is high throughout the year. Nuisance algal blooms occur episodically from May to July, probably due to non-point sources; however, there are no toxic blooms. Hypoxia has been observed periodically from July to August in bottom waters, water column stratification believed to be a moderate contributing factor. Depending on the location, the plankton community is dominated by blue-green algae or diatoms; the benthic community is diverse or dominated by mollusks. SAV coverage is considered to be very low; salt marsh covers approximately 110,000 acres.

Texas Coast Estuaries: The shoreline of this region is dominated by large bays, lagoons and barrier islands. The estuaries, which encompass approximately 2565 square miles of water surface area, are typically bordered by tidal marshes and mud-sand flats. Freshwater discharge is primarily from the Trinity, Brazos and Guadelupe river systems, although direct precipitation contributes significantly to the total freshwater inflow. The presence of barrier islands, however, coupled with low runoff and high evaporation rates, produces hypersaline conditions in these estuaries, especially in the summer. The tidal range for the region is from 0.5 to 1.5 ft.

Galveston Bay: Galveston Bay contains 540 square miles of water surface area, and is the largest estuary in Texas. The Galveston Bay system includes Galveston, Trinity, East, West, Dickinson, Chocolate, Christmas, Bastrop, Dollar, Drum, and Tabbs Bays and Clear, Moses, and Jones Lakes. The average depth of the estuary is 6.2 ft. However, ship channels leading from the Gulf of Mexico into Houston, Texas City, Galveston, and Bayport are dredged to a depth of approximately 40 ft. The bay is separated from the Gulf of Mexico by Fallets Island, Galveston Island and Bolivar Peninsula. The primary source of freshwater inflow is the Trinity and San Jacinto Rivers. Salinity generally ranges from 5 to15 ppt in the upper portion of the bay to 20-30 ppt in the lower bay. One man-made pass and two natural passes connect the estuary with the Gulf. Chlorophyll *a* concentrations are considered to be low to medium within the system and turbidity ranges from medium to high. Nutrients are elevated from April to October in the tidal fresh zone and from May to December in the mixing zone. In lower Galveston Bay nutrients levels are moderate. Nuisance and toxic blooms are noted in the summer. Both hypoxia and anoxia occur during the summer in bottom waters of the tidal fresh and mixing zones, due to some extent to water column stratification. In both of these zones, the benthic community is dominated by annelids. There has been a decrease in SAV due to watershed alterations and physical disturbances. Salt marshes cover approximately 94,900 acres.

Matagorda Bay: This is a broad, shallow lagoonal system separated from the Gulf of Mexico by the Matagorda Peninsula. Water exchange is through Pass Cavallo and a man-made ship channel. The Colorado River formed a delta that divides the bay into Matagorda Bay proper and east Matagorda Bay. Water exchange with the Gulf of Mexico to the eastern portion is through Brown Cedar Cut, which periodically closes due to climatic conditions. Other major bays making up the Matagorda system are Tres Palacios, Carancahua, and Lavaca Bays. The average depth of the Matagorda system is about 7.0 ft; bottom substrate is sand, shell, silt and clay. Freshwater inflow into Matagorda Bay is primarily from the Tres Palacios, Carancahua, Lavaca and Navidad Rivers. Partial flow comes from the Colorado River, which was diverted to empty directly into the Gulf of Mexico. Vertically homogeneous conditions commonly exist in the open bay. The bay is characterized as having low to hypereutrophic chlorophyll *a* levels, maximums occurring periodically from March to August, with light and nitrogen the limiting factors. Turbidity and nutrient levels are generally high throughout the year - elevated nitrogen and phosphorus levels in the seawater zone are seen from April to July and also in October and November. Nuisance and toxic algal blooms are also observed in the summer and fall. Hypoxic conditions occur episodically from August to October in bottom waters, due largely to water column stratification. The planktonic community is largely dominated by flagellates and diatoms, and the benthic community by annelids. SAV coverage is low, but is on the increase. Salt marshes cover approximately 43,500 acres.

San Antonio Bay: The San Antonio Bay system, comprised of Espiritu Santo, San Antonio, Guadalupe, Itynes, Mesquite, and Ayers bays, and Mission Lake, covers some 205 square miles at mean low water. Freshwater inflow is provided mainly by the Guadalupe and San Antonio Rivers. Salinity ranges from 0.0 to 8.0 ppt in the upper bay to 14.0 to 21.0 ppt in the lower portion. The system is separated from the Gulf of Mexico by Matagorda Island. Water exchange is through Pass Cavallo (located in Matagorda Bay) and Cedar Bayou Pass (located in Mesquite Bay). The average depth of bay is about 4.3 ft; substrates generally consist of mud, sand and shell. Chlorophyll *a* concentrations range from low to high, with nitrogen and phosphorus the limiting factors. Turbidity is high, probably due to point and non-point sources. High nutrient concentrations occur throughout the year in the tidal fresh zone and from November to March in the mixing zone. Hypoxia occurs episodically in bottom waters, a significant factor being water column stratification. The planktonic and benthic communities are diverse. SAV coverage is low and on the decrease, due to point and non-point sources. Salt marshes within the system cover approximately 32,900 acres.

Aransas Bay: The Aransas Bay complex, which comprises Copano, St. Charles, Dunham, Port, Mission and Aransas Bays, covers approximately 208 square miles. It is separated from the Gulf of Mexico by San Jose Island, with water exchange through Aransas Pass and Cedar Bayou Pass. Bottom sediments consist of mud, sand and shell; average depth for the system is approximately 5.3 ft. Freshwater inflow to the system tends to be from isolated pulses during high flow months, which depresses salinities within Copano Bay. The existence of oyster reefs across Copano Bay impedes circulation and affects salinity patterns in the upper estuary. Chlorophyll *a* concentrations in the Bay range from medium to high, with nitrogen the limiting factor, and turbidity is high. Nutrient concentrations range from low to moderate, with elevated nitrogen levels from November to May and high phosphorus throughout the year in the mixing zone, showing increasing trends. The increases are due primarily to non-point sources. Although anoxia and hypoxia do not occur, nuisance and toxic algal blooms occur episodically in the summer in the mixing zone, and toxic algal blooms occur in the fall in the seawater zone. SAV ranges from very low in the mixing zone to moderate in the seawater zone; salt marshes cover approximately 30,700 acres.

Corpus Christi Bay: Corpus Christi Bay is a bar-built system comprised of Redfish, Corpus Christi, Nueces, and Oso Bays, containing 192 square miles of water surface area with an average daily inflow of 1200 cfs. . The average depth of the estuary is 7.8 ft. The bay is separated from the Gulf of Mexico by Mustang Island, with water transfer through Aransas Pass and the Corpus Christi Water Exchange Pass. Bottom sediments consist of mud, sand and silt. Evaporation is the dominant influence on salinity structure; and salinities in the bay can reach hypersaline levels, especially near Laguna Madre. While turbidity is high throughout the year, nutrient levels range from low to high. Chlorophyll *a* concentrations are medium to high (periodically) from February to October in the mixing and seawater zones, with the limiting factor being nitrogen. Nuisance and toxic algal blooms occur in both the mixing and seawater zones. Although hypoxia occurs in seawater zone bottom waters periodically from June to August, anoxia has not been observed. Within the various zones, the planktonic community ranges from one dominated by blue-green algae and diatoms to one that is generally diverse. The benthic community is dominated by annelids in the mixing and seawater zones. SAV ranges from low coverage to being absent; salt marshes cover approximately12,200 acres within the watershed.

Laguna Madre/Baffin Bay: This area is one of mud-sand flats inundated by wind-driven flows. Direct precipitation contributes approximately 65 percent of the total freshwater inflow to the system. However, the salinity structure is determined by isolated pulses and intense evaporation rather that seasonal freshwater discharges. The Baffin Bay system consists of Alexin Bay, Capo del Inferno, Laguna Salad, and Capo del Grail. The average depth is 4.2 ft. No major rivers drain into the Laguna Madre, and the area is generally hypersaline. Both Upper and Lower Laguna Madre are bar-built coastal lagoons separated from the Gulf of Mexico by Padre Island. The average depth is 2.5 ft. Lower Laguna Madre, including the South Bay and La Barilla Grande complex, contains 366 square miles of water surface area. Water transfer is through Bravos Santiago Pass and Port Mansfield Pass to the south and passes in Corpus Christi Bay to the north. Bottom sediments consist of mud, silt, sand and quartzose (sand-small rocks). The only natural oyster reefs in Laguna Madre are in South Bay, the southernmost area of the lagoon. Chlorophyll *a* within this system ranges from medium to hypereutrophic, with nitrogen the limiting factor. Turbidity is high and is attributed largely to “brown tides”; these and other nuisance algal blooms are persistent throughout the year and are associated primarily with non-point sources. Hypoxia is observed periodically in the system during the summer, while anoxia occurs only in bottom waters of Lower Laguna Madre, from June to September. Although nutrient levels are generally low in Upper Laguna Madre, they are elevated throughout the year in other portions of the system. Depending on the area, the planktonic community is dominated by blue-green algae, flagellates, and diatoms. The benthic community is diverse in some areas, and dominated by annelids in others. SAV coverage is low but on the increase in Baffin Bay, but high in Upper and Lower Laguna Madre. Salt marsh coverage is approximately 67,800 acres.

6.2.3 U.S. Caribbean

(Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993 and sources of original information are referenced in that document.)

The waters of the Caribbean region include the coastal waters surrounding the U.S. Virgin Islands and Puerto Rico. The marine habitats found within the region are both the products of and key factors shaping local terrestrial, geological, and hydrological regimes. The territory of the U.S. Virgin Islands includes roughly 63 islands in total, the largest of which are St. Thomas (83 square kilometers or 32 square miles), St. John (52 square kilometers or 20 square miles), and St. Croix (207 square kilometers or 80 square miles). The commonwealth of Puerto Rico includes many islands, the largest of which is Puerto Rico. To the south lie numerous cays covered with sand, coral, and mangroves. To the west lie Mona, Monito, and Desecheo Islands. To the northeast lies the chain of islands called La Cordillera. To the southeast lies Vieques Island. All of these Caribbean islands, with the exception of St. Croix, are part of a volcanic chain of islands formed by the subduction of one tectonic plate beneath another. Tremendously diverse habitat (rocky shores, sandy beaches, mangroves, seagrasses, algal plains, and coral reefs) and the consistent light and temperature regimes characteristic of the tropics are conducive to high species diversity.

The waters of the Florida Keys and southeastern Florida are intrinsically linked with the waters of the Gulf of Mexico and the waters of the Caribbean to the west, south, and east, and to the waters of the South Atlantic Bight to the north. These waters represent a transition from insular to continental regimes and from tropical to temperate regimes. This zone, therefore, contains one of the richest floral and faunal complexes.

Insular Shelf/Slope Features: (Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993, and sources of original information are referenced in that document.)

Puerto Rico and the US Virgin Islands contain a wide variety of coastal marine habitats, including coral and rock reefs, seagrass beds, mangrove lagoons, sand and algal plains, soft bottom areas, and sandy beaches. These habitats are, however, very patchily distributed. Near shore waters range from 0 to 20 meters in depth and outer shelf waters range from 20 to 30 meters in depth, the depth of the shelf break. Along the north coast the insular shelf is very narrow (2-3 km wide), seas are generally rough, and few good harbors are present. The coast is a mixture of coral and rock reefs, and sandy beaches. The east coast has an extensive shelf that extends to the British Virgin Islands. Depth ranges from 18 to 30 m. Much of the bottom is sandy, commonly with algal and sponge communities. The southeast coast has a narrow shelf (8 km wide). About 25 km to the southeast is Grappler Bank, a small seamount with its top at 70 m depth. The central south coast broadens slightly to 15 km and an extensive seagrass bed extends 9 km offshore to Caja de Muertos Island. Further westward, the shelf narrows again to just 2 km before widening at the southwest corner to over 10 km. The whole of the southern shelf is characterized by hard or sand-algal bottoms with emergent coral reefs, grassbeds, and shelf edge. Along the southern portion of the west coast, the expanse of shelf continues to widen, reaching 25 km at its maximum. A broad expanse of the shelf is found between 14 and 27 m; habitats are similar to those of the south coast. To the north, along the west coast, the shelf rapidly narrows to 2-3 km.

Physical Oceanography (Water movements and Marine Habitats) (Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993; and sources of opriginal information are referenced in that document.)

Hydrologic patterns link the waters of the U.S. Caribbean with the Florida Keys and southeastern Florida. The marine waters of the U.S. Caribbean are primarily influenced by the waters of the westward flowing North Equatorial Current, the predominant hydrological driving force in the Caribbean region. It flows from east to west along the northern boundary of the Caribbean plateau and splits at the Lesser Antilles. The North Equatorial Current flows westward along the north coasts of the islands. North of the Mona Channel it splits, with one branch flowing north of Silver and Navidad

Banks, past Turks and Caicos to form the Bahamas Current. The southern branch stays along the north coast of Hispañiola about 30 km offshore. A small gyre has been documented off the northwest corner of Puerto Rico resulting in an east flow nearshore in this area.

The north branch of the Caribbean Current flows west into the Caribbean Basin at roughly 0.5 meters (1.7 feet) per second. It is located about 100 km south of the islands, but its position varies seasonally. During the winter it is found further to the south than in summer. Flow along the south coast of Puerto Rico is generally westerly, but this is set-off by gyres formed between the Caribbean Current and the island. The Antilles Current flows to the west along the northern edge of the Bahamas Bank and so links the waters of the Caribbean to those of southeastern Florida.

Several rivers exert intermittent but important influence on the waters of the Caribbean Basin including the Amazon, the Orinoco, the Magdelana, and the Columbian. The plume from the Orinoco River that flows up the Lesser Antilles and along the Greater Antilles, for example, can carry with it high concentrations of suspended particles, unique chemical properties, and biota near to the south coast of Puerto Rico. The plume, therefore, can be responsible for events of high turbidity and algal blooms that usually occur in the Caribbean Basin in October.

Coastal surface water temperatures remain fairly constant throughout the year and average between 26° and 30° C. Salinity of coastal waters is purely oceanic and so is usually around 36 parts per thousand, but in enclosed or semi-enclosed embayments, salinity may vary widely depending on fluvial and evaporational influences.

It is believed that no up-welling occurs in the waters of the U.S. Caribbean (except perhaps during storm events) and, since the waters are relatively stratified, they are severely nutrient-limited. In tropical waters nitrogen is the principal limiting nutrient.

Coastal and Estuarine Habitats: (Material in this section is largely a summary of information in Appeldoorn and Meyers 1993 and original sources of information are available in that document.)

The U.S. waters of the Caribbean are relatively nutrient poor and so have low rates of primary and secondary productivity, but these waters display some of the greatest diversity of any part of the south Atlantic region. High and diverse concentrations of biota are found where habitat is abundant. Coral reefs, seagrass beds, and mangrove ecosystems are the most productive of the habitat types found in the Caribbean, but other areas such as soft-bottom lagoons, algal hard grounds, mud flats, salt ponds, sandy beaches, and rocky shores are also important in overall productivity. These diverse habitats allow for eclectic floral and faunal populations.

Offshore, between the seagrass beds and the coral reefs and in deeper waters, sandy bottoms and algal plains dominate. These areas may be sparsely or densely vegetated with a canopy of up to one meter of red and brown algae. Algal plains are not areas of active sand transport. These are algae-dominated sandy bottoms, often covered with carbonate nodules. They occur primarily in deep water (> 15 m or 50 ft) and account for roughly 70 percent of the area of the insular shelf of the U.S. Virgin Islands. Algal plains support a variety of organisms including algae, sponges, gorgonians, solitary corals, molluscs, fish, and worms. Algal plains may serve as critical juvenile habitat for commercially important (and diminishing) species such as queen triggerfish and spiny lobsters.

Coral reefs and other coral communities are some of the most important ecological (and economic) coastal resources in the Caribbean. They act as barriers to storm waves and provide habitat for a wide variety of marine organisms, including most of the economically important species of fish and shellfish. They are the primary source for carbonate sand, and serve as the basis for much of the tourism. Coral communities are made by the build up of calcium carbonate produced by living animals, coral polyps, in symbiosis with a dinoflagellate, known as zooxanthellae. During summer and early fall, most of the coral building organisms are at or near the upper temperature limit for survival and so are living under natural conditions of stress. Further increase in local or global temperature could prove devastating.

Seagrass beds are highly productive ecosystems that are quite extensive in the Caribbean - some of the largest seagrass beds in the world lie beyond the shore on both sides of the Keys. Seagrass beds often occur in close association with shallow-water coral reefs. Turtle grass *(Thalassia testudinium),* manatee grass *(Syringodium filiforme),* and shoal grass *(Halodule wrightii)* are the three most abundant species. Seagrasses are true flowering plants that spread through the growth of roots and rhizomes. Seagrasses act to trap and stabilize sediments, reduce shoreline erosion, and buffer coral reefs; they provide food for fish, sea turtles (heavy grazers), conch, and urchins; they provide shelter and habitat for many adult species and numerous juvenile species who rely on the seagrass beds as nursery areas; and they provide attachment surfaces for calcareous algae.

Mangrove habitats are very productive coastal systems that support a wide variety of organisms. The mangrove food web is based largely on the release of nutrients from the decomposition of mangrove leaves, and in part on the trapping of terrestrial material. Red mangroves *(Rhizophora mangle),* with their distinctive aerial prop roots, grow along the shoreline, often in mono-specific stands. The roots of the red mangroves help to trap sediments (and pollutants) associated with terrestrial runoff and help to buffer the shore from storm waves. Red mangrove forests support a diverse community of sponges, tunicates, algae, larvae, and corals, as well as juvenile and adult fish andshellfish. Black mangroves (*Aveicennia germinans*) and white mangroves (*Laguncularia racemosa)* grow landward of the red mangroves. They also act as important sediment traps. Exposed and sheltered mangrove shorelines are common throughout the U.S. Caribbean.

Throughout the U.S. Caribbean, both rocky shores and sandy beaches are common. While many of these beaches are high-energy and extremely dynamic, buffering by reefs and seagrasses allows some salt-tolerant plants to colonize the beach periphery. Birds, sea turtles, crabs, clams, worms, and urchins use the intertidal areas.

Salt ponds, common in the U.S. Virgin Islands, are formed when mangroves or fringing coral reefs grow or storm debris is deposited, effectively isolating a portion of a bay. The resulting "pond" undergoes significant fluctuations of salinity with changes in relative evaporation and runoff. The biota associated with salt ponds, are, therefore very specialized, and usually somewhat limited. Salt ponds are extremely important in trapping terrestrial sediments before they reach the coastal waters.

6.3 Life History Descriptions and Essential Fish Habitat

For highly mobile, pelagic species such as tunas, swordfish and sharks, defining EFH offers unique challenges. Collectively, these species are widely dispersed in oceanic, neritic (waters over the continental shelf), coastal and estuarine waters and move frequently over great horizontal distances and commonly migrate vertically within the water column. In the following accounts, these movements will only be referred to as migrations for those species for which there is evidence of seasonality or regularity.

The NMFS regulatory interpretation (EFH regulation) of the Magnuson-Stevens Act (1996) requires that NMFS and the regional fishery management councils use the best available scientific information to determine EFH for all managed species. According to the EFH regulations, an initial inventory of available environmental and fisheries data sources should be undertaken to compile information necessary to describe and identify EFH and to identify major species-specific habitat data gaps. Available information should be evaluated through hierarchical analysis based on: 1) presence/absence of the species in specific habitats; 2) habitat-related densities or relative abundances; 3) growth, reproduction, or survival rate comparisons between habitats; and 4) habitat-dependent production rates (quantified by habitat quantities, qualities and specific locations). The information gathered should be interpreted with a risk-averse approach to ensure that adequate areas are protected as EFH for the managed species. In this chapter, habitats that satisfy the criteria from the Magnuson-Stevens Act and EFH regulations have been identified and described as EFH; some additional habitats that have been identified as necessary for a sustainable fishery, but that lie outside the U.S. EEZ and therefore cannot be identified as EFH under the Magnuson-Stevens Act (e.g., the Gulf of Guinea off the African coast) have been highlighted as particularly important habitats to the HMS, as suggested in the EFH regulations.

In order to fulfill the requirements of the EFH regulations and the Magnuson-Stevens Act, NMFS scientists (NEFSC and SEFSC) conducted a complete review of the most recent information available. Their review covered the life histories of all HMS species with emphasis on the factors that influence distribution of the species. Much of the descriptive information for tunas and swordfish species is from the 1970s to the 1980s, although each year the Standing Committee on Research and Science (SCRS) of ICCAT reviews and updates available information on species biology and stock structure. NMFS scientists made full use of the latest annual reports to ensure that the habitat information utilized was up-to-date. Dr. Castro, (SEFSC) recently completed a review of available information regarding the status of sharks worldwide for an upcoming United Nations Food and Agricultural Organization (FAO) publication. He and his assistants contributed information directly from the manuscript and undertook additional literature review to ensure that the information was the most current available. For all HMS, i.e., Atlantic tunas, swordfish and sharks additional information was available in the form of fishery-independent sources (directed research investigations) and fishery-dependent sources (capture and bycatch reporting); although the location information is suitable for Geographic Information System (GIS)-based spatial analysis of distributions, there is a general lack of accompanying environmental or habitat data with which to define tolerances or preferences. All of the written accounts detailing life history, distributional and habitat use for HMS were submitted to independent reviewers who submitted separate reviews of the draft manuscripts. Their comments were considered and assessed by the scientific authors and included as appropriate. We are grateful to these reviewers for their excellent contribution to this chapter, ensuring that the information is complete and up-to-date.

Identifying EFH for tunas, swordfish and many pelagic shark species is unique because they are primarily blue-water (i.e., open-ocean) species, although some may frequent the neritic waters of the continental shelf. Their distributions are usually not correlated with the areas or features one commonly thinks of as fish habitat (e.g., seagrass beds or estuarine subtidal rock bottoms) and for which one can describe parameters such as bottom sediment type or vegetative density. These fishes most often associate with physiographic structure in the water column (features including oceanic fronts, river plumes, current boundaries, shelf edges, sea mounts, and temperature discontinuities, and the interactions of these); it is these features that must be characterized as habitat for the pelagic life stages of these species. Distribution of juveniles, adults, and especially early life stages (larvae for tunas and swordfish; neonates for sharks), may be constrained by tolerance of temperature, salinity or oxygen levels. These physicochemical properties may be used to define the boundaries of essential habitat in a broad sense. However, even when these parameters and tolerances are well understood and can be used to define the limits of a habitat, the distribution of these characteristics is not fixed in space or time, varying over seasons and years. Although the EFH regulations allow for inferring habitat between species with similar ecological niches, the basic lack of knowledge of the proximate factors that attract HMS to particular habitats precludes inference of EFH between these species at this time. By including a review of the ecological roles as predator and prey of the HMS, the amendment establishes a framework for using a broader ecosystem approach to evaluating habitat use and EFH requirements that will be pursued in future amendments.

The EFH regulations also require the identification of actions that might potentially impact EFH and conservation measures to mitigate these potential threats. Many of the threats occur in inshore or estuarine areas but have the potential to impact offshore habitats because of current patterns in the nearshore and on the continental shelf. The wide distribution of the HMS and their EFH requires that a broad approach to habitat protection be taken. Many of the sharks use estuarine and coastal waters, particularly for mating, pupping and neonate stages. Loss of these crucial habitats has been highlighted as a concern of shark researchers, who for many years have warned of concomitant declines in productivity.

Habitat protection is equally important for the pelagic life stages of the sharks, swordfish and tunas. In spite of the apparent distance of their prime habitats from shore, they are susceptible to adverse effects from inshore activities because their distributions are correlated with river plumes, current boundaries, canyons and convergence zones which either serve to transport or concentrate materials directly into offshore habitats. In addition various life stages of most of these species frequent coastal habitats. Threats to EFH from both fishing and non-fishing activities are treated in detail under Section 6.4.

6.3.1 Process Used for Identification of EFH for Tunas and Swordfish

There is evidence that certain areas serve important habitat functions for tunas and swordfish, either throughout the year or seasonally, such as spawning grounds. Although actual spawning has not been observed for many of these species, the presence of eggs and larvae is frequently used as a proxy for spawning areas. Therefore, the location of spawning grounds has only been defined in a very broad sense. It is not known what parameters, beyond some temperature boundaries, define these as appropriate spawning areas. Additionally, eggs and larvae of these species are some of the rarest collected, and the picture of spawning and distribution of eggs and larvae is far from complete. Larvae and juveniles have a rapid growth rate, and few specimens, especially of early juveniles, are ever collected. When larvae have been collected, their identification to species has proven to be very difficult and it must be assumed that many earlier identifications have been incorrect (W.J. Richards, per. comm.). In some cases even the identification of adults is problematic and therefore caution is required when interpreting data. It is clear that much more research is needed on spawning grounds, species identifications, and habitat requirements before areas of importance to tunas and swordfish can be more clearly delineated.

Under the Magnuson-Stevens Act, EFH includes areas necessary for feeding. Tunas and swordfish may exhibit different feeding characteristics in different parts of their ranges. While researchers have identified relative proportions of prey in their diets, it appears that they are opportunistic feeders able to exploit a large diversity of fishes, cephalopods and crustaceans. This precludes using the distributions of any major prey species as indicators of HMS EFH. Additional research into prey dynamics is necessary to gain a better under-standing of the importance of prey species to the tunas and swordfish. It is suggested that the tunas and swordfish associate with water column structure because it offers prime feeding opportunities; these structural habitats tend to coincide with areas of upwelling, convergence zones, and other hydrographic features. Much of the information on the distribution of tunas and swordfish suggests that the utilization of these feeding areas has a temporal or seasonal component that should be more fully explored and delineated in future research.

There are few additional guidelines that help refine EFH for these species. Some species appear to be primarily distributed above the thermocline or between certain isotherms; these temperature limits may define the outer boundaries of EFH for those species. As mentioned above, some species aggregate at frontal boundaries in the ocean, with floating objects (such as sargassum), or at bottom features such as the continental shelf break, submarine canyons, and even shipwrecks. Occasionally, the aggregations form where a front or boundary lies above one of these bottom features. These aggregations are most likely associated with prime feeding grounds and as such are identified as EFH.

Based on the available data or scientific knowledge, EFH for tunas and swordfish has been identified for each species. Life history stages have been combined into ecological groupings indicative of habitat use:

- "**Spawning, eggs and larvae**" largely depend on spawning locations and water motion to control their distributions. Spawning locations are identified based on published accounts that identify concentrations of spawning activity or extrapolate probable locations upcurrent of egg and larval distributions.
- "**Juveniles and subadults**" are swimming stages that show increased mobility patterns and develop transient lifestyles. Some fish in this size class are taken by targeted fishing and as bycatch.
- "**Adults**" are fish that are sexually mature; the size criterion is "those fish greater than or equal to the size at first maturation of females."

The current EFH descriptions and delineations for tunas and swordfish conform to the standards proposed by the NMFS regulations. Since the current status of the scientific knowledge of these species is such that habitat preferences are largely undefined or are difficult to determine, EFH is based on presence/absence and relative abundance data, as available. To the extent that environmental information is available, it has been included in the EFH descriptions. The most common factors included are temperature and salinity ranges, depths (isobaths), and association with particular water masses or currents. The textual accounts for each species serve as the legal description of EFH and where environmental characterizations are known, they have been included. Maps are provided as supplemental material to facilitate visualization of EFH locations. On the maps, shaded polygons have been drawn, based on analysis of the available data, marking the outer boundaries of EFH for each life stage. Locations, within the boundaries of EFH for a species' life stage, that do not meet the added environmental factors provided (e.g., salinity or temperature) are not considered EFH.

The life history accounts (Section 6.3.3) detail what is known about each species' life history, distribution and ecological roles as they relate to habitat use. Current status of the fishery is included since it may have implications in the current or historic range of the species. In general, the designations of EFH for tunas and swordfish as they currently stand are a combination of life history information, expert opinion regarding the importance of certain areas, and presence/absence and relative abundance information from fishery independent and dependent sources. It should be noted that much of the work on the basic ecology of these fishes is not recent; most is from the 1980s or before. Without more basic research on life history, habitat use, behavior and distribution of all life stages of tunas and swordfish, it will continue to be difficult to define EFH for these species.

6.3.2 Process used for identification of EFH for Atlantic Sharks

It is difficult to define the habitat of sharks of the temperate zone because most species are highly mobile or migratory, utilizing diverse habitats in apparently non-specific or poorly understood ways. Most migratory sharks traverse a variety of habitats in their movements. Generally, the migrations of sharks are poorly understood, and can be defined only in very broad terms. In addition, the different life stages[1] of a given shark species are often found in different habitats. In most cases, the neonate (newborn) and juveniles occupy different habitats from the adults. For example, neonate blacktip sharks are found in very shallow waters, juvenile blacktip sharks inhabit a variety of coastal habitats, and adults are found in both coastal and oceanic waters. There is little published information correlating life stages and migratory movements; and, there are few descriptions correlating shark habitat use to physical characteristics. Parameters that could describe shark habitat are: temperature, salinity, depth, dissolved oxygen, light levels, substrate, and food availability. There are probably other important factors or requirements that remain unknown.

Temperature is a primary factor affecting the migration and distribution of sharks. Thus, the movements of sharks in coastal waters of the temperate zone are usually correlated with seasonal changes in water temperature, as these animals attempt to remain within their temperature tolerance limits. Most of the coastal species of sharks undertake north-south migrations that coincide with the change of seasons.

Warm-water adapted species of sharks are found off Florida and in Caribbean waters in winter. They travel northward in spring, spending the summer in the warm waters of Georgia, the Carolinas, and Virginia. When the water temperature drops in mid-October, these species migrate southward again towards warmer waters. Cold-water adapted species spend their summer in the high latitudes off eastern Canada, and migrate southward in winter to areas off Virginia and North Carolina. Some species migrate seasonally from shallower waters in the summertime to deeper, more temperature-stable waters during winter. In addition, some sharks also perform diurnal (day-night) movements, either from deep water during daytime to shallow waters during the night, or from deep waters to surface waters. Some pelagic species may have very large home

[1]The life history of sharks is generally divided into four stages: embryo, neonate, juvenile, and adult (Castro, 1993b). The neonates are recently born young bearing fresh umbilical scars (in the case of placental sharks) or those at or near the birth size (in the case of aplacental sharks). Juveniles are all the post-neonatal individuals prior to sexual maturation. Adults are the sexually mature individuals of the population.

ranges; their movements may cover entire ocean basins and may be conducted over long time scales.

Since temperature is likely the most important factor in defining the habitat of sharks, it may be appropriate, in some cases, to define the habitat of a species of shark by the location of a given isotherm at a given time of the year. This may be applicable in the case of pelagic or migratory species but it is unlikely to be sufficient to describe the habitat of coastal species. Obviously, there are other factors that control the distribution of coastal species; however, less is known about them.

Salinity is another factor that may influence the distribution of sharks. However, salinity data is generally confusing in defining the habitat of coastal shark species. First, many coastal species inhabit estuaries where the salinity fluctuates widely, or where fresher water may overlay deeper, more saline waters (such as in highly stratified estuaries). Thus, the salinity data often depends on when or where it is measured, and such data may not accurately reflect the conditions where the sharks were encountered. Second, many of the coastal species have a wide salinity tolerance. For example, the Mote Marine Laboratory CSR data shows blacktip sharks have been captured in salinities ranging from 15.8 to 37.0 parts per thousand (ppt), and bull sharks in salinities ranging from 3.0 to 28.5 ppt sharks (bull sharks are known to enter fresh water and live in salt water of 36 ppt). Other factors must contribute significantly to the distribution of sharks, some likely parameters include light levels, pressure, substrate, dissolved oxygen, and probably others.

With the constraint of current knowledge, any generalizations on the habitat of a given coastal species can be made only on very broad terms. Given the lack of precise data to define the habitat characteristics of shark species in a specific yet consistent manner, a more practical approach may be to define the habitat by geographic location instead of by the physical parameters of the location. For example: neonate blacktip sharks have been reported in Bulls Bay, South Carolina, by Castro (1993b) and in Charlotte Harbor, Florida, by Hueter (CSR data). In South Carolina, the sharks are found over shallow muddy bottoms while in Florida, blacktip sharks are found over shallow, clear seagrass beds. In both cases the blacktip shark has been found over a wide range of temperatures and salinities. The habitats have not been sufficiently studied to allow us to find what the common parameters are, if there are any. Thus, based on these two studies, one can only say that blacktips have nurseries in Bulls Bay and in Charlotte Harbor; it is impossible to predict accurately why. This approach has been embraced in our approach of using spatial data in our analysis of EFH for Atlantic sharks, coupled with expert knowledge.

EFH has been identified for each shark species for which there was available data or scientific knowledge. Many of the dominant species of the fisheries display complex habitat use that varies with ontogenetic development. Although there is considerable controversy over the proper terminology and delineation of the various life stages of sharks, we have avoided that academic debate and grouped life stages into three classifications based on general shifts in habitat use. For the analysis we have used the large coastal sharks (LCS) and some of their habitat use characteristics as our model. As temperatures warm in the spring or summer, species such as blacktip and sandbar move north along the coast. Pups (neonates) are born in specific areas (e.g., estuaries or coastal habitats) and they typically remain in the same general area until the arrival of cooler temperatures in the late fall or early winter. At that time, they typically move offshore and/or southward, although the extent of these movements is not well defined. The following year, their seasonal movements change, more closely mimicking the migrations of the adults, until they actually join the adult migrations in subsequent years. For purposes of this amendment, we tried to capture these three variations in habitat use[2]. Our smallest size class "neonates and early juveniles" includes both the life stage traditionally defined as neonates (see footnote p. 6-61) and the animals that remain in the same or adjacent habitats throughout that first warm season. Assuming that birth of the pups could occur early in the season, and a late arrival of winter, the longest period for this initial habitat use might be 9-10 months. Size at one-year is a reasonable approximation of the size at which this habitat shift occurs. We have identified this upper boundary (length-at-age-1) for the smallest size of the various species (1) from published information; (2) from calculating size-at-age using the von Bertalanffy growth functions; or (3) by estimating the growth rate based on ecologically and biologically similar species for which (1) or (2) was available. The largest size class, "Adults," is intended to portray age at maturity and is based on the size at first maturity for females of the species. Frequently, in the literature the size-at-maturity criteria have not been specified and in those cases we have used the lengths as cited. The middle size range, "juveniles and subadults," is a cumulative group into which all life stages between age 1 and maturity have been lumped. This size class may frequently show the largest distribution based on their continued return to inshore habitats and their developing conformity to adult migration patterns. Additionally, we have identified "EFH Habitat Areas of Particular Concern (EFH-HAPC)" for some species where the data support the designation based on the criteria proposed in the EFH regulations. We have also found instances where tagging or fishery-dependent data have indicated large concentrations of a species in an area that conflicts with the available scientific information. In these cases we have identified "Research Areas" to encourage directed efforts to resolve the apparent conflicts. In many cases these may simply be species misidentifications but they may also represent areas that have not been systematically sampled in fishery independent research.

The current EFH descriptions and delineations for sharks conform to the standards proposed by the NMFS regulations. Since the current status of the scientific knowledge of these species is such that habitat preferences are largely undefined or are difficult to determine, EFH is based on presence/absence and relative abundance data, as available. To the extent that environmental information is available, it has been included in the EFH descriptions. The most common factors included are temperature and salinity ranges, depths (isobaths), seasons, and association with particular water masses or currents. The

[2]The suggestion has been, and is under consideration, to modify the names of the three size classes by using the following: 1) Pupping, neonates and young-of-the-year; 2) Juveniles; and 3) Adults. The final amendment may reflect this change in name.

textual accounts for each species serve as the legal description of EFH and where environmental characterizations are known, they have been included. Maps are provided as supplemental material facilitate visualization of EFH locations. On the maps, shaded polygons have been drawn, based on analysis of the available data, marking the outer boundaries of EFH for each life stage. Locations within the boundaries of EFH for a species' life stage that do not meet the added environmental factors (e.g., salinity or temperature) are not EFH.

The life history accounts (section 6.3.3) detail what is known about each species' life history, distribution and ecological roles as they relate to habitat use. Current status of the fishery is included since the current or historic range of the species may affect habitat use. "U.S. Fishery Status" is based on the most recent NMFS report to congress, required under the Magnuson-Stevens Act, "Status of Fisheries of the United States, September 1997." For some species inadequate information is currently available to evaluate species-specific stock status; in these species, stock status is derived from analysis of the management group, e.g., large coastal sharks. At this time, that is the best information available on stock status both for management of the species group and for analyzing species habitat use.

In general, the designations of EFH for sharks as they currently stand are a combination of life history information, expert opinion regarding the importance of certain areas, and a combination of presence/absence and relative abundance information from fishery independent and dependent sources analyzed using GIS technology. It should be noted that much of the work on the basic ecology of these fishes is on-going. Without more basic research on life history, habitat use, behavior and distribution of different life stages, it will continue to be difficult to refine EFH for these species.

6.3.3 Life History Accounts and Essential Fish Habitat Descriptions[3]

6.3.3.1 TUNAS

6.3.3.1.1 Atlantic Albacore (*Thunnus alalunga*)

Distribution: Albacore is a circumglobal species. In the western Atlantic albacore range from 40-45° N to 40° S latitude. It is an epipelagic, oceanic species found in surface waters in temperatures between 15.6° C and 19.4° C. Larger individuals have a larger depth and temperature range (13.5° C- 25.2° C). Albacore may dive into cold water (9.5° C) for short periods, and can be found at depths up to 600 m in the Atlantic. However, they do not tolerate oxygen levels lower than 2 ml/l. Albacore undergo extensive horizontal movements. Aggregations are composed of similarly sized individuals; groups comprised of the largest individuals make the longest journeys. Aggregations of albacore may include other tuna species, such as skipjack, yellowfin and bluefin tuna. North Atlantic and South Atlantic stocks are

[3] Supplemental materials referenced in these accounts may be found in Volume 2: Appendix 6 (Tables): Life History and Habitat Associations.; Appendix 7 (Figures): Essential Fish Habitat (EFH) Maps (by species and life stage).

considered separate, with no evidence of mixing between the two (ICCAT, 1997; Collette and Nauen, 1983).

Predator–prey relationships: A wide variety of fishes and invertebrates have been found in the few stomachs of Albacore tunas that have been examined. As with other tunas, albacore probably exhibit opportunistic feeding behavior, with little reliance on a specific prey item. (Dragovich, 1969; Matthews *et al.*, 1977).

Life history: Albacore spawn in the spring and summer in the western tropical Atlantic (ICCAT, 1997). Larvae are also taken in the Mediterranean Sea and historically in the Black Sea (Vodyanitsky and Kazanova, 1954).

Fisheries (U.S. Fishery Status - fully fished)**:** For assessment purposes, three stocks of albacore are assumed: northern and southern Atlantic stocks (separated at 5° N latitude) and a Mediterranean stock (SCRS, 1997). In the north Atlantic, albacore are taken by surface and longline fisheries. Surface fisheries target juveniles at 50 - 90 cm fork length, and longlines catch sub-adult and adult fish at 60 – 120 cm fork length.

Growth and mortality: The maximum size of albacore has been reported at 127 cm fork length (Collette and Nauen, 1983). For both sexes, sexual maturity is reached at five years at 90 - 94 cm fork length (ICCAT, 1997; Collette and Nauen, 1983). Mortality is higher for females (Collette and Nauen, 1983).

Habitat associations: Albacore tend to aggregate near temperature discontinuities and migrate within water masses; they do not seem to cross temperature and oxygen boundaries. Transition zones are preferred over upwelling areas, due to the low oxygen content of water in these particular areas (Collette and Nauen, 1983). Albacore schools may also be associated with floating objects, including *Sargassum* (Collette and Nauen, 1983). Habitat associations are summarized in Table 6.3-2.

Essential Fish Habitat (EFH) for Albacore Tuna (reference Fig. 6-2 a-c):

- **Spawning, eggs and larvae:** At this time, available information is insufficient for the identification of EFH for this life stage within the US EEZ.
- **Juveniles/Subadults (<90 cm FL):** In surface waters with temperatures between 15.6° C and 19.4° C, offshore of the US east coast in the Middle Atlantic Bight from the 50m isobath to the 2000m isobath with 71° W as the northeast boundary and 38° N as the southwestern boundary.
- **Adults (>90 cm FL):** In surface waters with temperatures between 13.5° C-25.2° C, offshore of United States eastern seaboard between the 100m and 2000m isobaths from southeastern Georges Bank at 41.25° N, south to 36.5° N, offshore of the VA-NC border; also, in the Blake Plateau and Spur region, from 79° W east to the US EEZ and 29°N south to the US EEZ.

6.3.3.1.2 Atlantic Bigeye Tuna (*Thunnus obesus*)

Distribution: Scientific knowledge of Atlantic bigeye tuna is limited. Its range is almost the entire Atlantic from 50° N to 45° S latitude. It is rarely taken in the Gulf of Mexico (W. J. Richards, pers. comm.). Its distribution with depth in the water column is varied; it is regularly found in deeper waters than other tunas - to a depth of 250 m. Smaller fish are probably restricted to the tropics, while larger individuals migrate to temperate waters. There is probably one population in the Atlantic (ICCAT, 1997). Young bigeye tuna form schools near the sea surface, mixing with other tunas such as yellowfin tuna and skipjack (Collette and Nauen, 1983).

Predator-prey relationships: The diet of bigeye tuna includes fishes, cephalopods and crustaceans (Dragovich, 1969; Matthews *et al.*, 1977). Predators include large billfish and toothed whales (Collette and Nauen, 1983).

Life history: Bigeye tuna probably spawn between 15° N and 15° S latitude. A nursery area is known to exist in the Gulf of Guinea (Richards, 1967) of the coast of Africa. Larvae have been collected offshore below the 25° C isotherm in that region (Richards and Simmons, 1971), where peak spawning occurs in January and February. In the northwestern tropical Atlantic spawning occurs in June and July (SCRS 1978/79). The collection of larvae in U.S. waters has not been confirmed (W. J. Richards, pers. comm.).

Fisheries (U.S. Fishery Status - approaching overfished)**:** The bigeye tuna stock has been exploited by three major gear types -- longline, baitboat, and purse seine -- and by many countries throughout its range of distribution. ICCAT currently recognizes one stock for management purposes, based on time-area distribution of fish and movements of tagged fish. However, other possibilities, such as northern and southern stocks, should not be disregarded (SCRS, 1997).

Growth and mortality: Growth rate for bigeye tuna is believed to be rapid. Sexual maturity is attained in the fourth year, at approximately 100 cm FL (fork length) (SCRS, 1997).

Habitat associations: Juvenile bigeye form schools near the surface mostly mixed with other tunas such as yellowfin and skipjack. These schools often associate with floating objects, whale sharks and sea mounts (SCRS, 1997). Habitat associations are summarized in Table 6.3.3.

<u>Essential Fish Habitat (EFH) for Bigeye Tuna (reference Fig. 6-3 a-c):</u>

- **Spawning, eggs and larvae:** At this time, available information is insufficient for the identification of EFH for this life stage within the U.S. EEZ; although it can not be identified as EFH under the Magnuson-Stevens Act because it is outside the U.S. EEZ, the Gulf of Guinea, off the coast of Africa, is identified as important habitat for spawning adults, eggs and larvae.
- **Juveniles/Subadults (<100 cm FL):** In surface waters from southeast Georges Bank at the boundary of the EEZ to Cape Hatteras at 35° N from the 200 m isobath to the EEZ; also, in the Blake Plateau region off Cape Canaveral, FL, from 29° N south to the EEZ (28.25° N) and from 79° W east to the EEZ (~76.75° W).
- **Adults (100 cm FL):** In pelagic waters from the surface down to 250 meters deep: from southeastern Georges Bank at the EEZ boundary to offshore of Delaware Bay at 38° N, from the 100 m isobath to the EEZ; from offshore of Delaware Bay south to Cape Lookout, NC (~35° N), between the 100m and 2000 m isobaths; also, in the Blake Plateau region off Cape Canaveral, FL, from 29° N south to the EEZ (28.25° N) and from 79° W east to the EEZ (76.75° W).

<u>6.3.3.1.3 Atlantic Bluefin Tuna (*Thunnus thynnus*)</u>

Distribution: In the western north Atlantic, Bluefin tunas range from 45° N to 0° (Collette and Nauen, 1983). However, they have recently been found to up to 55° N in the western Atlantic (Vinnichenko, 1996). Bluefin tuna move seasonally from spring (May and June) spawning grounds in the Gulf of Mexico, through the Straits of Florida, to feeding grounds off the northeastern U.S. coast (Mather *et al.*, 1995). It is believed that there is a single stock which ranges from Labrador and Newfoundland south into the Gulf of Mexico and the Caribbean, and also off Venezuela and Brazil. The Labrador Current may separate this western stock from that found in the eastern Atlantic (ICCAT, 1997; Mather *et al.*, 1995; Tiews, 1963).

From November to January, bluefin tuna are concentrated in one of two groups, in either the northwestern or northcentral Atlantic. In February, the central Atlantic aggregation breaks up, with some fish moving southeast to the Azores and some moving southwest (Suda, 1994). Southerly movements from the feeding grounds off the northern U.S. and wintering areas are not well understood. A three-way movement between spawning, feeding and wintering areas is assumed for mature fish, as is a shorter, two-way feeding-to-wintering movement for juveniles (Mather *et al.*, 1995).

Bluefin tuna distributions are probably constrained by the 12° C isotherm, though individuals can dive into 6-8° C waters to feed (Tiews, 1963). Year-to-year variations in movements have been noted (Mather *et al.*, 1995). While bluefin tuna are epipelagic and usually oceanic, they do come close to shore seasonally (Collette and Nauen, 1983). They often occur over the continental shelf and in embayments, especially during the summer months when they feed actively on herring, mackerel and squids in the north Atlantic (Houde, pers. com.). Larger individuals move into higher latitudes than smaller fish. Bluefin tunas are often found in mixed schools with skipjack tuna, these schools consisting of similarly sized individuals (Tiews, 1963).

Predator-prey relationships: Bluefin tuna larvae are initially zooplanktivorous but switch to a piscivorous diet at a relatively small size. Small larvae prey on other larval fish and are subject to the same predators as other larval fishes, primarily larger fishes and gelatinous zooplankton (McGowan and Richards, 1989). Adults consume squids, pelagic crustaceans, and schooling fishes such as anchovies, sauries and hakes depending on seasonal prey availability (Collette and Nauen, 1983; Dragovich, 1969, 1970a; Mathews *et al.*, 1977). Predators of adult bluefin tuna include toothed whales, swordfish, sharks and other tunas (especially of smaller individuals) (Tiews, 1963; Chase, 1992).

Life history: Western north Atlantic bluefin tuna spawn from mid-April to mid-June in the Gulf of Mexico and in the Florida Straits (McGowan and Richards, 1989). Though individuals may spawn more than once a year, it is assumed that there is a single annual spawning period. Larvae have been confirmed from the Gulf of Mexico and off the Carolinas (Richards, 1991). Most of the larvae found were located around the 1000 fathom curve in the northern Gulf of Mexico, with some sporadic collections off Texas. In the Florida Straits they are primarily collected along the western edge of the Florida Current, suggesting active transport from the Gulf of Mexico. This would also explain their occasional collection off the southeastern U.S. Atlantic bluefin tuna have never been observed spawning (Richards, 1991)

It is not believed that much spawning occurs outside of the Gulf of Mexico (Richards, 1991; McGowan and Richards, 1989) Also, it appears that larvae are mostly retained in the Gulf until they grow into juveniles; in June, young of the year begin movements in schools to juvenile habitats (McGowan and Richards, 1989). Juveniles are thought to be located over the continental shelf around 34° N latitude and 41° W longitude in the summer and offshore of that area in winter. Also, they have been identified from the Dry Tortugas area in June and July (ICCAT, 1997; Richards, 1991). Juveniles migrate to nursery areas between Cape Hatteras and Cape Cod (Mather, Mason and Jones, 1995).

Fisheries (U.S. Fishery Status: Overfished)**:** Atlantic bluefin tuna are caught using a wide variety of gear types, including longlines, purse seines, traps, and various handgear. ICCAT recognizes two management units of Atlantic bluefin, one in the eastern and one in the western Atlantic, however, some mixing is probably occurring, as fish tagged in one location have been retrieved in the other. These management units are divided as follows: North of 10° N latitude they are separated at 45° W longitude; below the equator they are separated at 25° W longitude, with an eastward shift between those parallels (SCRS, 1997). The effects of reduced stock size on distribution and habitat use is unknown at this time.

Growth and mortality: Bluefin tuna can grow to more than 650 kg in weight and 300 cm in length. There does not appear to be a difference between growth rates of males and females (Mather et al, 1995). Maximum age is estimated to be more than 20 years. Bluefin tuna reach sexual maturity at approximately 196 cm (77 in) FL, weighing around 145 kg (320 lbs). This size are believed to be reached in the western Atlantic at eight years as opposed to five years in the eastern Atlantic. Not only do bluefin tuna in the western Atlantic mature more slowly than bluefin in the eastern Atlantic, but they also are believed to grow more slowly and reach a larger maximum size (SCRS, 1997). The rapid larvae growth rate is estimated as 1 mm/day up to 15 mm, the size at transformation (McGowan and Richards, 1989).

Habitat associations: It is believed that there are probably certain features of the bluefin tuna larval habitat in the Gulf of Mexico which determine growth and survival rates, and that these features show variability from year to year and may account for a significant portion of the fluctuation in yearly recruitment success (McGowan and Richards, 1989). The habitat requirements for larval success are not known, but larvae are collected within narrow ranges of temperature and salinity - approximately 26° C and 36 ppt. Along the coast of the southeastern U.S., onshore meanders of the Gulf Stream can produce upwelling of nutrient rich water along the shelf edge. In addition, compression of the isotherms on the edge of the Gulf Stream can form a stable region which, together with the upwelled nutrients, provides an area favorable to maximum growth and retention of food for the larvae (McGowan and Richards, 1989). Size classes used for habitat analysis for the bluefin tuna are based on the sizes at which they shift from a schooling behavior to a more solitary existence. Bluefin have traditionally been grouped by "small schooling," "large schooling," "giant," etc. Future analyses should more fully evaluate habitat differences between the traditional size classes if the data are available. Habitat associations are summarized in Table 6.3.4.

Essential Fish Habitat for Atlantic Bluefin Tuna (reference Fig. 6-4 a-d):

- **Spawning, eggs and larvae:** In pelagic and near coastal surface waters from the NC-SC border at 33.5 ° N, south to Cape Canaveral from 15 miles from shore to the 200 m isobath; all waters from offshore Cape Canaveral, Fl at 28.25° N south around peninsular Florida to the US/Mexico border from 15 miles from shore to the EEZ.
- **Juveniles/Subadults (<145 cm TL):** All inshore and pelagic surface waters warmer than 12°C of the Gulf of Maine and Cape Cod Bay from Cape Ann (~42.75°N), east to 69.75°W, (including waters of the Great South Channel west

of 69.75°W); continuing south to and including Nantucket Shoals at 70.5 °W to off of Cape Hatteras (~ 35.5 °N), in pelagic surface waters warmer than 12°C, between the 25m and 200m isobaths; also in the Florida Straits, from 27°N south around peninsular Florida to 81°W in surface waters from the 200m isobath to the EEZ.

- **Adults (>145 cm TL):** In pelagic waters of the Gulf of Maine from the 50m isobath to the EEZ, including the Great South Channel, then south of Georges Bank to 39°N from the 50 m isobath to the EEZ; also, south of 39°N, from the 50m isobath to the 2000m isobath to offshore of Cape Lookout, NC at 34.5° N. In pelagic waters from offshore Daytona Beach, FL (29.5 ° N) south to Key West (82°W) from the 100 m isobath to the EEZ; in the Gulf from offshore Terrebonne Parish, LA (90° W) to offshore Galveston, TX (95° W) from the 200 m to the EEZ.

6.3.3.1.4 Atlantic Skipjack (*Katsuwonus pelamis*)

Distribution: Skipjack are circumglobal in tropical and warm-temperate waters, generally limited by the 15° C isotherm. In the western Atlantic skipjack range as far north as Newfoundland (Vinnichenko, 1996) and as far south as Brazil (Collette and Nauen, 1983). Skipjack are an epipelagic and oceanic species and may dive to a depth of 260 m during the day. Skipjack is also a schooling species, forming aggregations associated with hydrographic fronts (Collette and Nauen, 1983). There has been no trans-Atlantic recovery of tags; eastern and western stocks are considered separate (ICCAT, 1997).

Predator-prey relationships: Skipjack is an opportunistic species which preys upon fishes, cephalopods and crustaceans (Dragovich, 1969, 1970b; Dragovich and Potthoff, 1972; ICCAT, 1997, Collette and Nauen, 1983). Predators include other tunas and billfishes (Collette and Nauen, 1983). Skipjack are believed to feed in surface waters down to a depth of five meters. Stomach contents often include sargassum or sargassum associated species (Morgan *et al.*, 1985).

Life history: Skipjack spawn opportunistically in equatorial waters throughout the year, and in subtropical waters from spring to early fall (Collette and Nauen, 1983). Larvae have been collected off the eastern coast of Florida from October to December (Far Seas Fisher. Res. Lab., 1978), and in the Gulf of Mexico and Florida Straits from June to October (Houde, pers. comm.). However, most spawning takes place during summer months in the Caribbean, off Brazil (with the peak in January through March), in the Gulf of Mexico (April to May), and in the Gulf of Guinea (throughout the year) (SCRS, 1978/79; Richards, 1967).

Fisheries (US Fishery Status - fully fished)**:** This fishery is almost exclusively a surface gear fishery, although some skipjack are taken as longline bycatch. Most skipjack are taken in the eastern Atlantic and off the coast of Brazil, most recently with the use of floating objects to attract them.

Growth and mortality: Maximum size of the species is reported at 108 cm fork length and a weight of 34.5 kg. Size at sexual maturity is 45 cm (18 in.) for males and 42 cm for females. This size is believed to correspond to about 1-1.5 yrs of age, although significant variability in interannual growth rates make size-to-age relationships difficult to estimate (ICCAT, 1997; Collette and Nauen, 1983). Growth rate is variable and seasonal, with individuals from the tropical zone having a higher growth rate than those from the equatorial area (SCRS, 1997). Life span is estimated to be 8-12 years (Collette and Nauen, 1983).

Habitat associations: Aggregations of skipjack are associated with convergences and other hydrographic discontinuities. Also, skipjack associate with birds, drifting objects, whales, sharks and other tuna species (Colette and Nauen, 1983). The optimum temperature for the species is 27° C, with a range from 20° C to 31° C (ICCAT, 1995). Habitat associations are summarized in Table 6.3.5.

Essential Fish Habitat (EFH) for Skipjack Tuna (reference Fig. 6-5 a-d):

- **Spawning, eggs and larvae:** In offshore waters, from the 200m isobath out to the US EEZ, from 28.25° N south around peninsular Florida and the Gulf Coast to the US/Mexico border.
- **Juveniles/subadults (<45 cm FL):** In pelagic surface waters from 20°C- 31°C in the Florida Straights off southeastern Florida, from the 25m isobath to the 200m isobath from 27.25°N south to 24.75° N southwest of the coast of Key Largo.
- **Adults (> 45 cm FL):** In pelagic surface waters from 20°C- 31°C in the Middle Atlantic Bight, from the 25 meter isobath to the 200m isobath, from 71°W, off the coast of Martha's Vineyard, south and west to 35.5° N, offshore of Oregon Inlet, NC.

6.3.3.1.5 Atlantic Yellowfin Tuna (*Thunnus albacares*)

Distribution: Atlantic yellowfin tuna are circumglobal in tropical and temperate waters. In the western Atlantic they range from 45° N to 40° S latitude. Yellowfin tuna is an epipelagic, oceanic species, found between 18° C and 31° C. It is a schooling species, with juveniles found in schools at the surface mixing with skipjack and bigeye tunas. Larger fish are found in deeper water and also extend their ranges into higher latitudes. All individuals in the Atlantic probably comprise a single population, but movement patterns are not well known (SCRS, 1997; Collette and Nauen, 1983). There are possible movements of fish spawned in the Gulf of Guinea to more coastal waters off Africa, followed by movements toward the U.S. coast, when they reach a length of 60-80 cm (ICCAT, 1977). In the Gulf of Mexico yellowfin tuna occur beyond the 500 fathom isobath (Idyll and de Sylva, 1963).

Predator-prey relationships: Atlantic yellowfin tuna are opportunistic feeders. Stomachs contain a wide variety of fish and invertebrates (Dragovich, 1969, 1970b; Dragovich and Potthoff, 1972; Matthews *et al.*, 1977). Stomach contents of yellowfin from St. Lucia and the Caribbean have been found to contain squid and the larvae of stomatopods, crabs and squirrelfish (Idyll and de Sylva, 1963). Stomach contents often contain sargassum or sargassum associated fauna. Yellowfin tuna are believed to feed primarily in surface waters down to a depth of 100 m (Morgan *et al.*, 1985).

Life history: Spawning occurs throughout the year in the core areas of the species' distribution - between 15° N and 15° S latitude - and also in the Gulf of Mexico and the Caribbean, with peaks occurring in the summer (ICCAT, 1994; Richards, pers. comm.). Yellowfin tuna are believed to be multiple spawners (Houde, pers. comm.), and larval distribution appears to be limited to water temperatures above 24° C and salinity greater than 33 ppt (Richards and Simmons, 1971). Larvae have been collected near the Yucatan peninsula, and during September in the northern Gulf of Mexico along the Mississippi Delta (ICCAT, 1994).

Fisheries (U.S. Fishery Status - fully fished)**:** Yellowfin are caught by surface gears (purse seine, baitboat, troll, and handline) and with sub-surface gears (longline). A single stock is assumed for the Atlantic, based on transatlantic tag recaptures, time-area size frequency distribution, etc. (SCRS, 1997).

Growth and mortality: The maximum size of yellowfin tuna is over 200 cm FL (Collette and Nauen, 1983). Sexual maturity is reached after at about three years of age, 110 cm FL and 25 kg. It is not known if there is a differential growth rate between males and females (ICCAT, 1994), but males are predominant in catches of larger sized fish (SCRS, 1997). Natural mortality is 0.8 for fish less than 65 cm in length, and 0.6 for fish greater than 65 cm. Mortality is higher for females of this size (ICCAT, 1994).

Habitat associations: Adult yellowfin tuna are confined to the upper 100 m of the water column due to their intolerance of oxygen concentrations less than 2 ml /l (Collette and Nauen, 1983). Association with floating objects has been observed, and in the Pacific, larger individuals often school with porpoises (Collette and Nauen, 1983). Juveniles are found nearer to shore than are adults (SCRS, 1994). In the Gulf of Mexico adults usually occur 75 km or more offshore, while in the Caribbean they are found closer to shore. Although there appears to be a year-round population in the southern part of the Gulf of Mexico (Idyll and de Sylva, 1963), in June there appears to be some movement from this region to the northern part, resulting in greater catches there from July to December. Habitat associations are summarized in Table 6.3.6.

Essential Fish Habitat (EFH) for Yellowfin Tuna (reference Fig. 6-6 a-d):

- **Spawning, eggs and larvae:** In offshore waters, from the 200m isobath out to the US EEZ, from 28.25° N south around peninsular Florida and the Gulf Coast to the US/Mexico border, especially associated with the Mississippi River plume and the Loop Current. Also, all US waters in the Caribbean Sea from the 200m isobath to the EEZ.
- **Juveniles/subadults (<110 cm FL):** Pelagic waters from the surface to up to100m deep between 18°C and 31°C from offshore of Cape Cod (70° W) southward to Jekyll Island, GA (31° N), between 500m and 2000 m; off Cape Canaveral from 29° N south to the EEZ (~ 28.25° N) and from 79° W east to the EEZ (~76.75° W); in the Gulf of Mexico from the 200 m isobath to the EEZ.
- **Adults (> 110 cm FL):** (Identical to juveniles/subadults EFH): Pelagic waters from the surface to up to100m deep between 18°C and 31°C from offshore of Cape Cod (70° W) southward to Jekyll Island, GA (31° N), between 500m and 2000 m; off Cape Canaveral from 29° N south to the EEZ (~ 28.25° N) and from 79° W east to the EEZ (~76.75° W); in the Gulf of Mexico from the 200 m isobath to the EEZ.

6.3.3.2 SWORDFISH (*Xiphias gladius*)

Distribution: Swordfish are circumglobal, ranging through tropical, temperate and sometimes cold water regions. Their latitudinal range is from 50° N to 40-45°S in the western

Atlantic, and 60° N to 45-50° S in the eastern Atlantic (Nakamura, 1985). The species moves from spawning grounds in warm waters to feeding grounds in colder waters. In the western north Atlantic two movement patterns are apparent: some fish move northeast-ward along the edge of the U.S. continental shelf in summer, and return southwest-ward in autumn; another group moves from deep water westward toward the continental shelf in summer, and back into deep water in autumn (Palko *et al.*, 1981). Swordfish are epipelagic to mesopelagic, and are usually found in waters warmer than 13° C. Their optimum temperature range is believed to be 18° - 22° C but they will dive into 5° - 10°C water at depths of up to 650 m (Nakamura, 1985). Swordfish migrate diurnally, coming to the surface at night (Palko *et al.*,1981). Carey (1990, in Arocha, 1997) observed different diel migrations in two groups of fish: swordfish in neritic (shallow, near-coastal) waters of the northwestern Atlantic were found in bottom waters during the day and moved to offshore surface waters at night. Swordfish in oceanic waters migrated vertically from a daytime depth of 500 m to 90 m at night.

Predator-prey relationships: Adult swordfish are opportunistic feeders, having no specific prey requirements. They feed at the bottom as well as at the surface, in both shallow and deep waters. In waters greater than 200 m in depth they feed primarily on pelagic fishes including small tunas, dolphinfishes, lancetfish (Alepisaurus), snake mackerel (Gempylus), flyingfishes, barracudas and squids such as Ommastrephes, Loligo, and Illex. In shallow water they prey upon neritic fishes, including mackerels, herrings, anchovies, sardines, sauries, and needlefishes. In deep water swordfish may also take demersal fishes such as hakes, pomfrets (Bromidae), snake mackerels, cutlass fish (trichiurids), lightfishes (Gonostomatidae), hatchet fishes (Sternoptychidae), redfish, lanternfishes, and cuttlefishes (Nakamura, 1985).

In the Gulf of Mexico swordfish were found to feed primarily on cephalopods (90 percent of stomach contents consisted of 13 species of teuthoid squids, of which most were Illex, and two species of octopus) (Toll and Hess, 1981). Stillwell and Kohler (1985) found that 80 percent of the stomach contents of swordfish taken off the northeast coast of the U.S. consisted of cephalopods, of which short-finned squid (Illex illecebrosus) made up 26.4 percent. Adult swordfish in neritic waters will feed inshore near the bottom during the daytime, and head seaward to feed on cephalopods at night. The movement of larger individuals into higher latitudes in the summer and fall may be in part to allow those individuals access to high concentrations of Illex (Arocha, 1997). Predators of adult swordfish are probably restricted to sperm whales (*Physeter catodon*), killer whales (*Orcinus orca*) and large sharks such as mako (*Isurus* spp).

Typically, swordfish larvae less than 9.0 mm in length consume small zooplankton, those 9.0-14.0 mm feed on mysids, phyllopods and amphipods, and at sizes greater than 21 mm they begin to feed on the larvae of other fishes. Juveniles feed on squids, fishes and some pelagic crustaceans (Palko *et al.*, 1981). Larvae are preyed upon by other fishes, and juveniles fall prey to predatory fishes, including sharks, tunas, billfishes, and adult swordfish (Palko *et al.*, 1981).

Life history: First spawning for north Atlantic swordfish occurs at 4 - 5 years of age (74kg) in females. Fifty percent (50 %) maturity in females is reached at 179-182 cm LJFL, and in males at 112-129 cm LJFL (21 kg) at approximately 1.4 yrs (Arocha, 1997; Nakamura, 1985; Palko *et al.*, 1981). Most spawning takes place in waters with surface temperatures above 20° - 22° C, between 15° N and 35° N latitude (Arocha, 1997; Palko *et al.*, 1981). In the western north Atlantic, spawning occurs in distinct locations at different times of the year: south of the Sargasso Sea and in the upper Caribbean from December to March, and off the southeast coast of the U.S. from April through August (Arocha, 1997). Major spawning grounds are probably located in the Straits of Yucatan and the Straits of Florida (Grall *et al.*, 1983). Larvae have been found in largest abundance from the Straits of Florida to Cape Hatteras, and around the Virgin Islands. Larvae are associated with surface temperatures between 24° and 29° C. The Gulf of Mexico is believed to serve as a nursery area (Palko *et al.*, 1981). Grall *et al.* (1983) found larvae 10 mm and larger to be abundant in the Caribbean, Straits of Florida and the Gulf Stream north of Florida from December to February. In the western Gulf of Mexico, large larvae were found from March to May and from September to November; many larvae of all sizes were collected in the Caribbean and were also present year-round in the eastern Gulf of Mexico, Straits of Florida and the Gulf Stream. Juvenile fish are frequently caught in the pelagic longline fishery in the Gulf of Mexico, the Atlantic coast of Florida, and near the Charleston Bump, regions that may serve as nurseries for north Atlantic swordfish (Cramer and Scott, 1998).

Fisheries (U.S. Fishery Status-Overfished)**:** Swordfish in the Atlantic are taken by a directed longline fishery and as bycatch of the tuna longline fishery. There are also seasonal harpooning and gillnetting efforts off Nova Scotia (harpooning) and off the northeast U.S. coast and Grand Banks (gillnettting) (Arocha, 1997). The effect that this reduction in stock size has on habitat use and species distributions is unknown.

Growth and mortality: Swordfish reach a maximum length of 445 cm TL (total length) and a maximum weight of 540 kg. Males and females have different growth rates, with females longer and heavier at any given age (Nakamura, 1985). Natural mortality rate was estimated at 0.21 – 0.43 by Palko *et al.* (1981), but ICCAT presently uses an estimate of 0.2 (Arocha, 1997). Berkeley and Houde (1981) found a higher growth rate for females than males over two years old, and also found males to have a higher mortality rate than females.

Habitat associations: In the winter in the north Atlantic, swordfish are restricted to the warmer waters of the Gulf Stream, while in the summer their distribution covers a larger area. Distribution is size and temperature related, with few fish under 90 kg found in waters of temperatures less than 18° C. Larvae are restricted to a narrow surface temperature range, and are distributed throughout the Gulf of Mexico, in areas of the Caribbean, and along the coast of the U.S. in the Gulf Stream as far north as Cape Hatteras. Concentrations of adult swordfish seem to occur at ocean fronts between water masses associated with boundary currents, including the Gulf Stream and Loop Current of the Gulf of Mexico (Arocha, 1997). Habitat associations are summarized in Table 6.3.7.

Essential Fish Habitat for Atlantic Swordfish (reference Fig. 6-7 a-d):

- **Spawning, eggs and larvae:** from offshore Cape Hatteras (~35° N) extending south around peninsular Florida through the Gulf of Mexico to the US/Mexico border from the 200 m isobath to the EEZ; associated with the Loop current boundaries in the Gulf and the western edge of the Gulf Stream in the Atlantic; also, all US waters of the Caribbean Sea from the 200m isobath to the EEZ.
- **Juveniles/subadults (180 LJFL):** In pelagic waters warmer than 18°C from the surface to 500m, from offshore of Manasquan Inlet, NJ at 40°N, east to 73°N, and south to the waters off Georgia at 31.5°N, between the 25m and 2000m isobaths; offshore Cape Canaveral (~29° N) extending from the 100 m isobath to the EEZ (south and east) around peninsular Florida; in the Gulf of Mexico from Key West to offshore Galveston (95° W) from the 200 m isobath to the EEZ with

the exception of between 86° W and 88.5° W where the seaward boundary of EFH is the 2000 m isobath.

- **Adults (>180 LJFL):** In pelagic waters warmer than 13°C from the surface to up to 500m deep, offshore of the US East and Gulf coast from the intersection of the 100 m isobath and the EEZ southeast of Cape Cod to south and offshore of Biscayne Bay at 25.5 °N, from the 100 m isobath to the 2000 m isobath or the EEZ , which ever is closer to land; from offshore of Tampa Bay at 85° N to offshore Mobile Bay at 88° N between 200 and 2000 m; from offshore south of the Mississippi delta 89° N to offshore waters south of Galveston, TX 95° N from the 200 m isobath to the EEZ.

6.3.3.3 LARGE COASTAL SHARKS [4] (U.S. Fishery Status: overfished.)

6.3.3.3.1 Basking Sharks

Basking shark (*Cetorhinus maximus*). The basking shark is the second largest fish in the world, its size exceeded only by the whale shark. Like the whale shark, it is a filter-feeding plankton eater. It is a migratory species of the subpolar and cold temperate seas throughout the world. It spends the summer in high latitudes, moving into warmer water in winter (Castro 1983). In spite of its size and local abundance in summer, its habits are very poorly known. Sims and Quayle (1998) have shown that basking sharks forage along thermal fronts and seek the highest densities of zooplankton. During the European autumn, basking sharks disappear and are not seen until the following summer, when they return after giving birth. Habitat associations are summarized in Table 6.3.8.

Reproductive potential: Little is known about basking shark reproductive processes. Males are believed to reach maturity between 460 and 610 cm (Bigelow and Schroeder 1948) and an estimated age of 4-5 years (Parker and Stott 1965). These age estimates have not been validated. Females mature at 810-980 cm (Compagno 1984). It is believed that female basking sharks give birth to young measuring about 180 cm TL, probably in high latitudes. There are no modern reports on the size of litters nor data on reproductive cycles.

Impact of fisheries: Fishing for the basking shark is prohibited in U.S. waters, although basking sharks are common off the east coast in winter.

Essential Fish Habitat for Basking Shark (reference Fig. 6-8 a-c):

- **Neonate/early juveniles (270 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Late juveniles/subadults (271-810 cm TL):** Offshore of Mid-Atlantic US south of Nantucket Shoals at 70°W to North edge of Cape Hatteras at 35.5° N in

[4] The majority of the information included in this and the follow sections of shark life histories provided by Dr. José I. Castro from the following publication: Castro, Jose I, Christa M. Woodley, and Rebecca L. Brudek. Status of shark species. unpublished manuscript to be published by FAO in 1999. 89 pp. Additional information has been added or modified in this chapter as appropriate to meet the objectives of this FMP.

waters from 50m to 200m deep; associated with boundary conditions created by the western edge of the Gulf Stream.

• **Adults (810 cm TL):** Offshore of southern New England, west of Nantucket Shoals at 70° W to Montauk, Long Island at 72° W, out to the continental shelf in waters 50m to 200m deep, where water column physical conditions create high abundances of zooplankton.

6.3.3.3.2 Hammerhead Sharks

Great hammerhead (*Sphyrna mokarran*). This is a large shark found both in open oceans and shallow coastal waters. It is circumtropical in warm waters (Castro 1983). It is one of the largest sharks. It is usually a solitary fish, unlike the more common scalloped hammerhead that often forms very large schools. Habitat associations are summarized in Table 6.3.9.

Reproductive potential: In Australian waters, males mature at about 210-258 cm TL and females mature usually at 210-220 cm TL (Stevens and Lyle 1989). Pups measure about 67 cm TL at birth (Stevens and Lyle 1989) and litters consist of 20-40 pups (Castro 1983). The gestation period lasts about 11 months (Stevens and Lyle 1989). The reproductive cycle is biennial (Stevens and Lyle 1989). There are few reports and little data on its nurseries. Hueter (CSR data) found small juveniles from Yankeetown to Charlotte Harbor from May to October at temperature of 23.9-28.9°C, and salinities of 21.9 –34.2 ppt.

Impact of fisheries: Great hammerheads are caught in coastal longline shark fisheries as well as in pelagic tuna and swordfish longlines. Its fins bring the highest prices in the fin market. In many fishing operations, the fins are removed while the carcasses are discarded at sea, although finning is prohibited in the Atlantic. The great hammerhead is vulnerable to overfishing because its biennial reproductive cycle, and because it is caught both in directed fisheries and as bycatch in tuna and swordfish fisheries.

Essential Fish Habitat for Great Hammerhead (reference Fig. 6-9 a-c):

• **Neonate/early juveniles (70 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Late juveniles/subadults (71-220 cm TL):** Off the Florida coast, all shallow coastal waters out to the 100m isobath from 30 °N south around peninsular Florida to 82.5° W, including Florida Bay and adjacent waters east of 81.5° W (north of 25° N), and east of 82.5W (south of 25° N)

• **Adults (221 cm TL):** Off the entire east Florida coast, all shallow coastal waters out to the 100m isobath, south of 30°N, including the West Coast of Florida to 85.5° W.

Scalloped hammerhead (*Sphyrna lewini*). This is a very common, large, schooling hammerhead of warm waters. It is the most common hammerhead in the tropics and is readily available in abundance to inshore artisanal and small commercial fisheries as well as offshore operations (Compagno 1984). It migrates seasonally north-south along the eastern United States. Habitat associations are summarized in Table 6.3.10.

Reproductive potential: Males in the Atlantic mature at about 180-185 cm TL (Bigelow and Schroeder 1948) and in the Indian Ocean at 140-165 cm TL (Bass *et al.* 1973). Females mature at about 200 cm TL (Stevens and Lyle 1989). The young are born at 38-45 cm TL, and litters consist of 15-31 pups (Compagno 1984). The reproductive cycle is annual (Castro 1993b) and the gestation period is 9-10 months (Stevens and Lyle 1989). Castro (1993b) found nurseries in the shallow coastal waters of South Carolina. Hueter (CSR data) found small juveniles from Yankeetown to Charlotte Harbor in the West Coast of Florida, in temperatures of 23.2-30.2 °C, salinities of 27.6-36.3 ppt, and DO of 5.1-5.5 ml/l.

Impact of fisheries: Because the scalloped hammerhead forms very large schools in coastal areas, it is targeted by many fisheries for their high priced fins. Castro *et al.*,(in prep.) consider the scalloped hammerhead vulnerable to overfishing, because its schooling habit makes it extremely vulnerable to gillnet fisheries, and because scalloped hammerheads are actively pursued in many fisheries throughout the world.

Essential Fish Habitat for Scalloped Hammerhead (reference Fig. 6-10 a-e):

- **Neonate/early juveniles (45 cm TL):** Shallow coastal waters of the South Atlantic Bight, off the coast of South Carolina, Georgia, and Florida, west of 79.5° W and north of 30°N, from the shoreline out to 25 miles offshore.
- **Late juveniles/subadults (46-249 cm TL):** All shallow coastal waters of the US Atlantic seaboard from the ocean shoreline to the 200m isobath from 39° N, south to the vicinity of the Dry Tortugas and the Florida Keys at 82° W; also, in the Gulf of Mexico, in the area of Mobile Bay and Gulf Islands National Seashore, all shallow coastal waters from the shoreline out to the 50m isobath
- **Adults (250cm TL):** In the South Atlantic Bight from the 25m to the 200m isobaths from 36.5° N to 33°N, then continuing south from the 50m isobath offshore to the 200m isobath to 30° N, then from the 25m isobath to the 200m isobath from 30°N south to 28°N; also, in the Florida Straights between the 25m and 200m isobaths, from 81.5 °W west to 82.25 °W in the vicinity of Key West and the Dry Tortugas.
- **Research Area (unsubstantiated data):** On the West Coast of Florida, from Charlotte Harbor to Yankeetown, from the shoreline to 25 miles offshore, including estuarine waters of Tampa Bay and other local estuaries.

Smooth hammerhead (*Sphyrna zygaena*). This is an uncommon hammerhead of temperate waters. Fisheries data for hammerheads includes this species and the scalloped and great hammerheads. There is little data specific to the species. Habitat associations are summarized in Table 6.3.11.

Essential Fish Habitat for Smooth hammerhead (reference Fig. 6-11a):

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.3.3 Mackerel Sharks

White shark (*Carcharodon carcharias*). The white shark is the largest of the lamnid, or mackerel, sharks. It is a poorly known apex predator found throughout temperate, subtropical and tropical waters. Its presence is usually sporadic throughout its range, although there are a few localities (off California, Australia, and South Africa) where it is seasonally common. Large adults prey on seals and sealions, and are sometimes found around their rookeries. The white shark is also a scavenger of large dead whales. It has been described as the most voracious of the fish-like vertebrates and has been known to attack bathers, divers, and even boats. Habitat associations are summarized in Table 6.3.12.

Reproductive potential: Very little is known of its reproductive processes, because only two gravid females have been examined by biologists in modern times. Both specimens contained seven embryos. Recent observations show that white sharks carry 7-10 embryos that are born at 120-150 cm TL (Uchida *et al.* 1996, Francis 1996). The lengths of the reproductive and gestation cycles are unknown. White sharks are believed to mature between 370 and 430 cm at an estimated age of 9-10 years (Cailliet *et al.* 1985). Cailliet *et al.* (1985) estimated growth rates of 25.0-30.0 cm/yr for juveniles and 21.8 cm/yr for older specimens, and gave the following von Bertalanffy parameters: n= 21, L = 763.7 cm, K= 0.058, t_o= -3.53. They estimated that a 610 cm TL specimen would be 13-14 yrs old. The types of habitats and locations of nursery areas are unknown. It is likely that the nurseries will be found in the warmer parts of the range in deep water.

Impact of fisheries: The white shark is a prized gamefish because of its size. It is occasionally caught in commercial longlines or in near-shore gillnets but it must be released in a manner to maximize its survival. Its jaws and teeth are often seen in specialized markets where they bring high prices. Preliminary observations (Strong *et al.* 1992) show that populations may be small, highly localized, and very vulnerable to overexploitation. The white shark has been adopted as a symbol of a threatened species by some conservation organizations. The species has received protected status in South Africa and Australia. In 1997, the Unites States implemented a catch and release only recreational fishery for the white shark, while prohibiting possession of the species. There are no published population assessments, or even anecdotal reports, indicating any population decreases of the white shark. Nevertheless, the white shark is a scarce apex predator, a long-lived species of a limited reproductive potential that is vulnerable to longlines.

Essential Fish Habitat (EFH) for White Shark (reference Fig. 6-12 a-b):

• **Neonate/early juveniles (175 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Late juveniles/subadults (175-479 cm TL):** Offshore of northern New Jersey and Long Island in pelagic waters from 25m to 100m depth in the New York Bight area, bounded to the east at 71.5° W and to the south at 39.5° N; also, offshore of Cape Canaveral, Fl between the 25m and 100m isobaths from 29.5° N south to 28° N.

• **Adults (480cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.3.4 Nurse Sharks (nurse shark may also be classified into the family of carpet sharks along with the whale shark)

Nurse shark (*Ginglymostoma cirratum*). The nurse shark inhabits littoral waters in both sides of the tropical and subtropical Atlantic, ranging from tropical West Africa and the Cape Verde Islands in the east, and from Cape Hatteras to Brazil in the west. It is also found in the eastern Pacific, ranging from the Gulf of California to Panama and Ecuador (Bigelow and Schroeder 1948). It is a shallow water species, often found lying motionless on the bottom under coral reefs or rocks. It often congregates in large numbers in shallow water (Castro 1983). Habitat associations are summarized in Table 6.3.13.

Reproductive potential: The nurse shark matures at about 225 cm TL (Springer 1938). The young measure about 30 cm TL at birth and litters consist of 20-30 pups. The gestation period is about five to six months and reproduction is biennial (Castro unpubl.). The age at maturity is unknown, but the nurse shark is a long-lived species. Clark (1963) reported an aquarium specimen living up to 24 years in captivity. Its nurseries are in shallow turtle grass (*Thalassia*) beds and shallow coral reefs (Castro unpubl.). Juveniles are also found around mangrove islands in South Florida. Hueter (CSR data) found numerous juveniles in the Florida west coast, in temperatures of 17.5-32.1° C, salinities of 28.5-35.1 ppt, and DO of 4.7-97 ml/l. Large numbers of nurse sharks often congregate in shallow waters of the Florida Keys and the Bahamas at mating time in June and July (Fowler 1906, Gudger 1912). A small area has been set up for protection of mating sharks at Fort Jefferson in the Dry Tortugas. However, it is not certain whether this area is a primary mating ground or a refuge for mated females.

Impact of fisheries: In North America and the Caribbean, the nurse shark has often been pursued for its hide. Its hide is said to be more valuable than that of any other shark (Springer 1950a). The fins have no value and the meat is of questionable value (Springer 1979).

Essential Fish Habitat for Nurse Shark (reference Fig. 6-13 a-d):

• **Neonate/early juveniles (60 cm TL):** Shallow coastal areas from West Palm Beach south to the Dry Tortugas in waters less than 25 m.

• **Late juveniles/subadults (61-225 cm TL):** Shallow coastal waters (from the shoreline to the 25 m isobath) off the east coast of Florida from south of Cumberland Island (at 30.5 ° N) to the Dry Tortugas; also shallow coastal waters from Charlotte Harbor (at 26° N) to the north end of Tampa Bay (at 28° N); also, in southern Puerto Rico, shallow coastal waters out to the 25m isobath from 66.5°W to the southwestern tip of the island.

• **Adults (226cm TL):** (Identical to EFH for Late juveniles/Subadults): Shallow coastal waters (from the shoreline to the 25 m isobath) off the east coast of Florida from south of Cumberland Island (at 30.5 ° N) to the Dry Tortugas; also shallow coastal waters from Charlotte Harbor (at 26° N) to the north end of Tampa Bay (at 28° N); also, in southern Puerto Rico, shallow coastal waters out to the 25m isobath from 66.5°W to the southwestern tip of the island.

6.3.3.3.5 Requiem Sharks

Bignose shark (*Carcharhinus altimus*). The bignose shark is a poorly known, bottom dwelling shark of the deeper parts of the continental shelves. It is found in tropical and subtropical waters throughout the world (Castro 1983). Habitat associations are summarized in Table 6.3.14.

Reproductive potential: The smallest mature specimens recorded by Springer (1960) were a 213 cm TL male and a 221 cm TL female. Springer (1950c) reported litters of 7 to 8 pups, while Stevens and McLoughlin (1991) noted from 3 to 15 pups. Birth size is probably around 70 cm TL based on the largest embryos (65-70 cm TL) reported by Fourmanoir (1961) and free swimming specimens with fresh umbilical scars seen by Bass *et al.* (1973). The lengths of the gestation period and of the breeding cycle have not been reported. The location of the nurseries is unknown.

Impact of fisheries: Springer (1950c) stated that the bignose shark appeared to be the most common large shark of the edges of the continental shelves in the West Indian region, and that the species made up a substantial portion of the catch in the Florida shark fishery of the 1940's. In some areas, bignose sharks are mistaken for sandbar sharks.

Essential Fish Habitat for Bignose Shark (reference Fig. 6-14 a-c):

- **Neonate/early juveniles (155 cm TL):** From offshore Delmarva Peninsula at 38° N, to offshore of Bull's Bay, SC at 32° N, between the 100m and 200m isobaths.
- **Late juveniles/subadults (156-220 cm TL):** From offshore Delmarva Peninsula at 38° N, to offshore of Bull's Bay, SC at 32° N, between the 100m and 500m isobaths; also, from St. Augustine, FL at 30°N, south to offshore of West Palm Beach at 27° N, between the 100m and 500m isobaths.
- **Adults (221 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Blacktip shark (*Carcharhinus limbatus*). The blacktip shark is circumtropical in shallow coastal waters and offshore surface waters of the continental shelves. In the southeastern United States, it ranges from Virginia to Florida and the Gulf of Mexico. Garrick (1982), on examining a large number of museum specimens, believed it to be a single worldwide species. Dudley and Cliff (1993a) working off South Africa and Castro (1996) working on blacktip sharks off the southeastern United States, showed that there were significant differences among the various populations. The blacktip shark, or "blacktip" is a fast moving shark that is often seen at the surface, frequently leaping and spinning out of the water. It often forms large schools that migrate seasonally north-south along the coast. This species is much sought after in the eastern United States because of the quality of its flesh. The blacktip and the sandbar shark are the two species of greatest importance to the commercial fisheries in that region. In the markets of the

United States, "blacktip" has become synonymous with good quality shark; therefore, many other species are also sold under that name. Habitat associations are summarized in Table 6.3.15.

Reproductive potential: Off the southeastern United States, males mature at between 142 and 145 cm TL and females mature at about 156 cm TL (Castro 1996). According to Branstetter and McEachran (1986), in the western North Atlantic, males mature at 139-145 cm TL at 4-5 years, and females at 153 cm TL at 6-7 years. These ages are unvalidated and based on a small sample. Branstetter and McEachran (1986) estimated the maximum age at 10 years, and gave the von Bertalanffy parameters for combined sexes as: L = 171, K= 0.284, t_o= -1.5. The young are born at 55-60 cm TL in late May and early June in shallow coastal nurseries from Georgia to the Carolinas (Castro 1996). Litters range from 1-8 pups (Bigelow and Schroeder 1948) with a mean of 4 . The gestation cycle lasts about a year; the reproductive cycle is biennial (Castro 1996). According to Castro (1993b) the nurseries are on the seaward side of coastal islands of the Carolinas, at depths of 2-4m. Carlson (pers. comm.) found neonates in depths up to 11 m. Castro (1993b) found neonates over muddy bottoms off Georgia and the Carolinas, while Hueter *et al.* found them over seagrass beds off west Florida (unpublished Mote Laboratory CSR data). Analysis of the Mote Laboratory CSR data reveals that neonates and juveniles were found off west Florida (from the Florida Keys to Tampa Bay) at temperatures 18.5-33.6ºC, salinities of 15.8-37.0 ppt, and D.O. of 3.5-9.0 ml/l. The neonates were found from April to September while juveniles were found there nearly year-round.

Impact of fisheries: The blacktip shark is caught in many diverse fisheries throughout the world. Off the southeastern United States, it is caught in commercial longlines set in shallow coastal waters, but it is also pursued as a gamefish. There are localized gillnet fisheries in federal waters off Florida, Georgia and south Carolina that target blacktips during their migrations, when the schools are close to shore in clear waters. Aircraft are often used to direct net boats to the migrating schools, often resulting in the trapping of very large schools. The species is considered vulnerable, because it is pursued commercially throughout its range, has a low reproductive potential, and is often found in shallow coastal waters. Its habit of migrating in large schools along shorelines makes it extremely vulnerable to organized gillnet fisheries.

<u>Essential Fish Habitat for Blacktip Shark (reference Fig. 6-15 a-e):</u>

- **Neonates/Early Juveniles (99 cm):** Shallow coastal waters to the 80 ft (25 m) isobath, from Bull's Bay, SC at 33.5° N, south to Cape Canaveral, FL at 28.5° N; also, on the west coast of Florida from Thousand Islands at 26° N to Cedar Key at 29° N, especially Tampa Bay and Charlotte Harbor.
- **Late Juveniles/Subadults (100-155 cm):** Shallow coastal waters from the shoreline to the 25m isobath: from Cape Hatteras at 35.25°, to 29° N at Ponce de Leon Inlet; the west coast of Florida, including the Florida Keys and Florida Bay, north to Cedar Key at 29° N; from Cape San Blas, Fl north of 29.5° N to the east coast of the Mississippi River delta north of 29° N; also, the west coast of Texas from Galveston, west of 94.5° N, to the US/Mexico border.
- **Adults (156 cm):** Shallow coastal waters of the Outer Banks, NC from the shoreline to the 650 ft (200m) isobath between 36° N and 34.5° N; shallow coastal waters offshore to the 50m isobath from St. Augustine (30° N) to offshore of Cape Canaveral (28.5° N); on the west coast of Florida, shallow coastal waters to the 50m isobath from 81°W in Florida Bay, to 85°W, east of Cape San Blas, Fl.

• **Research Area (unsubstantiated data):** In southwestern Louisiana, from the 25m isobath to the 200m isobath, from the western side of the Mississippi River delta to south of the Atchafalaya River mouth near 92.5° N; also, in southern Texas, from the shoreline to the 25m isobath, from Corpus Cristi south to the US/Mexico border.

Bull shark (*Carcharhinus leucas*). The bull shark is a large, shallow water shark that is cosmopolitan in warm seas and estuaries (Castro 1983). It often enters fresh water, and may penetrate hundreds of kilometers upstream. Habitat associations are summarized in Table 6.3.16.

Reproductive potential: Males mature at 210-220 cm TL or 14-15 years of age; females mature at >225 cm TL or 18+ years of age (Branstetter and Stiles 1987). Growth parameters have been estimated by Branstetter and Stiles (1987) as L = 285 cm TL, K= 0.076, t_o = -3.0 yr. Thorson and Lacy (1982) estimated that females reached "their larger size" at approximately 16 years and that males of maximum size were 12 years old. The pups measure about 75 cm TL at birth (Clark and von Schmidt 1965). Jensen (1976) stated that litters ranged from 1 to 10 pups and that the average size was 5.5 pups. The gestation period is estimated at 10-11 months (Clark and von Schmidt 1965). The length of the reproductive cycle has not been published, but it is probably biennial. In the United States, the nursery areas are in low-salinity estuaries of the Gulf Coast (Castro 1983) and the coastal lagoons of the east coast of Florida (Snelson *et al.* 1984). Hueter (CSR data), working off the Florida West Coast, found neonates in Yankeetown, Tampa Bay, and Charlotte Harbor from May to August. The neonates were in temperatures of 28.2-32.2°C, salinities of 18.5-28.5 ppt. Hueter (CSR data) found juveniles off the Florida West Coast in temperatures of 21.0-34.0° C, salinities of 3.0 to 28.3 ppt, and DO of 3.7-8.4 ml/l.

Impact of fisheries: The bull shark is a common coastal species that is fished in both artisanal and industrial/modern fisheries. Clark and von Schmidt (1965) found it to be the most common shark caught in their survey of the sharks of the central gulf coast of Florida, accounting for 18% of the shark catch. Dodrill (1977) reported it to be the seventh most commonly taken shark at Melbourne Beach, Florida, composing 8.6% of all longline landings. Thorson (1976) recorded a marked decline of the Lake Nicaragua-Rio, San Juan population from 1963 to 1974 resulting from a small-scale, but sustained commercial fishing operation. This fishery intensified in 1968 and by 1972 bull sharks in the area had become so scarce that Thorson (1976) predicted that any other developments would eliminate the bull shark from Lake Nicaragua. Russell (1993) indicated that the bull shark constituted 3% of the shark catch in the directed shark fishery in the U.S. Gulf of Mexico. Castillo (1992) referred to the species in Mexico as "intensely exploited in both coasts". The bull shark is vulnerable to overfishing because of its slow growth, limited reproductive potential, and because it is pursued in numerous fisheries.

Essential Fish Habitat for Bull Shark (reference Fig. 6-16 a-d):

• **Neonate/early juveniles (110 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from just north of Cape Canaveral, Fl at 29° N to just south of Cape Canaveral, Fl at 28° N; from just south of Charlotte Harbor, Fl at 26.5° N north to Cedar Key, FL at 29° N; the mouth of Mobile Bay, AL from 87.75°W to 88.25° W; the mouth of Galveston Bay, TX from 94.5°W to

95°W; from south Padre Island, TX south of 28.5°N to Laguna Madre, TX at 27°N.

• **Late juveniles/subadults (111- 225 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from Savannah Beach, Ga at 32°N southward to the Dry Tortugas, Fl; from Ten Thousand Islands, FL at 26° N north to northern Cedar Key, Fl at 29° N; from Apalachiacola, FL at 85°W to the Mobile Bay area at 88.5°W; from just east of Galveston Bay at 94.5° W to the US/Mexico border.

• **Adults (226 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from just south of Charlotte Harbor at 26.5°N north to Anclote Key, FL at 28° N.

Caribbean reef shark *(Carcharhinus perezi)*. The Caribbean reef shark inhabits the southeast coast of Florida, the Caribbean Sea, and the western Atlantic south to Brazil. This is a poorly known, bottom-dwelling species that inhabits shallow coastal waters, usually around coral reefs (Castro 1983). Habitat associations are summarized in Table 6.3.17.

Reproductive potential: Males mature about 170 cm TL and females at about 200 cm TL. Pups are born at about 70 cm TL and litters consist of 4 to 6 pups. The reproductive cycle is biennial. (Castro unpub.). The nurseries have not been described.

Essential Fish Habitat for Caribbean Reef Shark (reference Fig. 6-17 a-c):

• **Neonate/early juveniles (105 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Late juveniles/subadults (106-199 cm TL):** Shallow coastal waters of the Florida Keys less than 25m deep from Key Largo to the Dry Tortugas.

• **Adults (200 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

• Research Areas (unsubstantiated data): Coastal waters less than 25 meters deep off Cape Canaveral; off Miami; off west and southwest Florida, including Florida Bay, the western half of the south coast of Puerto Rico.

Dusky shark (*Carcharhinus obscurus*). The dusky shark is common in warm and temperate continental waters throughout the world. It is a migratory species which moves north-south with the seasons. This is one of the larger species found from inshore waters to the outer reaches of continental shelves. It is important as a commercial species as well as a gamefish. Habitat associations are summarized in Table 6.3.18.

Reproductive potential: Males mature at 290 cm TL and reach at least 340 cm TL. The females mature at about 300 cm TL and reach up to 365 cm TL. The dusky shark matures at about 17 years and is considered a slow growing species (Natason 1990). Litters consist of 6-14 pups, which measure 85-100 cm TL at birth (Castro 1983). The gestation period is believed to be about 16 months (Clark and von Schmidt 1965), but this has not been confirmed. Natason (1990) gave the following parameters for males L_{max}= 351 cm FL (420 cm TL), K= .047, t_o =   5.83; and females at L_{max}= 316 cm TL (378 cm TL) K= .061, t_o=-4.83. The growth rate is believed to be about 10 cm/yr for the young and 5 cm/yr for the adults. The nursery areas are in coastal waters. Castro (1993c) reported that dusky sharks gave birth in Bulls Bay, South Carolina, in April and May. Musick and Colvocoresses (1986) stated that the species gives birth in the Chesapeake Bay in June and July.

Impact of fisheries: The dusky shark plays an important role in the coastal shark fisheries for flesh and fins, and is commonly taken as bycatch in the swordfish/tuna fisheries. The dusky shark is one of the slowest growing requiem sharks and is often caught on both coastal and pelagic longlines, making it highly vulnerable to overfishing.

<u>Essential Fish Habitat for Dusky Shark (reference Fig. 6-18 a-e):</u>

- **Neonate/early juveniles (115 cm TL):** Shallow coastal waters, inlets and estuaries to 25m deep from the east end of Long Island, NY at 72°W south to Cape Lookout, NC at 34.5 °N; from Cape Lookout, NC south to offshore Bull's Bay SC at 32.5°N, between the 25m and 100m isobaths; shallow coastal waters, inlets and estuaries to 200m deep from St. Augustine, Fl (30°N) to West Palm Beach, FL (27.5°N).
- **Late juveniles/subadults (116-300 cm TL):** Pelagic waters from the southwestern edge of Georges Bank at 68.5°W west to 70° W, between the 100 and 2000 m isobaths; from 70°W off the coast of southern New England west and south to 39.5° N of the New Jersey coast, coastal and pelagic waters between 25 and 2000m deep; shallow coastal waters, inlets and estuaries to the 200m isobath from Assateague Island at the Va-MD border (38°N) to offshore South Carolina at 33° N; shallow coastal waters, inlets and estuaries to the 500 m isobath from Jacksonville, Fl at 30°N south to the Dry Tortugas, Fl at 83°W.
- **Adults (301 cm TL):** Pelagic waters offshore of the Va-NC border at 36.5°N south to Ft. Lauderdale, FL at 28°N between the 25m and 200 m isobaths.
- **Research Areas (unsubstantiated data):** Offshore NJ, DE, MD from the lower, Delaware Bay out to 200 m isobath; in the Gulf of Mexico from Cape San Blas, Fl to the eastern side of the Mississippi Delta, all inshore coastal and estuarine waters and pelagic waters out to 200 m.

<u>Galapagos shark (*Carcharhinus galapagensis*)</u>. The Galapagos shark is circumtropical in the open ocean and around oceanic islands (Castro 1983). It is very similar to the dusky shark and is often mistaken for it, though the dusky prefers continental shores (Castro 1983). The Galapagos shark is very seldom seen in the continental United States. A few Galapagos sharks are undoubtedly caught off the East Coast every year, but they can be easily misidentified as dusky sharks (Castro, pers. comm.). Habitat associations are summarized in Table 6.3.19.

Reproductive potential: Males reach maturity between 205 and 239 cm TL and females between 215 and 245 cm TL (Wetherbee *et al.* 1996). Pups are born at slightly over 80 cm TL and litters range from 4 to 16 pups, the average being 8.7. The gestation cycle is estimated to last about a year (Wetherbee *et al.* 1996), but the length of the reproductive cycle is not known.

<u>Essential Fish Habitat for Galapagos Shark (reference Fig. 6-19 a):</u>

• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults (215 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Lemon shark (*Negaprion brevirostris*). The lemon shark is common in the American tropics. It inhabits shallow coastal areas, especially around coral reefs. It is reported to use coastal mangroves as some of its nursery habitats, although this is not well reported in the literature (S. Gruber, pers. comm.). The primary population in continental US waters is found off South Florida, although adults stray north to the Carolinas and Virginia in the summer. Habitat associations are summarized in Table 6.3.20.

Reproductive potential: Lemon sharks mature at about 228 cm TL (Springer 1950b). Brown and Gruber (1988) estimated an age at maturity of 11.6 years for males and 12.7 years for females, showing the species to be slow growing and long lived. Brown and Gruber reported the von Bertalanffy parameters as: L =317.65, K= .057, and t_o= -2.302. Litters consist of 5-17 pups, which measure about 64 cm TL at birth (Springer 1950b, Clark and von Schmidt 1965). Its reproductive cycle is biennial (Castro 1993c) and gestation lasts ten (Springer 1950b) to twelve months (Clark and von Schmidt 1965). Its nurseries are in shallow waters around mangrove islands (Springer 1950b) off tropical Florida and the Bahamas. Hueter (CSR data) found lemon shark neonates in Tampa Bay during the month of May, at temperatures of 22.0-25.4° C, salinities of 26.8-32.6 ppt, and DO of 5.9-9.6 ml/l. He also found juveniles over a wider area of western Florida and in a wider range of temperatures and salinities.

Impact of fisheries: The lemon shark is caught throughout its range, although it is not a primary commercially important species along the Atlantic coast.

Essential Fish Habitat for Lemon Shark (reference Fig. 6-20 a-d):
• **Neonate/early juveniles (90cm TL):** Shallow coastal waters, inlets and estuaries out to the 25m isobath from Savannah, GA at 32°N, south to Indian River Inlet, Fl at 29°N; shallow coastal waters, inlets and estuaries from Miami around peninsular Florida to Cape Sable at 25.25°N including the Keys in waters less than 25 m; waters of Tampa Bay, including waters immediately offshore of the mouth of the bay; shallow coastal waters, inlets and estuaries from South Padre Island at 95.5°N south to the US/Mexico border in waters less than 25 m.
• **Late juveniles/subadults (91-228 cm TL):** Shallow coastal waters, inlets and estuaries offshore to the 25m isobath, west of 79.75° W from Bull's Bay, SC to south of Cape Canaveral (West Palm Beach), FL at 28° N; Shallow coastal waters, inlets and estuaries offshore to the 25m isobath from Miami at 25.5 °N, around peninsular Florida to Tampa Bay (including the Keys) to 28°N; Shallow coastal waters, inlets and estuaries offshore to the 25m isobath on the south coast of Puerto Rico from 66°W to 67°W .
• **Adults (229 cm TL):** Shallow coastal waters, inlets and estuaries offshore to the 25m isobath from Cumberland Island, GA at 31°N to St. Augustine, FL at

31°N; from West Palm Beach at 27°N around peninsular Florida to 28.5 °N near Anclote Key in shallow coastal waters, inlets and estuaries and offshore to 25m deep.

Narrowtooth shark (*Carcharhinus brachyurus*). This is a coastal-pelagic species of widespread distribution in warm temperate waters throughout the world. In general, it is a temperate shark, absent or rare in tropical waters (Bass *et al.* 1973). Although the species has been reported for the California coast by Kato *et al.* 1967 (as C. remotus), and for the southwestern Atlantic (Chiaramonte pers. comm.), few data exist for the western North Atlantic. Habitat associations are summarized in Table 6.3.21.

Reproductive potential: Males mature between 200 and 220 cm TL, and females mature below 247 cm TL. The young are born at about 60-70 cm TL. Six pregnant females averaged 16 embryos, with a range of 13 to 20 pups per litter (Bass *et al.* 1973). Walter and Ebert (1991) calculated age at sexual maturity at 13-19 years for males and 19-20 years for females. Gestation is believed to last a year (Cliff and Dudley 1992). The length of the reproductive cycle is not known, but it is probably biennial as it is for most large carcharhinid sharks.

Impact of fisheries: Because it appears to be a very slow growing carcharhinid (based on the unvalidated ages by Walter and Ebert (1991)) , the narrowtooth shark is probably vulnerable to overfishing.

Essential Fish Habitat for Narrowtooth Shark (reference Fig. 6-21 a):

- **Neonate/early juveniles (100 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Late juveniles/subadults (101-230 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Adults (231cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Night Shark (*Carcharhinus signatus*). This carcharhinid shark inhabits the waters of the western North Atlantic from Delaware to Brazil and the western coast of Africa. It is a tropical species that seldom strays northward. It is usually found at depths greater than 275-366 m during the day and about 183 m at night (Castro 1983). Habitat associations are summarized in Table 6.3.22.

Reproductive potential: There is little information on its reproductive processes. Litters usually consist of 12-18 pups, which measure 68-72 cm TL at birth (Castro 1983). Length at maturity has been reported for females as 150 cm FL (178 cm TL) (COMPAGNO, 1984). The nurseries remain undescribed.

Impact of fisheries: The night shark was abundant along the southeastern coast of the United States and the northwestern coast of Cuba before the development of the swordfish fishery of the 1970's. Martinez (1947) stated that the Cuban shark fishery relied heavily on the night shark, which constituted 60-75% of the total shark catch, and that the average annual catch for 1937-1941 was 12,000 sharks. Guitart Manday (1975) documented a precipitous decline in night shark catches off the Cuban northwestern coast during the years 1971-1973. Berkeley and

Campos (1988) stated that this species represented 26.1% of all sharks caught in swordfish fisheries studied by them along the east coast of Florida from 1981 to 1983. Anecdotal evidence from commercial swordfish fishermen also indicates that, in the late 1970's, it was not unusual to have 50-80 dead night sharks, usually large gravid females, in every set from Florida to the Carolinas. During the 1970's, sports fishermen in South Florida often resorted to catching night sharks when other more desirable species (marlins) were not biting. The photographic record of sport fishing trophies landed shows that large night sharks were caught daily and landed at the Miami docks in the 1970's. The species is rare along the southeastern coast of the United States today. The decline of the night shark may be an example of how a species can decline due to bycatch mortality.

Essential Fish Habitat for Night Shark (reference Fig. 6-22 a-d):

- **Neonate/early juveniles (100 cm TL):** At this time, the information available is insufficient to identify EFH for this life stage.
- **Late juveniles/subadults (101-178 cm TL):** From offshore of Assateague Island, MD at 38° N south to offshore of Cape Fear at 33.5° N, from the 100m isobath to the 2000m isobath
- **Adults (179 cm TL):** In the South Atlantic Bight, from the 100m isobath to either the 2000m isobath, 100 miles from shore, or the US EEZ whichever is nearest, from 36° N offshore of Oregon Inlet, NC to 25.5° N, off the coast of Miami, Fl.
- **Research Area (unsubstantiated data):** In the Florida Straights south of the Dry Tortugas and Key West between 100m and 2000m of water, between 81.75°W and 82.25°W.

Sandbar shark (*Carcharhinus plumbeus*). The sandbar shark is cosmopolitan in subtropical and warm temperate waters. It is a common species found in many coastal habitats. It is a bottom-dwelling species most common in 20-55 meters of water, but occasionally found at depths of about 200 m. Habitat associations are summarized in Table 6.3.23.

Reproductive potential: The sandbar shark is a slow growing species. Both sexes reach maturity at about 180 cm TL (Castro 1983). Alternative lengths of maturity cited have been >136 cm PCL (Sminkey and Musick 1995) and 150 cm FL (Casey and Natanson, 1992); all are roughly equivalent when converted using equations of Sminkey and Musick (1995) and Kohler, *et al.* (1996). Estimates of age at maturity range from 15-16 years (Sminkey and Musick 1995) to 29-30 years (Casey and Natanson 1992); although 15-16 years is the commonly accepted age of maturity. The von Bertalanffy growth parameters were proposed for combined sexes are L = 186 cm FL (224 cm TL; 168 cm PCL), K= 0.046, t_o= -6.45 by Casey and Natanson (1992); and reevaluated by Sminkey and Musick (1995) as L = 164 cm PCL (219 cm TL; 182 cm Fl), K= 0.089, t_o= -3.8. Young are born at about 60 cm TL (smaller in the northern parts of the North American range), from March to July. Litters consist of 1-14 pups with 9 being the average (Springer 1960). The gestation period lasts about a year and reproduction is biennial (Musick *et al.* 1993). Hoff (1990) used an age at maturity of 15 years, a lifespan of 35 years, and two year reproductive cycle, to calculate that each female may reproduce only ten times. New maturity estimates and the increased mortality in the fishery may reduce that reproductive potential much further. In the United States, the sandbar shark has its nurseries in shallow coastal waters from Cape Canaveral, Florida (Springer, 1960), to Great Bay, New Jersey (H.L. Pratt, Jr, pers. comm.). Delaware Bay and Chesapeake Bay are important nurseries. Juveniles return to Delaware Bay after a winter absence around May 15, and are found as far north as Martha's Vineyard in the summer. Neonates have been captured in Delaware Bay in late June. The young of the year were present in Delaware Bay until early October when the temperature fell below 21° C. Sandbar sharks were captured in varying salinities but no specimens were caught there at salinities below 22ppt (H.L.Pratt, Jr, pers. comm., SEW, 1998). Another nursery may exist in the West Coast of Florida and along the northeastern Gulf of Mexico. Hueter (CSR data) found neonates off Yankeetown, Florida, from April to July, in temperatures of 25.0-29.0°C, and salinities of 20.4-25.9 ppt. Neonate sandbar sharks were found in an area between Indian Pass and St. Andrew Sound in June when the temperature had reached 25°C (J. Carlson, NMFS, ms1998).

Impact of fisheries: The sandbar shark is one of the most important commercial species in the shark fishery of the southeastern United States, along with blacktip sharks. It is a preferred species because of the high quality of its flesh and large fins. Commercial longline fishermen pursue sandbar stocks in their north-south migrations along the coast; their catches can be as much as 80-90% sandbar sharks in some areas. Large numbers of juvenile sandbar sharks are caught in gillnets set in shallow waters along the southeastern coast of the United States. Many of those gillnet fisheries have been, or are being, prohibited by state governments. Musick *et al.* (1993) have documented a severe decline in CPUE of the sandbar shark in the Chesapeake Bay area. The sandbar shark is considered highly vulnerable to overfishing because of its slow maturation and heavy fishing pressure, as evidenced in the catch per unit effort (CPUE) declines in U.S. fisheries.

<u>Essential Fish Habitat (EFH) for Sandbar Shark (reference Fig. 6-23 a-e):</u>

- **Neonates/Early Juveniles (90 cm):** Shallow coastal areas to 80 ft (25m) from Montauk, Long Island at 72°W, south to Cape Canaveral, FL at 80.5° (all year). Nursery areas in shallow coastal waters from Great Bay, NJ to Cape Canaveral, Fla; especially Delaware and Chesapeake Bays (seasonal-summer); also shallow coastal waters to up to 50m deep on the west coast of Florida and the Florida Keys from Key Largo at 80.5°W north to south of Cape San Blas at 85.25°W. Typical parameters: Salinity-greater than 22 ppt; Temperatures-greater than 70° F (21°C).
- **Late Juveniles/Subadults (91-179 cm):** Offshore of southern New England and Long Island, all waters, coastal and pelagic, north of 40°N and west of 70°W; also, south of 40°N at Barnegat Inlet, NJ, to Cape Canaveral, FL (27.5°N), shallow coastal areas to the 80 ft (25 m) isobath; also, in the winter, from 39°N to 36°N, in the Middle Atlantic Bight, at the shelf break, benthic areas between 100m and 200m deep; also, on the west coast of Florida, from shallow coastal waters to the 165 ft (50m) isobath, from Florida Bay and the Keys at Key Largo north to Cape San Blas at 85.5°W.
- **Adults (180 cm):** On the east coast of the US, shallow coastal areas from the coast to the 165 ft (50 m) isobath from Nantucket, MA, south to Miami, FL; also, shallow coastal areas from the coast to the 330 ft (100m) isobath around

peninsular Florida to the Florida panhandle at 85.5°W, near Cape San Blas, including the Keys and saline portions of Florida Bay.

• **Habitat Areas of Particular Concern:** Important nursery and pupping grounds have been identified in shallow areas and the mouths of Great Bay, NJ, lower and middle Delaware Bay, lower Chesapeake Bay, and on the Outer Banks, NC, in areas of Pamlico Sound adjacent to Hatteras and Ocracoke Islands and offshore of those islands.

Silky shark (*Carcharhinus falciformis*). The silky shark inhabits warm tropical and subtropical waters throughout the world. Primarily, the silky is an offshore, epipelagic shark, but juveniles venture inshore during the summer. The silky shark is one of the most abundant large sharks in the world. Habitat associations are summarized in Table 6.3.24.

Reproductive potential: Data on the silky shark are variable. There is a strong possibility that different populations may vary in their reproductive potential. Litters range from six to fourteen pups which measure 75-80 cm TL at birth (Castro 1983). According to Bonfil *et al.* (1993), the silky shark in the Campeche Bank, Mexico, has a twelve month gestation period, giving birth to 10-14 pups with average of 76 cm TL during late spring and early summer, possibly every two years. Males mature at 225 cm TL (about 10 yrs.) and females at 232-245 cm TL (>12 yrs of age). The von Bertanffy parameters estimated by Bonfil *et al.* (1993) are: L = 311 cm TL, K= 0.101, t_o= -2.718 yr. Maximum ages were 20+ years for males and 22+ years for females (Bonfil *et al.* 1993). Springer (1967) describes reefs on the outer continental shelf as nursery areas. Bonfil *et al.*(1993) mentions the Campeche Bank as a prime nursery area in the Atlantic.

Impact of Fisheries: The silky shark is caught frequently in swordfish and tuna fisheries. Berkeley and Campos (1988) found it to constitute 27.2% of all sharks caught in swordfish vessels off the Florida east coast (U.S.) in 1981-83. Bonfil *et al.* (1993), "consider the life-history characteristics of slow growth, late maturation, and limited offspring... point towards a very fragile resource. In all probability, local stocks of this species cannot support sustained heavy fishing pressure".

Essential Fish Habitat for Silky Shark (reference Fig. 6-24 a-c):

• **Neonate/early juveniles (97 cm TL):** Waters off Cape Hatteras between 100 and 2000 m; plus shallow coastal waters just north and immediately west of Cape Hatteras; waters off St. Augustine, FL south to off Miami in depths 25 to 2000 (1000m?) likely along the western edge of the Gulf Stream); off northwest FL- De Soto Canyon area between 200 and 2000 m .

• **Late juveniles/subadults (98-231 cm TL):** Waters off the mouth of the Chesapeake Bay south to waters offshore west of the NC-SC border from 50 to 2000m; from NC-SC border south to Key West paralleling the 200 m isobath; area north west of Key West to west of Ten Thousand Islands between 50 and 2000 m.

• **Adults (232 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Spinner shark (*Carcharhinus brevipinna*). The spinner shark is a common, coastal-pelagic, warm-temperate and tropical shark of the continental and insular shelves (Compagno 1984). It is often seen in schools, leaping out of the water while spinning. It is a migratory species, but its patterns are poorly known. In eastern North America it ranges from Virginia to Florida and the Gulf of Mexico. Habitat associations are summarized in Table 6.3.25.

Reproductive potential: Males mature at 130 cm TL or 4-5 years, females mature at 150-155 cm TL or 7-8 years (Branstetter 1987). According to Branstetter (1987), males reach maximum size at 10-15 years and females at 15-20 years. However, he added the caveat that "as sharks near their maximum size, growth is slower, therefore their maximum ages may be much greater". Branstetter (1987) gave von Bertalanffy parameters for both sexes were: L = 214 cm, K= 0.212, t_o = -1.94 yr. The ages have not been validated. According to Garrick (1982), the species reaches 278 cm TL. The young are born at 60-75 cm TL in late May and early June. The litters usually consist of 6-12 pups (Castro 1983). It has a biennial reproductive cycle (Castro 1993c). In the Carolinas, the nursery areas are in shallow coastal waters (Castro 1993c). The extent of nursery areas is unknown. Hueter (CSR data) found juveniles in the Florida West Coast in temperatures of 21.9-30.1°C, salinities of 21.0-36.2 ppt, and DO 3.5-5.0 ml/l.

Impact of fisheries: Unknown. The spinner shark is similar in reproductive potential and habits to the blacktip shark, and its vulnerability to fisheries is probably very similar to that of the blacktip. In fact, the "blacktip-spinner complex" is a commonly used category that combines the landings of these two species because of species similarities and difficulties in distinguishing the two species.

<u>Essential Fish Habitat for Spinner Shark (reference Fig. 6- 25 a-d):</u>

- **Neonate/early juveniles (90 cm TL):** Along the coast of the southeastern US and the west coast of Florida, shallow coastal waters out to the 25m isobath, from Cape Hatteras at 35.25° N around Florida including Florida Bay and the Florida Keys, and north to 29.25° N.
- **Late juveniles/subadults (91 - 154 cm TL):** Off the east coast, from the Florida/Georgia border at 30.7° N south to 28.5° N, from shallow coastal waters to the 200m isobath.
- **Adults (155 cm TL):** Off the east coast of Florida, from shallow coastal waters out to the 100m isobath, from 30° N to 28.5 °N offshore of Cape Kennedy.

Tiger shark (*Galeocerdo cuvieri*). The tiger shark inhabits warm waters in both deep oceanic and shallow coastal regions (Castro 1983). It is one of the larger species of sharks, reaching over 550 cm TL and over 900 kg. Its characteristic tiger-like markings and unique teeth make it one of the easiest sharks to identify. It is one of the most dangerous sharks and is believed to be responsible for many attacks on humans (Castro 1983). Habitat associations are summarized in Table 6.3.26.

Reproductive potential: Tiger sharks mature at about 290 cm TL (Castro 1983, Simpfendorfer 1992). The pups measure 68-85 cm TL at birth. Litters are large, usually consisting of 35-55 pups (Castro 1983). According to Branstetter *et al.* (1987), males mature in 7 years and females in 10 years, and the oldest males and females were 15 and 16 years of age. The ages have not been validated. Branstetter *et al.* (1987) gave the growth parameters for an

Atlantic sample as L = 440 cm TL, K= 0.107, t_o= -1.13 years, and for a Gulf of Mexico sample as L = 388 cm TL, K= 0.184, and t_o= -0.184. There is little data on the length of the reproductive cycle. Simpfendorfer (1992) stated that the females do not produce a litter each year. The length of the gestation period is also uncertain. Clark and von Schmidt (1965) stated that the gestation period may be "slightly over a year". While this estimate has not been confirmed, it is probably correct, given that many large carcharhinid sharks have biennial reproduction and year-long gestation periods. The nurseries for the tiger shark appear to be in offshore areas, but they have not been described.

Impact of Fisheries: Unknown.

Essential Fish Habitat for Tiger Shark (reference Fig. 6-26 a-d):

- **Neonate/early juveniles (120cm TL):** From shallow coastal areas to the 200 m isobath from Cape Canaveral, FL north to Off Montauk, Long Island, NY (south of Rhode Island); and from offshore southwest of Cedar north to the Florida-Alabama border from shallow coastal areas to the 50 m isobath.
- **Late juveniles/subadults (121-289cm TL):** Shallow coastal areas from Mississippi Sound (just west of Mississippi-Alabama border) to the 100 m isobath south to the Florida Keys; around the peninsula of Florida to the 100 m isobath to the Florida Georgia border; north to Cape Lookout, from the 25 m to the 100 m isobath; from Cape Lookout north to just south of the Chesapeake Bay from inshore to the 100 m isobath; north of the mouth of the Chesapeake to off Montauk, Long Island, NY (to south of Rhode Island between 25 and 100 m isobaths; south and southwest coasts of Puerto Rico from inshore to the 2000 m isobath.
- **Adults (290 cm TL):** Offshore from Chesapeake Bay south to Ft. Lauderdale to the western edge of the Gulf Stream; from Cape San Blas, FL to Mississippi Sound between 25 - 200 m isobaths; south and southwest coasts of Puerto Rico from inshore to the 2000 m isobath.

6.3.3.3.6 Sand Tiger Sharks

Bigeye sand tiger *(Odontaspis noronhai)*. This is one of the rarest large sharks. Its large eye and uniform dark coloration indicate that it is a deep-water species.   The few catch records that exist indicate that it frequents the upper layers at night. The species was originally described based on a specimen from Madeira. A few specimens were caught at depths of 600-1000 m off Brazil (Compagno 1984).   A 321 cm TL immature female was caught in the Gulf of Mexico, about 70 miles east of Port Isabel, Texas in 1984. Another specimen was caught in the tropical Atlantic (5°N; 35° W) at a depth of about 100 m where the water was about 3,600 m deep (J. Castro, pers. comm.). These appear to be all the records of the species. Nothing is known of its habits. Possession of this species is prohibited in Atlantic waters of the U.S. Habitat associations are summarized in Table 6.3.27.

Essential Fish Habitat for Bigeye Sand Tiger Shark (reference Fig. 6-27 a):

• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

<u>Sand tiger shark (*Carcharias taurus*)</u>. The sand tiger is a large, coastal species found in tropical and warm temperate waters throughout the world. It is often found in very shallow water (<4 m) (Castro 1983). It is the most popular large shark in aquaria, because, unlike most sharks it survives easily in captivity. It has been fished for its flesh and fins in coastal longline fisheries; although possession of this species in Atlantic waters of the U.S. is now prohibited. Habitat associations are summarized in Table 6.3.28.

Reproductive potential: According to Gilmore (1983) males mature at about 191.5 cm TL. According to Branstetter and Musick (1994), males reach maturity at 190-195 cm TL or 4-5 years, and females mature at more than 220 cm TL or 6 years. The largest immature female seen by J. Castro (pers. comm.) was 225 cm TL and the smallest gravid female was 229 cm TL, suggesting that maturity is reached at 225-229 cm TL. The oldest fish in Branstetter and Musick's (1994) sample of 55 sharks was 10.5 years old, an age that has been exceeded in captivity (Govender *et al.* 1991). The von Bertalanffy parameters according to Branstetter and Musick (1994) are for males: L_{max}= 301 cm, K= 0.17, t_o= -2.25; and for females: L_{max}= 323 cm, K= 0.14, t_o= -2.56 yrs. Gilmore (1983) gave growth rates of 19-24 cm /yr for the first years of life of two juveniles born in captivity. The sand tiger has an extremely limited reproductive potential, producing only two young per litter (Springer 1948). In North America, the sand tiger gives birth in March and April to two young that measure about 100 cm TL. Parturition (birth of the young) is believed to occur in winter in the southern portions of range and the neonates migrate northward to summer nurseries. The nursery areas are mid-Atlantic bight estuaries: Chesapeake, Delaware, Sandy Hook, and Narrangansett bays, as well as coastal sounds (R. Grant Gilmore, Harbor Branch Foundation, and J. A. Musick, VIMS, pers. comm.). Branstetter and Musick (1994) suggested that the reproductive cycle is biennial, but other evidence suggests annual parturition (R. G. Gilmore, pers. comm.). In the United States, there was a very severe population decline in the early 1990's, with sandtigers practically disappearing from North Carolina and Florida waters (R. Grant Gilmore, pers. comm.). Musick *et al.* (1993) documented a decrease in the Chesapeake Bight region of the U.S. Mid-Atlantic coast.

Impact of fisheries: The species is extremely vulnerable to overfishing, because it congregates in coastal areas in large numbers during the mating season. These aggregations are attractive to fishermen although the effects of fishing these aggregations probably contributes to local declines in the population abundance. Its limited fecundity (two pups per litter), probably contributes to its vulnerability. In 1997, the U.S. prohibited possession of this species in U.S. Atlantic waters.

<u>Essential Fish Habitat for Sand Tiger Shark (reference Fig. 6-28 a-c):</u>

• **Neonate/early juveniles (125 cm TL):** Shallow coastal waters from Barnegat Inlet, NJ south to Cape Canaveral, FL to 25 m.

• **Late juveniles/subadults (126- 220 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults (221 cm TL):** Shallow coastal waters to 25 m from Barnegat Inlet, NJ to Cape Lookout; from St. Augustine to Cape Canaveral, FL..

6.3.3.3.7 Whale Sharks (whale shark may also be classified into the family of carpet sharks along with the nurse shark)

Whale shark (*Rhincodon typus*). The whale shark is a sluggish, pelagic filter feeder, often seen swimming on the surface. It is the largest fish in the oceans, reaching lengths of 1210 cm TL and perhaps longer. It is found throughout all tropical seas, usually far offshore (Castro 1983). Habitat associations are summarized in Table 6.3.29.

Reproductive potential: For many years the whale shark was believed to be oviparous, based on a presumably aborted eggcase trawled from the Gulf of Mexico many years ago. Recent discoveries (Joung *et al.* 1996) proved the whale shark to be viviparous and the most prolific of all sharks. The only gravid female examined carried 300 young in several stages of development. The embryos measured 580-640 mm TL, the largest appearing ready for birth. The length of the reproductive cycle is unknown. It is probably biennial like the closely related nurse shark (*Ginglymostoma cirratum*) and most other large sharks (Castro 1996). Based on unpublished information on the growth rate of one of surviving embryos from the female reported by Joung *et al.* (1996), the whale shark may be the fastest growing shark. Only a handful of small juveniles has ever been caught, probably because of the extremely fast growth rate. The location of the whale shark nurseries is unknown and remains as one of the interesting mysteries of shark biology.

Impact of fisheries: There are very few observations of aggregations of whale sharks. The range of the whale shark may be extremely vast, perhaps encompassing entire ocean basins. Thus it may be necessary to consider whale shark fisheries on an ocean-wide perspective.

There have been a few small fisheries for whale sharks in India, the Philippines, and Taiwan, but it is of little commercial importance elsewhere. The whale shark used to be fished for its flesh, but presently the fins and oil are also used. Generally, the size of the whale shark safeguards it from most fisheries. Records of the Taiwanese fishery demonstrate that whale sharks, like most elasmobranchs, are susceptible to overfishing.

Essential Fish Habitat for Whale Shark (reference Fig. 6-29 a):
• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.4 SMALL COASTAL SHARKS (U.S. Fishery Status - fully fished)

6.3.3.4.1 Angel Sharks

Atlantic angel shark *(Squatina dumerili)*. The angel shark is a flattened shark that resembles a ray. It inhabits the coast of the United States from Massachusetts to the Florida Keys, the Gulf of Mexico, and the Caribbean Sea. It is common from southern New England to the Maryland coast (Castro 1983). Habitat associations are summarized in Table 6.3.30.

Reproductive potential: Maturity is probably reached at a length of 90-105 cm TL. The pups measure 28-30 cm TL at birth. Up to 16 pups in one litter have been observed (Castro 1983). Very little is known about its biology.

Impact of fisheries: Unknown.

Essential Fish Habitat for Atlantic Angel Shark (reference Fig. 6-30 a-e):

- **Neonate/early juveniles (50 cm TL):** Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to 25 meters, including the mouth of Delaware Bay.
- **Late juveniles/subadults (51 -105 cm TL):** (Identical to neonate EFH): Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to 25 meters, including the mouth of Delaware Bay.
- **Adults (106 cm TL):** (Identical to neonate EFH): Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to 25 meters, including the mouth of Delaware Bay.
- **Research Area (unsubstantiated data):** Along the US east coast, from 38.25° N to 36° N between the 100m and 200m isobaths.

6.3.3.4.2 Hammerhead Sharks

Bonnethead (*Sphyrna tiburo*). The bonnethead is a small hammerhead that inhabits shallow coastal waters where it frequents sandy or muddy bottoms. It is confined to the warm waters of the western hemisphere (Castro 1983). Habitat associations are summarized in Table 6.3.31.

Reproductive potential: Males mature at about 70 cm TL, females mature at about 85 cm TL (Parsons 1993). Litters consist of 8-12 pups and the young measure 27-35 cm TL at birth (Castro 1983, Parsons 1993). Parsons (1993) estimated the gestation period of two Florida populations at 4.5-5 months, one of the shortest gestation periods known for sharks. The reproductive cycle is annual (Castro pers. obs.). Hueter (CSR data) found "young of the year" and juveniles in the west coast of Florida, at temperatures of 16.1-31.5° C , salinities of 16.5-36.1 ppt, and DO of 2.9-9.4 ml/l.

Impact of fisheries: The bonnet head is at a lesser risk of overfishing because it is a fast growing species that reproduces annually and it is generally not targeted by commercial fisheries due to its small size. Although bonnetheads are caught as bycatch in gillnet fisheries operating in shallow waters of the southeastern United States, many of these fisheries have been prohibited by various states and therefore forced into deeper Federal waters where gillnets are less effective. Bonnethead bycatch in the U.S. Gulf of Mexico shrimp fishery seems to have remained stable over the last twenty years, from 1974-94 (Pellegrin 1996).

Essential Fish Habitat for Bonnethead Shark (reference Fig. 6-31 a-d):

• **Neonate/early juveniles (50 cm TL):** Shallow coastal waters, inlets and estuaries less than 25 m deep from just Jekyll Island, GA to just north of Cape Canaveral; in shallow waters on the Gulf-side of the Florida Keys as far north as Cape Sable in water less than 25 m deep.

• **Late juveniles/subadults (51-84 cm TL):** Shallow coastal waters, inlets and estuaries from Cape Fear, NC southward to West Palm Beach, FL in waters less than 25 m deep; shallow coastal waters, inlets and estuaries from Miami around peninsular Florida as far north as Cedar Key in waters less than 25 m deep; shallow coastal waters, inlets and estuaries from the Mississippi River westward to the Rio Grande River (TX-Mexico border).

• **Adults (85 cm TL):** Shallow coastal waters, inlets and estuaries from Cape Fear, NC to Cape Canaveral, FL, shallow waters around the Florida Keys; shallow coastal waters from Mobile Bay west to South Padre Island, TX from inshore to 25 m deep.

6.3.3.4.3 Requiem Sharks

Atlantic sharpnose shark (*Rhizoprionodon terraenovae*). The Atlantic sharpnose shark is a small coastal carcharhinid. It inhabits the waters of the northeast coast of North America. It is a common year round resident along the coasts of South Carolinas, Florida and in the Gulf of Mexico. It is an abundant summer migrant off Virginia (Musick pers. comm.). Frequently, the sharks are found in schools of uniform size and sex (Castro 1983). Habitat associations are summarized in Table 6.3.32.

Reproductive potential: The male Atlantic sharpnose sharks mature around 65-80 cm TL and grow to 103 cm TL. The females mature at 85-90 cm TL and reach a length of 110 cm TL. Litters range from 4 to 7 pups, which measure 29-32 cm TL (Castro 1983). Mating is in late June; the gestation period is about 11-12 months (Castro and Wourms 1993). The von Bertalanffy growth parameter estimates for the species are L = 108, K= 0.359, t_o= -.985 yr (Branstetter 1987). Cortés (1995) calculated the population's intrinsic rate of increase was, at best, r= .044, or a finite increase of e_r = 1.045. Off South Carolina, the young are born in late May and early June in shallow coastal waters (Castro and Wourms 1993). Hueter (CSR data) found neonates at Yankeetown and Anclote Key in the west coast of Florida during the months of May to July. These neonates were found in temperatures of 24.0-30.7°C, salinities of 22.8-337 ppt, and DO of 5.7 ml/l. Larger juveniles were also found in the area in temperatures of 17.2-33.3°C, salinities of 22.8-35.5 ppt, and DO of 4.5-8.6 ml/l.

Impact of fisheries: Large numbers of sharpnose are taken as bycatch in the U.S. shrimp trawling industry. The Texas Recreational Survey, NMFS Headboat Survey, and the U.S. Marine Recreational Fishing Statistics Survey have estimated a slow increase in the sharpnose fishery.

The Atlantic sharpnose is a fast-growing species that reproduces yearly. In spite of being targeted by recreational fisheries and the large bycatch in the shrimp industry, the populations seem to be maintaining themselves.

Essential Fish Habitat for Atlantic Sharpnose (reference Fig. 6-32 a-d):

• **Neonate/early juveniles (55 cm TL):** Shallow coastal areas including bays and estuaries out to 25 m from Galveston Island south to the Rio Grande (Texas-Mexico border); from Daytona Beach north to Cape Hatteras .
• **Late juveniles/subadults (56-84 cm TL):** Shallow coastal areas including bays and estuaries out to 25 m from Galveston Island south to the Rio Grande (Texas-Mexico border); Louisiana from the Atchafalya River to Mississippi Delta out to 40 m; from Daytona Beach north to Cumberland Island; Hilton Head Island, SC north to Cape Hatteras out to 25 m (slightly deeper - to 50 m off North Carolina).
• **Adults (85 cm TL):** From Cape May, NJ south to the NC-SC border shallow coastal north of Cape Hatteras to 25 m/south of Cape Hatteras between 25-100 m; offshore St. Augustine, FL to Cape Canaveral, FL from inshore to 100 m isobath, Mississippi Sound from Perdido Key to the Mississippi delta to 50 m; coastal waters from Galveston to Laguna Madre, TX to 50 m.

Blacknose shark (*Carcharhinus acronotus*). The blacknose shark is a common coastal species that inhabits the western North Atlantic from North Carolina to southeastern Brazil (Bigelow and Schroeder 1948). It is very abundant in coastal waters from the Carolinas to Florida and the Gulf of Mexico during summer and fall (Castro 1983). Schwartz (1984) hypothesized that there are two separate populations in the western Atlantic. Habitat associations are summarized in Table 6.3.33.

Reproductive potential: Maturity is reached at about 100 cm TL. Litters consist of 3-6 pups, which measure 50 cm TL at birth (Castro 1983). Dodrill (1977) estimated the gestation period to be 10-11 months and suggested that the breeding cycle was biennial. Schwartz (1984) estimated that the largest adult male captured was 164 cm TL and was 9.6 years old, while an adult female 154 cm TL was also 9.6 years old. Castro (1983) stated that, in South Carolina, nursery areas were in shallow waters. The species is common throughout the year off Florida, suggesting that part of the population may be non-migratory and that nursery areas may exist in Florida as well. Hueter (CSR data) found 13 neonates in the Ten Thousand Islands and off Sarasota in June and July at temperatures 29-30.1° C, salinities of 32.2-37.0, ppt and DO of 6.5 ml/l. He also found “young of the year” and juveniles at temperatures of 17.3-34° C , salinities of 25.0-37.0 ppt, and DO of 4.8-8.5 ml/l.

Impact of fisheries: Large numbers of blacknose sharks are caught in shallow coastal waters of the southeastern United States. The species is vulnerable to overfishing because it has typical carcharhinid characteristics such as biennial reproductive cycle, and it is targeted in the shark fisheries in the southeastern United States.

Essential Fish Habitat for Blacknose Shark (reference Fig. 6-33 a-d):
• **Neonate/early juveniles (75 cm TL):** Shallow coastal waters to 25 m from NC-SC border south to Cape Canaveral, FL; shallow water to 25 m from Ten Thousand Islands north to just south of Tampa Bay, FL.
• **Late juveniles/subadults (76-99 cm TL):** Shallow coastal waters to 25 m from GA-FL border south to West Palm Beach, FL; shallow waters to 25 m from Florida Keys north to the mouth of Tampa Bay, FL.

• **Adults (100 cm TL):** Shallow coastal waters to 25 m from St. Augustine south to Cape Canaveral, FL; shallow water to 25 m from Florida Keys north to Cedar Key, FL; Mississippi Sound from Mobile Bay to the waters off Terrebonne Parish, LA in waters 25-100 m.

<u>Caribbean Sharpnose Shark (*Rhizoprionodon porosus*).</u> The Atlantic sharpnose and the Caribbean sharpnose sharks are cognate species, separable only by having different numbers of precaudal vertebrae (Springer 1964). They have non-overlapping ranges. The Caribbean sharpnose shark inhabits the Atlantic from 24° N to 35° S, the Atlantic sharpnose is found at latitudes higher than 24° N. Their biology is very similar. Habitat associations are summarized in Table 6.3.34.

<u>Essential Fish Habitat for Caribbean Sharpnose (reference Fig. 6-34 a):</u>
• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

<u>Finetooth shark (*Carcharhinus isodon*).</u> This is a common inshore species of the western Atlantic. It ranges from North Carolina to Brazil. It is abundant along the southeastern United States and the Gulf of Mexico (Castro 1983). Habitat associations are summarized in Table 6.3.35.

Reproductive potential: Males mature at about 130 cm TL and females mature at about 135 cm TL. The young measure 48-58 cm TL at birth. Litters range from 2 to 6 embryos, with an average of 4. The gestation period lasts about a year and the reproductive cycle is biennial. Some of the nurseries are in shallow coastal waters of South Carolina (Castro 1993b).

Impact of fisheries: Large numbers of finetooth sharks are caught in gillnet fisheries off South Carolina, but most are not recorded by species (Castro, pers. obs). The finetooth shark is caught in large numbers along the southeastern United States, including, very recently, in the shallow nursery areas of South Carolina. It is vulnerable to overfishing because its biennial reproductive cycle and small brood size.

<u>Essential Fish Habitat for Finetooth Shark (reference Fig. 6-35 a-e):</u>
• **Neonate/early juveniles (90 cm TL):** Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 meter isobath from 33°N to 30° N.
• **Late juveniles/subadults (91-135 cm TL):** (Identical to neonate EFH): Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 meter isobath from 33°N to 30° N.

• **Adults (136 cm TL):** (Identical to neonate EFH): Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 meter isobath from 33°N to 30°N.
• **Research Areas (unsubstantiated data):** On the west coast of Florida from the southern edge of Tampa Bay, north to Cedar Key, shallow coastal waters offshore to the 25 meter isobath; also, off the Texas coast, from Aransas Pass at Corpus Christi south to the United States/Mexico border, shallow coastal waters out to the 25m isobath.

Smalltail shark *(Carcharhinus porosus)*. This is a small, tropical and subtropical shark that inhabits shallow coastal waters and estuaries in the western Atlantic, from the Gulf of Mexico to southern Brazil, and the eastern Pacific from the Gulf of California to Peru (Castro 1983). A few specimens have been caught in the Gulf of Mexico off Louisiana and Texas (S. Branstetter, pers. comm.). Habitat associations are summarized in Table 6.3.36.

Reproductive potential: There is almost no published data on its reproductive processes. Females observed in Trinidad were in different stages of gestation, suggesting a wide breeding season. Embryos up to 35 cm TL were observed. The reproductive cycle appears to be annual.

Impact of fisheries: The species is marketed in many areas of Central America; Springer (1950a) stated that large numbers were sold in the Trinidad market.

Essential Fish Habitat for Smalltail Shark (reference Fig. 6-36 a):
• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.5 PELAGIC SHARKS (U.S. Fishery Status: Fully Fished)

6.3.3.5.1 Cow sharks

Bigeye sixgill shark (*Hexanchus vitulus*). This is a poorly known deep-water shark that was not described until 1969. Most specimens have been accidental captures at depths of 400 m in tropical waters (Castro 1983). In North America, most catches have come from the Bahamas and the Gulf of Mexico. Habitat associations are summarized in Table 6.3.37.

Essential Fish Habitat for Bigeye Sixgill Shark (reference Fig. 6-37 a):
• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

<u>Sevengill shark (*Heptranchias perlo*).</u> This is a deep-water species of the continental slopes, where it appears to be most common at depths of 180-450 m. It has worldwide distribution in deep tropical and warm temperate waters. In the US, it ranges from South Carolina to the Gulf of Mexico. Habitat associations are summarized in Table 6.3.38.

Reproductive potential: Maturity is reached at about 85-90 cm TL. Litters consist of 9-20 pups, which measure about 25 cm TL at birth (Castro 1983). According to Tanaka and Mizue (1977), off Kyushu, Japan the species reproduces year round. The lengths of the reproductive and gestation cycles are unknown. The location of the nurseries is unknown.

Impact of fisheries: The sharpnose sevengill shark is sometimes caught in large numbers as bycatch in fisheries using bottom trawls or longlines (Compagno 1984). In North America, it is occasionally seen in small numbers as bycatch of tilefish longlines (Castro, unpublished).

<u>Essential Fish Habitat for Sevengill Shark (reference Fig. 6-38 a):</u>
• **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
• **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

<u>Sixgill shark (*Hexanchus griseus*).</u> This is a common, bottom-dwelling, species usually reported from depths of 180-1100 m, in deep tropical and temperate waters throughout the world (Castro 1983). It often comes close to the surface at night, where it may take longlines set for other species. Juveniles stray into very shallow cool waters. This is one of the largest sharks. Habitat associations are summarized in Table 6.3.39.

Reproductive potential: Very few mature sixgill sharks have been examined by biologists; thus the reproductive processes are poorly known. Ebert (1986) reported a 421-cm TL female to be gravid with term embryos. Harvey-Clark (1995) stated that males mature at 325 cm TL, without providing any evidence for this. The species has not been aged. It is probably long-lived, like the Greenland shark, another deep-water giant shark. The pups measure 60-70 cm TL at birth. Litters are large; up to 108 pups have been reported (Castro 1983). Juveniles are often caught in coastal waters, suggesting that the nurseries are in waters much shallower than those inhabited by the adults. Nothing else is known about its nurseries.

Impact of fisheries: Although juveniles are common in deep continental waters and often enter coastal waters, the adults are seldom taken (Springer and Waller 1969, Ebert 1986). Apparently, adults are in waters deeper than those regularly fished, or perhaps these very large animals break the gear and escape. Thus, the very deep habitat of the adults or perhaps their large size seem to convey some measure of protection from most fisheries. According to Harvey-Clark

(1995), the sixgill shark became the target of a directed, subsidized, longline fishery off British Columbia, Canada, in 1991. At about the same time, the species also became of interest as an ecotourism resource, with several companies taking diving tourists to watch sixgill sharks in their environment. The fishery was unregulated, and lasted until 1993, when the commercial harvest of sixgill sharks was discontinued due to conservation and management concerns. According to Harvey-Clark (1995), diver observations of sharks decreased in 1993 and it was unclear at the time whether the fishery or the ecotourism could be sustained. It is difficult to evaluate the vulnerability of the sixgill shark, because of the lack of fisheries or landings data. The only fishing operations on record collapsed in a few years, suggesting that the species may be very vulnerable to overfishing.

Essential Fish Habitat for Sixgill Shark (reference Fig. 6-39 a):
- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.5.2 Mackerel Sharks

Longfin mako shark (*Isurus paucus*). This is a deep dwelling lamnid shark found in warm waters. The species was not described until 1966 and it is very poorly known. Habitat associations are summarized in Table 6.3.40.

Reproductive potential: There is very little data on the reproductive processes of the longfin mako. Litters consist of 2-8 pups, which may reach 120 cm TL at birth (Castro unpublished.).

Impact of fisheries: The longfin mako is a seasonal bycatch of the pelagic tuna and swordfish fisheries. Its flesh is of lesser quality than that of its congener, the shortfin mako.

Essential Fish Habitat for Longfin Mako Shark (reference Fig. 6-40 a-d):
Note: At this time, insufficient data is available to differentiate EFH by size classes, therefore EFH is the same for all life stages.
- **Neonate/early juveniles:** Off the northeast US coast from the 100m isobath out to the EEZ, from southern Georges Bank to 35° N; from 35°N south to 28.25°N off of Cape Canaveral, Florida, from the 100m isobath to the 500m isobath; from 28.25°N south around peninsular Florida and west to 92.5 ° W in the Gulf of Mexico, from the 200m isobath to the EEZ.
- **Late juveniles/subadults:** (Identical to neonate EFH):Off the northeast US coast from the 100m isobath out to the EEZ, from southern Georges Bank to 35° N; from 35°N south to 28.25°N off of Cape Canaveral, Florida, from the 100m isobath to the 500m isobath; from 28.25°N south around peninsular Florida and west to 92.5 ° W in the Gulf of Mexico, from the 200m isobath to the EEZ.

• **Adults:** (Identical to neonate EFH): Off the northeast US coast from the 100m isobath out to the EEZ, from southern Georges Bank to 35° N; from 35°N south to 28.25°N off of Cape Canaveral, Florida, from the 100m isobath to the 500m isobath; from 28.25°N south around peninsular Florida and west to 92.5 ° W in the Gulf of Mexico, from the 200m isobath to the EEZ.

Porbeagle (*Lamna nasus*). The porbeagle is a lamnid shark common in deep cold temperate waters of the North Atlantic, South Atlantic and South Pacific Oceans. It is highly esteemed for its flesh. There have been fisheries for this species in the North Atlantic for many years. Habitat associations are summarized in Table 6.3.41.

Reproductive potential: Very little is known about its reproductive processes. Aasen (1963) estimated that maturity was reached at 150-200 cm TL for males and 200-250 cm TL for females. Castro estimated that porbeagles reach 20 years of age and possibly 30. Shann (1911) reported an embryo 61 cm TL and estimated that porbeagles were probably born at about 76 cm TL. Bigelow and Schroeder (1948) recorded a free swimming specimen at 76 cm TL. Gauld (1989) gave 3.7 as the mean number of embryos in a sample of 12 females. The frequency of reproduction is not known. According to Aasen (1963), the porbeagle probably reproduces annually, but there is no evidence to support this claim. The nurseries are probably in continental waters.

Impact of fisheries: The porbeagle is presently targeted in northern Europe and along the northeastern coast of North America. Whether the porbeagles in the North Atlantic constitute one or more separate stocks is not known. A small porbeagle fishery resumed in the early 1990's in the northeastern United States, after being practically non-existent for decades. Intensive fisheries have depleted the stocks of porbeagles in a few years wherever they have existed, demonstrating that the species can not withstand heavy fishing pressure.

Essential Fish Habitat (EFH) for Porbeagle Shark (reference Fig. 6-41 a-d):

• **Neonate/early juveniles (100 cm TL):** From the 100 m isobath to the EEZ from offshore Cape May, approx. 39° N to approx 42° N (west of Georges Bank).

• **Late juveniles/subadults (101-224 cm TL):** From the 200 m isobath to the EEZ from offshore Great Bay, approx. 38° N to approx 42° N (west of Georges Bank).

• **Adults (225 cm TL):** From offshore Portland, ME south to Cape Cod along the 100 m isobath out to the EEZ and from Cape Cod south to the 2000 m isobath out to the EEZ.

Shortfin mako shark (*Isurus oxyrinchus*). The shortfin mako is found in warm and warm-temperate waters throughout all oceans. It is an oceanic species at the top of the food chain, feeding on fast-moving fishes such as swordfish, tunas, and other sharks (Castro 1983). It is considered one of the great gamefish of the world and its flesh is considered among the best to eat. Habitat associations are summarized in Table 6.3.42.

Reproductive potential: According to Pratt and Casey (1983), females mature at about 7 years of age. Cailliet. *et al.* (1983) estimated the von Bertalanffy parameters (n= 44) for the shortfin as: L = 3210 mm, K= .072, t_o= -3.75. Cailliet and Mollet (1997) estimated that a female mako lives for ~25 years, matures at 4-6 years, has a two-year reproductive cycle, and a gestation period of ~ 12 months. The litters range from 12 to 20 pups, though only a handful have been examined (Castro unpubl.). There is circumstantial evidence that the nursery areas are in deep tropical waters. The lifespan of the species has been estimated at 11.5 years (Pratt and Casey 1983).

Impact of fisheries: The shortfin mako is a common bycatch in tuna and swordfish fisheries. Because of their high market value, shortfin mako are usually the only sharks retained in some pelagic fleets with high shark bycatch rates. Off the northeastern coast of North America, most of the catch consists of immature fish (Casey and Kohler 1992). The index of abundance for shortfin makos in the commercial longline fishery off the Atlantic coast of the United States shows a steady decline (Cramer 1996a). The few indices available (Cramer 1996a, Holts *et al.* 1996, ICES 1995) indicate substantial population decreases. Because the species is commonly caught in widespread swordfish and tuna operations, it is reasonable to assume that similar decreases are occurring in areas for which there is limited data.

<u>Essential Fish Habitat (EFH) for Shortfin Mako (reference Fig. 6-42 a-d):</u>

- **Neonate/early juveniles (95 cm TL):** Between the 50 m and 2000 m isobaths from Cape Lookout (Hatteras), approx. 35° N, north to just southeast of Georges Bank (approx. 42° N and 66° W) to the EEZ; and between the 25 m and 50 m isobaths from offshore of the Chesapeake Bay (James River) (North Carolina-Virginia border) to a line running west of Long Island to just southwest of Georges Bank, approx. 67° W and 41° N.
- **Late juveniles/subadults (96-279 cm TL):** Between the 25 and 2000m isobaths from offshore of Onslow Bay, NC north to Cape Cod; and extending west between 38° N and 41.5° N to the EEZ.
- **Adults (280 cm TL):** Between the 25 m and 2000 m isobaths from offshore of Cape Lookout, NC north to Long Island, NY; and extending west between 38.5° N and 41° N to the EEZ.

<u>6.3.3.5.3 Requiem Sharks</u>

<u>Blue shark (*Prionace glauca*).</u> The blue shark is cosmopolitan in tropical, subtropical and temperate waters. It is one of the most common and widest-ranging of sharks. It is a pelagic species that inhabits clear, deep, blue waters, usually in temperatures of 10-20°C, at depths greater than 180 m (Castro 1983). Its migratory patterns are complex and encompass great distances, but are poorly understood. The biology, migrations, and the impact of fisheries on the blue shark must be considered on the basis of entire ocean basins. Males and females are known to segregate in many areas (Strasburg 1958, Gubanov and Grigoryev 1975). Strasburg (1958) showed that blue sharks are most abundant in the Pacific between latitudes of 40°N and 50°N. Habitat associations are summarized in Table 6.3.43.

Reproductive potential: Although some authors have examined very large numbers of blue sharks, the data on its size at maturity is imprecise. This may be due to poor criteria for maturity, incomplete samples, samples that did not include animals of all sizes, or some peculiarities of the blue shark. Pratt (1979) used different criteria for determining maturity of males and gave a range of 153-183 cm FL for male maturity, but when he used the standard criterion of clasper calcification, he observed that the males reached maturity at 183 cm FL (218 cm TL). Bigelow and Schroeder (1948) suggested that females mature at 213-243 cm TL. Strasburg (1958) stated that the smallest gravid female seen by him measured 214 cm TL. Nakano (1994) used data from 105,600 blue sharks and stated that females matured between 140 and 160 cm (166 and 191 cm TL, using the regression of Pratt), and that males matured at 130 to 160 cm PCL, based on clasper development.

This is probably the most prolific of the larger sharks; litters of 28 to 54 pups have been reported often (Bigelow and Schroeder 1948, Pratt 1979), but up to 135 pups in a litter have been reported (Gubanov and Grigoryev 1975). Nakano (1994) observed 669 pregnant females in the North Pacific and stated that the number of embryos ranged from 1 to 62, and the average was 25.6 embryos. Strasburg (1958) gave the birth size as 34-48 cm TL. Suda (1953) examined 115 gravid females from the Pacific Ocean and concluded that gestation lasts 9 months and that birth occurs between December and April. Pratt (1979) examined 19 gravid females from the Atlantic and used data from 23 other Atlantic specimens to arrive at a gestation period of 12 months. Nakano (1994) stated that gestation lasts about a year based on length frequency histograms, but did not state how many gravid animals had been observed nor showed any data. The length of the reproductive cycle is believed to be annual (W.L. Pratt, Jr, pers. comm.). Nakano (1994) gave the age at maturity as 4-5 years for males and 5-6 years for females based on “growth equations”. According to Cailliet *et al.* (1983), blue sharks become reproductively mature at 6 or 7 years of age and may reach 20 years. The nursery areas appear to be in open oceanic waters in the higher latitudes of the range. Strasburg (1958) attributed the higher CPUE in the 30-40°N zone of the Pacific Ocean in summer to the presence of new born blue sharks, and commented on the absence of small blue sharks in the warmer parts of the range. Nakano (1994) also stated that parturition occurred in early summer between latitudes of 30° to 40°N of the Pacific Ocean.

Impact of fisheries: Blue sharks have historically been finned and discarded because of the low value of their flesh, although finning is now prohibited in U.S. Atlantic waters. Large numbers of blue sharks are caught and discarded yearly in pelagic tuna and swordfish fisheries.

Although the blue shark is one of the most abundant large vertebrates in the world, it may be vulnerable to overfishing because it is caught in tremendous numbers as bycatch in numerous longline fisheries, however, CPUE data do not, yet, indicate any recent declines.

Essential Fish Habitat for Blue Shark (reference Fig. 6-43 a-d):

- **Neonate/early juveniles (75cm TL):** North of 40°N from Manasquan Inlet, NJ to Buzzards Bay, MA in waters from 25m.
- **Late juveniles/subadults (76-220 cm TL):** From 45°N (offshore Cape Hatteras) in waters from the 25 m isobath to the EEZ.
- **Adults (221 cm TL):** From 45°N (offshore Cape Hatteras) in waters from the 25 m isobath to the EEZ; extending around Cape Cod to include the southern part of the Gulf of Maine.

Oceanic whitetip shark (*Carcharhinus longimanus*). The oceanic whitetip is one of the most common large sharks in warm oceanic waters (Castro 1983). It is circumtropical and nearly ubiquitous in water deeper than 180 m and warmer than 21°C. Habitat associations are summarized in Table 6.3.44.

Reproductive potential: Both males and females appear to mature at about 190 cm TL (Bass *et al.* 1973). The young are born at about 65-75 cm TL (Castro 1983). The number of pups per litter ranges from 2 to 10 with a mean of 6 (Backus *et al.* 1956, Guitart Manday 1975). The length of the gestation period has not been reported; it is probably 10-12 months like most large carcharhinids. The reproductive cycle is believed to be biennial (Backus *et al.* 1956). The location of nurseries has not been reported. Preliminary work by Castro (pers. comm.) indicates that very young oceanic whitetip sharks are found well offshore along the southeastern United States in early summer, suggesting offshore nurseries over the continental shelves.

Impact of fisheries: Large numbers of oceanic whitetip sharks are caught as bycatch each year in pelagic tuna and swordfish fisheries. Strasburg (1958) reported that the oceanic whitetip shark constituted 28% of the total shark catch in exploratory tuna longline fishing south of 10^{0} N latitude in the central Pacific Ocean. According to Berkeley and Campos (1988), oceanic whitetip sharks constituted 2.1% of the shark bycatch in the swordfish fishery along the east coast of Florida in 1981-83. Guitart Manday (1975) demonstrated a marked decline in the oceanic whitetip shark landings in Cuba from 1971 to 1973. The oceanic whitetip shark is probably vulnerable to overfishing because of its limited reproductive potential and because it is caught in large numbers in various pelagic fisheries and in directed fisheries. There is no data on populations or stocks of the species in any ocean.

<u>Essential Fish Habitat for Oceanic Whitetip Shark (reference Fig. 6-44 a-d):</u>

- **Neonate/early juveniles (115 cm TL):** In the vicinity of the Charleston Bump, from the 200m isobath to the 2000m isobath, between 32.5° N and 31° N.
- **Late juveniles/subadults (116- 190 cm TL):** Offshore of the southeastern US coast from 32° N to 26° N, from the 200m isobath to the EEZ, or 75° W, whichever is nearer.
- **Adults (191 cm TL):** Offshore of the southeastern US coast from the 200m isobath out to the EEZ, from 36 ° N to 30° N; also, in the Caribbean, south of the US Virgin Islands, from east of 65° W to the EEZ or the 2000m isobath, whichever is nearer.

<u>6.3.3.5.4 Thresher Sharks</u>

<u>Bigeye thresher shark (*Alopias superciliosus*).</u> The bigeye thresher is cosmopolitan in warm and warm-temperate waters. It is a deep-water species which ascends to depths of 35-150 m at night. It feeds on squid and small schooling fishes (Castro 1983), which it stuns with blows from its tail. This is one of the larger sharks, reaching up to 460 cm TL (Nakamura 1935). Habitat associations are summarized in Table 6.3.45.

Reproductive potential: Males mature at about 270 cm TL and females at about 340 cm TL (Moreno and Moron 1992). Litters consist of two pups, one in each uterus. Gestation probably lasts about a year, but there is no evidence to support this. The length of the reproductive cycle is unknown. The location of the nursery areas is unknown.

Impact of fisheries: The bigeye thresher is often caught as bycatch of swordfish fisheries. A shark will often dislodge several baits before impaling or hooking itself. The flesh and fins of the bigeye thresher shark are of poor quality, thus it is usually discarded dead in swordfish and tuna fisheries. It is, however, marketed in some areas.

Essential Fish Habitat for Bigeye Thresher Shark (reference Fig. 6-45 a-c):

- **Neonate/early juveniles (135 cm TL):** At this time, available information is insufficient to identify EFH for this life stage.
- **Late juveniles/subadults (136-339 cm TL):** Offshore of North Carolina, from 36.5° N to 34° N, between the 200m and 2000m isobaths.
- **Adults (340 cm TL):** Offshore of North Carolina, from 35.5° N to 35° N, between the 200m and 2000m isobaths.

Thresher shark (*Alopias vulpinus*). The common thresher shark is cosmopolitan in warm and temperate waters. It is found in both coastal and oceanic waters, but according to Strasburg (1958) it is more abundant near land. It is a large shark that uses its tremendously large tail to hit and stun the small schooling fishes upon which it feeds. Habitat associations are summarized in Table 6.3.46.

Reproductive potential: According to Strasburg (1958), females in the Pacific mature at about 315 cm TL. According to Cailliet and Bedford (1983), males mature at about 333 cm TL. Cailliet and Bedford (1983) stated that the age at maturity ranges from 3 to 7 years. Litters consist of 4 to 6 pups, which measure 137-155 cm TL at birth (Castro 1983). According to Bedford (1985), gestation lasts 9 months and female threshers give birth annually every spring (March to June).

Impact of fisheries: Thresher sharks are caught in many fisheries. The most detailed data available are for the California drift gill net fishery which started in 1977 for thresher sharks, shortfin makos, and swordfish, extending from the Mexican border to San Francisco, California (Hanan 1984). After 1982, the fishery expanded northward yearly, ultimately reaching the states of Oregon and Washington (Cailliet *et al.* 1991). Thresher shark landings peaked in 1982, and the thresher shark resource quickly began to decline after that year (Bedford 1987). Catches have continued to decline and the average size has remained small in spite of numerous regulations restricting fishing (Hanan *et al.* 1993). Cailliet *et al.* (1991) summarized the condition of the resource by stating, "The coastwise fishery for this once abundant shark is now a thing of the past." Legislation passed in 1986 limited the directed thresher shark fishery in the Pacific. Off the U.S. coast in the Atlantic Ocean, the CPUE has shown a considerable decline (Kramer, 1996).

Essential Fish Habitat for Thresher Shark (reference Fig. 6-46 a-d):

- **Neonate/early juveniles (200 cm TL):** Offshore of Long Island and Southern New England in the northeastern US, in pelagic waters deeper than 50 meters, between 70° W and 73.5°W, south to 40° N.
- **Late juveniles/subadults (200- 319cm TL):** (Identical to neonate EFH): Offshore of Long Island and Southern New England in the northeastern US, in pelagic waters deeper than 50 meters, between 70° W and 73.5°W, south to 40°N.

- **Adults (320 cm TL):** (Identical to neonate EFH): Offshore of Long Island and Southern New England in the northeastern US, in pelagic waters deeper than 50 meters, between 70° W and 73.5°W, south to 40° N.

6.4 Threats to Essential Fish Habitat

This section identifies the principal fishing- and non-fishing-related threats to the sharks', tunas' and swordfish's EFH as identified and described in Section 6.3 of this FMP. It also provides examples and information concerning the relationship between those threats and EFH and describes conservation and enhancement measures that can minimize adverse impacts to HMS EFH. Other information sources and examples likely exist, and many new studies are underway or in various stages of completion or publication. Accordingly, the following discussion is presented as a starting point in the identification of threats to HMS EFH and is intended to satisfy requirements of the Magnuson-Stevens Act. The habitat provisions of this amendment represent an initial step in identifying EFH and the threats to EFH and provide a framework for continuing to focus attention on this critical area of fishery management. It is intended to stimulate further discussions, research and analyses that can improve future revisions of this document.

From the broadest perspective, fish habitat is the geographic area where the species occurs at any time during its life. Habitat can be described in terms of location; physical, chemical and biological characteristics; and time. Ecologically, habitat includes structure or substrate that focuses distribution (e.g., coral reefs, topographic highs, areas of upwelling, frontal boundaries, particular sediment types, or submerged aquatic vegetation) and other characteristics (e.g., turbidity zones, salinity, temperature or oxygen gradients) that are less distinct but are still crucial to the species' continued use of the habitat.

Species use habitat for spawning, breeding, migration, feeding and growth, and for shelter from predation to increase survival. Spatially, habitat use may shift over time due to changes in life history stage, abundance of the species, competition from other species, and environmental variability in time and space. Species distributions and habitat use can be altered by habitat change and degradation resulting from human activities and impacts, or other factors. The type of habitat available, its attributes, and its functions are important to species productivity, diversity and survival.

The role of habitat in supporting the productivity of organisms has been well documented in the ecological literature, and the linkage between habitat availability and fishery productivity has been examined for several fishery species. Because habitat is an essential element for sustaining the production of a species, and therefore fisheries based on those species, the goals of FMPs cannot be achieved if the managed species do not have sufficient quantities of suitable habitat available to each life stage of the animal.

The quantitative relationships between fishery production and habitat are very complex and no reliable models currently exist. Accordingly, the degree to which habitat alterations have affected fishery production is unknown. In one of the few studies that have been able to investigate habitat fishery productivity dynamics, Turner and Boesch (1987) examined the relationship between the extent of wetland habitats in the Gulf of Mexico and the yield of fishery species dependent on coastal bays and estuaries. They found reduced fishery stock production following wetland losses and stock gains following increases in the areal extent of wetlands. While most of the studies examined shrimp or menhaden productivity, other fisheries show varying degrees of dependence on particular habitats and likely follow similar trends. Accordingly, a significant threat facing fishery production is the loss of habitat by natural and anthropogenic causes.

Species of the HMS fisheries utilize diverse habitats that have been identified as essential to various life stages. Many of the shark species use bays, estuaries and shallow coastal areas for crucial pupping and nursery areas. In only a few cases are there particular bottom types that can be attributed to influencing the choice of habitats, e.g., the bonnethead shark juvenile stages are associated with sand or mud bottoms. Pelagic species (or life stages), such as the pelagic sharks, tunas and swordfish, are most often associated with areas of convergence or oceanographic fronts such those found over submarine canyons, the edge of the continental shelf or the boundary currents (edge) of the Gulf Stream. Although there is no substrate or hard structure in the traditional sense, these water column habitats can be characterized by their physical, chemical and biological parameters.

6.4.1 Fishing Activities That May Adversely Affect EFH

The Magnuson-Stevens Act requires that Councils (NMFS for Secretarial FMPs) identify adverse effects to EFH caused by fishing activities, and further requires that Councils manage the fisheries under their jurisdictions so as to minimize such impacts, to the extent practicable. The EFH regulations explain that "adverse effects from fishing may include 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 regulations require that FMPs contain an assessment of the potential adverse effects of all fishing gear and practices used in waters described as EFH. The assessment must consider the relative impacts of gears on all different types of EFH identified. Special consideration is to be given to analysis of impacts from gears that will affect habitat areas of particular concern (HAPC). The EFH regulations require that FMPs include management measures that minimize adverse effects on EFH from fishing, to the extent practicable. To decide if minimization of an adverse effect from fishing is practicable, the Council (NMFS) has to consider: 1) whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; 2) the nature and extent of the adverse effect on EFH; and, 3) whether the management measures are practicable, taking into consideration the long and short-term costs as well as benefits to the fishery and its EFH, along with other appropriate factors consistent with National Standard 7. Councils are advised to use the best scientific information available, as well as other appropriate information sources, as available. Where information gaps are identified through the assessment process, Councils should consider the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that physically alters EFH.

The following section includes an assessment of fishing gears and practices that are used in the HMS fisheries, accompanied by conservation recommendations to minimize the potential impacts. Following the assessment is a brief discussion of the scientific review of information relating to fishing impacts to habitat. In recent revies of fishing impacts to habitat, Jennings and Kaiser (1998) and Auster and Langton (1998) characterize fishing impacts hierarchically: impacts to structural components of habitat, effects on community structure, and effects on ecosystem processes. In this section the impacts of the HMS fishing activities will be addressed in the same format, followed by some comments on non-HMS fishery impacts to HMS EFH and the identification of research priorities to provide additional information that can be used to improve future amendments to the FMP EFH provisions.

Fishing Gear Assessment on EFH

The following gears have been identified for the HMS fisheries:

Atlantic Highly Migratory Species

Directed Fishery	Approved Gear
Atlantic Swordfish:	
A. Hook and line fishery	A. Rod and reel, handline.
B. Longline fishery	B. Longline.
C. Drift gillnet fishery*	C. Gillnet.
D. Harpoon fishery	D. Harpoon.
Atlantic Sharks:	
A. Hook and line fishery	A. Rod and reel, handline, bandit gear.
B. Longline fishery	B. Longline.
C. Drift gillnet fishery	C. Gillnet.
Atlantic Tunas:	
A. Hook and line fishery	A. Rod and reel, handline, bandit gear.
B. Purse seine fishery	B. Purse seine.
C. Longline fishery	C. Longline.
D. Harpoon fishery	D. Harpoon.
E. Recreational fishery	E. Rod and reel, bandit gear, harpoon, handline.

* Drift gillnet fisheries are currently being evaluated to determine whether they are appropriate in the HMS fisheries.

Physical Impacts of HMS Fishing Gears on EFH

Generally, the target species of the HMS fishery management units are associated with hydrographic structure in the water column, e.g., convergence zones or boundary areas between different currents. Because of the magnitudes of water column structures and the processes that create them, there is little effect that can be detected from the HMS fishing activities undertaken to pursue these animals. There are, however, some impacts that can be manifest on the biological or chemical characteristics of some of these sites, e.g., excess dead discards causing increased biological oxygen demand (BOD). For fisheries in which gear does contact the substrate, there is certainly the potential for disturbance of the habitat. An analysis of the effects and the impacts they may have on the associated fisheries is complicated by the fact that scientists are not certain of the particular characteristics that draw the fish to these habitats.

Of the gears that are used in the HMS fisheries, only bottom-set longlines, principally targeting coastal sharks, routinely contact the bottom substrate. Gear could become entangled on various elements of the substrate including rocks, boulders, hard- or live-bottoms, and hard or soft corals. In instances where target species are attracted to the habitat due to hydrographic characteristics, i.e., up-welling, convergences, etc., the scale of impact from careless placement of bottom-set longlines is probably not of sufficient magnitude to affect the characteristics of the habitat. If, however, the fish are attracted because of prey resources, the prey may be dependent on habitat characteristics that could be altered at these scales. It is recommended that fishers take appropriate measures to identify bottom obstructions and "hangs" and avoid setting gear in areas where it may become entangled and potentially disrupt benthic habitats. If gear is lost, diligent efforts should be made to recover the lost gear to avoid further fouling (disturbance) of the underwater habitat through "ghost fishing."

Population and Ecosystem Impacts of Removing Target Species

There is currently a great deal of interest in the ecosystem level effects of the removal of apex predators from aquatic systems. Although there has not been extensive research in this field, there are a few examples where population or ecosystem effects have been inferred from fishing activities. Branstetter and Burgess (1997) suggest that increased survival of young tiger, dusky and sandbar sharks may be due to the removal of large sharks that prey upon these juveniles. There is some evidence that removal of large sharks in coastal waters of South Africa has resulted in a proliferation of small shark species (C. Buxton, pers. comm.). Overfishing of cod in the northwest Atlantic has led to apparent "species replacement" where dogfish (sharks) have proliferated and assumed the ecological role previously served by cod. At the present time, it is believed that it may be difficult if not impossible to reverse the trend and re-establish cod populations.

Natural ecosystems maintain a dynamic equilibrium that will ensure stability, within natural variation, as long as ecological disturbance is neither too intense nor too frequent. Removal of one trophic level (e.g., apex predators) could be a major disturbance to an ecosystem. At moderate levels of disturbance, populations and ecosystems are likely able to compensate and maintain their biological integrity (Smith, 1990). Continued high rates of removal of tuna, swordfish and sharks, as adults and late juveniles (top predators), might constitute a frequent and intense disturbance with the capacity to induce large-scale changes in the biological characteristics of the habitat. Continued disturbance could result in unforeseen ecological changes, detrimental to the long-term productivity of the HMS species resulting from changes in the biological characteristics of their EFH. The time-area closures, suggested elsewhere in this document (Chapter 2, section 2.4.3) to reduce the bycatch or capture of juvenile swordfish, should be embraced as a risk-averse method to avoid changes to the biological characteristics of the HMS EFH and to help ensure the biological integrity of the habitats. Research into cascading ecological effects from apex predator removal should also be encouraged.

Impacts to HMS EFH from non-HMS Fishing Gears and Practices

Because some HMS use both estuarine and coastal inshore habitats, their EFH may be negatively impacted by fisheries that target species other than HMS. These fisheries may be either state or federally managed. In particular, shark pupping and nursery habitats are subjected to fishing impacts from gears of other fisheries, e.g., shrimp trawling; but the degree to which particular parameters are altered by that gear is, as yet, unquantified. Trawl fisheries that scrape the substrate, disturb boulders and their associated epiphytes or epifauna, re-suspend sediments, flatten burrows and disrupt seagrass beds have the potential to alter the habitat characteristics that are important for survival of early live stages of many targeted and non-targeted species.

The degree of impact and long term habitat modification depends on the severity and frequency of the impacts as well as the amount of recovery time between impacts (Auster and Langton, 1998). The extent to which particular parameters are altered by trawl gear is somewhat dependent on the configuration of the gear and the manner in which the gear is fished. Additional efforts are required to study the HMS EFH areas that are fished for non-HMS species and identify fishing gears that impact habitat; coordination efforts should be undertaken with the respective Councils to identify potential common areas. Research into the frequency of disturbance and the changes induced in the habitat are of primary importance. A better understanding of the characteristics of habitats that influence the abundance of managed species within those habitats is needed, in order to understand the effects of fishing activities on habitat suitability for HMS.

Besides altering the physical characteristics of EFH, other fisheries may remove prey species that make up the necessary biological components of the EFH for HMS fish. As an example, development or expansion of a squid fishery off the Atlantic coast has the potential to degrade the quality of EFH for tunas and swordfish since many of these species consume a high percentage of squid in their diets. Research into the dynamics of these inter-actions between fisheries should be investigated for future consideration. If there is evidence that another fishery is depleting the resources associated with the EFH of HMS animals, the issue of resource allocation will need to be addressed with the appropriate Council(s).

Additionally, other fisheries may actively remove habitat components that are important to the integrity of HMS EFH. Many of these impacts have been addressed in other fishery management plans (e.g., SAFMC, 1998 and GMFMC, 1998) that focus on restricting the removal of attached species such as corals or kelp that provide essential structure in their respective habitats; however for pelagic species other biological components must be considered. Some tuna and swordfish life stages have been found to be associated, or to co-occur, with floating mats of the brown algae, *Sargassum* sp.. The mats are pelagic and are moved extensively by winds and currents. They are frequently found in convergence zones, windrows, or at current boundaries. These areas are EFH for many of the HMS life stages. Whether the floating mats serve as shelter, act as a source of prey (because of the abundance of prey species associated with them), serve as a means of camouflage, or serve some other biological function is not entirely clear. It is a biological component that may focus, particularly on the small scale, the distribution of certain life stages of the tunas and swordfish and it should be maintained in its habitat. Under the Magnuson-Stevens Act definitions, harvesting of sargassum would qualify as a "fishing activity." As such, we have been urged by the HMS Advisory Panel to make strong recommendations against the harvest, possession or landing of *Sargassum* within the U.S. EEZ.

EFH Recommendations

The EFH regulations require that Councils act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing practice is having an identifiable adverse effect on EFH, based on the assessment of fishing gears on EFH.

At this time, there is no evidence that physical effects caused by fishing under this FMP are adversely affecting HMS EFH to the extent that detrimental effects can be identified on the habitat or the fisheries. Conservation recommendation, discussed above as NMFS' suggestions, should help to mitigate any impacts that are currently occurring but unverified:

- Fishers should take appropriate measures to identify bottom obstructions and avoid setting gear in areas where it may become entangled.
- If gear is lost, diligent efforts should be undertaken to recover the lost gear.

In addition, this FMP proposes the use of time-area closures to reduce the take of juvenile swordfish (Chapter 2, section 2.4.3). Besides serving as tools to reduce bycatch and rebuild stocks, these seasonal closures would also help maintain the biological integrity of the swordfish (HMS) EFH and reduce the chance of altering the biological characteristics of the HMS EFH. By preserving more of the age structure in the population and a diversity of trophic levels, the measure should lend added stability to the ecosystem upon which the HMS fisheries depend. From an EFH perspective, the alternative of time-area closures would be seen as a desirable step toward conserving and enhancing HMS EFH. As such, we recommend the time-area closures proposed in this FMP as a conservation measure for the protection of adult and juvenile swordfish EFH.

Initiation of limited access to the swordfish and shark fisheries (Chapter 4) has the potential to lessen fishing pressure on habitats by reducing the number of fishers harvesting these resources. It may also prevent some fishing by individuals less familiar with the gear and/or habitats who may be more likely to damage the habitat through improper setting of gear in EFH. Additional study is recommended to more adequately identify adverse impacts and to quantify impacts currently occurring. Any inshore areas that are closed to fishing in order to conserve pupping and juvenile habitats would be ideal locations to study the effects of gear impacts of EFH. Research in these areas is strongly advocated.

Further evaluations of fishing impacts on habitat will be undertaken as more research is conducted and information becomes available. Information will be reviewed annually to assess the state of knowledge in this field (section 6.6). Future revisions of the Habitat (and EFH) Provisions in this FMP will include any new information on the impacts of fishing activities on fish habitat, including EFH.

6.4.2 Non-fishing Threats to EFH

Section 600.815 (a)(5) of the EFH regulations requires that FMPs identify non-fishing related activities that may potentially affect essential fish habitat (EFH) of managed species, either quantitatively or qualitatively, or both. In addition, Section 600.815 (a)(7) of the regulations requires that FMPs recommend conservation measures describing options to avoid, minimize, or compensate for the adverse effects identified. Since the jurisdiction and the EFH of this Secretarial FMP overlaps with the EFH identified by the respective Councils of the eastern U.S., the threats to EFH and conservation measures compiled for this document are a synthesis of those listed in the Councils' EFH amendments. The information in this section has been adapted, with permission, from EFH amendments prepared by the Mid-Atlantic (MAFMC, 1998), South Atlantic (SAFMC, 1998) and Gulf of Mexico (GMFMC, 1998) Councils. Original sources of information are cited in those documents.

Broad categories of activities that may adversely affect HMS EFH include, but are not limited to: 1) actions that physically alter structural components or substrate, e.g., dredging, filling, excavations, water diversions, impoundments and other hydrologic modifications; 2) actions that result in changes in habitat quality, e.g., point source discharges, activities that contribute to non-point-source pollution and increased sedimentation, introduction of potentially hazardous materials, or activities that diminish, or disrupt the functions of EFH. If these actions are persistent or intense enough, they can result in major changes in habitat quantity, as well as quality, conversion of habitats, or in complete abandonment of habitats by some species.

Estuarine, coastal, and offshore waters are used by humans for a variety of purposes that often result in degradation of these and adjacent environments, posing threats to the associated biota. These effects, either alone or as cumulative effects combined with other activities within the ecosystem, may contribute to the decline of some species or biological components of the habitat. In many cases such effects are demonstrable, but they are often difficult to quantify.

Pollutants (e.g., heavy metals, oil and grease, excess nutrients, improperly treated human and animal wastes, pesticides, herbicides and other chemicals) can be introduced into the aquatic environment through a number of routes, including point sources, non-point sources and atmospheric deposition. These types of contaminants have been demonstrated to alter the growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, spawning seasons, migration routes and resistance to disease and parasites of finfish and invertebrates. In addition to the introduction of contaminants that cause direct effects on animal physiology, point source discharges also affect essential habitat characteristics such as water flow, temperature, pH, dissolved oxygen, salinity, and other parameters that affect habitat suitability for individuals, populations and communities. The synergistic effects of multiple discharge components such as heavy metals and various chemical compounds are not well understood but are increasingly the focus of research efforts. More subtle effects of contaminants such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food are also being identified and investigated.

Non-point source runoff may have a more significant impact on coastal water quality particularly since tighter controls on point source discharges have recently been instituted. Activities that tend to increase the input of contaminants to aquatic environments through non-point sources include coastal development, urbanization, certain agriculture and silviculture practices, marina and port development, commercial and recreational boating, and hydromodification. Related activities such as use of septic systems and improper disposal or treatment of wastes can contribute biological contaminants, as well. Many of these activities result in large quantities of pesticides, nutrients, and bacteria or pathogens in coastal waters. Excess nutrification is one of the greatest sources of coastal water contamination. Nutrient enrichment can lead to noxious algal blooms, fish kills, and oxygen depletion (as hypoxic or anoxic events). Researchers have found reduced or stressed fisheries populations to be common in areas where hypoxia occurs.

As required under the EFH regulations, the following discussion identifies activities with the potential to adversely affect HMS EFH. In many cases these activities are regulated under particular statutory authorities. As long as they are regulated within those guidelines, their potential to adversely affect EFH may be reduced, though not necessarily eliminated. Many of the standards that are used to regulate these activities are based on human health needs and do not consider long-term impacts to fish and fish habitats. Additionally, if the activity fails to meet or is operated outside its permitted standards, it may adversely affect EFH. The EFH regulations require NMFS and the Councils to identify actions with the **potential** (emphasis added) to adversely affect EFH, including its biological, chemical and physical characteristics. The EFH regulations also recommend the examination of cumulative impacts to EFH. It is possible that many permitted actions, operating within their regulatory bounds, may cause adverse impacts to EFH. These sections list a broad range of activities to ensure that their potential to adversely affect HMS EFH has been identified.

The review of habitat use, undertaken for this chapter, identified both benthic and water column habitats in coastal, estuarine and offshore areas as EFH, although in many cases, the particular habitat characteristics that control species habitat use are not clearly identified. Many of these factors seem to be related to water quality, (e.g., temperature, salinity, dissolved oxygen). Therefore water quality degradation has been a primary focus in this section. When analyzing the impacts that water quality changes can have on these species' EFH, it is important to examine all habitats. Although EFH for HMS includes offshore areas; these distant habitats are affected by actions that occur in coastal habitats (both terrestrial and aquatic) and adjacent estuaries. Many of the HMS aggregate over submarine canyons or along river plumes; these physiographic features can serve as conduits for currents moving from inshore, across the continental shelf and slope. These currents can carry and redistribute contaminants from the nearshore realm to offshore habitats. Until the precise zones of influence from various river and coastal discharges can be delineated, a precautionary view should be taken in order to protect the integrity of HMS EFH and the sustainability of the HMS fisheries.

In addition to identifying activities with the potential to adversely affect EFH, the Magnuson-Stevens Act and the EFH regulations require the inclusion of measures to conserve and enhance EFH. Each activity discussed below is followed by conservation measures to avoid, minimize or mitigate its adverse effects on EFH. These include examples of both general and specific conservation measures that might be appropriate for NMFS when consulting on similar proposed activities. In some cases, the measures are based on site-specific activities, in others the recommendations represent broad policy-type guidelines. It should be understood that during EFH consultations, each project will be evaluated on its merits and the threat to EFH, and the appropriate conservation measures will be assessed at that time. NMFS' role in the EFH consultation is no different from consultation under other authorities; it is to address the threats of proposed actions to fishery resources, including marine, estuarine and anadromous habitats, and EFH on behalf of their fisheries and their natural resources. The Federal action agency, with the statutory authority to regulate the proposed action, weighs the recommendations of all commenters and decides on the appropriate action, modifications or mitigation before proceeding with a project. The conservation measures included in this amendment are meant to be examples of agency recommendations that might be made regarding particular projects. They are intended to assist other Federal agencies and entities during the planning process when minimization of adverse impacts to EFH can most effectively be incorporated into project designs and goals.

6.4.2.1 Marine Sand and Minerals Mining

Mining for sand (e.g., for beach nourishment projects), gravel, and shell stock in estuarine and coastal waters can result in water column effects by changing circulation patterns, increasing turbidity, and decreasing oxygen concentrations at deeply excavated sites where flushing is minimal. Deep borrow pits created by mining may become seasonally or permanently anaerobic. Marine mining also elevates suspended materials at mining sites; turbidity plumes may move several kilometers from these sites. Resuspended sediments may contain contaminants such as heavy metals, pesticides, herbicides, and other toxins. Ocean extraction of mineral nodules is a possibility for some non-renewable minerals now facing depletion on land. Such operations are proposed for the continental shelf and the deep ocean proper; resuspension of sediments can affect water clarity over wide areas, and could also potentially affect pelagic eggs and larvae.

Conservation measures:

- Sand mining and beach nourishment should not be allowed in HMS EFH during seasons when HMS are utilizing the area, particularly during spawning seasons.

- Gravel extraction operations should be managed to avoid or minimize impacts to the bathymetric structure in estuarine and nearshore areas.

- An integrated environmental assessment, management, and monitoring program should be a part of any gravel or sand extraction operation, and encouraged at Federal, and state levels.

- Plan and design mining activities to avoid significant resource areas important to HMS EFH.

- Mitigation and restoration should be an integral part of the management of gravel and sand extraction policies.

6.4.2.2 Offshore Oil and Gas Operations

Offshore oil and gas operations, exploration, development, production, transportation and decommissioning, pose a significant level of potential threat to marine, coastal and estuarine ecosystems. Exploration and recovery operations may cause substantial localized bottom disturbance. However, more pertinent to highly migratory species is the threat of contaminating operational wastes associated with offshore exploration and development, the major operational wastes being drilling muds and cuttings and formation waters. In addition, there are hydrocarbon products, well completion and work-over fluids, spill clean-up chemicals, deck drainage, sanitary and domestic wastes, ballast water, and the large volume of unrefined and refined products that must be moved within marine and coastal waters. Potential major contaminants used in oil and gas operations may be highly saline; have low pH; contain suspended solids, heavy metals, crude oil compounds, organic acids; or may generate high biological and chemical oxygen demands. Also, accidental discharges of oil - crude, diesel and other oil products - and chemicals can occur at any stage of exploration, development, or production, the great majority of these being associated with product transportation activities. Blowouts and associated oil spills can occur at any operational phase when improperly balanced well pressures result in sudden, uncontrolled releases of petroleum hydrocarbons. To remove fixed platforms, explosives are frequently used. All of these result in harmful effects on marine water quality as well as the marine biota in the vicinity.

In the Gulf of Mexico, oil and gas operations are extending to deeper and deeper waters, throughout which highly migratory species are known to range.

Locations such as the De Soto Canyon area in the northern Gulf and the Blake Plateau north of the Bahamas repeatedly show up in the analysis of EFH as highly productive areas important to many species. Oil and gas production in these areas should be discouraged because of the potential impact to HMS EFH.

Considerable documentation exists that highlights the benefits of offshore production platforms as artificial reefs that attract numerous species of fish including highly migratory pelagic species. It is likely that the attraction of species increases the potential for exposure to contaminants, that may be released into the aquatic habitat from the platform.

Conservation measures:

- A plan should be in place to avoid the release of hydrocarbons, hydrocarbon-containing substances, drilling muds, or any other potentially toxic substance into the aquatic environment. Storage of these materials should be in enclosed tanks whenever feasible or, if not, in lined mud pits or other approved sites. Equipment should be maintained to prevent leakage. Catchment basins for collecting and storing surface runoff should be included in the project design.

- Exploration/production activities and facilities should be designed and maintained in a manner that will maintain natural water flow regimes, avoid blocking surface drainage, and avoid erosion in adjacent coastal areas.

- Activities should avoid wetlands. Drilling should be conducted from uplands, existing drill sites, canals, bayous or deep bay waters (greater than six feet), wherever possible, rather than dredging canals or constructing board roads. When wetland use is unavoidable, work in previously disturbed wetlands is preferable to work in high quality or undisturbed wetlands. If this is not possible, temporary roads (preferably board roads) to provide access are more desirable than dredging canals because roads generally impact less acreage and are easier to restore than canals. If the well is a producer, the drill pad should be reduced to the minimum size necessary to conduct production activities and the disturbed area should be restored to pre-project conditions.

- Upon completion or abandonment of wells in wetlands, all unnecessary equipment should be removed and the area restored to pre-project elevations. The well site, various pits, levees, roads and other work areas should be graded to pre-project marsh elevations and then restored with indigenous wetland vegetation. Abandoned canals frequently need plugging and capping with erosion-resistant material at their origin to minimize bank erosion and to prevent saltwater intrusion. In addition, abandoned canals will frequently need to be backfilled to maximize fish and wildlife production in the area and to restore natural sheet flows. Spoil banks containing uncontaminated materials should be backfilled into borrow areas or breached at regular intervals to re-establish hydrological connections.

- In open bays maximum use should be made of existing navigable waters already having sufficient width and depth for access to the drill sites.

- An oil spill response plan should be developed and coordinated with federal and state resource agencies.

- Activities on the OCS 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: 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; drilling and production structures, including pipelines, generally should not be located within one mile of the base of a live reef.

- Prior to pipeline construction, less damaging, alternative modes of oil and gas transportation should be explored.

- State natural resource agencies should be involved in the preliminary pipeline planning process to prevent violations of water quality and habitat protection laws and to minimize impact of pipeline construction and operation on aquatic resources.

- 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.

- All vessels transporting fuels and other hazardous materials should be required to carry equipment to contain and retrieve the spill. Dispersants shall not be used to clean up fuels and hazardous materials unless approved by the EPA/Coast Guard and fishery agencies.

- NPDES permit conditions such as those relating to dissolved oxygen, temperature, impingement and entrainment, under the Clean Water Act should be monitored and strictly enforced in HMS EFH.

- NPDES permits should be reviewed every five years for all energy production facilities.

6.4.2.3 Coastal Development

Coastal development activities include urban, suburban, commercial and industrial construction, along with development of corresponding infrastructure. These activities may result in erosion and sedimentation, dredging and filling (see following sub-section), point and non-point source discharges of nutrients, chemicals, and cooling water into streams, rivers, estuaries and ocean waters. Industrial point source discharges result in the contamination of water and degradation of water quality by introducing organics and heavy metals or altering other characteristics such as pH and dissolved oxygen. Improperly treated sewage treatment effluent has been shown to produce changes in water quality as a result of chlorination and increased contaminant loading, including solids, phosphorus, nitrogen and other organics, and human pathogens and parasites. Non-point source pollution - that which results from land runoff, atmospheric deposition, drainage, groundwater seepage, or hydrologic modification - results in the deposition of pathogens, nutrients, sediments, heavy metals, oxygen demanding substances, road salts, hydrocarbons and other toxics. Coastal development can also lead to the destruction of coastal wetlands, resulting in the elimination of protective buffer zones that serve to filter sediments, nutrients, and contaminants such as heavy metals and pesticides that are transported to the coastal zone in ground and surface waters. In addition, hydrological modifications associated with coastal development alter freshwater inflow to coastal waters, resulting in changes in salinity, temperature, and nutrient regimes, and thereby contributing to further degradation of estuarine and nearshore marine habitats. The variety of pollutants and the severity of their effects from coastal development activities depend upon a number of factors, such as the nature of the construction, physical characteristics of the site involved, and proximity of the pollutant source to the coastline. However, all of these factors ultimately serve to degrade estuarine and coastal water quality to some degree in terms of dissolved oxygen levels, salinity concentrations, and contaminants.

Conservation measures:

- Adverse impacts resulting from construction should be avoided whenever practicable alternatives are identified. For those impacts that cannot be avoided, minimization through implementation of best management practices should be employed. For those impacts that can neither be avoided nor minimized, compensation through replacement of equivalent functions and values should be required.

- Coastal development traditionally has involved dredging and filling of shallows and wetlands, hardening of shorelines, clearing of riparian vegetation, and other activities that adversely affect the habitats of living marine resources. Mitigative measures should be required for all development activities with the potential to degrade HMS EFH whether conducted in EFH or in adjacent areas that influence HMS EFH.

- Destruction of wetlands and shallow coastal water habitats should not be permitted in areas adjacent to HMS EFH. Mitigating or compensating measures should be employed where destruction is unavoidable. Project proponents should demonstrate that project implementation will not negatively affect HMS, their habitat, or their food sources.

- Flood control projects in waterways draining into EFH should be designed to include mitigative measures and constructed using Best Management Practices (BMPs). For example, stream relocation and channelization should be avoided whenever practicable. However, should no practicable alternatives exist, relocated channels should be of comparable length and sinuosity as the natural channels they replace to maintain the quality of water entering receiving waters (i.e., HMS EFH).

- Watershed protection/site development should be encouraged. Comprehensive planning for development on a watershed scale (and for small-scale site development as well) should be undertaken, including planning and designing to protect sensitive ecological areas, minimizing land disturbances and retaining natural drainage and vegetation whenever possible. To be truly effective, watershed planning efforts should include existing facilities even though they are not subject to EFH consultation.

- Pollution prevention activities, including techniques and activities to prevent non-point source pollutants from entering surface waters, should be implemented. Primary emphasis should be placed on public education to promote methods for proper disposal and/or recycling of hazardous chemicals, management practices for lawns and gardens, onsite disposal systems (OSDSs), and commercial enterprises such as service stations and parking lots.

- Construction erosion/sediment control measures should be used to reduce erosion and transport of sediment from construction sites to surface water. A sediment and erosion control plan should be developed and approved prior to land disturbance.

- Runoff from new development should be managed so as to meet two conditions: 1) The average annual total suspended solids loadings after construction is completed are no greater than pre-development loadings; and 2) To the extent practicable, post-development peak runoff rate and average volume are maintained at levels that are similar to pre-development levels.

- Construction site chemical control measures should address the transport of toxic chemicals to surface water by limiting the application, generation, and migration of chemical contaminants (i.e., petrochemicals, pesticides) and providing proper storage and disposal.

- New onsite disposal systems (OSDS) should be built to reduce nutrient/pathogen loadings to surface water. OSDS are to be designed, installed and operated properly and to be situated away from open waterbodies and sensitive resources such as wetlands, and floodplains. Protective separation between the OSDS and the groundwater table should be established. The OSDS unit should be designed to reduce nitrogen loadings in areas where surface waters may be adversely affected. Operating OSDSs should prevent surface water discharge and reduce pollutant loadings to ground water. Inspection at regular intervals and repair or replacement of faulty systems should occur.

- Roads, highways, bridges and airports should be situated away from areas that are sensitive ecosystems and susceptible to erosion and sediment loss. The siting of such structures should not adversely impact water quality, should minimize land disturbances, and should retain natural vegetation and drainage features.

- Construction projects of roads, highways, bridges and airports should implement approved erosion and sediment control plans prior to construction, to reduce erosion and improve retention of sediments onsite during and after construction.

- Construction site chemical control measures for roads, highways, and bridges should limit toxic and nutrient loadings at construction sites by ensuring the proper use, storage, and disposal of toxic materials to prevent significant chemical and nutrient runoff to surface water.

- Operation and maintenance activities should be developed for roads, highways, bridges, and airports to reduce pollutant loadings to receiving waters during operation and maintenance.

- Runoff systems should be developed for roads, highways, bridges, and airports to reduce pollutant concentrations in runoff from existing roads, highways, and bridges. Runoff management systems should identify priority pollutant reduction opportunities and schedule implementation of retrofit projects to protect impacted areas and threatened surface waters.

- The planning process for new and maintenance channel dredging projects should include an evaluation of the potential effects on the physical and chemical characteristics of surface waters that may occur as a result of the proposed work and reduce undesirable impacts. When the operation and maintenance programs for existing modified channels are reviewed, they should identify and implement any available opportunities to improve the physical and chemical characteristics of surface waters in those channels.

- Bridges should be designed to include collection systems which convey surface water runoff to land-based sedimentation basins.

- Sewage treatment discharges should be treated to meet state water quality standards. Implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances is encouraged.

- Use of land treatment and upland disposal/storage techniques of solid waste from sewage treatment should be implemented where possible. Use of vegetated wetlands as natural filters and pollutant assimilators for large scale wastewater discharges should be limited to those instances where wetlands have been specifically created for this purpose. The use of such constructed wetlands for water treatment should be encouraged wherever the overall environmental and ecological suitability of such an action can been demonstrated.

- Sewage discharge points in coastal waters should be located well away from critical 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.

- Dechlorination facilities or lagoon effluent holding facilities should be used to destroy chlorine at sewage treatment plants.

- No toxic substances in concentrations harmful (synergistically or otherwise) to humans, fish, wildlife, and aquatic life should be discharged. The EPA's Water Quality Criteria Series should be used as guidelines for determining harmful concentration levels. Use of the best available technology to control industrial waste water discharges should be required in areas adjacent to habitats essential to HMS. Any new potential discharge that will influence HMS EFH must be shown not to have a harmful effect on HMS or their habitat.

- The siting of industries requiring water diversion and large-volume water withdrawals should be avoided in areas influencing HMS EFH. Project proponents should demonstrate that project implementation will not negatively affect HMS, their EFH, or their food supply. Where such facilities currently exist, best management practices should be employed to minimize adverse effects on the environment.

- All NPDES permits should be reviewed and strictly enforced in areas affecting HMS EFH.

- Hazardous waste sites should be cleaned up (i.e., remediated) to prevent contaminants from entering aquatic food chains. Remedial actions affecting aquatic and wetland habitats should be designed to facilitate restoration of ecological functions and values.

6.4.2.4 Dredging and Disposal of Dredge Material

Dredging operations occur in estuaries, nearshore areas, and offshore, in order to maintain certain areas for activities such as shipping, boating, construction of infrastructure (e.g., offshore oil and gas pipelines), and marine mining. Disposal of the dredged material takes place in designated open water disposal areas, often near the dredge site. These operations result in negative impacts on the marine environment. Of particular concern regarding HMS EFH is the temporary degradation of water quality due to the resuspension of bottom materials, resulting in water column turbidity, potential contamination due to the release of toxic substances (metals and organics), and reduced oxygen levels due to the release of oxygen-consuming substances (e.g., nutrients, sulfides). 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, and localized turbidity plumes and reduced oxygen zones will persist.

Conservation measures:

- Best engineering and management practices (e.g., seasonal restrictions, modified dredging methods, and/or disposal options) should be employed for all dredging and in-water construction projects. Such projects should be permitted only for water dependent purposes when no feasible alternatives are available. Mitigating or compensating measures should be employed where significant adverse impacts are unavoidable. Project proponents should demonstrate that project implementation will not negatively affect HMS, their EFH, or their food sources.

- When projects are considered and in review for open water disposal permits for dredged material, Federal permitting agencies should identify the direct and indirect impacts such projects may have on HMS EFH.

- Uncontaminated dredged material may be viewed as a potentially reusable resource if properly placed and beneficial uses of these materials should be investigated. Materials that are suitable for beach nourishment, marsh construction or other beneficial purposes should be utilized for these purposes as long as the design of the project minimizes impacts to HMS EFH.

- "Beneficial Use" proposals in areas of HMS EFH should be compatible with existing uses by HMS. If no beneficial uses are identified, dredged material should be placed in contained upland sites. The capacity of these disposal areas should be used to the fullest extent possible. This may necessitate dewatering of the material or increasing the elevation of embankments to augment the holding capacity of the site. Techniques could be applied that render dredged material suitable for export or for use in re-establishing wetland vegetation.

- No unconfined disposal of contaminated dredge material should be allowed in HMS EFH.

- Disposal sites should be located in uplands when possible.

6.4.2.5 Agriculture (and Silviculture)

Agricultural and silvicultural practices can affect estuarine, coastal and marine water quality through nutrient enrichment and chemical contamination from animal wastes, fertilizers, pesticides and other chemicals via non-point source runoff or via drainage systems that serve as conduits for contaminant discharge into natural waterways. In addition, uncontrolled or improper irrigation practices can contribute to non-point source pollution, and may exacerbate contaminant flushing into coastal waters. Major impacts also include nutrient over-enrichment with subsequent deoxygenation of surface waters, algal blooms, which can also produce hypoxic or anoxic conditions, and stimulation of toxic dinoflagellate growth. Excessively enriched waters often will not support fish, and also may not support food web assemblages and other ecological assemblages needed to sustain desirable species and populations. Agricultural activities also increase sediment transport in adjacent water bodies, resulting in high turbidity. Many of these same concerns may apply to silviculture, as well.

Conservation measures:

- Federal agencies, in conjunction with state agencies, should establish and approve criteria for vegetated buffer strips in agricultural areas adjacent to HMS EFH to minimize pesticide, fertilizer, and sediment loads to these areas critical for HMS survival. The effective width of these vegetated buffer strips should vary with slope of terrain and soil permeability.

- Concerned Federal (such as Natural Resources Conservation Service) agencies should conduct or contribute to programs and demonstration projects to educate farmers on improved agricultural practices that would minimize the use and wastage of pesticides, fertilizers, and top soil and reduce the adverse effects of these materials on HMS EFH.

- Delivery of sediment from agricultural lands to receiving waters should be minimized. Land owners have a choice of one of two approaches: 1) apply the erosion component of the U.S. Department of Agriculture's Conservation Management System through such practices as conservation tillage, strip cropping, contour farming, and terracing, or 2) design and install a combination of practices to remove settleable solids and associated pollutants in runoff for all but the largest storms.

- New confined animal facilities and existing confined animal facilities should be designed to limit discharges to waters of the U. S. by storing wastewater and runoff caused by all storms up to and including the 25-year frequency storms. For smaller existing facilities, the management systems that collect solids, reduce contaminant concentrations, and reduce runoff should be designed and implemented to minimize the discharge of contaminants in both facility wastewater and runoff caused by all storms up to and including 25-year frequency storms.

- Stored runoff and solids should be managed through proper waste utilization and use of disposal methods which minimize impacts to surface/ground water.

- Development and implementation of comprehensive nutrient management plans should be undertaken, including development of a nutrient budget for the crop, identification of the types and amounts of nutrients necessary to produce a crop based on realistic crop yield expectations, and an identification of the environmental hazards of the site.

- Pesticide and herbicide management should minimize water quality problems by reducing pesticide use, improving the timing and efficiency of application (not within 24 hours of expected rain or irrigation), preventing backflow of pesticides into water supplies, and improving calibration of pesticide spray equipment. Improved methods should be used such as integrated pest management (IPM) strategies. IPM strategies include evaluating current pest problems in relation to the cropping history, previous pest control measures, and applying pesticides only when an economic benefit to the producer will be achieved (i.e., application based on economic thresholds). If pesticide applications are necessary, pesticides should be selected to minimize environmental impacts such as persistence, toxicity, and leaching potential.

- Livestock grazing should protect sensitive areas, including streambanks, wetlands, estuaries, ponds, lake shores, and riparian zones. Protection is to be achieved with improved grazing management that reduces the physical damage and direct loading of animal waste and sediment to sensitive areas, i.e., by restricting livestock access or providing stream crossings.

- Upland erosion should be reduced by either applying the range and pasture components of a Conservation Management System, or maintaining the land in accordance with the activity plans established by either the Bureau of Land Management or the Forest Service. Such techniques include the restriction of livestock from sensitive areas through locating salt, shade, and alternative drinking sources away from sensitive areas, and providing livestock stream crossings.

- Irrigation systems that deliver necessary quantities of water yet reduce nonpoint pollution to surface waters and groundwater should be developed and implemented.

- BMPs should be implemented to minimize habitat impacts when agricultural ditches are excavated through wetlands that drain to HMS EFH.

- NPDES/SPDES permits, in consultation with state fishery agencies, should be required for agricultural ditch systems that discharge into areas adjacent to HMS EFH.

6.4.2.6 Aquaculture and Mariculture

Aquaculture is an expanding industry in the U.S., with most facilities located in farmland, tidal, intertidal and coastal areas. Aquaculture related impacts that adversely affect the chemical and biological nature of coastal ecosystems include discharge of excessive waste products and the release of exotic organisms and toxic substances. Problems resulting from the introduction of food and fecal wastes may be similar to those resulting from certain agricultural activities. However, greater nutrient input and localized eutrophic conditions are currently the most probable environmental effect of aquaculture activities. Extremely low oxygen levels and fish kills, of both natural stocks and cultured fish, have been known to occur in impounded wetlands where tidal and wind circulation are severely limited and the enclosed waters are subject to solar heating. In addition, there are impacts related to the dredging and filling of wetlands and other coastal habitats, as well as other modifications of wetlands and waters through the introduction of pens, nets, and other containment and production devices.

Conservation measures:

- Mariculture operations should be located, designed and operated to avoid, or minimize adverse impacts to estuarine and marine habitats and native fishery stocks. The impacts that cannot be eliminated must be fully mitigated.

- Mariculture facilities should be operated in such a manner that minimizes impacts to the local environment by utilizing water conservation practices and effluent discharge standards that protect existing designated uses of receiving waters.

- Federal and state agencies should cooperatively promulgate and enforce measures to ensure that diseases from culture operations do not adversely affect wild stocks. Animals that are to be moved from one biogeographic area to another or to natural waters should be quarantined to prevent disease transmission.

- To prevent disruption of natural aquatic communities, cultured organisms should not be allowed to escape; the use of organisms native to each facility's region is strongly encouraged.

- Commercial aquaculture facilities and enhancement programs should consider the genetic make-up of the cultured organisms in order to protect the genetic integrity of native fishes.

- Aquaculture facilities should meet prevailing environmental standards for wastewater treatment and sludge control.

6.4.2.7 Navigation

Navigation-related threats to estuarine, coastal, and offshore environments that have the potential to affect HMS EFH include navigation support activities such as excavation and maintenance of channels (including disposal of excavated sediments), which results in the elevation of turbidity and resuspension of contaminants; construction and operation of ports, mooring and cargo facilities; construction of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. In offshore locations, the disposal of dredged materials is the most significant navigation related threat, resulting in localized burial of benthic communities and degradation of water quality. In addition, threats to both nearshore and offshore waters are posed by vessel operation activities such as the discharge and spillage of oil, other hazardous materials, trash and cargo, which may result in localized water quality degradation and direct effects to HMS, especially eggs and larvae, that may are present. Wakes from vessel operation may also exacerbate shoreline erosion, effecting habitat modification and potential degradation.

Conservation measures:

- Permanent dredged material disposal sites should be located in upland areas. Where long-term maintenance is anticipated, upland disposal sites should be acquired and maintained for the entire project life.

- Construction techniques (e.g. silt curtains) must minimize turbidity and dispersal of dredged materials into HMS EFH.

- Propwashing is generally not a recommended dredging method.

- Channels and access canals should not be constructed in areas known to have high sediment contamination levels. If construction must occur in these areas, specific techniques, including the use of silt curtains, will be needed to contain suspended contaminants.

- Alignments of channels and access canals should utilize existing channels, canals and other deep water areas to minimize initial and maintenance dredging requirements. All canals and channels should be clearly marked to avoid damage to adjacent bottoms from propwashing.

- Access channels and canals should be designed to ensure adequate flushing to avoid creating low dissolved oxygen (DO) conditions or sumps for heavy metals and other contaminants. Widths of access channels in open water should be minimized to avoid impacts to aquatic bottoms. In canal subdivisions, channels and canals within the development should be no deeper than the parent body of water and should be of a uniform depth or become gradually shallower inland.

- To ensure adequate circulation, confined and dead-end canals should be avoided by utilizing bridges or culverting that ensures exchange of the entire water column. In general, depths of canals should be minimized, widths maximized, and canals oriented towards the prevailing summer winds to enhance water exchange.

- Consideration should be given to the use of locks in navigation channels and access canals which connect more saline areas to fresher areas.

- To the maximum extent practicable, all navigation channels and access canals should be backfilled upon abandonment and restored to as near pre-project condition as possible. Plugs, weirs or other water control structures may also be necessary as determined on a case-by-case basis.

- All vessels transporting fuels and other hazardous materials should be required to carry equipment to contain and retrieve the spill.

- Dispersants should not be used to clean up fuels and hazardous materials unless approved by the EPA/Coast Guard after consultation with fisheries agencies.

6.4.2.8 Marinas and Recreational Boating

Marinas and recreational boating are increasingly popular uses of coastal areas. As marinas are located at the water's edge, there is often no buffering of the release of associated pollutants into the water column. Impacts caused by marinas include lowered dissolved oxygen, increased temperatures, bioaccumulation of pollutants by organisms, toxic contamination of water and sediments, resuspension of sediments and toxics during construction, eutrophication, change in circulation patterns, shoaling, and shoreline erosion. Pollutants that result from marina activities include nutrients, metals including copper released from antifouling paints, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls. Also, chemicals commonly used to treat timber used for piers and bulkheads - creosote, copper, chromium, and arsenic salts - are introduced into the water. Other potential impacts associated with recreational boating are the result of improper sewage disposal, fuel and oil spillage, cleaning operations, and disposal of fish waste. Propellers from boats can also cause direct damage to multiple life stages of organisms, including eggs, larvae/neonates, juveniles and adults; destratification; elevated heat, and increased turbidity and contaminants by resuspending bottom materials.

Conservation measures:

- Water quality must be considered in the siting and design of both new and expanding marinas.

- Marinas are best created from excavated uplands that are designed so that water quality degradation does not occur. Applicants should consider basin flushing characteristics and other design features such as surface and waste water collection and treatment facilities. Marina siting and design should allow for maximum flushing of the site. Adequate flushing reduces the potential for the stagnation of water in a marina and helps to maintain the biological productivity and reduce the potential for toxic accumulation in bottom sediment. Catchment basins for collecting and storing runoff should be included as components of the site development plan.

- Marinas should be designed and located so as to protect against adverse impacts to important habitat areas as designated by local, state, or federal governments.

- Where shoreline erosion is a non-point source pollution problem, shorelines should be stabilized. Vegetative methods are strongly preferred.

- Runoff control strategies, which include the use of pollution prevention activities and the proper design of hull maintenance areas, should be implemented at marina sites.

- Marinas with fueling facilities should be designed to include measures for reducing oil and gas spillage into the aquatic environment. Fueling stations should be located and designed so that, in the case of an accident, spill contaminants can be contained in a limited area. Fueling stations should have fuel containment equipment as well as a spill contingency plan.

- To prevent the discharge of sewage directly to coastal waters, new and expanding marinas should install pumpout, pump station, and restroom facilities where needed.

- Solid wastes produced by the operation, cleaning, maintenance, and repair of boats should be properly disposed of to limit their entry to surface waters.

- Sound fish waste management should be part of the project design, including a combination of fish cleaning restrictions, public education, and proper disposal facilities.

- Appropriate storage, transfer, containment, and disposal facilities for liquid materials commonly used in boat maintenance along with the encouragement of recycling of these materials, should be required.

- The amount of fuel and oil leakage from fuel tank air vents should be reduced.

- Potentially harmful hull cleaners and bottom paints (and their release into marinas' and coastal waters) should be minimized.

- Public education/outreach/training programs should be instituted for boaters, as well as marina operators, to prevent improper disposal of polluting materials.

- Pumpout facilities should be maintained in operational condition and their use should be encouraged to reduce untreated sewage discharges to surface waters.

6.4.3 Cumulative Impacts

The EFH regulations suggest that cumulative impacts should be analyzed for adverse effects on EFH. Cumulative impact analysis is a locale-specific activity that will be undertaken as additional information on specific habitat locations and threats to that habitat can be accessed, and as additional spatial techniques are developed to properly analyze that information. For this amendment, cumulative impacts will be addressed by describing the types of threats and effects that have been documented to have adverse effects on fish habitat, cumulatively.

Cumulative impacts on the environment are those that result from the incremental impact of actions added to other past, present and reasonably foreseeable future actions. Such cumulative impacts generally occur in inshore and estuarine areas, and can result from individually minor, but collectively significant, actions taking place over a period of time. These impacts include water quality degradation due to nutrient enrichment, other organic and inorganic contaminants associated with coastal development, activities related to marine transportation, and loss of coastal habitats, including wetlands and sea grasses. The rate and magnitude of these human-induced changes 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. These multiple effects can, however, result in adverse impacts to HMS EFH.

Wetland loss is a cumulative impact that results from activities related to coastal development: residential and industrial construction, dredging and dredge spoil placement, port development, marinas and recreational boating, sewage treatment and disposal, industrial wastewater and solid waste disposal, ocean disposal, marine mining, and aquaculture. In the late 1970s and early 1980s the country was losing wetlands at an estimated rate of 300,000 acres per year. The Clean Water Act and state wetland protection programs have helped to decrease wetland losses to 117,000 acres per year, between 1985 and 1995. Estimates of wetlands loss differ according to agency. The USDA estimates attributes 57 percent wetland loss to development, 20 percent to agriculture, 13 percent to deepwater habitat, and ten percent to forest land, rangeland, and other uses. Of the wetlands lost to uplands between 1985 and 1995, the USFWS estimates that, 79 percent of wetlands were lost to upland agriculture. Urban development, and “other” types of land use activities were responsible for six percent and 15 percent, respectively.

Nutrient enrichment has become a large cumulative problem for many coastal waters. Nutrient loading results from the individual activities of coastal development, non-point source pollution, marinas and recreational boating, sewage treatment and disposal, industrial wastewater and solid waste disposal, ocean disposal, agriculture and aquaculture. Excess nutrients from land based activities accumulate in the soil, pollute the atmosphere, pollute ground water, or move into streams and coastal waters. Nutrient inputs are known to have a direct effect on water quality. For example, in extreme conditions excess nutrients can stimulate excessive algal blooms of dinoflagellate growth that can lead to increased metabolism and turbidity, decreased dissolved oxygen, and changes in community structure, a condition known as eutrophication. Examples of such dinoflagellates or algae include *Gynodinium breve* the dinoflagellate that causes neurotoxic shellfish poisoning, dinoflagellates of the genus *Alexandrium* which causes paralytic shellfish poisoning, *Aureococcus anophagefferens* the algae which causes “Brown tide”, and diatoms of the genus *Pseudo-nitzschia* which causes amnesic shellfish poisoning. *Pfiesteria piscicida* is a recently-described toxic dinoflagellate that has been documented in the water column in Delaware, Maryland and North Carolina. Another *Pfiesteria*-like organism has been documented in St. John's River, Florida. This organism has been associated with fish kills in some areas.

In addition to the direct cumulative effects incurred by development activities, inshore and coastal habitiats are also jeopardized by persistent increases in certain chemical discharges. The combination of incremental losses of wetland habitat, changes in hydrology, and nutrient and chemical inputs produced over time can be extremely harmful to marine and estuarine biota, resulting in diseases and declines in the abundance and quality of the affected resources.

Future investigations will seek to analyze cumulative impacts to specific geographic locations (certain estuaries, coastal and offshore habitats) in order to evaluate the cumulative impacts to HMS EFH. Information and techniques that are developed for this process will be used to supplement future revisions of these EFH provisions as the information becomes available.

Conservation measures:

Conservation measures for individual activities that are included under cumulative impacts are covered in the previous sections. Participation in watershed scale planning efforts should be encouraged.

6.5 Research and Information Needs

During the identification of EFH for the HMS covered in this amendment, numerous information gaps were also identified. This was not unexpected considering the broad distribution of these species in estuarine, coastal, neritic, and oceanic habitats, as well as the pelagic nature of these fishes. In many cases, the movements of these animals are poorly understood or have only been defined in broad terms. Furthermore, although the habitats through which these animals transit may be intensely studied, and the physical and biological processes fairly well understood in broad terms, there is little understanding of the particular characteristics that influence the distribution of tunas, swordfish and sharks within those systems. Unlike many estuarine or coral reef species that can be easily observed, collected or cultured, the extensive mobility and elusiveness of the species, combined with their rarity, has delayed the generation of much of the basic biological and ecological information needed to analyze their habitat affinities. Moreover, there is a general lack of technology to study habitat associations of these species *in situ*, as well as in laboratory cultures.

Based on the present state of information concerning the habitat associations of HMS, the following research and information needs have been identified. The NMFS National Habitat Research Plan lays out a framework within which research priorities may be grouped. Many of the research and information needs for the HMS fit well within that plan and it has been used to define general topics for research and information collection:

6.5.1 Tunas and swordfish

Ecosystem Structure and Function

✦ Investigate the influence of habitat characteristics such as temperature (e.g., the relation to thermal fronts) and salinity on tuna and swordfish distributions, spatially as well as seasonally.

✦ Monitor animal movements using advanced archival and satellite telemetry technology in order to better define tuna and swordfish distributions, seasonality, environmental tolerances and preferred habitats.

✦ Identify spawning areas and investigate the role of environmental factors which affect distribution and survival of larval and juvenile tunas and swordfish, leading to variations in year class abundance.

✦ Characterize submarine canyon processes, eddies, gyres, and fronts as they interact with tunas and swordfish and characterize their importance as zones of aggregation.

✦ Further identify major prey species for tunas and swordfish (by species), including preferred feeding areas and influences of environmental factors.

- Gain a better understanding of the life histories of tunas and swordfish; including the development of culture methods to keep tuna and swordfish alive in captivity for life history studies.

- Improve the capability to identify eggs and early life stages of the tuna and swordfish species.

Effects of Habitat Alteration

- Identify fisheries that operate in tuna and swordfish EFH and characterize threats to tuna and swordfish EFH, particularly spawning and nursery areas.

- Investigate the effects of contaminants on tuna and swordfish life stages, especially eggs and larvae; this would require development of better laboratory culture techniques for these species.

- Determine the effects of contaminants (e.g., oil spills) in offshore epipelagic habitats where tunas and swordfish are known to aggregate.

- Identify habitat linkages between inshore and offshore habitats to better define the zone of influence for inshore activities that may adversely affect tuna and swordfish habitats.

Synthesis and Information Transfer

- Incorporate/develop spatially consistent databases of environmental conditions throughout the tuna and swordfish ranges (e.g., Temperature, Salinity, currents).

- Further analyze fishery dependent data to construct a clearer view of relative abundances.

- Contour abundance information to better visualize areas where tuna and swordfish are most commonly encountered.

- Construct spatial databases for early life history stages (eggs and larvae).

- Derive objective criteria to model areas of likelihood for relative abundances of tunas and swordfish based on environmental parameters.

- Define and model habitat suitability based on seasonal analyses of tolerances of environmental conditions.

6.5.2 Sharks

Ecosystem Structure and Function

- ✦ Continue the delineation of shark nurseries; establish the geographic boundaries of the summer nurseries of commercially important species.

- ✦ Determine the location of the winter nurseries of commercially important species.

- ✦ Expand the use of archival tagging and satellite telemetry in shark species, particularly of juvenile shark in seasonal migrations, to better define locations, distributions, and environmental tolerances.

- ✦ Determine if sharks return to their natal nurseries; determine if females return to the same nursery each time they give birth.

- ✦ Determine growth and survival rates of each life stage; develop age determination validations.

- ✦ Determine habitat relationships such as temperature (e.g., the relation to thermal fronts) and salinity, spatially as well as seasonally; determine the significance of areas of aggregation; determine the role of coastal/inshore habitats in supporting neonates and juveniles.

Effects of Habitat Alteration

- ✦ Document the effects of habitat alteration, including the inflow of organic and inorganic pollutants, increased turbidity, loss of coastal marshes and sea grasses, and changes in freshwater inflow, on the survival of neonates and juveniles in inshore and estuarine areas.

- ✦ Identify fisheries that operate in shark EFH and characterize threats from fishery practices to shark EFH, particularly nursery areas.

Impact and Recovery Indicators

- ✦ Analyze historical changes that have occurred in locations such as Tampa Bay, Florida where trends in environmental degradation appear to have been reversed in recent years resulting in rebounds of depressed shark (blacktip) populations.

Synthesis and Information Transfer

- ✦ Incorporate/develop spatially consistent databases of environmental conditions throughout the sharks' ranges (e.g., temperature, salinity, currents).

- ✦ Further analyze fishery dependent data to construct a clearer view of relative abundances.
- ✦ Contour abundance information to better visualize areas where sharks are most commonly encountered.
- ✦ Construct spatial databases for early life history stages (neonates and early juveniles) incorporating seasonal changes.
- ✦ Derive objective criteria to model areas of likelihood for relative abundances of sharks based on environmental parameters.
- ✦ Define and model habitat suitability based on seasonal analyses of species tolerances of environmental conditions.

6.6 Review and Revision of FMP EFH Components

Throughout the preparation of this document, numerous sources of information have been identified. Some of these have been accessed and incorporated into the identification and description of HMS EFH for this amendment. These sources include fishery scientists both inside and outside of NMFS and databases maintained in the Miami Science Center- SEFSC (e.g., Billfish, Pelagic Longline Logbook, Southeast observer program, Large Pelagic Survey, etc.), in the Naragansett Laboratory -NEFSC (Apex Predator Program) and at the University of Florida (Directed Shark Observer Program), and state data from South Carolina on seine catches of sharks in state waters. The most up-to-date and reliable information available was used to describe and identify EFH for HMS in this amendment. NMFS will continue to identify other sources of information that can be incorporated into these analyses to further refine EFH. Other data sources might include programs such as state habitat characterization and mapping programs (e.g., those being conducted in Florida and Texas), ichthyoplankton sampling and shark sampling programs for the Gulf of Mexico and several recent or on-going investigations into shark nursery utilization in the Gulf of Mexico. Additionally, the COASTSPAN Program is currently investigating the shark nurseries along the Atlantic coast. Additional results from this annual sampling program should be available within 1-2 years. This will further the effort to characterize areas that are used as pupping or nursery grounds for numerous species of shark.

The tagging, catch and bycatch information used from these databases for preparation of the EFH provisions of this amendment are part of a continuing effort to monitor HMS fisheries over broad spatial scales. They are continually being updated with newly reported information and are being scrutinized to ensure that a high standard is maintained. Additional analytical techniques and database queries will be possible to more fully evaluate trends and patterns in the data such as seasonal, interannual and interdecadal variations. Because these databases incorporate such long time series of data, additional investigations of the historic ranges and temporal changes in species distributions should be possible in the future.

NMFS is committed to monitoring and participating in these on-going research efforts in order to update the information in the EFH provisions of this amendment. New and updated information, if available, will be reviewed as part of the annual Stock Assessment and Evaluation (SAFE) report prepared by NMFS. If the additional information provides significant improvement over the current document, the amendment will be revised to refine the EFH descriptions, identification, conservation and enhancement and/or threats sections of the EFH provisions of this management plan.

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