3.0 DESCRIPTION, DISTRIBUTION, AND USE OF ESSENTIAL FISH HABITAT

3.1 Estuarine and Inshore Habitats

3.1.1 Estuarine

3.1.1.1 Estuarine Emergent (Saltmarsh and Brackish Marsh)

3.1.1.1.1 Description and Ecological Role and Function

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

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

3.1.1.1.2 Distribution of Marsh Habitat

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

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

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

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

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

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

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

b. Values in parentheses represent the percent of total Estuarine Drainage Area wetlands grid sampled by NOAA.

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

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

3.1.1.1.3 Species Composition (Flora)

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

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

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

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

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

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

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

3.1.1.1.4 Species Composition (Fauna)

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

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

3.1.1.1.5 Habitat Restoration

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

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

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

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

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

3.1.1.2 Estuarine Shrub/Scrub (Mangroves)

3.1.1.2.1 Description, Distribution and Mangrove Habitat Types.

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

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

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

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

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

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

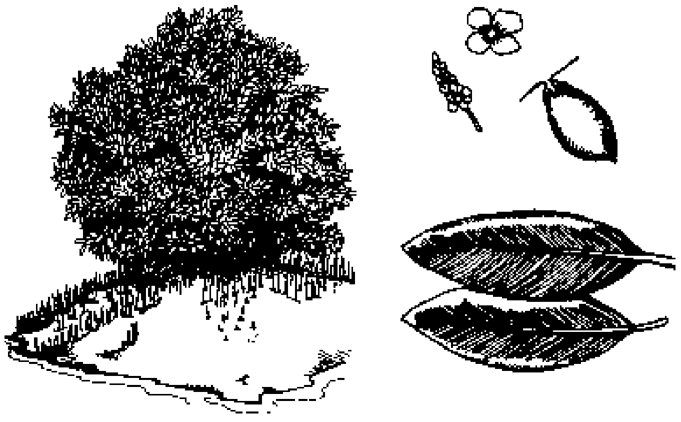
	Mangrove Types				
Characteristics	Fringe Forest	Overwash Forest	Riverine Forest	Basin Forest	Dwarf Forest
Forest height (m)	7.65	6.37	12.64	12.14	<1.0
Mean stand diameter (cm)	8.31	11.12	19.37	10.53	1.75
Complexity Index[b]					
Trees	26.44	13.17	38.77	18.41	1.5
Saplings	1.54	2.17	22.76	4.09	--
Litter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

[a] Data are averages.

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

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

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



Black Mangrove

White Mangrove

Red Mangrove

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

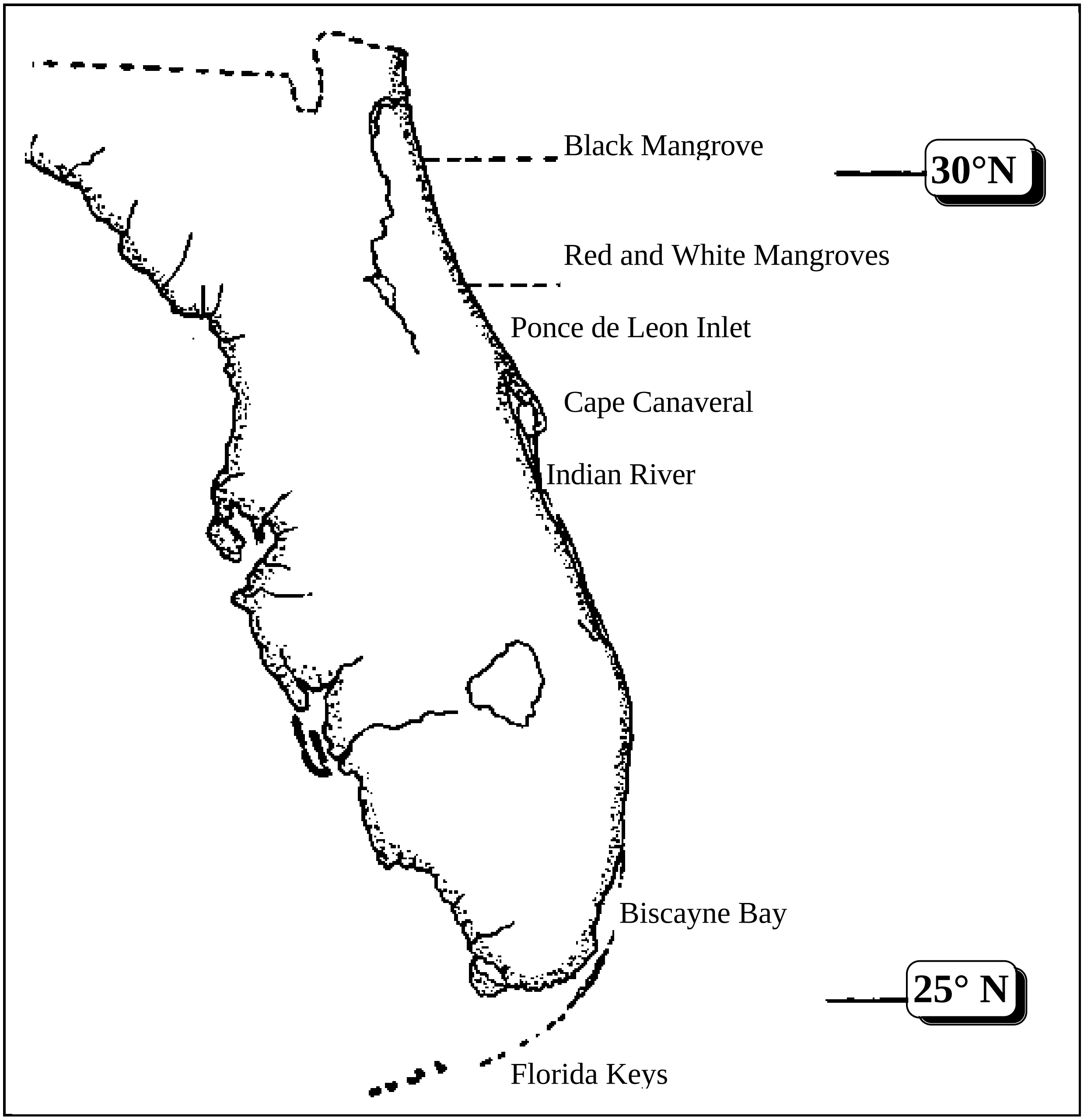


Figure 3. Approximate northern limits for the red mangrove, black mangrove, and white mangrove in Florida (in Odum et al., 1982 based on Savage 1972).

3.1.1.2.2 Stresses on Mangrove Ecosystems

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

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

3.1.1.2.3 Ecological Roles and Function

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

3.1.1.2.3.1 The linkage between mangroves and fishery organisms

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.1.1.2.4 Information/Research Needs.

Thayer et al. (In press) presented a discussion on research needs for mangrove systems based on a NOAA Coastal Ocean Program-sponsored workshop held in 1988. The following summarizes this paper and is separated into 6 priority areas of information need.

3.1.1.2.4.1 Food web-related information needs.

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

3.1.1.2.4.2 Information needs on productivity and structure of mangroves.

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

3.1.1.2.4.3 Habitat use information needs.

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

3.1.1.2.4.4 Nutrient cycling information needs.

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

3.1.1.2.4.5 Restoration and Succession of damaged mangrove ecosystems.

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

3.1.1.2.4.6 Synthesis and modeling needs.

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

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

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

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

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

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

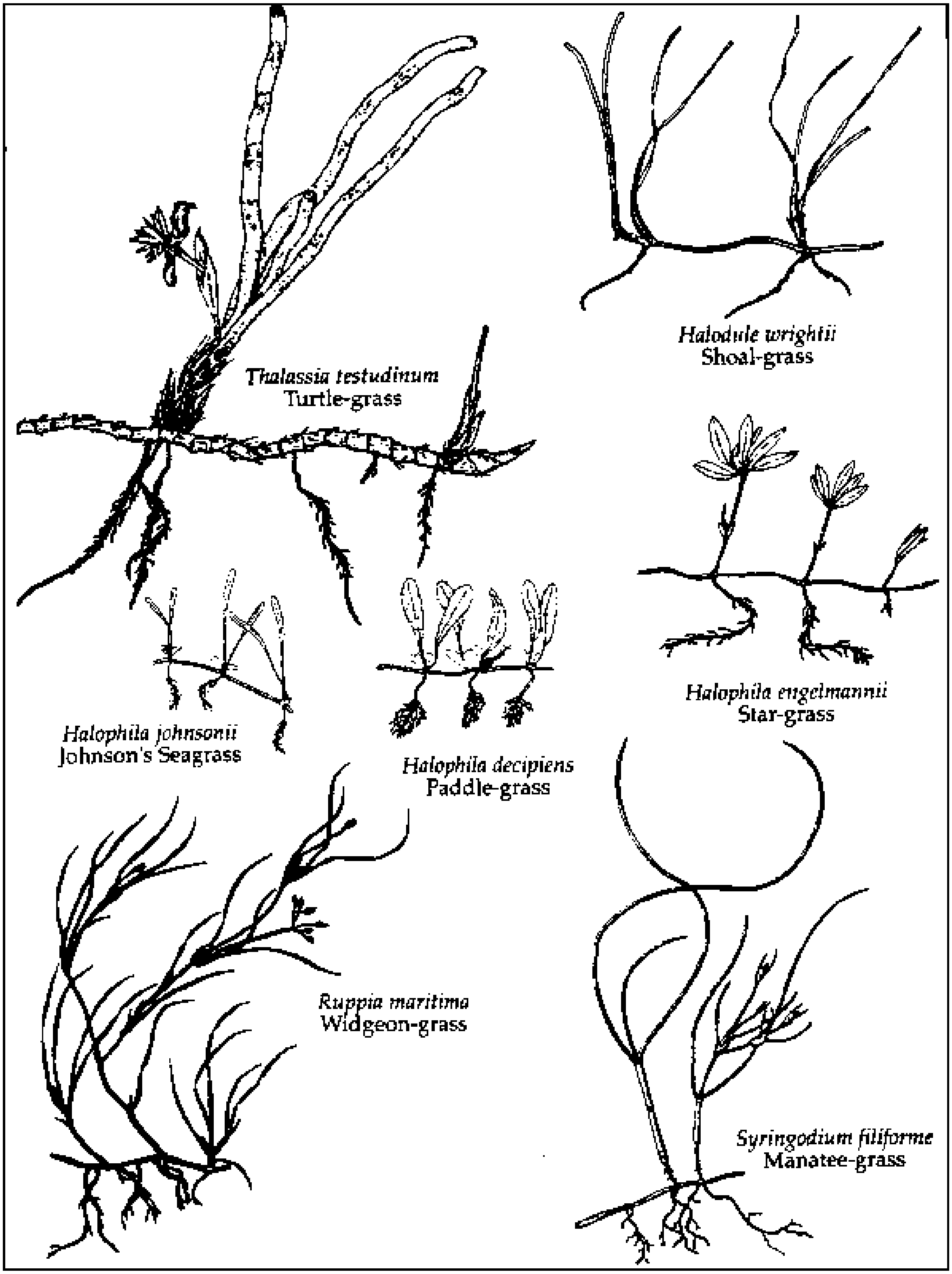
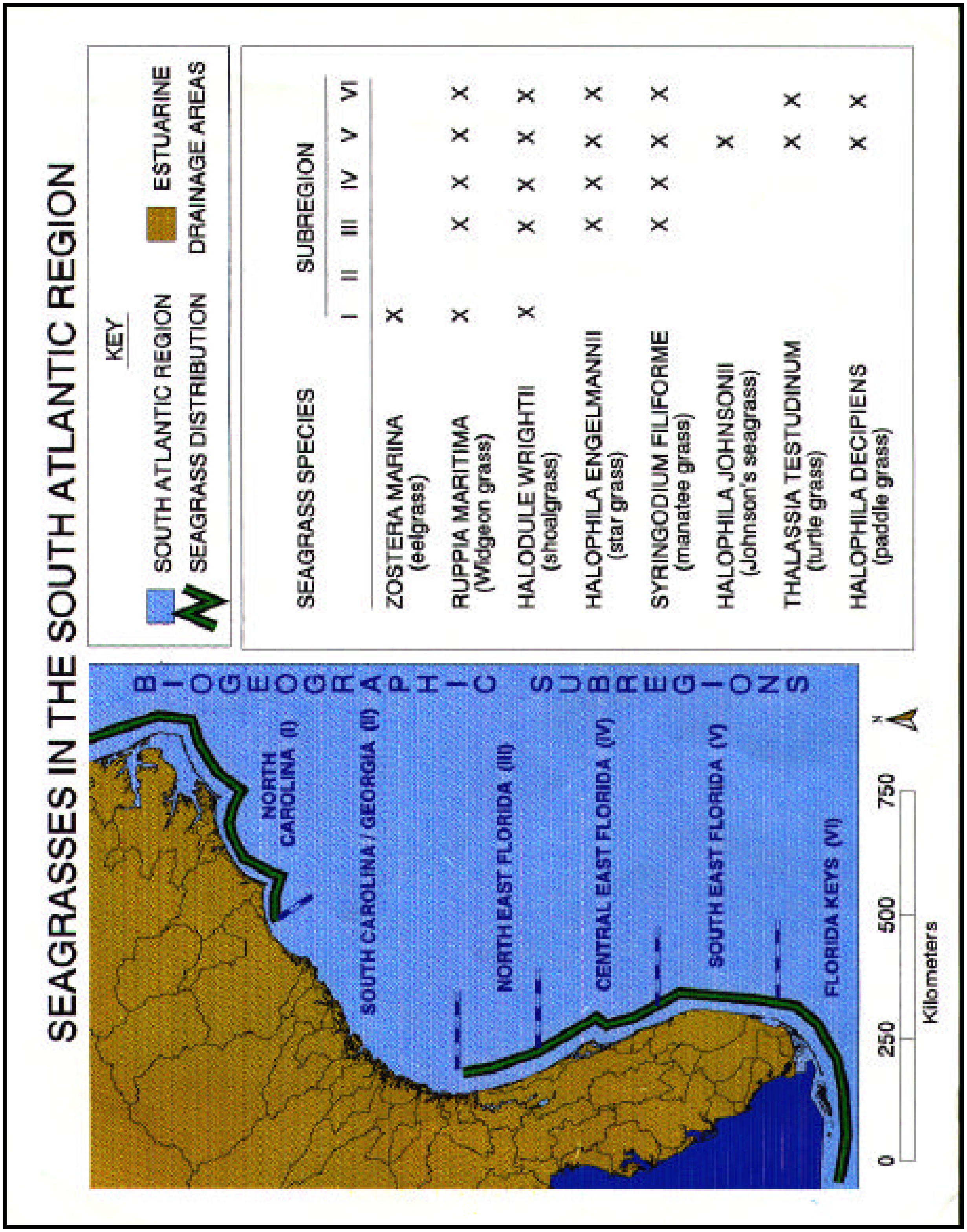


Figure 4. Illustration of seagrass species in the South Atlantic Region (Source: NMFS 1997).

3.1.1.3.2 Seagrass Meadow Dynamics

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

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



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

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

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

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

3.1.1.3.3 Threats to Seagrass Systems

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

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

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

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

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

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

3.1.1.3.4 Seagrass As Essential Fish Habitat

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

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

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

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

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

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

3.1.1.3.5 Specific Examples of Seagrass As Essential Fish Habitat

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

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

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

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

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

3.1.1.3.6 Aspects of Conservation and Restoration

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

3.1.1.4 Oyster Reefs and Shell Banks

3.1.1.4.1 Introduction

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

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

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

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

3.1.1.4.2 Habitat Description and Environmental Requirements

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

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

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

3.1.1.4.3 Habitat Distribution

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

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

3.1.1.4.4 Habitat Function

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

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

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

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

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

3.1.1.4.5 Species Composition

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

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

3.1.1.4.6 Habitat Restoration Efforts

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

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

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

3.1.1.5.1 Introduction

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

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

3.1.1.5.2 Tidal Flats as Essential Fish Habitat

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

3.1.1.5.3 Benthic Nursery Function

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

3.1.1.5.4 Refuge Function

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

3.1.1.5.5 Feeding Ground Function

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

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

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

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

3.1.1.5.6 Impacts to Intertidal Flats

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

3.1.1.5.7 Conservation of Intertidal Flats

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

3.1.2 Palustrine Emergent and Forested (Freshwater Wetlands)

3.1.2.1 Introduction

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

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

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

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

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

3.1.2.2 Description

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

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

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

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

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

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

3.1.2.2.2 Palustrine Emergent Species and Community Structure

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

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

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

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

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

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

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

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

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

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

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

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

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

3.1.2.2.3 Palustrine Emergent Dynamics and Function

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

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

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

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

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

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

3.1.2.2.4 Palustrine Forested Species and Community Types

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

3.1.2.2.5 Palustrine Forested Dynamics

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

3.1.2.2.6 Distribution by Estuarine Drainage Area

North Carolina

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

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

South Carolina

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

Georgia

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

Florida

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

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

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

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

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

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

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

3.1.2.3.1 Description

Introduction

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

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

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

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

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

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

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

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

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

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

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

3.1.2.3.3 Aquatic Bed Meadow Dynamics

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

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

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

3.1.2.3.4 Aquatic Beds As Essential Fish Habitat

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.1.2.3.5 Distribution by Estuarine Drainage Area

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

North Carolina

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

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

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

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

South Carolina

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

Georgia

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

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

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

Florida

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

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

3.1.3 Estuarine Water Column

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

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

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

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

3.2 Marine/Offshore Habitats

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

3.2.1.1 Coral and Coral Reefs

3.2.1.1.1 Geographical Range of Habitat Types

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2.1.1.1.1 Solitary Corals

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

3.2.1.1.1.2 Hard bottom

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

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

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

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

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

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

3.2.1.1.1.3 Deepwater Banks

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

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

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

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

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

3.2.1.1.1.4 Patch Reefs

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

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

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

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

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

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

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

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

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

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

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

3.2.1.1.1.5 Outer Bank Reefs

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

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

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

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

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

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

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

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

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

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

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

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

3.2.1.1.2 Condition and Trends

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

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

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

3.2.1.1.3 Coral Habitat Areas of Particular Concern

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

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

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

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

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

1. Ecological
    a. An area that contains an outstanding example of a coral community type found over a broad ocean area. (For example, a deepwater *Lophelia-Enallopsammia* bank, a shallow-water *Acropora* coral reef, patch reefs, etc.).
    b. Areas known to possess rare species of coral.
    c. Areas whose coral diversity contributes to a highly unusual or unique biologic relationship or ecologic condition.

2. Research
    a. Areas with a substantial history of coral research and study. Such areas offer an opportunity to develop a long-term history of corals in their natural setting which should enhance the identification of trends in growth or response to stress - both vital information for coral managers.
    b. Areas which display in an especially clear cut fashion, coral habitat features of particular research interest such as spur and groove formations or particular biotic zonation patterns.

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

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

4. Recreation
   a. Areas that are documented as locations frequented on a regular basis by recreational divers, sports fishermen, or glass bottom boat sightseers.
   b. Areas that offer a high but underutilized recreational resource because of their outstanding aesthetic qualities and proximity to population centers or boat access points.

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

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

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

Table 12. Habitats Meeting Coral HAPC Criteria.

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

3.2.1.1.3.1 Gray's Reef National Marine Sanctuary

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

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

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

3.2.1.1.3.2 Oculina Bank Habitat Area of Particular Concern

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

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

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

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

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

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

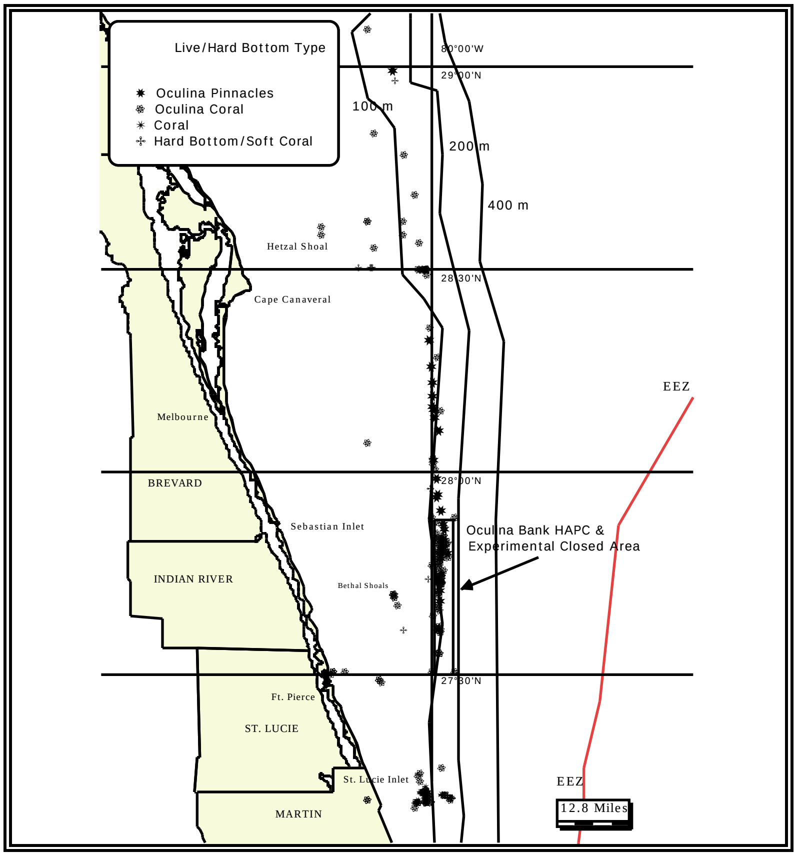


Figure 6. Map of coral (*Oculina varicosa*), coral reef and live/hard bottom habitat distributed along the south Atlantic shelf off the central east coast of Florida (Source: SAFMC 1995).

3.2.1.1.3.3 Biscayne National Park

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

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

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

3.2.1.1.3.4 Florida Reef Tract

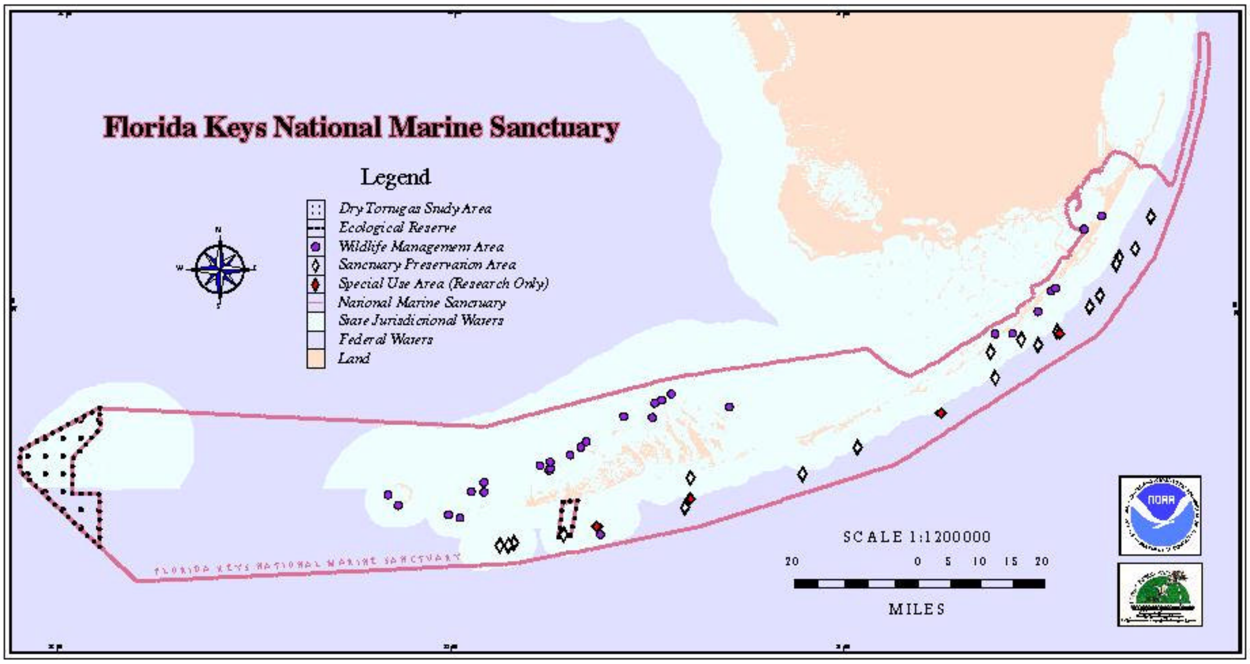
The Florida reef tract contains the continental United States' most extensive coral habitat. Composed of a chain of individual reefs, the tract stretches in a curve of some 370 km (200 nm) from Miami to the Dry Tortugas (DiSalvo and Odum, 1974). The tract is bounded on the shoreward side by the Florida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

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

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

3.2.1.1.3.5 Florida Keys National Marine Sanctuary

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



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

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

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

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

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

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

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

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

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

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

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

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

3.2.1.2 Live/Hard Bottom Habitat

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

3.2.1.2.1 Cape Hatteras to Cape Canaveral

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

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

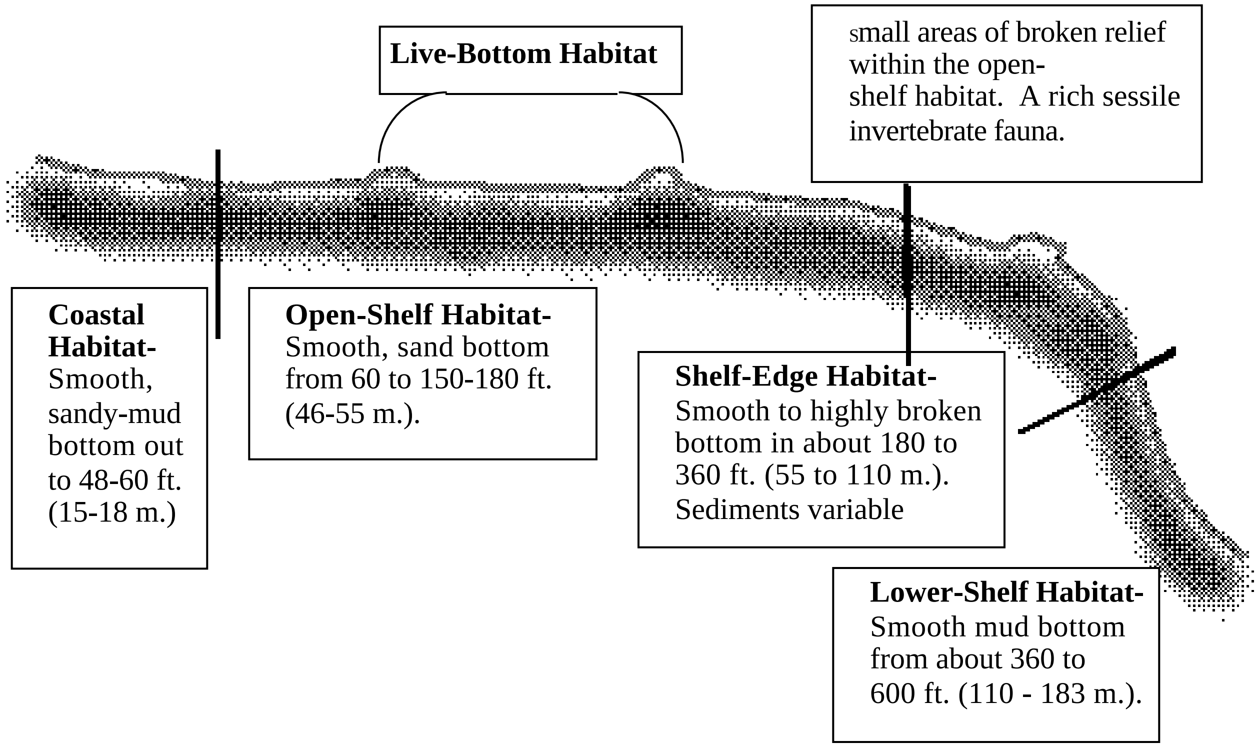


Figure 7. The five major types of habitat on the Continental Shelf off the Southeastern United States North of Cape Canaveral (Source: Struhsaker, 1969).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[1] Sampling effort was extended beyond the 3-year study periods in an effort to obtain more winter data.

[2] Some totals differ from the published study because three stations were eliminated for locality comparison, and counting errors were corrected.

[3] Nondesignated species were not the main concern of this study (e.g., sharks, jacks, and mackerels).

[4] *Opsanus sp.* is likely an undescribed offshore form.

[5] Although invertebrates usually were not recorded, the first observation of basket sponges was noted during our initial resurvey of the "210 Rock", and basket sponges were the subject of many underwater pictures and notations on cleaning stations throughout the second survey period.

* Target species (important in the recreational and commercial fisheries).

S Tropical species.

N Temperate species.

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

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

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

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

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

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

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

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

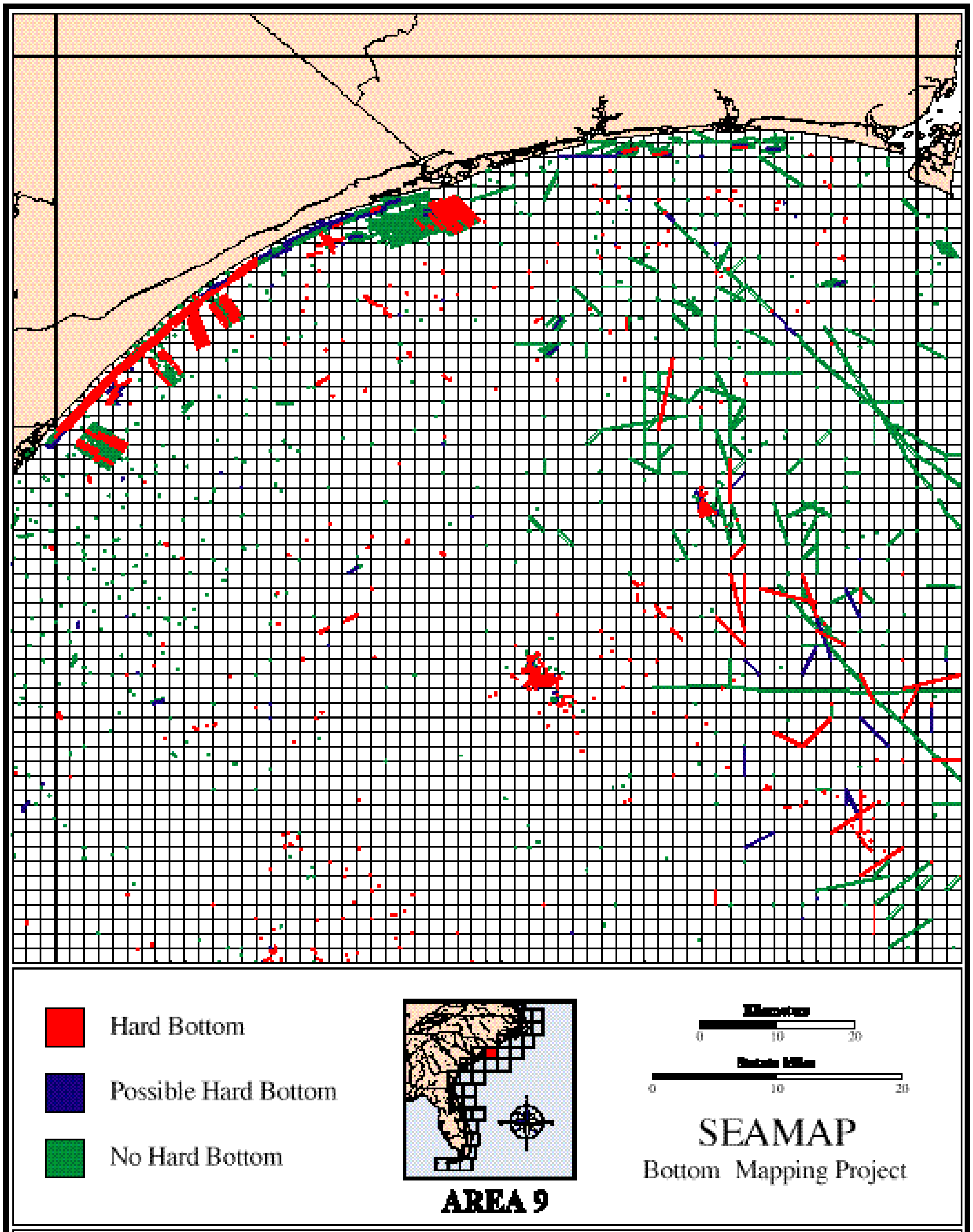


Figure 9. Location of point and line data that provide information on bottom type of the survey area shown.

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

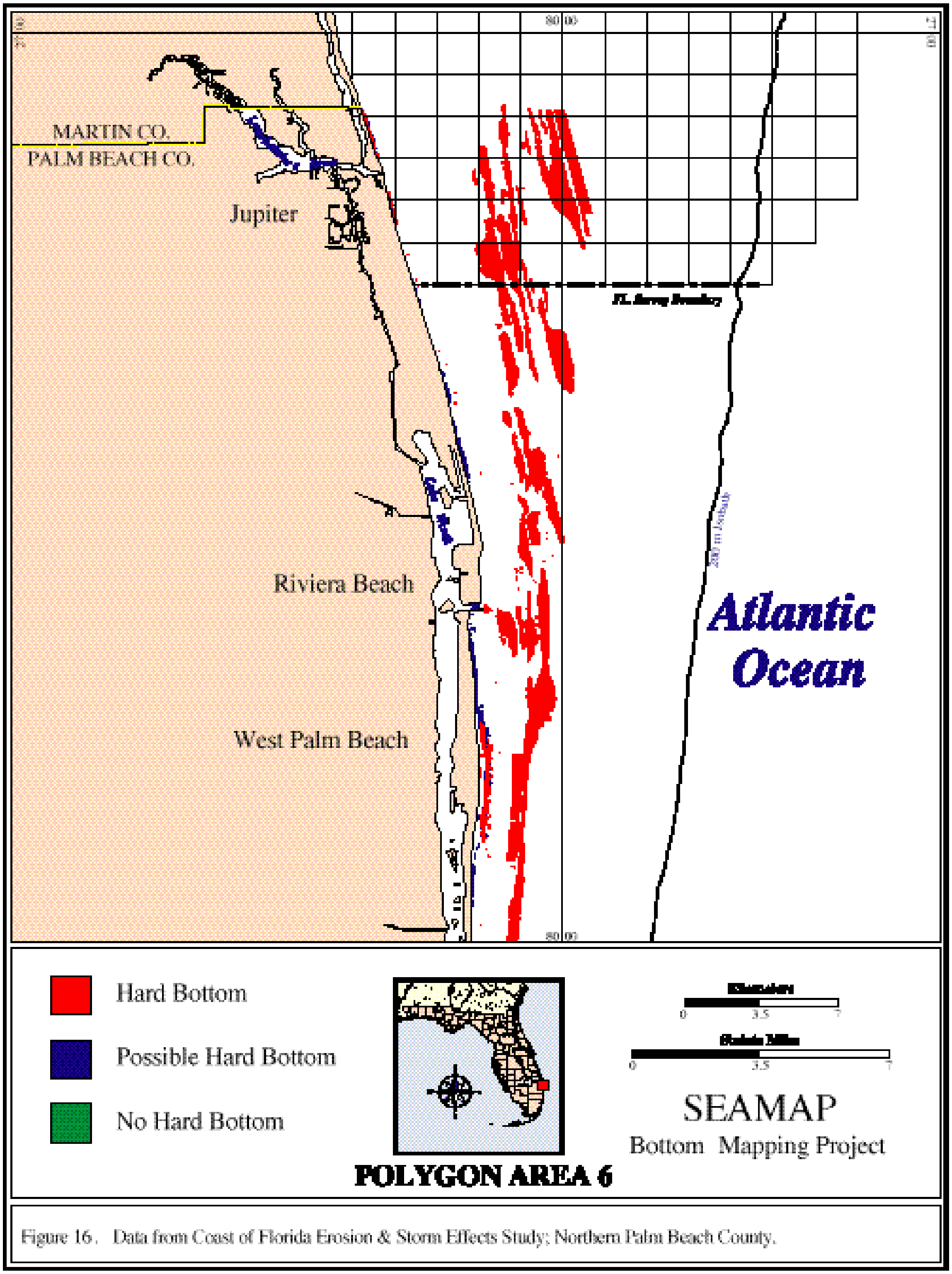


Figure 8b. Hardbottom distribution Offshore Northern Palm Beach County, Florida (1998 SEAMAP Bottom-Mapping Project) (Source: FMRI 1998).

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

3.2.1.2.2 Cape Canaveral to Dry Tortugas

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

3.2.1.2.2.1 Mainland Southeast Florida

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

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

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

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

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

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

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

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

Species	Lindeman	Gilmore	Vare
Rhinocodontidae-Carpet sharks			
Ginglymostoma cirratum	x	x	x
Carcharhinidae-Requiem Sharks			
Carcharhinus brevipinna	x		x
Carcharhinus leucas		x	
Carcharhinus limbatus		x	
Carcharhinus plumbeus		x	
Rhinobatidae-Guitarfishes			
Rhinobatos letiginosus			x
Dasyatidae-Stingrays			
Dasyatis americana			x
Urolophidae-Round stingrays			
Urolophus jamaicensis			x
Muraenidae-Moray eels			
Echidna catenata	x		
Enchelycore carychora			x
Enchelycore nigricans			
Gymnothorax funebris		x	x
Gymnothorax miliaris	x		
Gymnothorax moringa	x	x	x
Ophichthidae-Snake eels			
Ahlia egmontis			
Myrichthys breviceps	x		x
Elopidae-Tarpons			
Megalops atlanticus	x		x
Clupeidae-Herrings			
Harengula clupeola	x	x	
Harengula humeralis		x	
Harengula jaguana	x	x	
Opisthonema oglinum		x	x
Sardinella aurita	x	x	
Clupeid sp.	x		
Engraulidae-Anchovies			
Anchoa cubana		x	
Anchoa hepsetus		x	
Anchoa lyolepis		x	
Gobiesocidae-Clingfishes			
Gobiesox strumosus		x	
Mugilidae-Mullets			
Mugil cephalus	x		x
Mugil curema	x		
Exocoetidae-Halfbeaks			
Hemiramphus brasiliensis	x		
Hyporhamphus unifasciatus		x	
Hyporhamphus sp.		x	
Belonidae-Needlefishes			
Strongylura marina			x
Atherinidae-Silversides			
Membras martinica		x	
Menidia peninsulae		x	
Scorpaenidae-Scorpionfishes			
Scorpaena plumieri	x	x	x
Holocentridae-Squirrelfishes			
Holocentrus adscensionis			x
Holocentrus rufus	x		
Pomacentridae-Damselfishes			
Abudefduf saxatilis	x	x	x
Abudedfuf taurus		x	
Microspathodon chrysurus			x
Pomacentrus fuscus	x		x
Pomacentrus leucostictus	x	x	x
Pomacentrus partitus	x		x
Pomacentrus planifrons			x
Pomacentrus variabilis	x	x	x

Species (cont.)	Lindeman	Gilmore	Vare
Serranidae-Sea Basses and Groupers			
Centropristis striata		x	x
Diplectrum formosum			x
Epinephelus adscensionis			x
Epinephelus itajara		x	
Epinephalus morio		x	
Mycteroperca bonaci	x		x
Mycteroperca microlepis		x	
Serranus subligarius		x	
Grammistidae-Soapfishes			
Rypticus maculatus	x	x	
Rypticus saponaceus			x
Lutjanidae-Snappers			
Lutjanus analis		x	x
Lutjanus apodus	x	x	x
Lutjanus chrysurus	x	x	x
Lutjanus griseus	x	x	x
Lutjanus jocu		x	x
Lutjanus mahogoni		x	
Lutjanus synagris	x	x	x
Haemulidae-Grunts			
Anisotremus surinamensis	x	x	x
Anisotremus viginicus	x	x	x
Haemulon album			?
Haemulon aurolineatum	x	x	x
Haemulon carbonarium	x	x	x
Haemulon chrysargyreum	x	x	x
Haemulon flavolineatum	x	x	x
Haemulon macrostomum	x		x
Haemulon melanurum	x	x	x
Haemulon parra	x	x	x
Haemulon plumieri	x	x	x
Haemulon sciurus	x		x
Haemulon striatum			?
Orthopristis chrysoptera			?
Inermiidae-Bogas			
Inermia vittata			?
Apogonidae-Cardinalfishes			
Apogon		x	
Apogon maculatus	x	x	x
Apogon pseuomaculatus		x	
Astrapogon stellatus			
Phaeoptyx conklin			
Pomatomidae- Bluefishes			
Pomatomus saltatrix		x	
Carangidae-Jacks and Pompanos			
Caranx bartholomaei	x	x	x
Caranx crysos	x	x	x
Caranx hippos	x	x	x
Caranx latus		x	x
Caranx ruber	x	x	x
Chloroscombrus chrysurus	x	x	
Decapterus punctatus	x		
Oligoplites suarus	x	x	x
Selar crumenopthalamus	x		
Selene setapinnis		x	
Selene vomer		x	
Seriola drumerili		x	
Trachinotus carolinus	x		
Trachinotus falcatus	x		
Trachinoyus goodei			x
Mullidae-Goatfishes			
Mulloidicthys martinicus	x		x
Pseudupeneus maculatus	x	x	x

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

Species	Lindeman	Gilmore	Vare
Centropomidae-			
Centropomus undecimalis	x		x
Sparidae-Porgies			
Archosargus probatocephalus	x	x	x
Calamus bajonado		x	x
Diplodus argenteus	x	x	
Diplodus holbrooki		x	x
Coryphaenidae-Dolphins			
Coryphaena equiselis		x	
Sciaenidae-Drums			
Bairdiella sancteluciae		x	
Equetus acuminatus	x	x	x
Equetus lanceolatus			x
Equetus umbrosus		x	
Odontoscion	x	x	x
Umbrina coroides	x		x
Gerreidae-Mojarras			
Eucinostomus argenteus	x	x	x
Eucinostomus gula	x	x	
Eucinostomus sp.	x		
Gerres cinerus	x	x	x
Echeinidae-Remoras			
Echeneis naucrates			x
Priacanthidae-Bigeyes			
Priacanthus arenatus			x
Pempheridae-Sweepers			
Pemphurus schomburgki	x	x	x
Aulostomidae-Trumpetfishes			
Aulostomus maculatus		x	
Fistularidae-Coronetfishes			
Fistularia tabacaria			x
Ephippidae-Spadefishes			
Chaetodipterus faber		x	x
Chaetodontidae-Butterflyfishes			
Chaetodon			x
Chaetodon	x		x
Chaetodon			x
Chaetodon			x
Pomacanthidae-Angelfishes			
Holocanthus bermudensis	x		x
Holocanthus ciliarus		x	
Pomacanthus arcuatus	x	x	x
Pomacanthus paru	x		x
Labridae-Wrasses			
Bodianus rufus	x		x
Dorotonatus megalepis		x	
Halichoeres bivittatus	x	x	x
Halichoeres garnoti			x
Halichoeres maculipinna	x	x	x
Halichoeres poeyi	x	x	
Halichoeres radiatus	x	x	x
Hemipteronotus splendens			x
Hemipteronotus sp.	x		
Lachnolaimus maximus	x		x
Thalassoma bifasciatum	x	x	x
Scaridae-Parrotfishes			
Scarus coelestinus		x	
Scarus guacamaia		x	
Scarus teaniopterus			x
Scarus vetula	x		
Sparisoma atomarium		x	
Sparisoma aurofrenatum	x		
Sparisoma chrysopterum	x		x
Sparisoma radians			x
Sparisoma rubripinne	x	x	x
Sparisoma viride	x		x
Scarid sp.	x		
Synodontidae-Lizardfishes			
Synodus intermedius			x
Sphyraenidae-Barracudas			
Sphyraena barracuda	x	x	x
Sphyraena		x	
Kyphosidae-Sea chubs			
Kyphosus incisor	x	x	
Kyphosus sectatrix	x	x	x
Kyphosus sp.	x		
Scombridae-Mackerels			
Scomberomorus regalis	x		x
Opistognathidae-Jawfishes			
Opistognathus		x	
Dactyloscopidae-Sand Stargazers			
Dactyloscpous		x	
Platygillellus rubrocinctus			
Uranoscopidae-Stargazers			
Astroscopus y-graecum		x	
Oglocephalidae-Batfishes			
Oglocephalus radiatus			x
Labrisomidae-Clinids			
Labrisomus bucciferus	x		
Labrisomus gobio		x	
Labrisomus nuchipinnis	x	x	x
Malacoctenus macropus	x	x	
Malacoctenus triangulatus	x	x	
Paraclinus nigripinnis		x	
Starskia ocellata	x		
Blenniidae-Combtooth Blennies			
Entomacrodus nigricans		x	
Parablennius marmoreus	x		x
Scartella cristata	x	x	
Gobiidae-Gobies			
Coryphopterus glaucofrenum	x		
Gobisoma	x		x
Nes longus	x		
Eleotridae-Sleepers			
Erotelis smaragdus		x	
Triglidae-Searobins			
Prionotus ophryas			x
Acanthuridae-Surgeonfishes			
Acanthurus bahianus	x	x	x
Acanthurus chirurgus	x	x	x
Acanthurus coeruleus	x	x	x
Bothidae-Lefteye Flounders			
Bothus lunatus			x
Balistidae-Triggerfishes			
Balistes capriscus			x
Balistes vetula			x
Canthidermis sufflamen			x
Monocanthidae-Filefishes			
Aluterus scriptus	x		x
Cantherhines pullus	x		x
Monocanthus	x	x	
Ostraciidae-Boxfishes			
Lactophrys triqueter	x	x	x
Lactophrys quadicornis	x		x
Tetrodontidae-Pufferfishes			
Canthigaster rostrata	x		x
Sphoeroides spengleri			x
Diodontidae-Porcupinefishes			
Diodon			x
Diodon hystrix	x		x

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

3.2.1.2.2.2 Florida Keys and Reef Tract

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

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

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

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

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

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

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

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

3.2.1.2.3.1 Charleston Bump and Gyre

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

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

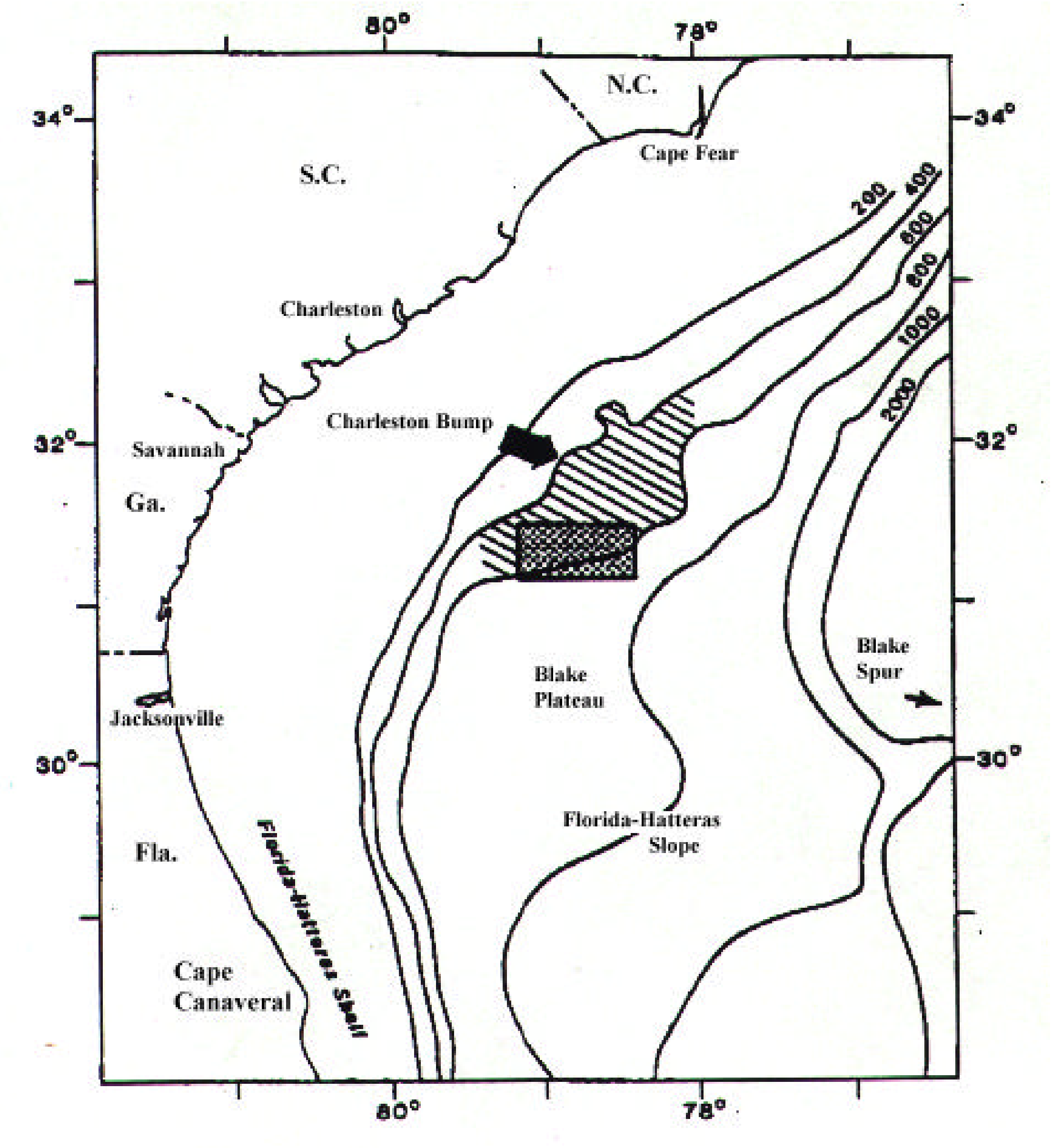


Figure 9. Southeastern U.S. continental shelf and slope, showing major topographic featues (diagnol lines indicate the Charleston Bump) and boundaries of the primary commercial wreckfish grounds (heavy dots). (Source: Sedberry et. al., 1994).

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2.1.2.3.2 Ten Fathom Ledge and Big Rock

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

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

3.2.1.2.3.3 Shelf Break Area from Florida to North Carolina

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

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

3.2.1.2.3.4 Gray's Reef National Marine Sanctuary

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

3.2.1.2.3.5 Nearshore Hard Bottom of Mainland Southeast Florida.

Extending semi-continuously from Cape Canaveral (28^{o}30' N) to at least Boca Raton (26^o 20' N), nearshore hard bottom was evaluated in terms of the four HAPC criteria in Section 600.815 of the final interim rule. In terms of ecological function, several lines of evidence suggest that nearshore hard bottom reefs may serve as nursery habitat. The following summary is based on the quantitative information available (Lindeman, 1997, Lindeman and Snyder, manuscript), which also included life stage-specific abundance data. First, pooled early life stages consistently represented over 80% of the total individuals at all sites censused. Second, eight of the top ten most abundant species were consistently represented by early stages. Third, use of hard bottom habitats was recorded for newly settled stages of more than 20 species.

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

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

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

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

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

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

3.2.2 Artificial/Manmade Reefs

3.2.2.1 Artificial/Manmade Reefs Defined

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

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

3.2.2.1.1 Function and Ecology of New Hard Bottom Habitats

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

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

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

3.2.2.1.2 Function and Ecology of Manmade Reefs

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

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

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

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

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

3.2.2.2 Manmade Reef Development in the South Atlantic Bight

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

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

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

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

3.2.2.2.1 North Carolina

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

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

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

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

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

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

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

3.2.2.2.2 South Carolina

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

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

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

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

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

3.2.2.2.3 Georgia

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

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

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

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

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

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

3.2.2.2.4 Florida (East Coast)

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2.2.3 Manmade Reef Construction Practices

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

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

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

3.2.2.3.1 Secondary Use Materials

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

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

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

3.2.2.3.2 Designed Habitat Structures

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

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

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

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

3.2.2.3.3 Standards for Manmade Reef Construction

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

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

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

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

3.2.2.4 Manmade Reefs in Marine Resource Management

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

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

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

3.2.2.4.1 Fisheries Enhancement

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

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

3.2.2.4.1.1 Special Management Zones

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

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

3.2.2.4.1.2 Stock Enhancement Potential

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

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

3.2.2.4.2 Hard Bottom Habitat Enhancement

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

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

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

3.2.2.4.3 Manmade Marine Reserves / Sanctuaries

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

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

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

3.2.2.4.4 Enhancement of Eco-Tourism Activities

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

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

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

3.2.2.5 Current Manmade Reef Management Practices

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

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

3.2.2.5.1 Federal Role

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

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

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

3.2.2.5.2 State Role

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

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

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

3.2.2.5.3 Regional Activities

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

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

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

3.2.2.6 Use of Manmade Reefs by Managed Species

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

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

3.2.3 Pelagic Habitat

3.2.3.1 Sargassum Habitat

3.2.3.1.1 Description of Sargassum Habitat

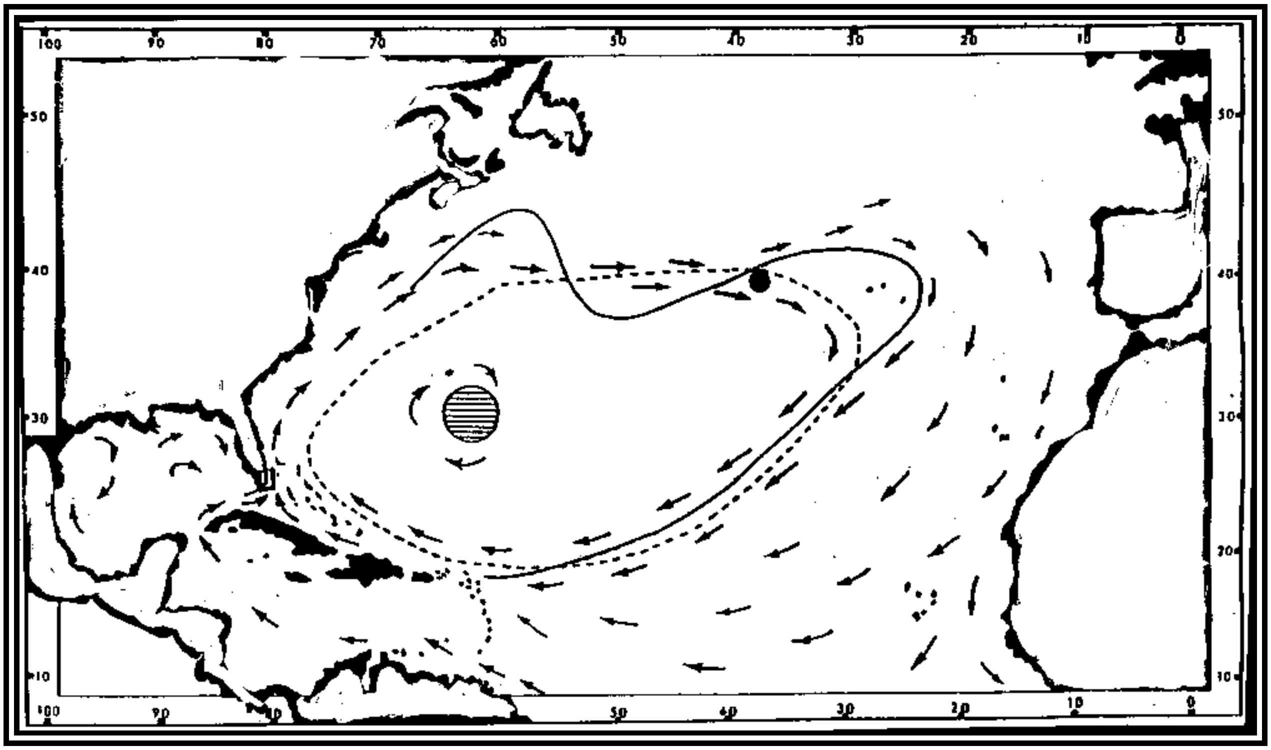
Within warm waters of the western North Atlantic, pelagic brown algae *Sargassum natans* and *S. fluitans* (Phaeophyta: Phaeophyceae: Fucales: Sargassaceae) form a dynamic structural habitat. These holopelagic species are believed to have evolved from benthic ancestors at least 40 million years ago.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

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

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

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

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



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

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

3.2.3.1.2 Utilization of Sargassum Habitat

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

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

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

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

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

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

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

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

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

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

3.2.3.1.3 Measuring Sargassum Distribution and Abundance

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

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

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

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

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

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

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

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

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

3.2.3.2 Water Column

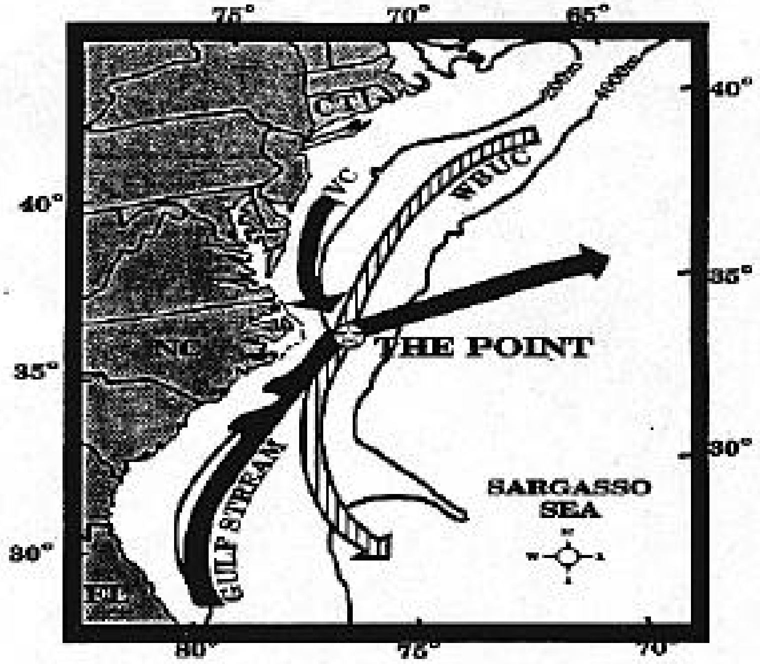
3.2.3.2.1 Description of Water Column Habitats

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

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

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

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



A.
WATER MASSES OFF CAPE HATTERAS

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

3.2.3.2.2 Use of Water Column Habitats

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

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

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

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

1 - bongo / neuston data

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

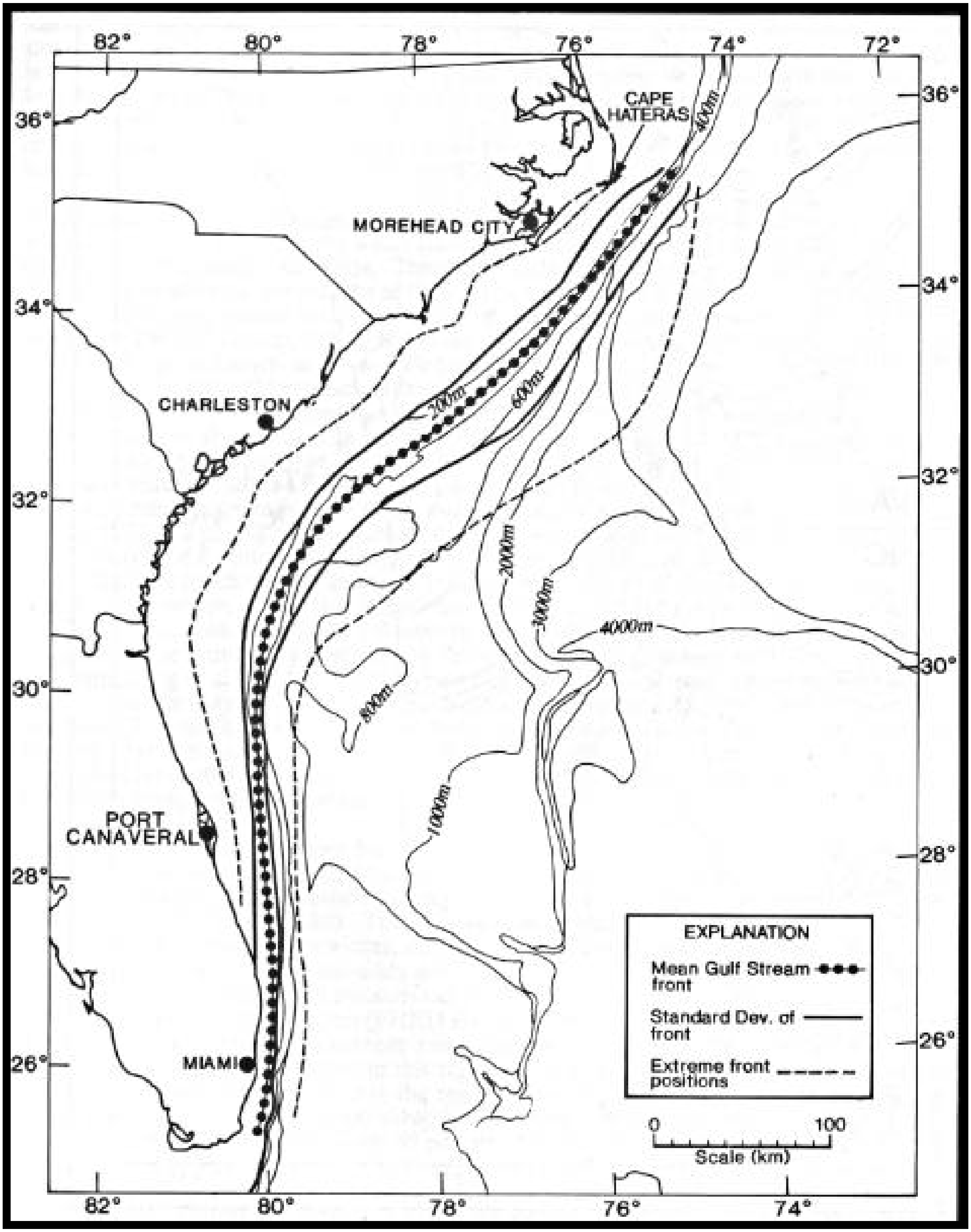


Figure 10b. Gulf Stream front location (Source: MMS 1990).

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

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

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

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

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

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

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

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

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

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

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

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

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

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