Shallow Coral Reef Habitat and Shallow Coral

CHAPTER: Shallow Coral Reef Habitat

Description and distribution

Shallow water coral reefs and coral communities exist within the southern geographical areas under Council authority. In this document these habitats are defined as occurring in depths generally less than 50 meters. Depending upon many variables, stony corals (those secreting reef-building habitat structure) may dominate a habitat, be a significant component, or be individual colonies within a community characterized by other fauna (e.g., sponges or macroalgae). In some areas stony corals have grown in such profusion that their old skeletons accumulate and form reef structure (e.g., coral reefs). In other areas, corals grow as a less dominant component of benthic communities on geologically derived hard substrates (e.g., coral communities). Octocorals, though they do not contribute to reef framework, do contribute greatly to reef complexity and diversity. This section focuses on those ecosystems under Council authority having Scleractinians as an important member of the community. Hardbottom communities that have little or no Scleractinians are treated in the Live/Hardbottom Habitat section of this document (Section XXXX).

Section 1: Reef biogeography, habitat, and community types:

North Florida to North Carolina

Coral assemblages from north Florida north to North Carolina, are dominated by ahermatypic stony coral species and gorgonians, although some hermatypic species do occur off North Carolina (MacIntyre and Pilkey 1969) and Georgia (Hunt 1974). The very limited coral assemblages within this area are found on shallow-water hardbottom habitats ((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)) and deep-water banks (*Oculina* spp.). These are further described in Section XXX of this document.

North Florida to St. Lucie Inlet

From St. John's Inlet to St. Lucie Inlet coral assemblages are relatively sparse and low in diversity as compared to reefs further south. Coral colonies are commonly located on non-coral-derived consolidated carbonate sediments (Avent et al. 1977). Corals are most common in the nearshore hardbottom and along two reef tracts (20 m, 30 m). The two major reef tracts consist of ledges of up to 3 m relief; while the outer 30 m shelf tract runs through the majority of this region, the 20 m shelf tract runs intermittently. Coral assemblages include octocorals (*Lophogorgia, Leptogorgia, Eunicea, Antillorgia* spp.), and scleractinian coral (*Oculina diffusa*, *Oculina varicosa*, and *Siderastrea* spp.). Both temperate and subtropical fish and invertebrate species are represented in this region. At the shelf-edge, high relief (up to 25 m) pinnacles begin at 50 m depth where *Oculina varicosa* form massive branching colonies (Reed 1980). For a more extensive review of the deep water *Oculina* reefs refer to Section XXX.

SE Florida

The Florida Reef Tract (FRT) extends approximately 577 km from the St. Lucie Inlet (Martin County), southward to the Dry Tortugas banks. Off the mainland coast of southeast Florida, the northern extension of the FRT extends from Martin County approximately 170 km south into Miami-Dade County. From central Palm Beach County south to, in particular offshore Broward County, southern Miami-Dade County the reef system is described as a series of linear (Inner, Middle, and Outer) reef complexes (referred to as reefs, reef tracts, or reef terraces). These complexes run parallel to shore, generally at depths approximately 6m to 20m. In addition there are extensive nearshore ridges and colonized pavement areas nearer to shore (Moyer et al. 2003; Banks et al. 2007; Walker et al. 2008). Although these high latitude habitats are near the environmental threshold for significant coral reef growth, they are colonized by an extensive coral reef community which is quite similar within the linear reefs. This region has a similar diversity of key functional groups (stony corals, octocorals, sponges, and macroalgae) to that of the southern regions of the FRT (the Florida Keys and Dry Tortugas) but contributions of these groups to benthic cover may vary (Ruzicka et al. 2010; Ruzicka et al. 2012, Gilliam et al. 2015).

The nearshore ridges and colonized pavement areas occur within a km of shore in water depths generally less than 5 m and are most prominent off Palm Beach, Broward, and Miami-Dade counties. This habitat is defined as flat, low relief, solid carbonate rock with variable sand cover within the most nearshore areas (Walker et al. 2008). In Palm Beach and Martin Counties, the sessile community in less than 3 m is dominated primarily by turf and macroalgae. The dominant scleractinian at these depths are *Siderastrea* species (CSA 2009). In a number of these shallow water areas, the sabellariid polychaete *Phragmatopoma lapidosa* (know as worm rock) can be a dominant component of the habitat. South of these counties, these habitats have been documented to contain areas with the highest stony coral cover and the greatest abundance of larger (>2m) stony corals (dominated by *Montastrea cavernosa* and *Orbicella faveolata)* in the region (Gilliam et al. 2015; Gilliam et al. 2015, Walker...). In this area, this habitat also contains perhaps the most abundant population of staghorn coral, *Acropora cervicornis,* in the Council management area (Vargas-Angel et. al 2006, Walker et al. 2012, Gilliam et al. 2015; Gilliam et al. 2015, D'Antonio et al. 2016).

The Inner Reef occurs within 1 km of shore and crests in 3 to 7 m depths. The Middle Reef crests in 12 to 14 m depths, and Outer Reef crests in 15 to 21 m depths. A large sand area generally separates the Inner and Middle, and the Middle and Outer, reef complexes. The Inner and Middle Reefs extend from northern Broward County south into Miami-Dade County. The Outer Reef occurs within 3 km of shore and is the most continuous reef complex extending from central Palm Beach County south into Miami-Dade County. The community in these reefs includes over 30 species of stony corals and a diverse assemblage of gorgonians and sponges (Gilliak et al. 2015). The common stony coral species include: *Montastrea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Solenastrea bournoni*, *Meandrina meandrites*, and *Dichocoenia stokesii*. Octocorals (gorgonians) and sponges generally have a greater density than stony corals. Some of the common octocoral genera include: *Eunicea*, *Antillogorgia*, *Muricea*, *Plexaurella*, *Pterogorgia* and *Icilogorgia* (Goldberg 1973). Very large (>1m wide) barrel sponges, *Xestospongia muta*, are conspicuous and quite abundant in certain areas of the Middle and Outer Reefs.

Florida Keys

The southernmost component of the Florida Reef Tract includes the area south of Soldier Key to the Dry Tortugas banks. Along the nearshore environs to the deep fore reef adjacent to the straits of Florida, coral-associated habitats consist of nearshore hardbottom communities, patch reefs, and a semi-continuous series of offshore bank-barrier reefs (reef flats, spur and groove) (summarized in Marszalek et al. 1977, Jaap 1984, and Chiappone 1996). These habitats boast a wide bathymetric distribution, from the intertidal to great depths, and are currently colonized by calcifying algae (e.g., *Halimeda*), sponges, octocorals, and a few species of stony corals. Local environmental conditions, driven by water exchange between Florida Bay and the Atlantic Ocean, dictate which species colonize the substrate.

Low relief hardbottom communities occur within 2 km of shore on the Florida Bay and Atlantic sides of the islands. These communities are highly diverse (as described in Chiappone and Sullivan 1994) and dominate the Florida Keys in terms of areal extent (Chiappone 1996).

The patch reef habitat is constructed by a few species of massive stony corals; most often the principal species is *Orbicella annularis*, boulder star coral. Other common foundation building species include *Colpophyllia natans* and *Siderastrea siderea*. Common octocoral genera found on patch reefs include: *Antillogorgia*, *Pseudoplexaura*, *Gorgonia*, *Muricea* and *Plexaurella*. Patch reefs are concentrated in the area off Elliott Key (Biscayne National Park), north Key Largo (John Pennekamp Coral Reef State

Park, Florida Keys National Marine Sanctuary, FKNMS), and in the Hawk Channel area from Marathon to Key West (FKNMS).

The outer bank reefs are the seaward-most reefs in the Florida Keys coastal ecosystem. These reefs are most commonly visited by the diving and snorkeling charters. Their principal, unique feature is the spur and groove system (Shinn 1963). The system is a series of ridges and channels facilitating water transport from seaward to inshore. The coral most responsible for building the spurs was *Acropora palmata* (Shinn 1963), whose population has since experienced significant decline. The spur and groove systems occur in depths that range from a few centimeters to 10 meters. Beyond 10 meters, the spur and groove formation may or may not continue seaward as very low relief structures. Often, this habitat subunit is referred to as the fore-reef and may continue to about 30 m depth. Seaward, sediment beds separate the fore-reef from deeper reef formations in 40 m depth. Stony coral cover has significantly declined over time in this system at both shallow and offshore fore-reefs, and a transition to octocoral dominance is most evident at shallow fore-reefs (Ruzicka et al. 2014). Octocorals of the genus *Antillogorgia*, *Gorgonia*, *Pseudoplexaura, Muricea*, *Eunicea* and *Plexaurella* are commonly found in these outer bank reefs.

The Tortugas Banks are a variation of the deeper reefs found in Dry Tortugas National Park. The depths are greater than 20 m and extend to 40 m. The foundation is Pleistocene karst limestone. The extensive banks host a major grouper and snapper fishery, including a critical 46 square mile spawning ground currently protected as a Research Natural Area. The banks have abundant coral of a few species. Black coral (Order Antipatharia) are common on the outer edge of the bank.

Section 2 - Ecological Functions

Coral reefs and hardbottom have many functional roles within the SAFMC jurisdiction. These functions include complex issues such as trophic relationships, shelter, and cross-shelf and large-scale population connectivity via reproduction. High diversity of reef residents support complex trophic relationships and novel routes of productivity, including significant bio-calcification which provides the architectural structure. The details of these relationships and functions have been examined in several recent large compilations such as Mora (2015) and Riegl and Dodge (2012) and Birkeland (2015).

Section 3 - Use

Note: Track down values for commercial and recreational fisheries, diving and tourism, etc.

Healthy coral reefs are among the most biologically diverse and economically valuable ecosystems on earth, providing valuable and vital economic goods and ecosystem services. Coral ecosystems are a source of food for millions; protect coastlines from storms and erosion; provide habitat, spawning, and nursery grounds for economically and recreationally important fish species; provide jobs and income to local economies from fishing, recreation, and tourism; are a source of new medicines, and are hotspots of marine biodiversity.

Section 4 - Current Habitat Management

Federal

Essential Fish Habitat

The 1996 federal reauthorization of the Magnuson Stevens Act (the Sustainable Fisheries Act) mandated that all eight federal fishery management councils identify Essential Fish Habitat (EFH) in their jurisdiction and amend all Fishery Management Plans (FMPs) as applicable. The SAFMC followed the enabling language and treated EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity”. The SAFMC also identified EFH - Habitat Areas of Particular Concern (HAPCs), which are EFH areas that include one of these four attributes: provide important ecological functions; are sensitive to environmental degradation; include a habitat type that is/will be stressed by development; or include a habitat type that is rare (SAFMC, 1998a).

EFH applies to each life stage of managed species and different life stages of the same species often use different habitats. All coral and hardbottom habitats are designated as EFH-HAPC for the 60 reef species currently in the Snapper Grouper FMP as well as the Spiny Lobster. Additionally, other components of reef habitat such as sponges are EFH for Spiny Lobster. The habitat source document for these designations (SAFMC, 1998b) provided much rationale and content used also in first FEP document. Many administrative details on how EFH is used in coral conservation permitting among federal, state, and local agencies are reviewed in Lindeman and Ruppert (2011).

Place-based management:

The South Atlantic region includes a range of federally managed areas with coral reef habitats, most notably the Florida Keys National Marine Sanctuary (NOAA) and two units of the National Park Service (Dry Tortugas and Biscayne National Parks). Each of these areas has its own management plan, including some areas set aside as marine reserves.

The Florida Keys National Marine Sanctuary (FKNMS) was designated in 1990 for protection in response to concerns about the decline of the reef ecosystem in the area (FKNMS Protection Act 1990). Today, the FKNMS protects more than 9,946 km2 (2,900 nautical mi2) of Florida Keys coastal and ocean waters. With the designation, several protective measures were immediately put into place, such as prohibiting oil exploration, mining, or any type of activity that would alter the seafloor, and restricting large shipping traffic. Anchoring on, touching, and collecting coral are all restricted within sanctuary waters. The FKNMS is jointly administered by the State of Florida and the National Oceanic and Atmospheric Administration (NOAA). The FKNMS management plan was first established in 1998 and implemented a network of zones and protected areas as well as strategies including mooring buoys and a water quality protection program. Additional Ecological Reserves were implemented in the the Dry Tortugas region in 2001. NOAA is currently undertaking the first comprehensive review of the management plan, zoning plan and regulations. This review is a public process that will eventually culminate in an updated management plan and potential modifications to regulations, marine zones, and the sanctuary boundary.

Two components of the National Park system manage coral reef habitats in the south Atlantic region, Biscayne National Park and Dry Tortugas National Park. Biscayne National Park was designated in 1980 (after prior status as Biscayne National Monument) and protects habitats adjacent to the south Florida urban area including Biscayne Bay, the barrier islands, and out to the reef tract. Biscayne NP recently released its first general management plan (June 2015) which includes a marine reserve zone incorporating both fore-reef and patch reef habitats. Dry Tortugas, administered under the management of Everglades National Park, was designated in 1992 and protects relatively remote marine habitats, 113 km southwest of Key West with visitation largely limited to ferry or sea plane. The general management plan for Dry Tortugas NP was amended in 2001 incorporating a zoning scheme including 46% of the park area in a Research Natural Area, the highest level of habitat protection where natural processes are protected from human impact (including fishing).

Endangered Species Act Critical Habitat:

Under the Endangered Species Act of 1973, critical habitat may be designated by NOAA Fisheries for the conservation of threatened and endangered species under its jurisdiction. Critical Habitat designations were made for ESA listed corals, *Acropora palmata* and *A. cervicornis*, in 2008 to include hardbottom habitats < 30m depth deemed suitable to support recruitment of these corals (namely, stable hard substrate free of algae and sediment). Under this designation, over 3,000 sq km of habitat in the south Atlantic region are protected from destruction or ‘adverse modification’ by actions undertaken, funded, or permitted by federal entities.

State of Florida

In 2009, the Florida Legislature passed the Coral Reef Protection Act (CRPA, s. 403.93345, Florida Statutes [F.S.]) to increase protection of coral reef resources on sovereign submerged lands off the coasts of Martin, Palm Beach, Broward, Miami-Dade, and Monroe counties.

The CRPA authorizes the Florida Department of Environmental Protection (FDEP), as the state’s lead trustee for coral reef resources, to protect coral reefs through timely and efficient assessment and recovery of monetary damages resulting from vessel groundings and anchoring-related injuries. To carry out the intent of the Act, the FDEP also has the authority to enter into delegation agreements with state and local government agencies with coral reefs in their jurisdictions. The CRPA is overseen by the FDEP Coral Reef Conservation Program which works with FDEP regulatory or legal entities to ensure the Act is enforced.

In addition to the CRPA, the FWC‘s Marine Life Rule (Rule 68B-42.009, Florida Administrative Code [F.A.C.]) also provides protection for coral reef resources through the prohibition of take, destruction, and sale of marine corals, sea fans, and encrusting octocorals.

State Parks and Aquatic Preserves

Several Florida State Parks and Aquatic Preserves have boundaries extending into the nearshore marine environment (Chapter 258, Florida Statutes and Chapter 62D-2, Florida). These Parks and Preserves manage submerged lands within these boundaries while FWC manages fisheries resources.

Administrative Code and Florida Aquatic Preserve Act of 1975 (Section 258.35, Florida Statutes)). State parks are charged to, “*promote the state park system for the use, enjoyment, and benefit of the people of Florida and visitors; to acquire typical portions of the original domain … as to emblemize the state's natural values; conserve these natural values for all time; ... to enable the people of Florida and visitors to enjoy these values without depleting them; ...; to contribute to the tourist appeal of Florida”.*

While Aquatic preserves are charged to, “*be managed primarily for the maintenance of essentially natural conditions, the propagation of fish and wildlife, and public recreation,* *including hunting and fishing where deemed appropriate by the Board, and the managing agency. ...”*

State Park boundaries for John D. MacArthur Beach State Park in Palm Beach County, John U. Lloyd Beach State Park in Broward County, Bill Baggs Cape Florida State Park in Miami-Dade County, and Indian Key, Long Key, Curry Hammock, and Bahia Honda State, and Fort Zachary Taylor Historic state parks in Monroe County extend into the water up to 400 ft. from the Mean High Water Line (F.A.C 62D-2.014.9b). Other coastal managed areas such as St. Lucie Inlet Preserve State Park in Martin County; Biscayne Bay-Cape Florida to Monroe County Line Aquatic Preserve in Miami-Dade County; Lignumvitae Key Botanical State Park, San Pedro Underwater Archaeological Preserve State Park, and Lignumvitae Key and Coupon Bight Aquatic Preserves in Monroe County extend up to a mile offshore. As the first undersea park in the U.S., John Pennekamp Coral Reef State Park, was dedicated in 1960 and encompasses approximately 70 nautical square miles.

Local Action Strategies

While the reefs in the lower two-thirds of the FRT have had coordinated management for many years, the northern one-third in southeast Florida has lacked a comprehensive management plan and, until recently, an understanding of the local impacts and use in that region. Current initiatives in southeast Florida are bringing together the science and stakeholders to recommend management actions that preserve these reef resources while balancing resource use and protection.

In 1998, the United States Coral Reef Task Force (USCRTF) was established by Presidential Executive Order #13089 to lead U.S. efforts to preserve and protect coral reef ecosystems. During the eighth meeting of the USCRTF, held in Puerto Rico in 2002, the Task Force adopted the Puerto Rico Resolution, which called for the development of Local Action Strategies (LAS) by each of the seven member U.S. states, territories and commonwealths. These LAS are locally-driven roadmaps for collaborative and cooperative action among federal, state, territory and non-governmental partners which identify and implement priority actions needed to reduce key threats to coral reef resources. The goals and objectives of the LAS are closely linked to those found in the U.S. National Action Plan to Conserve Coral Reefs, adopted by the U.S. Coral Reef Task Force in 2000.

With guidance from the U.S. Coral Reef Task Force, the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Conservation Commission (FWC) coordinated the formation of a team of interagency marine resource professionals (state, regional, local, and federal), scientists, and reef resource stakeholders to form the Southeast Florida Coral Reef Initiative (SEFCRI) in 2004.

The SEFCRI which is coordinated and chaired by FDEP, while not a regulatory body, identified the reefs from St. Lucie Inlet in Martin County to the northern boundary of Biscayne National Park as their area of focus due to the lack of understanding of these reefs as well as the lack of a coordinated management plan. The SEFCRI identified the priority threats to southeast Florida's reef resources and developed 140 projects to better understand and reduce those threats. One of the original projects was to: "*Develop and* [sic] *effective, balanced, and comprehensive management strategy for improved resource protection...Organize and hold public workshops to obtain input on the condition and usage trends, possible resource goals, and the potential (i.e. rationale, effectiveness, alternative approaches, etc.) of traditional fishery management and special management zones to achieve targets*."

A major management effort, the *OUR FLORIDA REEFS* community planning process for southeast Florida's coral reefs, was recently completed in June 2016. Hosted by the SEFCRI, this planning process brought together the community of local residents, reef users, business owners, visitors, and the broader public in Miami-Dade, Broward, Palm Beach, and Martin counties to discuss the future of coral reefs in this region. This process is designed to increase public involvement in the future management of southeast Florida's coral reefs by seeking input from a broad range of community members and reef stakeholders on the development of recommendations that can become part of a comprehensive management strategy to ensure healthy coral reefs in the future. The recommended management actions (RMAs) developed through the process address issues from land based sources of pollution; maritime industry and coastal construction; fishing, diving, boating, and other uses; enforcement; education and outreach; and place-based management. The majority of these RMAs were broadly supported by the Community Working Groups, though a few were highly controversial.

Section 5 - Ongoing Threats

Many local actions create or exacerbate detrimental impacts to shallow coral reef ecosystems. Coastal construction and infrastructure development are particularly common near the urban centers from Palm Beach to Miami-Dade counties (Shivlani et al. 2011, Walker et al 2012). Dredge and fill activities such as beach nourishment and port maintenance and expansion result in direct loss of habitat and cumulative as well as acute effects to coral communities through increased turbidity and sedimentation (Wanless and Maier, 2007; Jordan et al. 2010). Beach nourishment activities are ongoing especially within Palm Beach, Broward, and Miami-Dade counties. Recent (2015) port dredging at Port Miami greatly exceeded planned impacts by sedimentation to coral reef habitat, with another large dredging project upcoming at Port Everglades (Fort Lauderdale).

Overfishing has been suggested to result in a global decline of piscine predators with subsequent significant changes in the numbers of herbivores (Mumby et al. 2006). In the Caribbean, parrotfish overfishing has been hypothesized to be pivotal in adversely affecting corals in this region (Jackson et al. 2014). Decreases in parrotfish could result in increased macroalgae which directly outcompetes corals for space or inhibits coral recruitment. However,in the Florida Keys, herbivore-targeting fishing efforts have been relatively nonexistent (Bohnsack et al. 1994). Fishing activities such as that of trap fisheries more clearly create disturbance to reef benthic communities. Although trap fishers report generally avoiding coral reef habitats, ocean dynamics result in an accumulation of trap debris in coral-associated habitats (Uhrin et al 2014). These authors estimate the presence of almost two million items of lobster trap debris in the Florida Keys National Marine Sanctuary. The cover of benthic sessile fauna is reduced by ~ 10 % in areas affected by trap movement, events occurring over a wind threshold of 2 days duration at 15 kt (Lewis et al. 2009).

Water quality degradation from regional water management activities, sewage, coastal runoff, and local use likely have detrimental impacts (reviewed by Gregg 2013) with documented detriments to coral health (see Section XXX corals;). However, reef-scale impacts of water quality are difficult to partition from the myriad stressors which co-occur on reefs in the region. It is highly likely that both coastal hardening/construction and coastal water quality degradation will be exacerbated in the near future by rapid sea level rise from global climate change (Koch et al. 2015).

Invasive lionfish (*Pterois* spp.) likely continue to alter the structure of coral reef fish and invertebrate communities (Albins and Hixon 2008; Albins 2013, 2015; Green et al. 2014), and thus potentially alter coral reef ecosystem function. Lionfish impacts arise predominantly via direct predation (lionfish are voracious generalist predators - Morris and Akins 2009, Muñoz et al. 2011), but also likely occur through competition - e.g., for habitat or prey. Assessing the community- and broader-level impacts of lionfish is a critical need (see related text in Section 6).

With nearly 6 million residents in Martin (146,000), Palm Beach (1.3 million), Broward (1.75 million), Miami-Dade (2.5 million); and millions of visitors every year, awareness and appreciation of reef resources in the northern portion of the reef tract is severely lacking (US Census Bureau 2010).

Section 6 - Recommendations

The United States Coral Reef Task Force (USCRTF) was established in 1998 by Presidential Executive Order to lead U.S. efforts to preserve and protect coral reef ecosystems. The USCRTF includes leaders of 12 Federal agencies, seven U.S. States, Territories, Commonwealths, and three Freely Associated States. The USCRTF helps build partnerships, strategies, and support for on-the-ground action to conserve coral reefs. (From http://www.coralreef.gov/ecosystem/)

USCRTF Recommendations:

- Understand coral reef community dynamics and the impacts of human-caused and natural stressors;
- Identify possible management strategies to mitigate negative impacts; and
- Evaluate the effectiveness of these management actions after they are implemented.

Knowledge Gaps:

- Tropicalization: effects of anticipated shifting species assemblages with warming temperatures.

- Where needed, expand knowledge of the distribution and benthic community attributes of coral reef ecosystems (e.g., via expanded mapping efforts in intermediate depths, 30-50m)

Lionfish:

- While there have been multiple studies documenting local-scale effects of invasive lionfish (*Pterois* spp.) predation on native fish species (Albins and Hixon 2008; Albins 2013, 2015; Green et al. 2014), none of those studies have occurred in SAFMC-managed waters (a majority of the studies were performed in Bahamian waters), and no studies in any area have assessed the effect of lionfish predation over relatively broad scales. Research is needed to assess the realized effects of lionfish, via predation and potentially competition, on coral reef fish community structure at broader spatial scales (e.g., sub-regional, regional, ecosystem).

- There is considerable interest in controlling, reducing or depleting local lionfish populations through culling efforts (e.g., via spearfishers). Research is needed into (1) the effectiveness of culling efforts, in terms of the frequency and intensity of culling needed to maintain lionfish below targeted densities, (2) what target densities are most appropriate (e.g., near-zero, low, moderate…) in terms of reducing probable ecosystem impacts, and (3) assessing the trade-offs between the costs of culling efforts and the benefits (ecological and fishery-related) derived from those efforts.

- Assess and monitor spatial and temporal patterns in use of coral reef ecosystems in terms of fishing, snorkeling / diving and other uses.

- Assess efficacy (direct and indirect results) of management actions such as MPAs.

- Identify fish and invertebrate spawning habitats or locations, and the degree to which spawning aggregations are targeted by fishers.

- Due to repeated reef impacts from large dredging and beach projects in the area, from direct disturbance and ongoing turbidity, (Wanless & Maier 2007), there is a need for better understanding chronic and acute turbidity and/or sedimentation on coral reef habitats.

Potential Management Recommendations:

- Develop and implement numeric water quality standards, including for turbidity, that are protective of coral reef habitats (Gregg 2013)

- “Focused removal of submerged trap debris from especially vulnerable habitats such as reefs and hardbottom, where trap debris density is high, would mitigate key habitat issues but would not address ghost fishing or the cost of lost gear.” (Uhrin et al 2014)

- Diadema restoration (Acropora Recovery Plan, and Florida Pillar Coral Action Plan)

- The Our Florida Reefs Community Working Groups have developed and vetted Recommended Management Actions to improve conservation of southeast Florida reef ecosystems. The final Recommended Management Actions, including a prioritized ranking, are available here:
- http://ourfloridareefs.org/rmacomment/.
  A key recommendation was for a coordinated management plan which includes a network of areas-of-interest for place-based management. This network of place-based management could include coordination with existing managed areas (e.g.

see State Parks and Aquatic Preserves), creation of areas for seasonal protection, marine reserves, and areas identified for restoration. This RMA, though ranked in the top priority category by the Community Working Groups, has met with sharp disagreement from some stakeholder sectors and FWC.

- Coral reef habitats are impacted by ongoing and repeated damage from dredging and coastal construction projects in the region. Given increasing environmental stressors on coral reefs in the region, added stress from construction projects may be temporally partitioned from predictable sensitive ecological processes and stressors (Fraser et al. 2017). Much construction-related damage should also be preventable under existing regulations, but improvements in permitting, monitoring, implementation, compliance and enforcement are needed. Specific recommendations for such improvement are provided in Lindeman and Ruppert (2011) include
    - Development of a template by permitting agencies with standard language for ‘special conditions’ to avoid, minimize, and monitor coral impacts
    - Development by NMFS of regulatory criteria to identify ‘destruction or adverse modification’ of ESA Critical Habitat, replacing the current working definition.

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CHAPTER: SHALLOW WATER CORALS -

Coral as used in this document means *Gulf and South Atlantic prohibited coral*, as defined in 50 CFR §622.2 as follows:

Gulf and South Atlantic prohibited coral means, in the Gulf and South Atlantic, one or more of the following, or a part thereof:
(1) Coral belonging to the Class Hydrozoa (fire corals and hydrocorals).
(2) Coral belonging to the Class Anthozoa, Subclass Hexacorallia, Orders Scleractinia (stony corals) and Antipatharia (black corals; though these are predominantly distributed in deeper (>50m) habitats).

Section 1 - Taxonomy and Life History

Stony corals are marine invertebrates that secrete a calcium carbonate skeleton. Stony corals include members of both the Class Hydrozoa (fire corals and lace corals) and Order Scleractinia (true stony corals). Most reef-building corals are zooxanthellate, hosting symbiotic algae from the genus *Symbiodinium* in their gastrodermal cells. These symbionts provide a phototrophic contribution to the coral's energy budget, enhance calcification, and give the coral most of its color. The largest colonial members of the Scleractinia help produce the carbonate structures known as coral reefs in shallow tropical and subtropical seas around the world.

For the purpose of this plan, Octocorals include species belonging to the Class Octocorallia , Order Alcyonacea (soft corals and gorgonians). Similar to stony coral corals, octocorals are colonial animals with a polyp as the individual building unit and may contain endosymbiotic algae (zooxanthellae). Unlike stony coral, octocorals do not secrete a calcium carbonate skeleton but have an axial skeleton mainly composed of collagen fibers in a proteinaceous matrix.

Table XXX Classification of corals included under the Council's Coral, Coral reefs and Live/ Hard Bottom Fishery Management Plan.

- Phylum Cnidaria
  - Subphylum Medusozoa
    - Class Hydrozoa
      - Order Anthoathecata
        - Suborder Capitata
          - Family Milleporidae (fire, stinging corals)
        - Suborder Filifera

- Family Stylasteridae (lace corals)

- Subphylum Anthozoa
  - Class Anthozoa
    - Subclass Hexacorallia (or Zoantharia)
      - Order Scleractinia
    - Subclass Octocorallia
      - Order Alcyonacea (soft corals)
        - Suborder Alcyoniidae (soft corals)
        - Suborder Scleraxonia (gorgonians)
        - Suborder Holaxonia (gorgonians)
        - Suborder Calcaxonia (gorgonians)

Corals can reproduce asexually when fragments break off and reattach to the reef. However, corals also have a complex life cycle including pelagic (sexual) larval and sessile, usually colonial, adult phases. There are a multitude of breeding systems described among scleractinian corals (Baird et al. 2009) with the primary categories being brooding vs. broadcast spawning, and hermaphroditic vs. gonochroic. The primary reef-building species in the region, including *Acropora* spp. and *Orbicella* spp. are hermaphroditic (colonies produce both eggs adn sperm), broadcast spawners (gametes are shed into the water column where they undergo fertilization and development). Dilution, advection, and other environmental stressors in the open ocean environment yield lower rates of fertilization, higher rates of larval mortality, and greater average dispersal distance by broadcasted, compared with brooded larvae. Brooded larvae are released with symbionts inherited from the parent colony enabling them to renew energy reserves via photosynthesis and are generally able to settle soon after they are released from the parent colony. In contrast, broadcast larvae must rely on lipid reserves from its egg and remain in the water column from a few days to weeks to complete larval development prior to settlement competence. Hence, broadcasting species (with few exceptions, predominantly *Siderastraea siderea*) generally display much lower rates of larval recruitment than brooding species, in some cases vanishingly low. It is likely that both low larval production and declining habitat quality (due to sediments, turf and macroalgae) contribute to low recruitment in broadcast-spawning, reef-building corals in the region.

After metamorphosis onto appropriate hard substrata, metabolic energy is diverted to colony growth and maintenance. Because newly settled corals barely protrude above the substratum, juveniles need to reach a certain size to reduce damage or mortality from impacts such as grazing, sediment burial, and algal overgrowth (Bak and Elgershuizen 1976; Birkeland 1977; Sammarco 1985). Generally, mounding corals grow slowly; most growth rates (linear extension) for *Montastraea*, *Porites*, and *Diploria* are less than 1 cm per year. Hubbard and Scaturo (1985) report average extension rates of 0.12-0.45 cm/yr for several species including *Stephanocoenia intersepta*, *Agaricia agaricites*, *Diploria labyrinthiformis*, *Colpophyllia natans*, *Montastraea cavernosa*, *Porites astreoides*, and *Siderastrea siderea*. Growth rates for branching species are generally higher, with branch extension rates over 10 cm per year commonly reported for *Acropora cervicornis* in the Florida Keys, and even higher rates of total productivity in local in situ *A.cervicornis* nurseries (Lirman et al. 2014). However, long term reductions in coral growth rates are expected under near term future scenarios of climate warming/temperature extremes and acidification (refs) as these stressors reduce the efficiency of calcification.

Octocorals have not been studied as extensively as scleractinian corals and their reproductive biology is poorly known for most species. In 2009, Simpson performed a review of published literature on octocoral reproduction and all known reproduction systems of octocorals are described therein. Like scleractinian corals, both sexual and asexual reproduction have been documented in octocorals. Types of asexual reproduction include fragmentation, fission (commonly observed in encrusting species), and development of new colonies from stolons or runners. Asexual reproduction is known to be more common in true “soft corals” and is limited to only a few octocoral species found in Florida. The vast majority of gorgonian octocorals reproduce sexually by broadcast spawning or brooding (either internally or externally). The reproductive strategy of external or surface brooding has been documented in octocorals, where eggs are released passively onto the surface of the colony (Benayahu and Loya 1983, Brazeau and Lasker 1990, Gutiérrez-Rodriguez and Lasker 2004). While sampling female colonies of *Antillogorgia* (*Pseudopterogorgia*) *elisabethae*, Gutiérrez-Rodriguez and Lasker (2004) did not find developing embryos or planulae inside the polyps, and they suggested that fertilization occurred either internally immediately before the eggs were released or externally on the surface of the maternal colony.

As with stony corals, octocoral planulae settle onto an appropriate substratum and undergo metamorphosis into a feeding polyp. Octocorals are known to settle in shaded microhabitats, such as the underside of settlement plates, small cavities in the substratum or under clumps of macroalgae. Studies suggest that this settlement behavior may be influenced by turbulent eddies that facilitate larval settlement and an avoidance response to unfavorable conditions such as high light intensity, low tides, predator grazing pressure, and sedimentation (Simpson 2009, Benayahu and Loya 1987). Studies have indicated that successful settlement and recruitment into a population occurs at a low rate (Lasker et al. 1998, Simpson 2009). Lasker et al. (1998) suggested that extremely high post-settlement mortality of new recruits indicates that successful settlement may be more related to water column and post-settlement survival than to gamete production and fertilization rates. Despite low recruitment rates, octocorals are excellent spacial competitors and are known to have much higher growth rates in general as compared to most species of scleractinian corals. Cary (1914) discussed the obvious advantage of young octocorals over stony coral recruits in that their most rapid growth is perpendicular to the substratum, keeping the most active growing part of the colony in a favorable position for resource allocation.

Section 2 - Abundance and Trends of coral populations

Scleractinians

SEFL

The reefs offshore the mainland coast of southeast Florida, the northern extension of the Florida Reef Tract (FRT), have a similar stony coral diversity to that of the southern regions of the FRT (the Florida Keys and Dry Tortugas) and much of the Caribbean, but benthic cover, 2-5%, is generally lower and colony size, average less than 20 cm diameter, is generally smaller (Gilliam et al 2014, Gilliam et al 2015). Nearly 30 species of stony corals have been identified, but six species (*Montastraea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Stephanocoenia intersepta*, *Agaricia agaricites*, and *Meandrina meandrites*) contribute greatly to benthic cover and colony density (Gilliam et al 2014, Gilliam et al 2015). Three of these species (*M. cavernosa*, *S. siderea*, and *P. astreoides*) were also identified as being three of the most common species in the Florida Keys (Ruzicka et al. 2013) and in the Dry Tortugas (Ruzicka et al. 2012). Two long-term monitoring programs have been operating since at least 2003 and neither had documented a significant trend in stony coral benthic cover up until 2015 (Gilliam et al 2014, Gilliam et al 2015),, in contrast to much of the Caribbean (Gardner et al. 2003, Jackson et al. 2014) and the southern regions of the FRT (Ruzicka et al. 2014). However, severe thermal stress events and a continuing coral disease outbreak have resulted in severe declines in colony density for several scleractinian species, approaching local extinction for *Dendrogyra cylindrus, Meandrina meandrites*, and *Dichocoenia stokesii* by 2016 (Gilliam et al. unpubl data).

FLK

Coral reefs are in a state of transition in the Florida Keys. Following the 1997/1998 El Niño event, stony corals showed little recovery and continued to be a dwindling part of the benthic assemblage at deep and shallow forereefs. The declines in stony coral cover at the deep and shallow forereefs can be attributed to the continued loss of the dominant, framework-building coral *M. annularis* (Ruzicka et al. 2013). Within the Florida Keys, patch reefs contain the highest cover of any habitat while backcountry patch reefs have the lowest. Coral cover in 2015 was 6.2%, nearly 1% lower than the steady trend recorded in 2013 and 2014 (Ruzicka et al. 2017). In terms of abundance, aggregated for the 40 CREMP sites, *Siderastrea siderea*, *Porites astreoides*, *Stephanocoenia intersepta*, and *Undaria/Agaricia agaricites* are the four most common corals. Of these four, only *Siderastrea siderea* and *Porites astreoides* are top contributors to coral cover. Corals like *Undaria/Agaricia agaricites* are relatively small in size and contribute little to overall coral cover. Between 2014 and 2015, the abundance of eight of the nine corals was not significantly different in 2015 as compared to previous years. *Undaria/Agaricia agaricites* was the only coral that demonstrated a significant decline in abundance between 2015 and all other years tested. It is plausible that even though the abundance of the other most abundant species has remained similar, partial mortality inflicted as a result of the 2014 bleaching event could have reduced the amount of living tissue associated with these corals.

Octocorals

SEFL

Octocorals are a significant component of the reef community along the FRT. Offshore southeast Florida octocoral colony density and species diversity tend to be greater than those of stony corals. Octocoral benthic cover, 3-20%, is also generally higher than stony coral. Octocoral cover has shown a significant decreasing trend in parts of the region (Gilliam et al 2015) which is in contrast to significantly increasing trend identified in the Florida keys (Ruzicka et al. 2014).

FLK

An overall trend of increasing cover was reported for octocorals Keys-wide and across all reef types, resulting in a shift in community structure at the deep and shallow forereefs (Ruzicka et al. 2013). Octocoral cover continued to rise following the 2010 winter cold-water mortality and is the second greatest contributor to benthic cover after macroalgae. Since the 2014 bleaching event, octocoral cover has declined from 15% to 12.8% between 2014 and 2015. The transition from stony coral to octocoral-dominated communities has been reported before; however, all examples are exclusive to the Pacific Ocean (Endean et al. 1988, Fox et al. 2003, Stobart et al. 2005).

Section 3- Threats

Mounting threats of myriad sorts have resulted in drastic declines in scleractinian corals, both in the South Atlantic region and throughout the Caribbean, over the past few decades. Recent analyses of extinction risk for seven coral species concluded that global changes (including warming and changing ocean chemistry) along with disease pose the greatest threat to coral extinction (Brainard et al 2011). These global threats are superimposed and interaction with additional stressors at the local level (also reviewed in Brainard et al. 2011). The relative importance of these local stressors vary somewhat across the South Atlantic region, related to the local human population density and use along the coast.

Global climate change has already caused significant coral declines in the region, with notable increases in year-round local reef sea surface temperature documented over the past century and is estimated at an annual rate of 0.9°C over the past 3 decades (Kuffner et al 2014). As a result, the occurrence of warm temperature stress above bleaching thresholds is projected to occur annually within the next decade, much sooner than global climate models predict (Manzello 2015). Mass coral bleaching events have resulted from warm temperature extremes in 1997-8, 2005, 2014 and 2015. Many corals die directly from bleaching and also from subsequent coral disease outbreaks following the physiological stress of bleaching (Brandt & McManus 2009). Due to high latitude, episodic cold water events also affect South Atlantic corals, particularly in 2010 when cold water caused mass coral mortality, especially in nearshore patch reef habitats (Lirman et al. 2011).

Coastal water quality in the region is affected by broad scale regional water management actions, sewage via both offshore outfalls and seepage from septic tanks, runoff and stormwater. The effect of these combined constituents, including endocrine disruptors, pesticides, nutrients, freshwater, etc. are poorly characterized (but see Downs et al. 2005, Edge et al 2013, Ross et al. 2015) but most certainly detrimental to health of corals in the region, consequently reducing their physiological scope to deal with global stressors.

Fishing is another factor which has imposed significant reduction in fish biomass in reef ecosystems in the South Atlantic region. Meanwhile, fishes are engaged in important positive feedbacks with corals including grazing to maintain benthic habitat quality and nutrient delivery (Shantz et al. 2015). Although parrotfishes are not highly targeted in local fisheries as in other Caribbean regions allowing persistence of high grazing (Paddack et al. 2006), this is a factor which should be monitored as fisheries preferences may change over time.

While the effects of many stressors causing direct coral mortality are relatively easy to observe, many sublethal stressors such as sedimentation, water-born toxicants, acidification, chronic temperature stress, and non-lethal diseases impair the replenishment capacity of coral populations both by impairing larval output and by impairing larval survival and/or recruitment (e.g., Jones et al. 2015, Albright et al 2010).

The effects of ocean acidification (i.e. changes in the carbonate chemistry of ocean waters), water quality, and trophic disruption threats are less well characterized for octocorals, though warm temperature bleaching and disease have both been documented, particularly in sea fans (refs). Unlike scleractinians, some octocorals are also subject to harvest (Miller et al. 2014).

Section 4 - Management

Scleractinian corals are currently managed under a zero-take FMP and are protected as Essential Fish Habitat - Habitat Areas of Particular Concern. Seven species in the region are also protected as threatened species under the US Endangered Species Act, with one of these (Dendrogyra cylindrus) previously designated as a Threatened species by the state of Florida. Hence, an ESA Recovery Plan (for Acropora palmata and A.cervicornis) and Florida Species Action Plan (for D. cylindrus) both provide relevant actions for coral conservation and restoration in the region.

Octocorals are currently managed by the State of Florida under chapter 68B of the Florida Administrative Code (FAC). The State of Florida defines octocorals as “any erect, non-encrusting species of the Subclass Octocorallia, except the species *Gorgonia flabellum* and *G. ventalina*” which are prohibited (FAC 68B-42.002). Up to six octocoral colonies per day may be collected recreationally with a Florida Recreational Saltwater Fishing License (FAC 68B-42.005). There are no trip limits on the harvest of octocorals for commercial purposes, though the fishery is limited to properly licensed commercial harvesters. However, the annual quota for octocorals harvested in State of Florida and adjacent Federal waters is 70,000 colonies (FAC 68-42.006). No power tools may be used to harvest colonies and only one inch of attached substrate around the perimeter of the base of the octocoral holdfast may be removed (FAC 68B-42.006, 68B-42.007, FAC 68B-42.008). Octocorals must be collected and landed live and stored in a re-circulating live-well or oxygenated system aboard the collection vessel (FAC 68B-42.0035).

Areas that are closed to octocoral collection include Atlantic Federal waters north of Cape Canaveral, Biscayne National Park, and in the Stetson-Miami Terrace Deep Water Coral Habitat Area of Particular Concern, as well as the Pourtales Terrace Deep Water Habitat Area of Particular Concern adjacent to Florida state waters (68B-42.0036 F.A.C.). Additional area closures for marine life collection exist in southeastern Florida, including National Parks (Everglades, Biscayne, Dry Tortugas) and specific areas within the Florida Keys National Marine Sanctuary, including the Key Largo Management Area (formerly Key Largo National Marine Sanctuary), the Looe Key Management Area (formerly Looe Key National Marine Sanctuary), and various smaller no-take zones including sanctuary preservation areas, special-use/research-only areas, and ecological reserves (Miller et al. 2014). For further information, Miller et al. (2014) prepared an in-depth description of the U.S South Atlantic Octocoral Fishery.

Section 5-Recommendations

Coral Knowledge Gaps:

- Efficacy and improvement of coral (proactive) restoration strategies (Hunt & Sharp 2014)
- Efficacy of coral predator removal or other mitigation (Acropora Recovery Plan)
- Carrying capacity of coral disease, predation, (Acropora Recovery Plan)
- Impact threshold levels for nutrients, sedimentation, toxicants (Acropora Recovery Plan)
- Determine causal factors in coral disease impacts, especially regarding interactions with temperature and local anthropogenic stressors. (Acropora Recovery Plan)
- Due to repeated reef impacts from large dredging and beach projects in the area, from direct disturbance and ongoing turbidity, there is a need for better understanding of chronic and acute turbidity and/or sedimentation on all life phases of shallow corals, including recruitment.

Coral Potential Management Recommendations

- Coral population enhancement/gardening (Acropora Recovery Plan and Our Florida Reefs Recommended Management Action (OFR-RMA))
- Enhanced mooring balls in sensitive areas (Florida Pillar Coral Aciton Plan; OFR-RMA)
- Enhanced legal enforcement of Florida Coral Reef Protection Act (Florida Pillar Coral Action Plan)
- Improve coastal construction project permitting/compliance/mitigation to achieve 'no net loss' of coral
- Develop improved water quality standard for turbidity that is protective of coral (OFR-RMA)

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Section - Live/Hardbottom Habitat

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. The prominent shoals there extend to the shelf break and are effective in trapping Gulf Stream eddies, whereas the Georgia Embayment to the south is smoother.

Shelf widths of the South Atlantic Bight vary from just a few kilometers off West Palm Beach, FL, to a maximum of 120 km off Brunswick and Savannah, Georgia. Gently sloping shelves (about 1m/km) can be divided into the following zones based on depth. The shallowest is the inner-shelf zone (5-20 m, 16-66 ft.), which is dominated by tidal currents, river runoff, local wind forcing and seasonal atmospheric changes (Table 1). The mid-shelf zone (20-30 m, 66-98 ft.) is dominated by winds but influenced by the Gulf Stream. Stratification of the water column changes seasonally; mixed conditions, in general, characterize fall and winter while vertical stratification prevails during spring and summer. Strong stratification allows offshore upwelled waters to advect farther onshore near the bottom and, at the same time,facilitates offshore spreading of lower-salinity water in surface layer. Further offshore, the outer-shelf zone (30-50 m, 98-164 ft.) is dominated by the Gulf Stream.

Generally, the shelf edge or break occurs between 50-100 m depth (164-328 ft.) but occurs shallower to the south of Cape Canaveral into the Florida Keys. The shelf edge is the transition from a gradually sloping shelf area to relatively steeper slopes. Offshore of the shelf edge, the upper slope occurs in 100 to 300 m (328 to 984 ft.), and the mid slope is slightly deeper at 300-400 m (984-1,312 ft.). The slope areas include habitats such as the Big Rock, Blake Plateau, Charleston Bump, and Pourtales Terrace. Deep offshore and deep areas occur in depths greater than 400 m (1,312 ft.).

Table 1. Approximate depth distribution of hardbottom habitat zones in the southeastern U.S.

There is a better chart in Word Doc

Hardbottom Habitat Zones	Depth (m)	Depth (ft)
Nearshore	0-5	0-16
Inner-shelf	5-20	16-66
Mid-shelf	20-30	66-98
Outer-shelf	30-50	98-164
Shelf-edge	50-100	164-328

Upper-slope	100-300	328-984
Mid-slope	300-400	984-1,312
Deep-offshore	400-5,000	1,312-16,404
Deep	>5,000	>16,404

Ecological Roles and Functions

Hardbottom is defined as exposed rock or other hard benthic substrate. Hardbottom provides protective cover for numerous fish and invertebrate species and increases the surface area available for colonization by sessile invertebrates and macroalgae through increased relief and irregularity of the structure. The variability in abundance and diversity of fish on hardbottom and artificial reefs is related to the amount and type of structural complexity of the reef (Carr and Hixon 1997, Schobernd and Sedberry 2008) and likely explains invertebrate diversity and abundance similarly. Because of their structural complexity, natural reefs can sustain >10 times the fish biomass compared to non-reef open shelf bottom (Huntsman 1979, Wenner 1983). In addition, areas with small patches of hardbottom surrounded by sand bottom supported greater fish abundance and diversity than one large area of equal material, suggesting the importance of habitat edge and diversity to ecosystem productivity (Bohnsack et al. 1994, Auster and Langton 1999).

Nearshore and inner-shelf hardbottom areas can serve as important settlement and nursery habitat for early life history stages of many important fisheries species (Lindeman and Snyder, 1999; Jordan et al. 2004). Species within the SAFMC Snapper-Grouper complex that have been commonly recorded as settlers on nearshore hardbottom (0-5 m) include Lane Snapper (*Lutjanus synagris*), Yellowtail Snapper (*Ocyurus chyrsurus*), White Grunt (*Haemulon plumerii*), French Grunt (*Haemulon flavolineatum*), Black Margate (*Anisotremus surinamensis*) and others. Nearshore hardbottom also serves as intermediate nursery habitat for late juveniles emigrating out of estuaries (CSA 2009).

In addition to providing important settlement and nursery habitat, hardbottom areas provide important spawning habitat for some reef fishes (Heyman et al. 2005, Sedberry et al. 2006, Coleman et al. 2011), including red snapper (Farmer et al. 2017). Spawning occurs on nearshore hardbottom for Black Sea Bass (*Centropristis striata*), Sand Perch (*Diplectrum formosum*), Sheepshead (*Archosargus probatocephalus*), Atlantic Spadefish (*Chaetodipterus faber*) and some additional non-fishery reef species (Powell and Robins 1998, F. Rohde, DMF, pers. com., 2001, CSA 2009). Spawning for most managed reef fish species occurs on mid- and outer-shelf reefs. Riley's Hump in the Dry Tortugas is a spawning location for Mutton Snapper (*Lutjanus analis*) and other species, and may serve in a similar fashion for other snapper/grouper species (Lindeman et al. 2000, Locascio and Burton 2016). Similarly, many deep-water reef species spawn on the upper slope and Blake Plateau (Sedberry et al. 2006, Locascio and Burton 2016, Farmer et al. 2017). Other potential hardbottom spawning areas were included in the SAFMC Snapper-Grouper (?) Amendment 14 for MPA protection (Figure xx), and additional sites have been identified in the Snapper-Grouper Amendment 36 as Spawning Special Management Zones to further protect spawning reef fishes (Figure xx). In the Amendment 14 MPAs and Spawning SMZs, fish in spawning condition have been observed in the area or have been reported anecdotally (SAFMC 2016a, SAFMC 2016b, Farmer et al. 2017). Although approved by the SAFMC, regulations for these Spawning SMZs have not been enacted as of March 2017.

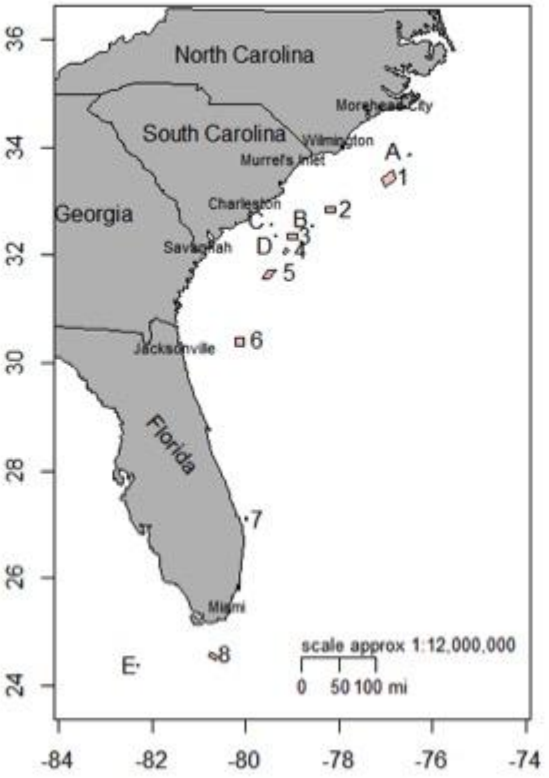

Figure xx. Map of the South Atlantic Region's Deepwater MPAs (Numerals) and Spawning Special Management Zones (Characters). 1=Snowy Wreck MPA, 2=Northern South Carolina MPA, 3=Edisto MPA, 4=Charleston Deep Artificial Reef MPA, 5=Georgia MPA, 6=North Florida MPA, 7=St. Lucie Hump MPA, 8=East Hump MPA, A=South Cape Lookout SMZ, B=Devil's Hole SMZ, C=Area 51 SMZ, D=Area 53 SMZ, E=Warsaw Hole SMZ.

Nearshore

Nearshore hardbottom habitats in the South Atlantic Region are predominantly found along the east coast of Florida in depths of 0-5 m. These habitats are primarily accretionary ridges of coquina shells, sand, and shell marl that lithified parallel to ancient shorelines during Pleistocene interglacial periods (Duane and Meisburger 1969) and are patchily distributed among large expanses of barren coarse sediments. The habitat complexity of nearshore hardbottom is expanded by mounds of tube-building polychaete worms (Kirtley and Tanner 1968; McCarthy 2001), and other invertebrates and macroalgae (Goldberg 1973; Nelson and Demetriades 1992). Hard corals are rare due to high turbidities and wave energy. However, hard corals that are found in the nearshore zone off southeastern Florida from St. Lucie to Broward counties include *Acropora cervicornis*, *Oculina diffusa, Oculina varicosa,* and *Siderastrea spp* (CSA 2009).

A large array of literature and many new species records are summarized for algae (277 species total), invertebrates (523 species), fishes (257) and sea turtles from nearshore hardbottom along the east coast of Florida (CSA 2009). The fish information is based in part on information in (Futch and Dwinell 1977, Gilmore 1977, Gilmore et al. 1983, Vare 1991, Gilmore 1992, Lindeman and Snyder 1999, Baron et al. 2004). At least 90 fish species that utilize nearshore hardbottom habitats are utilized in recreational, commercial, bait, or aquaria fisheries. Some of the important taxa identified included haemulids (grunts), clupeids (herrings and sardines), carangids (jacks), and engraulids (anchovies).

Nearshore hardbottom fish assemblages of east Florida are characterized by diverse subtropical faunas which are dominated by early life stages Based on visual censusing of fishes in three mainland southeast Florida sites over two years, 86 species from 36 families were recorded (Lindeman and Snyder 1999). Pooled early life stages (newly settled, early juvenile, and juvenile) represented over 80% of the individuals at all sites. Nearshore hardbottom habitats typically had more than thirty times the number of individuals per transect as natural sand habitats (Lindeman and Snyder 1999) and newly settled individuals were not recorded during any surveys of natural sand habitats.

Significant differences ($p<0.05$) in total fish (?) abundance, species richness and biomass were noted among the three reef tracts off Broward County, FL (Ferro et al. 2005). In general, greater species richness and fish abundance was found on the offshore reef tract than on the middle or inshore reef tracts. The juvenile grunts, an important forage base, were significantly higher on the inshore and middle reefs, which did not differ significantly from each other, than on the offshore reef. Of management interest, the results of this census highlight a scarcity of legal size groupers (2) and snappers (198) over the entire survey (Ferro et al. 2005?).

Off mainland east Florida, nearshore hardbottom is often colonized by sabellariid worm reefs (*Phragmatopoma lapidosa*) that go through predictable patterns of annual change which include high recruitment in early autumn through winter, rapid reef growth (~0.5 cm/day) resulting in maximum structure in spring and summer, and decay by early autumn (McCarthy 2001;

McCarthy 2003). As recruits grow, the structure of their reef changes and these changes are important in determining the resiliency of the reefs when disturbed. Juveniles form low-lying mounds and reefs that often survive winter wave and sand disturbance (McCarthy 2001). As individuals continue to grow and accrete sand, they form large reefs that reach maximum size during the summer. Many of the intertidal colonies grow into somewhat unstable mushroom-shaped mounds whereas subtidal *P. lapidosa* mounds generally remain carpet-like in shape (McCarthy 2001).

Mortality of *P. lapidosa* colonies increases during the summer as a result of the effects of several disturbance agents (McCarthy 2001). In the early summer, some individuals at the tops of intertidal mounds perish, leaving the tops susceptible to decay. It is likely that this mortality is caused by desiccation and/or heat stress from extreme summer temperatures. By the late summer and early autumn, wave activity from hurricanes results in maximum physical disturbance to sabellariid reefs. A large percentage of both intertidal and subtidal reefs are severely damaged at this time. Intertidal worms are more susceptible to physical destruction of their colonies, whereas subtidal worms get smothered by sand but the sand reef remains intact.

Almost simultaneously with peaks in lethal disturbance, however, larvae of *P. lapidosa* arrive in large numbers to renew the colonies by massive recruitment in cracks or atop mounds of adults (McCarthy 2001). This process results in low lying reefs that are highly resilient and will eventually restore the structure of the reefs. Consequently, as disturbance lowers adult abundance and creates new settlement space, new individuals arrive in sufficient numbers to restore the populations. Therefore, local metapopulations may remain at fairly high abundances year after year while experiencing moderately high mortality from various agents of disturbance. When these seasonal data are integrated with those of other researchers (Gilmore 1977; Gilmore et al. 1981; Lindeman and Snyder 1999), they reveal important links between the seasonal cycle of sabellariid reef expansion and degradation, and the occupation of those reefs by juvenile and adult organisms.

Nearshore hardbottom habitats of the Florida Keys can differ both geologically and biologically from mainland areas. Within the Keys, nearshore hardbottom is widely distributed and shows compositional differences based on proximity to tidal passes (Chiappone and Sullivan 1994). Near tidal passes, these habitats can be dominated by algae, gorgonians and sponges. In the absence 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 of mainland east Florida, presumably due to greater variability in key environmental parameters (temperature, turbidity, salinity).

Inner Shelf

The hardbottom areas of the inner shelf are typically found in depths between 5 and 20 meters. In more temperate regions, the inshore areas at depths less than ~ 18 m have seasonally variable temperatures, less diverse populations of invertebrates, and are inhabited primarily by

Black Sea Bass, Scup and associated warm-temperate species (Sedberry and Van Dolah 1984).

Most of the substrate on the inner shelf of the SAB is covered by a vast plain of sand and mud (Newton et al. 1971) underlain at depths of less than a meter by sand (Riggs et al. 1996; Riggs et al. 1998). The fish biomass associated with this sand- and mud-covered plain is relatively low. Scattered irregularly over the shelf, however, are patches of hardbottom characterized by highly concentrated invertebrate and algal growth, usually in association with marked deviations in relief that support substantial fish assemblages (Struhsaker 1969; Huntsman and Mcintyre 1971; Wenner et al. 1983; Chester et al. 1984; Sedberry and Van Dolah 1984; Sedberry et al. 1998; Sedberry et al. 2001). Studies that have examined fish assemblages on natural and artificial reef habitats include in the SAB inner-shelf-zone (?) include Huntsman and Manooch (1978), Miller and Richards (1980), Grimes et al. (1982), Lindquist et al. (1989), Potts and Hulbert (1994), Parker and Dixon (1998), SAFMC-SA (2001), Ojeda et al. (2004), and Whitfield et al. (2011).

South of Ft. Pierce Inlet, Florida, the shelf becomes increasingly tropical through the Florida Keys. This is reflected in an increase in corals and associated organisms (see the Coral Chapter of the Fishery Ecosystem Plan (SAFMC 2017) and Reigl and Dodge (2008) for greater detail). In southeast Florida, several parallel ridges of hardbottom reefs, derived from Pleistocene and Holocene reefs, begin in depths usually exceeding 8 m (Goldberg 1973; Lighty 1977). The geologic origins and biotic characteristics of these inner shelf reef systems are different from the nearshore hardbottom reefs (Lighty 1977), although reefs of both strata are lower in relief than reefs of the Florida Reef tract that parallels the Florida Keys. Using various collecting gears and literature reviews, Herrema (1974) recognized the occurrence of 206 fishes off the mainland southeast coast of Florida. 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 hardbottom obligate taxa.

Mid Shelf

Off the temperate 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 20 to 30 m (66 to 98 ft), especially off the coasts of North Carolina and South Carolina, and within Gray‘s Reef National Marine Sanctuary off Georgia. Studies of live bottom areas from North Carolina to northern Florida (Continental Shelf Associates, 1979; Wenner *et al.*, 1983) revealed three habitat types: 1) emergent hardbottom 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 hardbottom. See the Coral Chapter of the Fishery Ecosystem Plan (in prep.) and Reigl and Dodge (2008) for greater detail on mid-shelf hardbottom and coral associated fauna.

The federal waters of the inner shelf off Georgia includes an MPA, Gray's Reef National Marine Sanctuary. The Sanctuary contains excellent examples of high- and moderate-relief ledges, low relief hardbottom (often covered with a veneer of sand) and sand plains. Roughly one third of the Sanctuary (eight square miles) is a no-fishing zone; the remainder is a popular recreational fishing site.

Outer Shelf

[need to add outer-shelf text]

Shelf Edge

At the first break on the edge of the continental shelf, there are outcroppings of sedimentary rock and steep dropoffs (10 m or more) in the zone from 50 to 100 m. High-relief rock outcrops are especially evident at the shelf break, a zone from about 55-200 m where the continental shelf ends and the upper slope begins; this area is often characterized by steep cliffs and ledges (Huntsman and Manooch 1978; Sedberry et al. 2001; Wenner and Barans 2001; Fraser and Sedberry 2008; Schobernd and Sedberry 2009). At the shelf edge, the topography is a discontinuous series of terraces before sloping or dropping off into steep slopes dominated by unconsolidated sediments, with submarine canyons, the relatively flat Blake Plateau, or deep Straits of Florida, depending on latitude.

The shelf-edge habitat extends more or less continuously along the edge of the continental shelf at depths of 50 to 100 m (164 to 328 ft). The sediment types vary from smooth mud to areas that are characterized by great relief and heavy encrustations of coral, sponge, and other subtropical and 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. Fishes that generally inhabit the shelf-edge zone are more tropical, such as wrasses, snappers, groupers, and porgies. Fish distribution is often patchy in this zone, with fishes aggregating over broken bottom relief in associations similar to those formed at inshore live bottom sites and are important spawning grounds for many species of managed reef fish (Sedberry et al. 2006; Schobernd and Sedberry 2009; Farmer *et al*. in prep.).

Slope

The upper slope has a predominantly smooth mud bottom, but is interspersed with rocky and very coarse gravel substrates. In addition to rocky outcrops and manganese-phosphorite pavements, there are areas of rough bottom formed by iceberg scours. From North Carolina to south Florida, the retreat of the Northern Hemisphere ice sheets during the last deglaciation (20 to 6 thousand years ago) was accompanied by the discharge of meltwater and icebergs to the southeastern waters of North America, where they encountered then-shallow waters and created plow marks, rock piles and rough bottom (Hill et al. 2008, Hill and Condron 2014). Subsequent sea-level rise has submerged these features on the upper continental slope. These various rocky and mixed bottom types are where Snowy Grouper (*Hyporthodus niveatus*), Yellowedge Grouper (*H. flavolimbatum*) and tilefishes (Malacanthidae) are found (Sedberry and Schobernd 2008, Yeckley, in prep.). This habitat and its association of fishes roughly mark the transition between the faunas of the continental shelf and the slope. Depths represented by this zone range from 100 to 400 m (328 to 1,312 ft), where bottom water temperatures vary from approximately 11° to 14°C (51° to 57°F). Some species inhabiting the deeper live- or hard-bottom areas may be particularly susceptible to heavy fishing pressure due to limited habitat and life history characteristics.

The continental slope off North Carolina, Georgia and Northern Florida is interrupted by the relatively flat Blake Plateau, which divides the slope into the Florida-Hatteras Slope and the Blake Escarpment. On the northern Blake Plateau are important fish habitats, including coral mounds and the Charleston Bump, an important habitat for Wreckfish.

Deep Offshore

The Blake Plateau

Discontinuous large mounds of deep-sea coral reefs occur between the 360-500 m (1,181 to 1640 ft) depth contours on the Blake Plateau. While this deep coral habitat was previously described (Squires 1959; Stetson et al. 1962; Rowe and Menzies 1968), submersible dives have documented more information on their location and species composition (Popenoe and Manheim 2001; Ross 2004; Partyka *et al.* 2007 See Section 3.3.1.3). The mounds consist primarily of dense thickets of the branching ahermatypic coral *Lophelia pertusa*, although other coral species have also been identified. As coral colonies die, others form on top of the mound, and extensive coral rubble accumulates to the sides of the mound. In North Carolina, two areas of mounds have been documented off Cape Lookout and one area off Cape Fear. The vertical height of the mounds was estimated to range from 50 to 80 m over 0.4 to 1.0 km distance. Over 43 benthic or benthopelagic fish species have been identified on these coral mounds (Ross *et al.* 2004).

The Charleston Bump is a deep-water rocky bottom feature on the Blake Plateau southeast of Charleston, South Carolina (Sedberry et al. 2001). It includes a shoaling ramp and ridge/trough features on which the seafloor rises from 700 m to shallower than 400 m within a relatively short distance and at a transverse angle to both the general isobath pattern of the upper slope, and to Gulf Stream currents (Brooks and Bane, 1978). The Charleston Bump includes areas of nearly vertical, 100-200-m high rocky scarps with carbonate outcrops and overhangs; other complex bottom such as coral mounds (mostly dead coral); and flat hardbottom consisting of phosphorite-manganese pavement (Popenoe and Manheim 2001; Sedberry *et al.* 2001). The bottom relief is important to deep reef species and supports the Wreckfish (*Polyprion americanus*) (Sedberry *et al*. 1999) and pelagic longlining fisheries (Cramer 1996; Sedberry *et a*l. 2001; Cramer 2001).

The feature was first described by Brooks and Bane (1978), who noted that it deflected the Gulf Stream offshore. This deflection and the subsequent downstream eddies, gyres and upwellings may increase productivity and concentrate fishes and other organisms along thermal fronts downstream from the Charleston Bump (McGowan and Richards 1985; Dewar and Bane 1985; Haney 1986; Collins and Stender 1987; Lee et al. 1991) including the Charleston Gyre. The cyclonic Charleston Gyre is a permanent but highly variable oceanographic feature of the South Atlantic Bight induced by the deflection of rapidly moving Gulf Stream waters by the Charleston Bump. The gyre produces a large area of upwelling of nutrients, which contributes significantly to primary and secondary production within the SAB region. It is also important in retention and cross-shelf transport of larvae of reef fishes that spawn at the shelf edge (Sedberry et al. 2001). 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 (Bane et al. 2001).

The nutritional contribution of the large upwelling area to productivity of the relatively nutrient poor SAB is significant. While emphasis has generally been placed on shallow habitats, the South Atlantic Fishery Management Council (SAFMC 1998) designated the Charleston Gyre as an essential nursery habitat for some offshore fish species with pelagic stages, such as reef fishes, because of increased productivity that is important to ichthyoplankton (Govoni and Hare 2001; Sedberry et al. 2001).

Artificial Reefs

In addition to the natural hard or live bottom reef habitats, wrecks and other manmade structures (artificial reefs) also provide substrate for the proliferation of live bottom. although the areal coverage of artificial reefs and hardbottom n the SAB region has been not been quantified, the combined area of artificial reefs is thought to be low compared to the area of hardbottom. The effectiveness of artificial reefs to enhance populations has been reviewed by many researchers. The rugosity of the material, patchiness of the distribution of the reef mound, distance to other reefs, and other factors have been tested to determine the effectiveness of artificial reefs to enhance fish populations (DMF 1998; Strelcheck et al. 2005; Lindberg et al. 2006; Simon et al 2013; Syc and Szedlmayer 2012).

In some studies, the faunal species composition on artificial reefs is similar to that identified on natural hardbottom habitat at the same depth and in the same general area (Stone et al. 1979; Stephan and Lindquist 1989; Potts and Hulbert 1994; DMF 1998). However in some studies, species richness has been reported to be higher on natural reefs (Rook et al. 1994), CPUE on natural reefs was 71-85% greater than on nearby artificial reefs (DMF 1998), and fish were in better condition or grew faster on natural reefs (Lindberg et al. 2006).

The Charleston Deep Artificial Reef MPA was established under Snapper Grouper Amendment 14 (SAFMC 2007). The area is proposed to be adjusted in Snapper Grouper Amendment 36 to better match placement of artificial reef material (SAFMC 2016). Additionally, there are two artificial reef areas (Area 51 and Area 53) with proposed regulations through Snapper Grouper Amendment 36.

There is limited literature on the results of artificial reef mitigation of dredge and fill burial of nearshore hardbottom (via beach renourishment projects) using artificial reefs. Reviews of various aspects are provided in CSA (2009; 2014). A detailed empirical comparison among nearshore hardbottom and mitigation reefs off Ft. Lauderdale, Florida (Kilfoyle et al. 2013), revealed that mitigation habitat had high species richness but differed dramatically in structure from impacted nearshore hardbottom (?), creating an environment unlike nearshore hardbottom. The study concluded that “mitigation reefs in general, and boulder reefs specifically, should not be relied upon to provide an equitable replacement to nearshore hardbottomhabitat loss” (Kilfoyle et al. 2013). The impacts of elevated sedimentation from dredging are likely negative across many variables that indirectly and directly influence fishes (CSA, 2009, Jordan et al. 2010), yet are not addressed by reef mitigation.

Essential Fish Habitat

Hardbottom areas constitute essential fish habitat for a high number of species of warm-temperate and tropical species of snappers, groupers, and associated fishes (SAFMC, 1998). Fautin et al. (2011) reported 1200 species of fish from the entire South Atlantic region, including the Florida Keys. Distinct faunal assemblages have been associated with at least four hardbottom habitats: live/hardbottom on the open shelf; the shelf edge reef; upper slope reef; and Blake Plateau/Charleston Bump. Exploratory surveys for reef fishes have yielded 119 species representing 47 families of predominantly tropical and subtropical fishes off the coasts of North Carolina and South Carolina (Grimes et al., 1982; Lindquist et al 1989; Table 3.3-2). Parker and Dixon (1998, 2002) identified 119 species of reef fish representing 46 families during underwater surveys 44 km off Beaufort, North Carolina (Table 2.18). Off South Carolina and Georgia, 54 families, 98 genera and 128 species were taken in 83 trawl collections during winter and summer, in depths from 16-67 m (Sedberry and Van Dolah 1983). Sedberry and Schobernd (2009) reported 25 families and 54 species seen during nine shelf-edge submersible dives off Florida, Georgia and South Carolina. Three upper-slope dives yielded seven families, and seven species.

A total of 181 fish species has been reported from Gray‘s Reef National Marine Sanctuary, an inner-shelf (18-20 m) live bottom reef off Georgia (Fautin et al. 2010; J. Hare, unpublished data). 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. Hardbottom habitats off mainland southeast Florida and areas off the Carolinas 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 1999). This cross-shelf positioning, coupled with their role as the only natural structures in these areas, suggests nearshore hardbottom can represent important Essential Fish Habitat.

Section 600.815 (a) (9) of the final rule on essential fish habitat determinations recognizes that subunits of EFH can 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 (SAFMC 1998). Applications of EFH and EFH-HAPCs in the management of the SAFMC snapper-grouper complex was examined in Lindeman et al (2000), with a focus on developmental variation and MPAs. Hardbottom habitat types which have been identified as EFH-HAPCs include the following areas.
[The following subsections within the EFH section header have a smaller font but it isn't that clear/different in showing they are sub-headers when going through the doc. Therefore, i suggest un-bolding them and underlining them. Chip, this is your call. kl.]

Charleston Bump and Gyre

The South Atlantic Bight, the Charleston Bump and Gyre are described in greater detail in several research and review papers (e.g., Bane et al. 2001; Sedberry et al. 2001; Govoni and Hare 2001 and papers cited therein). The following synopsis is based on the review by Sedberry et al. (2001), Fautin et al. (2010) and O. Pashuk (unpublished MS).

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 two to three 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 water 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.

Ten Fathom Ledge and Big Rock

The Ten Fathom Ledge and Big Rock areas are hard-bottom habitats located south of Cape Lookout, North Carolina. The Ten Fathom Ledge is located at 34° 11‘ N. and 76° 07‘ W. 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, unpublished data.).

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 fish habitat for deep-water reef fish. A series of troughs and terraces are composed of bioeroded limestone and carbonate 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-water reef fish community likely consists of fewer than 60 species; however, many fishery species spawn there (Sedberry et al. 2006). Parker and Ross (1986) observed 34 species of deep-water 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. Schobernd and Sedberry (2009) reported 25 families and 54 species seen during nine shelf-edge submersible dives off Florida, Georgia and South Carolina. Three upper-slope dives yielded seven families, and seven species.

Gray's Reef National Marine Sanctuary

Gray's 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. Kendall et al. (2008) found that presence of dominant groupers, Gag and Scamp, was most strongly related to height of ledge undercut, whereas abundance of Black Sea Bass was best explained by percent cover of sessile biota. A designated research area was created within the sanctuary boundary in 2010 to potentially evaluate the effects of fishing, natural events and cycles, and climate change.

Nearshore Hardbottom of Mainland East Florida

Extending semi-continuously from at least St. Augustine Cape Canaveral to the Florida Keys, nearshore hardbottom was evaluated in terms of the four HAPC criteria in Section 600.815 of the final EFH interim rule: important ecological functions, sensitivity, probability of anthropogenic stressors, and rarity. In terms of ecological function, several lines of evidence suggest that nearshore hardbottom reefs may serve as nursery habitat ((Lindeman and Snyder 1999; Baron et al. 2004, Jordan et al. 2004, CSA, 2009, Kilfoyle et al. 2013, CSA 2014). Based on quantitative information available for Palm Beach County, Florida, (Lindeman and Snyder 1999, CSA, 2009): a) pooled early life stages consistently represented over 80% of the total individuals at all sites censused, b) eight of the top ten most abundant species were consistently represented by early stages, and c) use of hardbottom habitats was recorded for newly settled stages of more than 20 species.

The mere 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), ensuring that if distributions are homogeneous, all habitats will have more early stages than adults. 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 meters, despite substantial sampling efforts in deeper waters, with several interesting exceptions (Jordan et al. 2012). Adults are infrequent or absent from the same shallow habitats. There is habitat segregation among life stages of many species, with the earliest stages using the shallowest habitats in many species of grunts and snappers (Starck 1970; Dennis 1992; Lindeman et al. 1998). Similar ontogenetic differences in both distribution and abundance exist for many other taxa which utilize nearshore hardbottom habitats. Based on this and other evidence, Lindeman and Snyder (1999) concluded that at least 35 species utilize nearshore hardbottom 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 hardbottom, such structures may also have substantial value as reference points for spawning activities of inshore fishes, a major aspect of EFH-HAPCs (SAFMC, 1998). Many species 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, at least 15 species were estimated to spawn on nearshore reefs (CSA 2009). 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.

Based on the demonstrated or potential value of these areas as nurseries and spawning sites for many economically valuable species, nearshore hardbottom habitats were estimated to support highly important ecological functions, the first EFH-HAPC criterion for the SAFMC (SAFMC 1998). The second and third HAPC criteria, sensitivity and probability of anthropogenic stressors, are interrelated in terms of nearshore hardbottom. They are treated collectively here. Various stretches of nearshore hardbottom have been completely buried by dredging projects associated with beach management activities in this subregion (Section 7.4.2.2). 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 hardbottom reefs were buried by beach dredging projects at two sites in Palm Beach County. 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 hardbottom ranks high. In southeast mainland Florida, most shorelines between Dade and Broward Counties (25°30'-26°20' N) lack natural nearshore hardbottom with substantial three-dimensional structure (ACOE 1996). Although substantial stretches of nearshore hardbottom 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 nearshore 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 hardbottom 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 hardbottom can facilitate both inshore and offshore migrations during differing ontogenetic stages of some species. Their limited availability does not 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 hardbottom 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 blue striped grunt which typically settle inside inlets and primarily use nearshore hardbottom as older juveniles (Lindeman et al. 1998; CSA 2009).

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. Many of these other species, not currently managed under the SAFMC are important prey items (Randall, 1968) for those species under management.

New or possibly new citations:

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SAFMC. 1998. EFH source document….

[There may be references to Lindeman 1997a and 1997b for this chapter - take these out, thanks, KL.]

Oyster Reefs and Shell Banks

Description and Distribution

Reef-forming Species

In the western Atlantic, oysters, mussels, and one genus of gastropod build three-dimensional structures that are commonly called reefs (Figure 3.2-14). Wood (1998, 1999) reviews the term reef, and discusses its origin and those taxa and concepts that relate to reefs. The term derives from a Norse term rif, or hazardous rib of sand, rock, or biologically generated substrate near the surface. Wood (1999) includes the following as extant reef producers: corals, coralline and calcareous algae, sabellariid and serpulid polychaetes, oysters, vermetid gastropods, bryozoans, sponges, and stromatolites (i.e., *Cyanophytes*). Other terms such as bars and beds also refer to reef structures that are created by the organisms themselves. Holt et al. (1998) define biogenic reefs as: *solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms.*

The focus here includes many shellfish species (e.g., mussels, dense clam beds) that may be classified somewhere between non-reef and reef-forming biotopes. Holt et al. (1998) try to characterize these biotopes, but this is a difficult task. Furthermore, researchers often refer to the structure that a species generates as a habitat, biotope or biogenic reef. We focus on species that create unique and definable areas that are different from the surrounding unstructured sediments.
Although many species typically occur on shellfish reefs, the main structural component is formed by the attachment of many individual shellfish to each other. At least three species of oysters occur along the Atlantic coast, in addition to several mussel species and other molluscs (e.g., vermetid gastropods) (Abbott 1974). Of these, only the Eastern (or American) oyster (*Crassostrea virginica*), blue mussel (*Mytilus edulis*), and horse mussel (*Modiolus modiolus*) typically form reefs along the Atlantic coast. In the Chesapeake Bay and elsewhere, there is uncertainty over whether a non-native oyster from the Pacific (*C. ariakensis*) can serve both as a reef builder and suitable fisheries resource substitute for *C. virginica* (NRC 2004; Ruesink et al. 2005).

Figure 3.2-14. Examples of intertidal and subtidal shellfish habitats (Source: ASMFC, 2007). A and B: Pen shell, *Atrina zelandica*, aggregations in New Zealand (Source: Simon Thrush, National Institute of Water and Atmospheric Research, New Zealand); C: *Modiolus modiolus* reefs in St. Joe Bay, Florida (Source: Brad Peterson, State University of New York, Stony Brook); D: Nesting oyster catchers on intertidal shell accumulations along the Intracoastal Waterway (Source: Phil Wilkinson, South Carolina Department of Natural Resources); E: Intertidal oyster reefs at Canaveral National Seashore (Source: Loren Coen, South Carolina Department of Natural Resources); F: Close-up of intertidal oysters on South Carolina reefs (Source: Loren Coen, South Carolina Department of Natural Resources).

Estuarine and marine mussels

Reef-forming mussels include the *Mytilus* spp. complex (*M. edulis* and *M. trossulus*) and the horse mussel (*Modiolus modiolus*). *Mytilus* spp. (most widely recognized blue mussels) occurs from Labrador to Cape Hatteras, North Carolina, on the western Atlantic coast (Abbott 1974; Suchanek 1978, 1985; Gosling 1992, 2003; Albrecht 1998; Newell 1989; Witman and Sebens 1988; Witman and Dayton 2001; Hellou and Law 2003). In many areas, *M. edulis* and *M. trossulus* are sympatric and hybridize (Riginos and Cunningham 2005). Additionally, the occurrence of *Mytilus galloprovincialis* (originally from the Mediterranean and now cultured throughout Europe and China) and a west coast species, *Mytilus californianus*, further complicate systems as invaders in many areas (McDonald and Koehn 1988; Varvio et al. 1988; Lobel et al. 1990; Seed 1992, 1995; Geller et al. 1994; Suchanek et al. 1997; Riginos and Cunningham 2005).

Gastropods of the family Vermetidae

The only habitat-forming snails on the Atlantic coast are species in the family Vermetidae. Vermetid snails cement themselves together to form dense reefs in intertidal and shallow subtidal waters from southern New England (rarely) to the tropics (Shier 1969; Safriel 1966, 1975; Abbott 1974; Safriel and Ben-Eliahu 1991; Dame et al. 2001). These uniquely cemented gastropods feed using a mucous net (video available at http://www.mbayaq.org/video/video_snailnet_feeding_qt.asp).

Worldwide vermetid snails form an often-conspicuous group of sessile gastropods living in shallow tropical and temperate reefs, commonly constructed on *Crassostrea virginica* shell accumulations. In southwestern Florida they extend intermittently as far north as Sarasota. In addition, some researchers have reported that they consider the species that was found in the Ten Thousand Islands area of southwestern Florida extinct, as the reefs were formed during the last interglacial period that drowned the beach ridges that make up the present-day islands.

There are a number of reef-forming vermetid species in Florida waters. The most common Florida species of vermetid snail, *Dendropoma corrodens*, is a small (10 mm) entrenching and encrusting species that is extremely abundant in the Florida Keys. Vermetid reef formation is restricted to the west coast of Florida, involving gastropods of the genus *Petaloconchus* (e.g., *P. macgintyi*) (less than 35 mm length). This genus is gregarious, and may form large (<1 m height) reef structures in some shallow, intertidal waters (Ortiz-Corps 1985). In the Ten Thousand Islands area of Florida, longshore currents carry sand and shells to areas suitable for oysters to become established. These oyster reefs then provide stable substrate for mangroves, another important nursery habitat, to take hold (Lodge 1998). In some areas it has been hypothesized that vermetid gastropod reefs provide a similar substrate for mangrove initiation (Davis 1997). Unfortunately, some researchers note that vermetids appear to be in global decline (R. Bieler, Field Museum of Natural History, personal communication).

Aggregations of Living Shellfish

The term aggregation is used here to refer to shellfish species that are not attached to one another yet occur at densities sufficient to provide structural habitat for other organisms (Figure 3.2-14, Plate D). The term bed is also sometimes used to refer to the same type of structure. Three groups of bivalves— scallops, pen shells, and *Rangia* —form habitat in this way (Figure 3.2-14). Although not molluscan, brachiopods also form dense aggregations that function like other molluscan species. The major habitat-forming scallops that occur along the Atlantic and Gulf coasts are the bay scallop (*Argopecten irradians* with several recognized subspecies), calico scallop (*Argopecten gibbus*), and sea scallop (*Placopecten magellanicus*) (Bourne 1964; Shumway 1991; Blake and Graves 1995).

Pen shells (family Pinnidae) are large bivalves that bury partly into the substrate and are anchored by a substantial byssus (long, fine, silky filament). The upper portion of the shell protrudes above the substrate (often referred to as emergent shellfish beds), which provides habitat for other organisms when they occur in sufficient densities (Figure 3.2-14, Plates A & B). Three species of pen shell occur along the Atlantic coast of the Americas: the saw-toothed pen shell (*Atrina serrata*), the amber pen shell (*Pinna carnea*), and the stiff pen shell (*Atrina rigida*) (Abbott 1974).

The saw-toothed pen shell, *A. serrata,* is typically found in sandy mud at depths of up to 6 m. It ranges from North Carolina to Texas and northern South America, and is relatively common in many areas in North Carolina (Abbott 1974). Several recent studies have shown that pen shells are adept at repairing damage in a short time, pointing to potentially interesting resource allocation issues (e.g., cost of shell repair) with regard to this relatively large infaunal organism (T. Alphin, University of North Carolina at Wilmington, personal communication). Many small shrimp and crab species spend their adult lives in the mantle cavity of this species and other pen shells, where they find refuge and feed on particles brought into the mantle cavity (Abbott 1974).

Although the amber pen shell, *P. carnea,* is generally found in sandy areas with depths up to 4 m, it rarely is found in the intertidal zone. It ranges from southeastern Florida to northern South America. Finally, *A. rigida* is common in sandy muds from low intertidal to 27 m in depth. It ranges from North Carolina to southern Florida and the West Indies (Abbott 1974).

Shell Accumulations

The shells of dead molluscs sometimes accumulate in sufficient quantities to provide important habitat. The term shell hash refers to accumulations consisting mostly of pieces of broken shell (Anderson et al. 1979; Street et al. 2005), although this hash can also be composed of intact small bivalves and gastropod shells (e.g., Sanibel Island, FL).

Shell accumulations can occur from estuaries out to the continental slope, with several species present in each zone (Stanley and Dewitt 1983, Stanley 1985, Newell and Hidu 1986, Rice et al. 1989, MacKenzie and McLaughlin 2000, Kraeuter et al. 2003). For accumulations of smaller molluscs, we know little or nothing about their importance (W. Arnold, Florida Fish and Wildlife Research Institute, personal communication).

Accumulations of eastern oyster shells are a common feature in the intertidal zone of many southern estuaries, particularly along waterways impacted by wind and boat wakes (Figure 3.2-14, Plate D) (Anderson et al. 1979; Bahr and Lanier 1981; Grizzle et al. 2002). The dead shells of blue mussels (*Mytilus* spp.) occur intertidally in some northern estuaries. These accumulations, sometimes extending well above the high tide line, have not been well studied. Subtidal shell accumulations, however, provide habitat for many species of commercially and recreationally important fish (Auster et al. 1991, 1995; Holt et al. 1998).

Ecological Role and Function

The ecological processes that depend on the above characteristics of shellfish habitat can be thought of as ecosystem services. Hence, in addition to their direct habitat-related value for managed species, shellfish habitats provide important services for the ecosystem as a whole. Three of the most important of these services are discussed in more detail below: refuge, benthic-pelagic coupling, and erosion reduction (or shoreline protection).

Refuge

The term refuge is used here to describe the protective function that shellfish habitat provides for the shellfish themselves, as well as for other organisms that occur in shellfish habitat. This ecosystem service largely results from the increase in structural complexity in shellfish habitat compared to surrounding areas (particularly soft sediments). In other habitats, such as seagrasses or salt marshes, the concept of structural complexity is often associated with the notion of ―nursery areas, which refer to places where juvenile invertebrates and fish are protected from predators (Lindberg and Marshall 1984; Heck et al. 1995; Benaka 1999; Halpern et al. 2001; Williams and Heck 2001; Beck et al. 2003; Heck et al. 2003; Minello et al. 2003). Shellfish habitat plays a role similar to seagrasses and other structurally complex habitats in this respect. Most of the research dealing with these topics for shellfish habitat has been conducted on the reef-forming species, but some information is available for shellfish aggregations and shell accumulations.

Benthic-pelagic coupling

This term refers to the transfer of materials and energy between the bottom community and the water column. It is probably most often used to refer to the overall effect of suspension feeders as they remove suspended particulates from the water column (Dame 1996). The result is a transfer of materials and energy from the water column to the benthos (Frechette et al. 1989; Meyer and Townsend 2000; Cummings et al. 2001; Dame et al. 2001; Ellis et al. 2002).

These feeding activities also typically cause a reduction in turbidity of the water column which has a positive impact on submerged aquatic vegetation (SAV), allowing more light penetration and higher rates of photosynthesis (Meyer and Townsend 2000). The shellfish release ammonia and other metabolites that are nutrients for the SAV. Therefore, SAV (Peterson and Heck 1999, 2001a, 2001b; Williams and Heck 2001; Heck and Orth 2006) and oyster reefs potentially play mutually beneficial roles (Heck 1987; Newell 1988; Dame 1996; Dame et al. 2001; Newell and Koch 2004) (also see Pomeroy et al. 2006 for a different perspective).

Oyster reefs are likely to reduce eutrophication by mediating water column phytoplankton dynamics and denitrification (Dame 1996; Newell et al. 2002; Newell 2004). A decrease in oysters in the Chesapeake Bay has led to increased phytoplankton numbers and reduced competition with zooplankton. An increase in zooplankton leads to a rise in predators, such as ctenophores and jellyfish. An increase in phytoplankton also leads to a microbial shift and anoxic conditions of deeper waters in areas such as the Chesapeake Bay (Ulanowicz and Tuttle 1992; Newell 1988) (also see Pomeroy et al. 2006 for another view). Models have shown that an increase in oyster abundance would reduce phytoplankton primary productivity and secondary gelatinous consumers (e.g., ctenophores) to historically low levels (Ulanowicz and Tuttle 1992).

Erosion reduction

Estuaries in many areas are threatened by increased coastal population growth and associated industrial, residential, and recreational development and utilization (Vernberg et al. 1999). One major area of recreational growth has been in the number of people with Class A (< 16 ft) and Class 1 (16 to 25 feet) motorized boats utilizing these waterways (NMMA 2004). Some problems related to this increase in the number of small boats have been well documented (Crawford et al. 1998; Cyr 1998; Backhurst and Cole 2000; Bauer et al. 2002; Kennish 2002). For example, increases in seagrass scarring from boat propellers and the number of marine mammal collisions are both positively correlated with increased boating activity (R. Virnstein, personal communication; Sargent et al. 1995).

However, little is known about the direct and indirect impacts of boating on other critical estuarine habitats in the landscape, such as intertidal oyster reefs (Grizzle et al. 2002; Coen and Fisher 2002; Coen and Bolton-Warberg 2003, 2005; Piazza et al. 2005; Wall et al. 2005). Those areas dominated by intertidal oyster reefs form a protective breakwater for fringing *Spartina* marshes, retarding shoreline erosion (Coen and Fischer 2002; Coen and Bolton-Warberg 2005).

Additionally, shoreline erosion in tidal channels is an issue in many states (Cyr 1998; Gabet 1998). Undercutting by wind waves and boat impacts can cause slumping (calving) of large masses of sediment embedded with *Spartina* (Gabet 1998; Chose 1999; Piazza et al. 2005). *Spartina* has been documented to be an important habitat for estuarine productivity (e.g., as a feeding ground for juvenile fishes and their prey) and is known to perform many other ecological functions, such as buffering run-off (Weinstein and Kreeger 2000).

Data collected by researchers from the South Carolina Department of Natural Resources noted significant shoreline losses at numerous study sites (n = 11) across South Carolina (Coen and Bolton-Warberg 2005). By reducing erosion, oyster reefs reduce vegetation loss and preserve other habitat types (Meyer and Townsend 2000). They also stabilize creek banks and help to reduce erosion of marshes (Meyer et al. 1997; Chose 1999; Coen and Fischer 2002; Breitburg et al. 2000; Coen and Bolton-Warberg 2003, 2005; Piazza et al. 2005), but may be easily impacted by boat wake or storm damage (Grizzle et al. 2002; Coen and Bolton-Warberg 2005).

Research on recreational boating impacts on estuarine species is surprisingly still in its infancy (Anderson 1976, 2000; Kennish 2002; Bishop 2003, 2004, 2007; Bishop and Chapman 2004). Productivity, diversity, and survival of estuaries in the southeastern United States are threatened by explosive coastal population growth and associated industrial, residential and recreational development and utilization (Vernberg et al. 1999). In spite of the potentially far excursion distances of motorboats, and the large number of boats on the water on any given day, sparse data exist to quantitatively determine the impact of boat wakes on intertidal organisms.

In conclusion, it should be noted that each of the three types of shellfish habitats differ with respect to their major characteristics and the ecosystem services they provide. Shellfish reefs typically provide the most in the way of services because they consist largely of live animals that provide a food source for many fish and invertebrates, and typically have significant vertical structure. Shellfish aggregations consist mainly of live animals but typically do not occur at densities as high, or with vertical structure as extensive, as shellfish reefs. Shellfish accumulations consist only of the dead shell remains, but they provide hard substrate and may have significant vertical structure. There is a rich literature that documents the importance of all three types of shellfish habitat to many species of fish and invertebrates, including most managed species.

Habitat utilization

Shell bottom provides critical fisheries habitat not only for oysters, but also for recreationally and commercially important finfish, other mollusks, and crustaceans. The ecological functions of oyster reefs related to oyster production are well known and accepted (Coen et al. 1999). These functions include aggregation of spawning stock, chemical cues for successful spat settlement, and refuge from predators and siltation. Oysters have also been described as ecosystem engineers that create biogenic reef habitat important to estuarine biodiversity, benthic-pelagic coupling, and fishery production (Lenihan and Peterson 1998).

Data quantifying fish use of habitats vary from presence/absence and numerical abundance, to actual fish production value. In North Carolina, 18 fishery species have been documented utilizing both natural and restored oyster reefs in Pamlico Sound, including Atlantic croaker, southern flounder, Spanish mackerel, spotted seatrout, weakfish, American eel, and black sea bass (Lenihan et al. 2001). Numerical abundance and production compared to other habitats provides additional information on the importance of habitat for fish. The species found most abundantly on oyster reefs compared to adjacent soft bottom were silver perch, sheepshead, pigfish, pinfish, toadfish, and Atlantic croaker. Southern flounder was collected on both oyster reefs and adjacent soft bottom areas, while bluefish and Atlantic menhaden were not collected near oyster reefs (Lenihan et al. 2001).

Several studies have found higher abundance and diversity of fish on shell bottom than adjacent soft bottom, particularly pinfish, blue crabs, and grass shrimp (Harding and Mann 1999; Posey et al. 1999; Lenihan et al. 2001). A study in Back Sound also found that crabs were more abundant on shell bottom than restored SAV beds (Elis et al. 1996). Breitburg (1998) concluded that the importance of shell bottom to highly mobile species is very likely underestimated, partially due to the difficulty in sampling oyster beds.

Peterson et al. (2003a) estimated the amount of fish production that shell bottom provides in addition to adjacent soft bottom habitats. Using results from numerous studies, they compared the density of fish at different life stages on oyster reefs and adjacent soft bottom habitats. The published growth rates of species were then used to determine the amount of production gained from shell bottom. The species were separated into recruitment-enhanced, growth-enhanced, and not enhanced groups. Recruitment-enhanced species are those having early life stages showing almost exclusive association with shell bottom. For other species with higher abundance in shell bottom, diet and life history studies were used to determine the fraction of their production associated with the consumption of shell bottom-enhanced species. Species consuming relatively more shell bottom-enhanced species were classified as growth-enhanced. Analysis of the studies revealed that every 10m2 of newly constructed oyster reef in the southeast United States is expected to yield a benefit of an additional 2.6 kg of fish production per year for the lifetime of the reef (Peterson et al. 2003a).

Fish that utilize shell bottom can be classified into three categories: resident, transient, and facultative (Coen et al. 1999; Lowery and Paynter 2002). Resident species live on shell bottom and depend on it as their primary habitat. Transient species are wide-ranging species that use shell bottom for refuge and forage along with other habitats. Facultative species depend on shell bottom for food, but utilize other habitats with vertical relief or shelter sites.

At least seven fish species have been identified as resident species—naked goby, striped blenny, feather blenny, freckled blenny, skilletfish, and oyster toadfish (Coen et al. 1999; Lowery and Paynter 2002). These species were also considered recruitment-enhanced by Peterson et al. (2003a). Resident fish are important prey for transient and facultative predator species (Coen et al. 1999). For example, Breitburg (1998) found high densities of juvenile striped bass (15.4 individuals/m2 of reef surface) aggregating near the reef surface feeding on naked goby larvae congregated on the down-current side of the reef. Other common predator species sampled on oyster reefs in North Carolina are red and black drum, Atlantic croaker, sheepshead, weakfish, spotted seatrout, summer and southern flounder, blue crab, and oyster toadfish. Of these species, however, only sheepshead, southern flounder, and oyster toadfish were considered shell bottom-enhanced by Peterson et al. (2003a). Production of black drum, Atlantic croaker, blue crab, and summer flounder were classified as not enhanced by shell bottom. Oyster reefs in higher salinity waters are critical habitat for predators such as juvenile gag, snappers (*Lutjanus* spp.) and stone crab (Wenner et al. 1996; Peterson et al. 2003a).

There is some variation in fish use among salinity gradients as well. Oyster reefs in higher salinity waters tend to support a greater number of associated species than reefs in lower salinity waters (Sandifer et al. 1980). Studies summarized by Coen et al. (1999), which included work in North Carolina, identified 72 facultative, resident, and transient fish species in close proximity to oyster reefs. The ASMFC-managed species categorized as transient and also important to North Carolina‘s coastal fisheries are American eel, Atlantic croaker, Atlantic menhaden, black sea bass, bluefish, red drum, spot, striped bass, summer flounder, tautog, and weakfish. Only black sea bass and tautog were considered shell-bottom enhanced by Peterson et al. (2003a).

A partial list of macrofaunal species observed in collections from oyster habitat is provided in Table 3.2-6. Those species that use shell bottom as spawning and/or nursery areas are identified, as are those species that forage on shell bottom habitat and/or use it as a refuge (SAFMC, 1998a; Lenihan et al., 1998; Coen et al., 1999; Grabowski et al., 2000). More than 30 species are listed in Table 2.6, and there are many more not listed, emphasizing the importance of shell bottom as fisheries habitat.

Table 3.2-6. Partial listing of finfish and shellfish species observed in collections from shell bottom in North Carolina, and ecological functions provided by the habitat (Source: Street et al. 2005).

Resident species, such as gobies (naked and green), Atlantic midshipman, and northern pipefish depend on shell bottom as breeding habitat (Hardy 1978a and b; Johnson 1978; Coen et al. 1999). Other species documented to spawn on shell bottom include the oyster toadfish, mummichog, sheepshead minnow, eastern oyster, grass shrimp, and hard clams (NOAA 2001). Toadfish attach their eggs to the underside of oyster shells, whereas gobies, blennies, and skilletfish place their eggs in recently dead oyster shell (Coen et al. 1999). Well-developed oyster reefs with clean oyster shells in a variety of sizes were shown to accommodate reproduction by the greatest densities of all resident species (Breitburg 1998).

Shell bottom protects oyster spat and other juvenile bivalves, finfish and crustaceans from predators. Juvenile clams, in particular, settle in shell substrate for the protection it provides (Wells 1957; MacKenzie 1977; Peterson 1982; DMF 2001b). The nursery area function of shell bottom was demonstrated by Eggleston et al. (1998) who found that juvenile blue crabs and grass shrimp were equally abundant on shell bottom and SAV in Back Sound, North Carolina. Twelve of the 18 mobile and economically important coastal fisheries species sampled by Lenihan et al. (2001) on natural and restored oyster reefs in Pamlico Sound were juveniles.

In a study where shell structure was added to mud flat reefs, juvenile fish abundance increased on the augmented reefs compared to surrounding soft bottom (Grabowski et al. 2000). The study also found that this initial increase was higher than increases that occurred when SAV and/or salt marsh were added in the same area. The ASMFC considers shell bottom as important nursery habitat for juvenile fish such as sheepshead, gag, snappers, stone and blue crabs, and penaeid shrimps (Lowery and Paynter 2002). An analysis by Peterson et al. (2003a) confirmed that sheepshead, gag, and stone crab were recruitment-enhanced, as well as many non-fishery species, including anchovies, blennies, gobies, oyster toadfish, and skilletfish.

Oyster reefs are home to many important forage species including a number of small crabs, mostly the assorted xanthids lumped under the collective name of mudcrabs, and small mussels including …. The complex community formed by the oysters, crabs and mussels is discussed in Hadley et al.

2010. Wilber et al. 2012 discuss the impacts of sedimentation on crab populations and implications for secondary consumers.

While oyster reefs are the most recognized shell bottom habitat, shell hash concentrations on tidal creek bottoms provide important nursery habitat for young fish. For example, the preferred habitat of juvenile drum species in South Carolina is high marsh areas with shell hash and mud bottoms (Daniel 1988). However, the extent of shell hash in North Carolina tidal creeks is currently unknown; known locations of shell hash include concentrations along the Intracoastal Waterway. The value of designated nursery areas could be enhanced by low-density plantings of cultch material. However, the enhancement of fish stocks provided by planting could be negated if recruitment is not limiting the adult population. The recruitment enhancement provided by low-density cultch planting in nursery areas should be evaluated.

A group of important species that are largely understudied throughout their range, but includes important members of intertidal and subtidal oyster reef communities, are the grass (Caridean) shrimp species within the genus *Palaemonetes*. Grass shrimp are found in large numbers in estuarine waters along the Atlantic and Gulf coasts, where they occur from Massachusetts to Texas. They are a very common estuarine species in southeastern marshes and tidal creeks where they are usually associated with beds of submerged or emergent vegetation, oyster reef habitats, or structures such as oyster shell, fouling communities, woody debris (Ruiz et al. 1993), and docks or pilings (Coen et al. 1981). Caridean shrimp are rarely larger than 5 cm; their small size differentiates them from commercial shrimp, such as the penaieds and pendalids. Grass shrimp are an important species from an ecological perspective because they are instrumental in transporting energy and nutrients between trophic levels in the coastal food web. Grass shrimp are consumed in large quantities by commercially important fishes and forage species, including spotted seatrout, red drum, and mummichogs (*Fundulus heteroclitus*) (Heck and Thoman 1981; Anderson 1985; Wenner et al. 1990; Posey and Hines 1991; Wenner and Archambault 1996).

Although there are no estimates of population sizes of grass shrimp, they are amongst the most widely distributed, abundant, and conspicuous of the shallow water benthic macroinvertebrates in our estuaries, often reaching hundreds to thousands per square meter (Leight et al. 2005; Coen and Luckenbach 2000; Coen et al. 2006a). Grass shrimp can inhabit very shallow areas near the margins of intertidal habitats (e.g., marsh, mudflats, oyster reefs), but have been reported at depths as great as 15 meters. In winter during temperature lows, and in summer when water temperatures approach seasonal highs, daggerblade grass shrimp may move from shallow to relatively deeper water. The extent of the movement of grass shrimp among various depths often coincides with the distribution of oyster shell substrates, which, in some waters, are preferred by both *P. vulgaris* and *P. pugio*. They are abundant in these structured estuarine and marine habitats as shellfish habitats provide abundant food and protection from predators (Thorp 1976; Coen et al. 1981; Heck and Thoman 1981; Heck and Crowder 1991). Consequently, the association of shellfish habitats with primary producers and consumers may prove quite significant, given the importance of low trophic level species as food for managed species.

Shell bottom provides important foraging area for a variety of aquatic organisms. Fish, shrimp and crabs forage on the worms, algae, crustaceans, mollusks, and other invertebrates present on and in shell bottom habitat. Concentrations of prey organisms among the shell attract both specialized and opportunistic predators. Eggs from oysters and other organisms, and larvae from species belonging to the oyster shell bottom community, are eaten by protozoans, jellyfishes, ctenophores, hydroids, worms, mollusks, adult and larval crustaceans, and fishes (Loosanoff 1965). Blue crabs forage heavily on oyster reefs (Menzel and Hopkins 1955; Krantz and Chamberlin 1978; Mann and Harding 1997). Stomach contents of common finfish predators sampled near shell bottom in Middle Marsh, North Carolina, included fish, shrimp, tanaids, amphipods, isopods, polychaetes, bivalves, gastropods, and tunicates, as well as plant, algal and detrital material (Grabowski et al. 2000).

Grabowski et al. (2000) calculated an index of reef affinity (association) for fish species and analyzed the relative proportion of stomach contents originating from oyster reef versus non-reef habitats. Results showed:

Pigfish and pinfish foraged more on reefs (amphipods, bivalves, gastropods and polychaetes).

The ubiquitous spot foraged on both reef and non-reef habitats.

Gulf and southern flounder foraged on species slightly more common on reefs.

Blacktip sharks, spotted seatrout, and bluefish exhibited a feeding preference for oyster reef prey (fish, shrimp and crabs).

Red drum foraged slightly more off reefs.

Blacknose sharks rarely foraged on reef habitats.

The growth-enhanced species/groups identified in Peterson et al. (2003a) included sheepshead minnow, silversides, pigfish, southern flounder, and black sea bass. These results differ somewhat from those of Grabowski et al. (2000). The discrepancies between Peterson et al. (2003a) and Grabowski et al. (2000) could be due to regional differences in fish habitat use, or other unknown factors. Sheepshead also have an affinity for slow or sessile invertebrates found abundantly on shell bottom (Pattilo et al. 1997).

Oyster reefs are also a foraging ground for many juvenile and adult turtle species. Schmid (1998) found that both the Kemp‘s ridley and loggerhead sea turtles feed on organisms that inhabit the reef. Kemp‘s ridley turtles feed on the stone crabs (*Menippe* spp.) and blue crabs (*Callinectes sapidus*) found near the reef‘s surface. Loggerheads also feed on molluscs. Schmid (1998) also found that Kemp‘s ridleys will return to the same oyster reef for up to four years.

Another important species that utilizes intertidal and subtidal oyster reefs as foraging grounds is the blue crab, *Callinectes sapidus* (Coen et al. 1999b). Blue crabs forage heavily on oyster reefs (Mann and Harding 1997; Krantz and Chamberlin 1978), including consuming oyster spat as juveniles. A study by Menzel and Hopkins (1955) showed that juvenile blue crabs consumed as many as 19 juvenile oysters (or spat) per day.

Numerous mammals and birds directly and indirectly utilize intertidal oyster reef habitats and washed oyster shell accumulations, particularly along the IWW (Sanders et al. 2004). These include *Procyon lotor* (raccoon), and birds such as *Haematopus palliates* (American oyster catcher), *Egretta tricolor* (Tricolored Heron), *Nyctanassa violacea* (Yellow-crowned Night Heron), *Nycticorax nycticorax* (Black Heron), *Casmerodius albus* (Great Egret), *Egretta thula* (Snowy Egret), *Limosa fedoa* (Marbled Godwit), *Catoptrophorus semipalmatus* (Willet), *Pluvialis squatarola* (Black-bellied Plover), *Calidris pusilla* (Semipalmated Sandpiper), *Calidris mauri* (Western Sandpiper), *Arenaria interpres* (Ruddy Turnstone), *Tringa melanoleuca* (Greater Yellowleg), and *Tringa flavipes* (Lesser Yellowleg). Some recent observations in SC suggest that a single oystercatcher may be able to consume over 100 adult oysters per day on intertidal reefs (F. Sanders, South Carolina Department of Natural Resources, personal communication).

Corridor and Connectivity

Shell bottom serves as a nearshore corridor to other fish habitats, such as salt marsh and SAV for finfish and crustaceans; therefore, it plays a significant ecological role in landscape-level processes (Coen et al. 1999; Micheli and Peterson 1999). Vicinity (isolation) and connectivity of intertidal oyster reefs to other fish habitats, especially SAV, are two factors that affect fish utilization of shell bottom. For example, connectivity of oyster reefs to SAV enhanced blue crab predation, whereas isolation of oyster reefs enhanced hard clam survivorship (Micheli and Peterson 1999). In Middle Marsh, North Carolina, gag, gray snapper, and spottail pinfish preferred shell bottom habitat adjacent to SAV beds (Grabowski et al. 2000), allowing access to both refuge and prey.

Species composition and community structure

Eastern oyster (*Crassostrea virginica*)

The eastern oyster's range extends from the Gulf of St. Lawrence to Key Biscayne, and south to the West Indies and the Yucatan Peninsula in Mexico (Galtsoff 1964; Burrell 1986; Kennedy 1996; MacKenzie et al. 1997a). The eastern oyster is mainly an estuarine organism, but does occur in some near-shore coastal waters. These oysters grow sub-tidally throughout most of their range, but from southern North Carolina to northeastern Florida they occur predominantly in the intertidal zone (Figure 2.14) (Bahr and Lanier 1981; Kennedy 1996; Kennedy and Sanford 1999; Burrell 1986, 1997; Coen and Luckenbach 2000; Luckenbach et al. 2005). Although they occur to a depth of 30 m, the oyster's primary habitat is in shallow water less than 6 m, or intertidal (1 m to 5 m) from North Carolina to Florida. A typical feature of *C. virginica* is their extremely variable shell morphology (Galtsoff 1964; Carriker 1996; Kent 1992). Oysters have indeterminate growth; in historical times, prior to the influence of harvesting and other biological and anthropogenic factors, they often grew to sizes significantly greater than what we see today (20 cm or larger shell height).

The preferred substrate for larval settlement is oyster shell, an adaptation that assures the proximity of other oysters, which is essential for successful future reproduction. Oysters are attached to the substrate or to each other by the left valve, which tends to be thicker and more deeply cupped than the right valve (Galstoff 1964; Kennedy 1996; Soniat et al. 2004). Thus, dense reefs are formed by the setting of successive generations of oysters on the shells of their predecessors (Figure 3.2-14). In some places, oyster shell can be several meters deep or more with live animals only on the surface layer.

Long-term reef development is a complex process that involves interactions among a variety of physical and biotic factors (Bahr and Lanier 1981; Kennedy and Sanford 1999; Coen and Luckenbach 2000). In southern Atlantic waters, a reef-like structure may be achieved in three to five years, but in northern waters the process is apparently much slower. The long-term dynamics of oyster reefs have not been well studied, but some reefs in the Chesapeake Bay have persisted for millennia (Smith et al. 2003). In part because estuaries are geologically ephemeral, oysters must cope with changes in sea level, sediment, and climate. In contrast, within the past 50 years, some intertidal reefs in Florida have been completely destroyed and displaced landward by dredging and/or boat wakes (Figure 3.2-15). Hurricanes have also been implicated in a few instances for example, in the destruction of the windrows of shell in surf troughs along the Florida coast (Livingston et al. 1999; Grizzle et al. 2002; Walters et al. in press). Elsewhere, hurricanes may have significant impacts on shellfish habitats, particularly in shallow waters (Andrews 1973; Munden 1975; Lowery 1992; Dugas et al. 1998; Livingston et al. 1999; Perret et al. 1999). Bartol and Mann (1997) observed an increase in oyster survival when oysters settled in the interstitial spaces between shells below the reef surface. Additionally, vertically growing oysters in clusters on intertidal reefs provide oysters with a way to cope with siltation, so that they are not smothered (Coen et al. 1999a; Giotta 1999

Figure 3.2-15. Time series of intertidal oyster reef changes in east-central Canaveral National Seashore (CANA), Florida (Source: ASMFC 2007). Aerial imagery showing increase in dead reef areas (red) compared to living (green) over time, most probably caused by increased boating activities (Source: Grizzle et al. 2002).

Caribbean mangrove oyster (*Crassostrea rhizophorae*)

The Caribbean mangrove oyster is restricted to the south Atlantic and Gulf coasts (Abbott 1974) and does not typically form reefs. *C. rhizophorae* is well adapted to the warmer tropical and subtropical temperatures in its native range (Bacon et al. 1991). *C. virginica* and *C. rhizophorae* oysters are closely related species (Buroker et al. 1979; Hedgecock and Okazaki 1984). Mangroves are typically the primary hard substrate for attachment of these often common and flat oysters. Numerous other species of mangrove oysters have been described, all in the genus *Crassostrea*. For all these species, information is extremely limited, with even less known on how they may enhance habitat complexity along the southern coast of Florida. *C. rhizophorae* is commercially important, can grow to marketable size (50 -70 mm shell height) in 4 to 8 months (Rodriguez and Frias 1992), and is currently cultivated in aquaculture facilities in the Caribbean (Littlewood 1988; Bacon et al. 1991; Newkirk and Field 1991).

Currently, there is very little information on Caribbean mangrove oyster ecology (i.e. densities, filtering, etc.) or potential habitat value for other Florida mangrove-related species. However, it must be noted that the species adds considerable habitat to the recognized three-dimensional mangrove fish nurseries of the Caribbean (L. Stewart, University of Connecticut, personal communication). Presumably Caribbean mangrove oyster reefs are fouled by many different planktonic plant and animal species, thus providing a critically needed substrate for attachment.

In large part resulting from recent work on *Crassostrea ariakensis* in North Carolina (Grabowski et al. 2003, 2004; NRC 2004; Bishop et al. 2006; Carnegie et al. 2006; R. Carnegie, Virginia Institute of Marine Science, personal communication), researchers have begun to examine the dynamics of poorly studied native oyster species, such as the crested oyster (*Ostreola equestris*). Additional attention has been drawn to novel or endemic *Bonamia* spp. (newly described or observed) that may cause diseases in native or non-native species, or act as parasite reservoirs (Bishop et al. 2006; Carnegie et al. 2006; R. Carnegie, Virginia Institute of Marine Science, personal communication).

Blue mussels *(Mytilus spp.)*

Mytilus spp. occur mainly in shallow coastal waters and estuaries, and are most commonly considered a member of the fouling community because they are often found on rocks, pilings, and other hard substrates (King et al. 1990; Mathieson et al. 1991; Leichter and Witman 1997; Bertness 1999; Witman and Dayton 2001). In many areas mussels play an important role in benthic community structure (Bayne 1976; Witman 1985, 1987; Asmus and Asmus 1991; Lesser et al. 1991; Dame 1993, 1996; Hild and Günther 1999; Norén et al. 1999; Davenport et al. 2000). In some areas mussels also form dense reefs on hard bottom or on soft sediments in the intertidal and subtidal zones (Newell 1989; Nehls and Thiel 1993; Seed and Suchanek 1992; Seed 1996; Côté and Jelnikar 1999; Cranford and Hill 1999). Blue mussel reef formation and development have not been well studied, but they are recognized as being important food and habitat providers for many species (Tsuchiya and Nishihira 1985, 1986; Witman 1985, 1987; Newell 1989; Asmus and Asmus 1991; Seed 1996; Reusch and Chapman 1997; Ragnarsson and Raffaelli 1999). Mussel consumers include crabs, lobsters, starfish, whelks, fish (e.g., tautog), and birds (e.g., ruddy turnstone, American and European oystercatchers) (Marsh 1986; Meire and Ervynck 1986; Raffaelli et al. 1990; Marsh and Wilkinson 1991; Nol and Humphrey 1994; Nagarajan et al. 2002; Sanders et al. 2004). Mussel reefs perform essentially the same functions as oyster reefs; they provide food, filtration, benthic-pelagic coupling, and physical habitat (Verwey 1952; Suchanek 1978, 1985; Wildish and Kristmanson 1984, 1997; Witman and Suchanek 1984; Dame 1996; Smaal and Hass 1997).

Horse mussel *(Modiolus modiolus)*

The horse mussel has a geographic distribution similar to the blue mussels, but occurs mainly in deeper waters on the continental shelf; however, it can be found in intertidal pools or attached to laminarian holdfasts (Holt et al. 1998). It is a widespread mussel, found throughout the northern hemisphere from the White Sea and Norway, off the Faroes and Iceland to at least as far south as the Bay of Biscay and occasionally North Africa. It is also found from Labrador to North Carolina in the Atlantic and from the Bering Sea south to Japan and California in the Pacific. It most commonly occurs partly buried in soft sediments, or attached by byssal threads to hard substrates where it forms clumps or extensive beds (or reefs) that vary in size, density, thickness, and form (Holt et al. 1998; Wildish et al. 1998).

Horse mussel recruitment is often low and may be variable in some populations (JNCC UK 1999). *M. modiolus* is a long-lived species, with some individuals living for 25 years or more. Juvenile *M. modiolus* are heavily preyed upon, especially by crabs and starfish, until they are 3 to 6 years old, at which point they normally reach a size refuge from most of their native predators.

American horse mussel *(Modiolus americanus)*

The American horse mussel is a common mussel that often forms dense associations within seagrass habitats (Figure 3.2-14, Plate C) (Peterson and Heck 1999, 2001a, 2001b). It ranges from South Carolina to the Gulf of Mexico and south to Brazil; it is also found in Bermuda. Adults can reach 100 mm shell height and they occur from the intertidal to approximately 6 m water depth. The American horse mussel can be found in densities as high as 2,000 individuals/m$_2$ with mean densities reaching 625 individuals/m$_2$ (Valentine and Heck 1993). However, these aggregations of American horse mussels are typically quite patchy (L.D. Coen, personal observation). Little is known about the broader ecological importance of the facultative mutualistic association of seagrass and shellfish, but work in St. Joe Bay, Florida in dense seagrass beds has shown a more complex interaction between these abundant filter-feeders and the *Thalassia* beds within which they reside. Specially, the mussels increase seagrass productivity through their filtering activities, changing nutrient availability through mechanisms such as biodeposition and reducing epiphyte loads on seagrasses (L. Coen, personal observation).

Ribbed mussel (*Geukensia demissa*)

The ribbed mussel is a relatively large mussel, growing to nearly 100 mm shell height. The ribbed mussel is found in coastal waters from the Gulf of St. Lawrence to Texas. It is common on both subtidal and intertidal oyster reef habitats (Van Dolah et al. 1999; Coen et al. 2004b; Luckenbach et al. 2005) and in salt marsh (Bertness 1980, 1984; Lutz and Castagna 1980; Bertness and Grosholz 1985). Unlike oysters, ribbed mussels have the ability to reattach if dislodged, which makes this species better able to adapt following a disturbance event.

The basic biology of the ribbed mussel is well understood, but little is known about its habitat value either alive or as dead articulated shells (Lent 1969; Seed 1980; Brousseau 1984; Kraus and Crow 1985; Hilbish 1987; Lin 1989a, 1989b, 1990, 1991; Wilbur and Hilbish 1989; Kemp et al. 1990; Langdon and Newell 1990; Sarver et al. 1992; Stiven and Gardner 1992; Franz 1993, 1996, 1997, 2001; Nielsen and Franz 1995; Kreeger and Newell 2000). Ribbed mussels attach by byssal threads to any hard substrate (like oyster shells and cordgrass stems) and protrude above the surface. Typically, ribbed mussels occur embedded in and amongst salt marsh sediments attached by byssal threads to each other and/or to *Spartina* spp. stalks. Angelini et al. (2015) discuss the role of ribbed mussels in enhancing biodiversity and multifunctionality in southeastern saltmarshes.

Ribbed mussels occur throughout the mid- to low-intertidal regions in most southeastern estuaries. Upper intertidal limits are determined by both exposure to high temperatures and limited food availability during longer periods of tidal exposure. Lower intertidal limits are determined by the availability of effective refuge, mainly from crab predators. Although growth rates decline at higher shore levels, this is offset by increased survival (Bertness 1980; Bertness and Grosholz 1985; Stiven and Gardner 1992; Franz 2001).

A large volume of literature exists for ribbed mussels associated with salt marsh habitats on the east coast of the United States; however, much less is known about this mussel‘s association with oyster reefs. Researchers in South Carolina and Virginia (Coen et al. 1999a; Coen and Luckenbach 2000; Luckenbach et al. 2005) have noted large numbers of ribbed mussels often associated with intertidal and subtidal oyster reef habitats. In South Carolina, there are *G. desmissa* densities of over 500 individuals/m^2, cohabiting areas with one or more smaller (2.5 to 5 cm) mussel species (e.g., scorched mussel (*Brachidontes exustus*) and hooked mussel (*Ischadium recurvum*)). Scorched and hooked mussels can also occur at high densities, often exceeding ribbed mussel densities (L. Coen, personal observation). For example, at some restored South Carolina intertidal oyster sites, *B. exustus* densities exceeded 4,900 individuals/m^2 and *I. recurvum* densities reached 500 individuals/m^2. As a result of these high densities of individuals, mussels can be a significant nuisance species at many Gulf of Mexico oyster reef sites.

Recent emergence of a ribbed mussel fishery in South Carolina raises concerns about habitat damage that could result from widespread harvesting. Ribbed mussels have not been managed as a fishery in any southeastern states although South Carolina is considering a ribbed mussel management plan.

Green mussel (*Perna viridis*)

The green mussel is an invader to the Caribbean, Florida (Benson et al. 2001; Baker and Benson 2002), and Georgia (Power et al. 2004), reaching lengths up to 171.5 mm (J. Fajans, University of Florida, personal observation). This species should not be confused with two morphologically similar alien species, *P. perna* and *P. canaliculus* (Siddall 1980; Benson et al. 2001; Ingrao et al. 2001). Although the green mussel is overgrowing oyster reefs in Florida (Figure 3.2.16), and becoming a serious fouling problem in Florida and Georgia, it may ultimately generate a complex and important habitat not previously observed in the southeast (J. Fajans and S. Baker, University of Florida, personal communication). Recent (October 2006) collections in Charleston, South Carolina (D. Knott, South Carolina Department of Natural Resources, personal observation), collected *P. viridis*, resulting in a new northern range extension for this non-native fouling mussel species.

Figure 3.2-16. The green mussel, *Perna viridis* (Source: Jon Fajans, Keys Marine Lab, Long Key, Florida) (Source: ASMFC 2007).

Bay scallop (*Argopecten irradians*)

Bay scallops are found on the Atlantic and Gulf coasts from the north shore of Cape Cod, Massachusetts to Laguna Madre, Texas (Waller 1969; Fay et al. 1983). They can reach a maximum size of 60 to 70 mm. Seastars, wading birds, gulls, pinfish, lightning whelks, cow-nosed rays, crabs, starfish, and humans are among the numerous predators of the bay scallop (Peterson et al. 2001a). Scallops are hermaphroditic, with a single individual releasing sperm before eggs (Bricelj et al.

1987). Bay scallops reach sexual maturity within one year, spawning from August through October. The juvenile stage is reached after about 35 days post-fertilization, when they resemble a small adult in shape; their lifespan is less than two years (Peterson et al. 1989).

Bay scallops can migrate *en masse*. In many areas they have declined significantly (e.g., North Carolina). Red tides, often referred to as ―harmful algal blooms, can kill millions of adult and larval bay scallops each year. Scallops grow fastest during the warmer months when food is available. They prefer estuaries and bays where salinities are relatively high, waters are 0.3 to 0.6 m deep at low tide, and seagrasses such as eelgrass (*Zostera marina*) or shoal grass (*Halodule wrightii*) are common (Smith et al. 1988; Prescott 1990; Pohle et al. 1991; Garcia-Esquivel and Bricelj 1993; Bologna and Heck 1999, 2002; Bologna et al. 2001). These grass beds offer protection from predators as well as sites for juvenile attachment (Pohle et al. 1991; Bologna and Heck 1999).

Atlantic calico scallop *(Argopecten gibbus)*

The Atlantic calico scallop, a relatively small scallop ranging from 25 to 60 mm shell height, is patchily distributed on the Atlantic coast from Delaware Bay south into the Caribbean Sea to about 20° N latitude. It is most commonly found from just north of Cape Hatteras, North Carolina to the Greater Antilles, and throughout the Gulf of Mexico and Bermuda (Allen and Costello 1972; Blake and Moyer 1991). Genetic and morphological similarities (Waller 1969) between Florida and North Carolina populations and coastal currents support a hypothesis that Florida may be an important larval source for North Carolina stocks (Wells et al. 1964; Krause et al. 1994). Calico scallops can be found in depths of 10 to 400 m, but have been reported from shallower waters in Biscayne Bay (Coleman et al. 1993).

Spawning occurs throughout the year, but peaks in late fall and in the spring (Arnold 1995). As with bay scallops, calicos are simultaneous hermaphrodites that release sperm and eggs. Settling calico scallops require shell or other hard substrate to provide an anchor for byssal attachment. Laboratory studies suggest that after drifting freely for 14–16 days, larvae attach to hard substrates, which are often the disarticulated shells (dead accumulations that are separated or broken) from previous generations (Ambrose and Irlandi 1992; Ambrose et al. 1992). They reach a commercial length of 47 to 53 mm in six to eight months.

The maximum life span of an Atlantic calico scallop appears to be about 24 months. Predation (Wells et al. 1964) is a major factor affecting survival during various phases of the calico scallop life cycle. Aggregations of calico scallops provide habitat for numerous species, including other types of scallops, fish, and invertebrates. Schwartz and Porter (1977) collected 111 species of fish and 60 species of macroinvertebrates, including 25 crustaceans, 12 echinoderms, 4 coelenterates, and 1 annelid. Many of the fish caught used this habitat for feeding purposes (Schwartz and Porter 1977). See section 4.1.9 in this document for more detailed information on this species.

Pen Shells

As with other filter feeders, pinnids can filter large quantities of suspended sediments and plankton out of the water column, thereby affecting phytoplankton levels and water clarity. However, high densities generate both feces and pseudofeces affecting the surrounding sediments and associated organisms (Cummings et al. 2001; Ellis et al. 2002). For example, Ellis et al. (2002) showed that sedimentation can significantly impact *Atrina* spp. populations.

All three species -- the saw-toothed pen shell (*Atrina serrata*), the amber pen shell (*Pinna carnea*), and the stiff pen shell (*Atrina rigida*) -- can occur in large numbers and protrude above the sediment's surface (Figure 3.2-14, Plates A & B). Their shells are typically covered with a diverse assemblage of fouling organisms, including barnacles and slipper shells, which create vertical structure and fish habitat (Kuhlmann 1994, 1996, 1997, 1998; Munguia 2004). Many organisms use the shells as shelter, including crabs (e.g., *Pilumnus sayi*, *Menippe* spp., *Portunus ordwayi*) and benthic fishes such as blennies and gobies) within seagrasses (Kuhlmann 1994). Shells can reach densities of over 13 individuals/m2 (Kuhlmann 1994, 1996).

Additionally, the Florida blenny (*Chasmodes saburrae*), feather blenny (*Hypsoblennius hentzi*), clingfish (*Gobiesox strumosus*), and Gulf toadfish (*Opsanus beta*) use dead pen shells as nest sites (Kuhlmann 1994). Females lay a single layer of eggs on the inside of the pen shells. Similarly, Joubin‘s pygmy octopus (*Octopus joubini*) also lays its eggs on the inside of pen shells. Horse conchs (*Pleuroploca gigantea*) are the primary predators of pen shells (Kuhlmann 1994, 1996, 1997, 1998). Dead pen shells provide nesting sites and shelter for many fish species, but are not permanent benthic features. As the shells begin to break apart, the waves and currents sweep them away, thus changing the dynamics of the populations of the species that depend on them (Kuhlmann 1996, 1998).

The most extensive studies of pen shell communities as habitat were completed by researchers in New Zealand (Keough 1984; Cummings et al. 1998, 2001; Nikora et al. 2002; Gibbs et al. 2005). These habitats are also referred to as horse mussel (*Atrina zelandica* and *Atrina novaezelandiae*) beds. Research has included fine scale boundary layer flow studies (Nikora et al. 2002), mesoscale hydrodynamic interactions (Green et al. 1998), community interactions (Keough 1984; Cummings et al. 1998, 2001), and essential fish habitat delineation for juvenile finfish species (Morrison and Carbines 2006).

Estuarine wedge clam (*Rangia cuneata*)

The estuarine wedge clam is found in Atlantic coastal and Gulf of Mexico oligohaline estuaries (Cain 1975; LaSalle and de la Cruz 1985; Abadie and Poirrier 2000), tidal rivers, and backwater bays with regular inputs of fresh water. It occurs from the upper Chesapeake Bay to Mexico, often dominating benthic biomass in low salinity areas of estuaries (Cain 1975). This clam is regarded primarily as a subtidal species found in coastal areas with a large tidal range (Estevez 2005).

The species serves as an important link in the food chain, filtering large volumes of water when at high densities and serving as a food source for fish, crabs, and ducks (LaSalle and de la Cruz 1985). In North Carolina, *Rangia cuneata* are often found within the most critical oyster habitat areas where shells accumulate over long time periods. In these areas, accumulations of estuarine wedge clam shells provide substrate for formation of oyster reefs. In a majority of cases, both living and dead *Rangia cuneata* occur together. Estuarine wedge clams are more abundant in downstream reaches and as intertidal material in upstream reaches. Interestingly, live *Rangia cuneata* in intertidal areas can be larger than those in subtidal beds (Estevez 2005).

In Lake Pontchartrain, Louisiana, individual estuarine wedge clams have an average life span of four to five years. Deposits of wedge clam shells in the lake bottom supported a shell mining industry from 1933 to 1990 (Abadie and Poirrier 2000). As with oyster shells, clam shells used to be so abundant that they were used for construction of roadways, parking lots, levees, and in the production of cement. Large (> 20 mm) *Rangia cuneata* were abundant in Lake Pontchartrain in the early 1950s, but became rare by the 1970s and 1980s. They can dominate the benthos, with densities reaching 1,896 clams/m2 and dry weight biomass as high as 70 g/m2. However, clams are absent from areas that are subject to anoxia and hypoxia, or saltwater intrusions (Poirrier and Spalding 2005).

Current *Rangia cuneata* studies are seeking to document similar ecological services to oysters, in order to generate interest in its restoration (M. Poirrier, personal communication). Results indicate that increasing clam abundance by decreasing saltwater intrusion will improve water clarity; this in turn should increase submerged aquatic vegetation and add shell for mud stabilization and erosion reduction. These improvements should reduce eutrophication, improve water quality, and enhance fish habitat (M. Poirrier, personal communication).

Carolina marsh clam (*Polymesoda caroliniana*)

This brackish-water corbiculid clam (often reaching sizes over 50 mm, but typically 25- 40 mm) is often common in low salinity marshes comprised of plants such as *Juncus* sp. and near river mouths (Andrews and Cook 1951; Andrews 1977; Duobinis-Gray and Hackney 1982; Marelli 1990). The geographical range of this species is from Virginia through Florida along the Gulf of Mexico to Texas, with adult densities often exceeding 300 individuals/m2 (Duobinis-Gray and Hackney 1982) and juvenile (<20 mm) densities at almost 2,000/m2 (Marelli 1990). The Carolina marsh clam lives primarily in the intertidal zone (Marelli 1990), but may be found subtidally, in mud to fine sediments (Heard 1982). Some researchers have suggested competitive interactions with another common low salinity bivalve, *Rangia cuneata* (more often subtidal, as *Polymesoda* is a poor burrower in intertidal areas) (Duobinis-Gray and Hackney 1982). Early growth can be rapid (>1 mm/month) (Olsen 1973, 1976), and predation, competition, and inundation are often cited as factors controlling the distribution and abundance of this species (Andrews and Cook 1951, Andrews 1977). A related species *P. maritima*, the Florida marsh clam, is common in the Gulf coast region, and southern Florida to the Yucatan (Andrews 1977). Little is known about the habitat value of shell accumulations or live aggregations of *Polymesoda* spp. for other organisms.

Oyster Reefs and Shell Banks as Essential Fish Habitat

The three major types of shellfish habitat (reefs, aggregations, and accumulations) differ in their combinations of habitat characteristics. However, all shellfish habitats have three major features in common that are the basis for their ecological value for managed species: hard substrate (for settlement/refuge/prey), complex vertical (3-D) structure (for settlement/refuge/prey), and food (feeding sites for larger predators).

Perhaps the most fundamental characteristic of shellfish habitat is hard substrate. The shells provide attachment surfaces for algae and sessile invertebrates, such as polychaetes (e.g., sabellids, serpulids), hydroids, bryozoans, and sponges, which in turn provide substrate for other organisms. Planktonic larvae of some shellfish species, such as oysters, need a hard substrate on which to settle in order to grow into adults (Galtsoff 1964). In many estuarine areas, oyster shell and cultch are the primary settlement material for larval oysters (Kennedy 1996; Powell et al. 2006). All three types of shellfish habitat—reefs, aggregations, and accumulations—provide suitable substrate for other shellfish and many other species that require hard substrate on which to grow.

Sufficient accumulations of hard substrate result in complex habitat structure that provides increased vertical relief and internal complexity of the structure itself. Structural complexity has historically been considered an important factor affecting the spatial distribution and diversity of marine and estuarine organisms (Bell et al. 1991). An increase in the physical complexity of an environment is typically correlated with an increase in microhabitat diversity (Sebens 1991). The increase in surface area provides more refuge and feeding sites, which subsequently leads to greater species richness (Bell and Galzin 1984). The interstitial spaces provide recruiting oysters with adequate water flows for growth and refuge from predators, both of which are essential for long-term maintenance of the reef structure (Bartol and Mann 1997; Bartol et al. 1999; Coen et al. 1999b; Powell et al. 2006). Oysters and other reef-forming shellfish can be considered bioengineers because they create habitat that allows many additional species to thrive (Jones et al. 1994, 1997).

All three shellfish habitat types provide food for other organisms, whether it is the shellfish themselves or associated organisms. Oysters and mussels are consumed by many species of fish and invertebrates. Many other species of plants and animals also occur on shell accumulations and provide food for a variety of predators. When considered in combination with the hard substrate and complex structure provided by live shellfish, their direct food value results in shellfish reefs and aggregations being uniquely valuable habitat for many managed species.

Seagrasses

Description and Distribution

Out of the estimated 250,000 flowering plants existing on earth today, only about 50-60 species have adapted to life in the marine environment (den Hartog 1970; Hemminga and Duarte 2000; Green and Short 2003; Larkum et al. 2006). Collectively, we refer to this group of submersed aquatic vascular plants (SAV) as seagrasses. Seagrasses are clonal plants which reproduce and disperse by means of sexual and asexual reproduction. 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 environmental requirements, the most important of which is the fact that seagrasses anchor themselves in unconsolidated sediments with an extensive root and rhizome system, thus have a very significant influence on sedimentary processes and nutrient cycling. Only one seagrass genus, *Phyllospadix*, does not require unconsolidated sediments and this species does not grow in the South Atlantic. Taxonomically, seagrasses are divided into two families and 12 genera (den Hartog 1971; Phillips and Meinez 1988; Green and Short 2003). At least 13 species of seagrass occur in United States waters. In the south Atlantic region, with the exception of Georgia and South Carolina where highly turbid freshwater discharges, suspended sediments and large tidal amplitude combine to prevent their permanent establishment, there are 6 genera of seagrasses represented by 8 species. These species range in size from the three smallest, *Halophila decipiens* (paddle grass), *Halophila engelmannii* (star grass) and *Halophila johnsonii* (Johnson's seagrass), to the relatively larger species, *Zostera marina* (eelgrass), *Ruppia maritima* (widgeon grass), *Halodule wrightii* (shoal grass), *Syringodium filiforme* (manatee grass) and *Thalassia testudinum* (turtle grass) (Figure 3.2-4).

In the South Atlantic, seagrass habitat occurs in North Carolina and Florida, with Florida having the greatest amount of seagrass habitat (Figure 3.2-5). Along the Atlantic Peninsula and South Florida regions of Florida, there are an estimated 29,769 hectares (ha) and 574,875 ha of seagrass beds, respectively (Madley et al. 2003). The South Florida total includes seagrass in Florida Bay and the continental shelf off of the Keys (Florida Straits). Seagrass estimates in the Florida Straits include areas with continuous SAV as well as areas where SAV is patchy and intermixed with hardbottom. Along the Atlantic Peninsula, seagrasses are most concentrated in the Indian River Lagoon system. This area, while only supporting approximately 3% of the total seagrass coverage along all of Florida, has the highest seagrass diversity, with seven species present (*Zostera mariana* does not occur in Florida), including the federally threatened species, *Halophila johnsonii* (Johnson's seagrass) (FFWCC 2003). Over half of all seagrass habitat in Florida occurs in South Florida and Florida Bay supports the largest contiguous seagrass beds in the world with *Thalassia testudinum* (turtle grass) being the most dominant species. On the Atlantic side of the Florida Keys, seagrass habitat is closely associated with hardbottom, patch reefs, and mangroves (FFWCC 2003). North Carolina has the second largest seagrass distribution in the continental United States with an estimated 54,230 ha mapped (Ferguson and Wood 1994). This number includes primarily seagrasses and a small amount of visible oligohaline SAV along the western Pamlico and Albemarle tributaries. Unlike Florida, the 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 all protected by barrier islands. A unique feature of NC seagrasses is the overlap in distribution of a temperate species (*Z. marina*) and a tropical species (*H. wrightii*). Where these species co-occur there is a bimodal seasonal abundance, which extends the total annual abundance of seagrasses for a longer period of time (Thayer et al. 1984).

Figure 3.2-4. Illustration of seagrass species in the South Atlantic Region (Source: NMFS, 1997).

Figure 3.2-5. Illustration and table of the distribution of seagrasses in the South Atlantic Region (Source: NMFS, 1998).

Mapping history in North Carolina

The majority of seagrass habitat in North Carolina was mapped by National Oceanic and Atmospheric Administration (NOAA) using photo-interpretation and groundtruthing of aerial photography taken between 1981 and 1992 (Ferguson and Wood 1994). Bogue Sound was originally mapped in 1981 by Carraway and Priddy (1982), but because of differences in scale and methodology, were not comparable to later mapping. Mapping did not include areas south of Bogue Sound. Most of the oligohaline SAV in Albemarle Sound and western Pamlico Sound tributaries were not mapped during this NOAA project. . However, since then, North Carolina Division of Water Quality (DWQ) and NC Division of Marine Fisheries (DMF) has mapped additional SAV habitat in portions of the Neuse and Pamlico rivers and Pamlico Sound tributaries using field survey techniques, and portions of Albemarle Sound have been mapped by state universities. In 2003, Elizabeth City State University remapped Back Bay, Currituck Sound and Kitty Hawk Bay using aerial photography and specifications recommended by NOAA and Virginia Institute of Marine Science (VIMS) (Finkbeiner et al. 2001; Orth et al. 2001). Although mapping of the coast is not entirely complete, the most recent map of known SAV habitat is shown in Figure 3.2-6. The SAV distribution that is depicted in the figure is a mosaic of multiple projects that used imagery ranging from 1981 to 2003, as well as some mapping conducted completely from field surveys, and includes both seagrasses and oligohaline SAV. Unmapped or inadequately mapped areas should be a high priority for future mapping.

In 2005 a North Carolina SAV Cooperative Habitat Mapping Program was established among 26 state agencies, federal agencies, universities, and non-profit organizations. The purpose of the multi-agency workgroup and 2006 Memorandum of Understanding between organizations is to enhance and accelerate mapping and monitoring efforts by pooling resources and coordinating mapping efforts. The long-term goal of the program is to manage and conserve SAV habitat in North Carolina and southern Virginia in a comprehensive manner through cooperative research, monitoring, restoration, and education (http://www.apnep.org/pages/sav.html). The Albemarle-Pamlico National Estuary Program coordinates the program and is contributing substantial funds for aerial photography so that the entire coast can be mapped in a short time period. However, there is no comprehensive monitoring program yet underway. In 2005, the NC Coastal Habitat Protection Plan (CHPP) was approved by environmental regulatory commissions. The plan summarized the ecological value and status of coastal habitats in North Carolina, including seagrass habitat, and made management recommendations including mapping and monitoring of submerged aquatic vegetation (Street et al. 2005; http://www.ncfisheries.net/habitat/chppdocs/). The CHPP was updated in 2010, and again in 2015. Through the CHPP and APNEP programs, seagrass management, that includes comprehensive monitoring, should improve over the next few years.

Figure 3.2-6. Distribution of seagrasses and oligohaline SAV in North Carolina (compiled by Scott Chappell, NC DMF, 2007. Published sources include Carroway and Priddy 1983; Ferguson and Wood 1994. Unpublished data sources from NC DWQ; NC DMF bottom mapping program; Elizabeth City State University; North Carolina State University).

Mapping history in Florida

Seagrass cover estimates for Florida have been based on photo-interpretation of aerial photography, mostly at a scale of 1:24,000. Sargent et al. (1995) made the first coast wide effort to summarize statewide seagrass distribution, using photography from 1982-1990. Madley et al. (2003) constructed new statewide seagrass maps using photography from 1987 to 1999 (Figures 3.2-7-3.2-13). Seagrass habitat is regularly mapped every two to three years in the Southwest, St. Johns River, and South Florida Water Management Districts. Other agencies, such as Florida Department of Environmental Protection (DEP), Florida Fish and Wildlife Conservation Commission (FFWCC), National Oceanic and Atmospheric Administration (NOAA), US Army Corps of Engineers (USACOE), US Geological Service (USGS), and US Mineral Management Service (USMMS) have mapped other local areas on a sporadic basis.

Differences in habitat classification schemes and accuracy of methods make overall comparisons difficult. However trend analysis has been done with consistent methodology in several smaller regions of Florida. Overall it appears that seagrass losses have occurred in all regions of Florida, with the largest losses occurring near highly developed areas. Along the Atlantic peninsula, comparison of estimates from recent mapping to estimates in the 1940s found little change had occurred to SAV coverage in the northern Indian River Lagoon and Banana River around the federally protected lands of NASA (FFWCC 2003). Extensive losses have occurred in the southern portion of the Indian River lagoon adjacent to highly developed shorelines. Overall, approximately 59% of what is considered potential SAV habitat (based on SAV presence in 1940 maps) in the Indian River Lagoon is vegetated with seagrass. In South Florida, mapping data has indicated significant declines in SAV coverage in highly developed areas such as northern Biscayne Bay. Seagrass habitat in Dade and Monroe counties has the greatest amount of boat-related propeller damage. Florida Bay has also experienced a large decline in seagrass coverage beginning around 1987. The die-off was attributed to reduced water clarity due to multiple factors including algal blooms, sediment sulfide toxicity, hyper-salinity due to drought, and infection by the slime mold *Labyrinthula*. Although the rate of decline has slowed in recent years, losses continue, which has in turn lead to increased turbidity, further reducing water clarity.

In Florida there are several ongoing regional seagrass management programs, primarily in subtropical portions of the peninsula (e.g., Indian River Lagoon, Florida Bay, Sarasota Bay, and Tampa Bay). To improve coordination of and increase support for seagrass monitoring and management efforts, the Florida Fish and Wildlife Conservation Commission (2003) recommended that the state develop:

Consensus-based seagrass management strategies at the regional and statewide level;

- methodologically consistent, statewide seagrass mapping and monitoring program;
- schedule for reporting regional and statewide status and trends information;
- schedule for assessing the state‘s management strategies and the progress made toward achieving the adopted management goals;
- management-oriented, statewide seagrass research program; and
- statewide, public outreach program focused on seagrass management and conservation.

In both North Carolina and Florida, more funding is needed to support comprehensive SAV mapping and management programs. Maps of SAV in Florida can also be viewed on an internet map service at http://ocean.floridamarine.org/mrgis/viewer.htm

Figure 3.2-7. Seagrass distribution along the east coast of Florida, Indian River Lagoon. (Source: P. Carlson, FFWCC 2007).
Figure 3.2-8. Seagrass distribution along Florida‘s east coast – Melbourne to Ft. Pierce. (Source: P. Carlson, FFWCC 2007).

Figure 3.2-9. Seagrass distribution along Florida's east coast – Ft. Pierce to Delray Beach. (Source: P. Carlson, FFWCC 2007).
Figure 3.2-10. Seagrass distribution along Florida's southeast coast – Hollywood to Key Largo. (Source: P. Carlson, FFWCC 2007).
Figure 3.2-11. Seagrass distribution along the upper Florida Keys – Key Largo to Marathon. (Source: P. Carlson, FFWCC 2007).
Figure 3.2-12. Seagrass distribution along the lower Florida Keys - Marathon to Marquesas. (Source: P. Carlson, FFWCC 2007)
Figure 3.2-13. Seagrass distribution along lower Florida Keys - Key West to the Dry Tortugas. (Source: P. Carlson, FFWCC 2007).

General distribution of seagrass in the south Atlantic

As indicated previously, no seagrasses have been reported to occur in South Carolina and Georgia. Seven of the eight species that occur in the southeastern U.S. are found in Florida. The exception is *Z. marina* whose southern limit is north of Cape Fear, North Carolina (Thayer et al. 1984). In Florida seagrasses are distributed in protected inland waters as well as oceanic environments. In north central (approximately St. Augustine), and southeast Florida most of the seagrasses occur within protected coastal lagoons and in the Intracoastal Waterway (ICW) including; Mosquito Lagoon, Banana River, Indian River Lagoon, Lake Worth, and Biscayne Bay. The most northern distribution of *H. engelmannii* is in the Banana River at Cape Canaveral. The northern limit of *H. decipiens* and *H. johnsonii* is approximately Sebastian Inlet in the Indian River Lagoon. Beginning around the Palm Beach area and continuing south through the Florida Keys, *Halophila decipiens*, while more common inshore in Palm Beach, it is also found on offshore sandy sediments between reefs down to 30m depth. Open water and oceanic meadows of *H. wrightii*, *S. filiforme* and *T. testudinum* begin just south of Virginia Key on the seaward side of Biscayne Bay and continue through the Florida Keys to the Dry Tortugas in water depths up to approximately 30-40 m. (Sargent et al. 1995)

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. The maximum depth limits are determined by optical water quality and transparency and sometimes limited by water velocities associated with inlets, tidal channels and unstable sediments. In North Carolina maximum depths average between 1.5 and 2.5 m and are similar to the maximum depths of seagrasses in the lagoons and Intracoastal Waterway (ICW) along the east coast of Florida. In locations near inlets with clear water and stable sediments seagrasses grow to 3-5 m, while in nearshore and offshore areas of southeastern Florida and the Keys seagrasses grow to depths of 30m.

Salinity is a very important parameter in estuaries because of its potential to control physico-chemical attributes of the system that affect nutrient cycling, water transparency, floral and faunal composition, and productivity. Salinity also undergoes frequent fluctuations and may act as an important stressor. Given the fact that the south Atlantic region has extensive natural and manmade freshwater sources flowing into coastal systems, salinity is a critical parameter controlling seagrass distribution and abundance (Doering and Chamberlain 1999; Estevez 1999). The spatial distribution of seagrasses in coastal systems is controlled locally by salinity, especially the upper reaches of penetration by different seagrass species (Estevez 1999). Seagrass distribution throughout an estuary can also be affected by long-term modification of freshwater inflow such as has occurred in the St. Lucie River in east central Florida.

Of the eight species of seagrass, *R. maritima*, has the widest tolerance to salinity and can grow and thrive from freshwater to hypersaline conditions (Kantrud 1991). When matched with its fecundity, these two characteristics enable *Ruppia* to occur in a wide range of estuarine conditions as well as having the ability to thrive in fluctuating environments. *Ruppia* is a very important species in marginal and transitional environments which are not as suitable for other seagrasses. *H. wrightii* is considered to be the next most tolerant species for relatively lower salinities, and similar to *Z. marina* (McMillan and Moseley 1967; Thayer et al. 1984). Both of these species are considered euryhaline and regularly reported growing at salinities ranging from very low salinities (5-10 ppt) to full strength seawater. *Thalassia* is considered euryhaline and tolerant of salinities as low as 6-10 ppt for brief periods of time; optimum salinities range from 17-36ppt (Doering and Chamberlain 1999). The salinity tolerances of *Halopila* spp. have not been well studied, however, reports of distribution indicate they are euryhaline and found growing well upstream in estuaries experiencing low salinities and out into the open ocean (Dawes et al. 1989; Toquemada et al. 2005; Kenworthy 2000). The wide range of salinities tolerated by the species of seagrass in the South Atlantic is an important aspect of their function as essential fish habitat. Salinity tolerances enable them to be more widely distributed across the estuarine landscape and are therefore available as habitat to a broader spectrum of fishery species.

As in terrestrial grasslands, seagrass meadows may be seasonal or perennial. 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. This natural variation in ~~grass bed~~ patch morphology and patch spatial configuration is related to seagrass dynamics and affects the function of seagrasses as habitat (Fonseca 1996; Murphey and Fonseca 1995; Fonseca and Bell 1998; Fonseca et al. 2002). Seagrass meadows are dynamic spatial and temporal features of the coastal landscape which actually move and can disappear and reappear periodically (den Hartog 1971; Patriquin 1975; Fonseca and Bell 1998; Fonseca et al. 1998; Fonseca et al. 2002). The presence of a seagrasses canopy does not necessarily signify whether or not a location is capable of supporting seagrass habitat. Some species are ephemeral, for example, in North Carolina, shallow *Z. marina* meadows may completely exfoliate in late summer in response to warm temperatures, leaving a signature suggesting there are no seagrasses in the area when, in many instances, the meadows recovers in winter or spring. Because of this, identification of seagrass habitat at certain times of the year can be difficult to determine from visual inspections, which complicates the ability to properly permit water dependent activities such as dredging or marina construction. Environmental characterization of SAV habitat and the better understanding of the processes driving SAV occurrence and temporal changes in distribution are needed to properly identify and protect SAV habitat.

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. Seagrasses patches form and migrate across the sea bottom. In high current environments and areas exposed to wave turbulence, movement is considerable and beds tend to remain in a continuously patchy state. Whereas in low energy embayments and areas protected from large fetch, contiguous perennial beds will tend to form. 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; Kenworthy 2000).

Depending on the species and the environmental conditions, a meadow may attain full development of density and biomass in a few months (e.g., *Z. marina and 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 coasts 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; Kenworthy 2000). 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; Kenworthy 2000). 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; Kenworthy 2000).

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$_{o}$ C) summer water temperatures eliminate *Zostera* 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 *Zostera*, whereas in North Carolina during the summer months when water temperatures exceed 25-30°C, *Zostera* 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 (*Z. marina*) and northern (*H. wrightii*) range limits, and when one species is limited by seasonal thermal extremes the other species may be abundant.

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; Whitfield et al. 2004). When *T. testudinum* is compared to its congeners, *H. wrightii* and *S. filiforme*, it has the slowest rate of vegetative expansion (Fonseca et al., 1987; Kenworthy et al. 2002). 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* (Kenworthy et al. 2002). Thus, *T. testudinum* meadows form more slowly than any of the other species, yet if the environmental conditions allow the full development of a *T. testudinum* 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~~ weeks 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. 1998). 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.

Ecological Role and Function

The ecological role and function of seagrass habitat has been described by Hemminga and Duarte (2000), Larkum et al. (2006) and Duffy (2006). For more specific information of seagrasses in the South Atlantic region we recommend two U.S. Department of Interior Community Profiles: Thayer et al. (1984) and Zieman (1982). A *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, other 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; Bortone 1999; Short and Coles 2001). Additionally, *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 the ASMFC and the South Atlantic Fishery Management Council. Following is a brief summarization of the most important aspects of marine seagrasses which pertain directly to their distribution, abundance and function.

Seagrasses are rooted plants that can become nearly permanent, long-term features of coastal marine and estuarine ecosystems either as perennial or annual meadows. Because they are rooted, seagrasses directly link the sediments to the water column. No other marine plants are capable of providing this ecological service, to the extent that seagrasses can. Ecological functions provided by seagrass habitat that enhance conditions for fish species include: 1) primary productivity, 2) structural complexity, 3) the provision of substrate for attachement and productivity epiphytes, 4) modified energy regimes and stabilization of sediment and shorelines, and ~~4)~~ 5) nutrient cycling. 7. water quality, and 8) carbon sequestration.

On a unit area basis seagrasses are among the most productive ecosystems in the world (McRoy and McMillan 1977; Hemminga and Duarte 2000). High rates of primary production lead to the formation of complex, three dimensional physical structures consisting of a canopy of leaves and a dense matt of 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 hundreds of species of micro-organisms, meiofauna, carnivores, herbivores and detritivores. The most important aspects of these functions are listed below.

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 live among the canopy, 4) the plants that live on the sediments among the seagrass shoots, (micro- and macroalgae) and 5) the residual organic matter which decomposes in the sediments, on the sediment surface and in the water column. The high rates of primary productivity ensure an abundant supply of organic matter available to be used as an energy source in many different food webs. In some instances a significant portion of the organic matter is exported to adjacent ecosystems (e.g., beach wrack, mangrove forests, open ocean, deep ocean canyons) where it is processed into the food chain. Some fishery organisms consume seagrasses directly (e.g., amphipods and parrot fish), 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, and 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 centimeters (*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 surface area available for colonization 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 of organic biomass and a matrix for meiofauna and macrofauna (Kenworthy and Thayer 1984). The additional structure and productivity, in turn, can support a greater diversity and abundance of species. Several studies have shown significantly greater species richness and abundance in SAV beds compared to unvegetated bottom (Thayer et al. 1975; Heck et al. 1989; Ross and Stevens 1992; Irlandi 1994; ASMFC 1997; Wyda et al. 2002).

Modification of energy regimes and sediment stabilization

The leaf surfaces and the collective structure of the canopy provide frictional drag slows water motion and reduces wave turbulence (Zieman 1982). 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 directly for herbivores and indirectly to consumers as well as 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 which also sequester carbon.

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.

Species composition and community structure

Seagrass habitat supports other types of aquatic plants in addition to submerged grasses previously described. Macroalgae (benthic, drift, and floating forms) often co-occur with SAV and provide similar ecological services, but the plant taxa have distinctly different growth forms and contrasting life requirements. Macroalgae grow faster than SAV and do not require unconsolidated substrate for anchoring extensive root systems. Because of this growth pattern, macroalgae do not provide as much sediment stabilization as submerged rooted vascular plants, but do contribute to productivity and biodiversity. Macroalgal genera include salt/brackish (*Ulva*, *Codium*, *Gracilaria*, *Enteromorpha*, *Ectocarpus*, and *Cladomorpha* (Thayer et al. 1984; Mallin et al. 2000). In Florida, calcareous benthic algae, such as *Penicillus* and *Halimeda*, grow among seagrasses and contribute a significant source of calcareous sediment to the system.

Epibiota are another important component of SAV habitat. Epibiota are organisms that attach or grow on the surface of a living plant and may or may not derive nutrition from the plant itself. Micro- and macroalgae (i.e., seaweed) can grow on the leaves of SAV. Invertebrates attached to the SAV leaves include protozoans, nematodes, polychaetes, hydroids, bryozoans, sponges, mollusks, barnacles, shrimps and crabs.

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

The three dimensional structure provides protective cover for small resident fish and invertebrates and juvenile fish species. Because of this, the nursery role of SAV is critical for many estuarine dependent fishery species in the South Atlantic region such as gag groupers, flounders, red drum, weakfish, striped mullet, pinfish, pigfish, and silversides, just to list a few of the fish taxa documented to utilize seagrass habitats (Thayer et al. 1984; DMF 1990; ASFMC 1997). Sampling in seagrass beds in North Carolina in the 1980s documented over 150 juvenile fish and invertebrate species, of which 40 were commercially important species. In addition, at least 49 adult fish species were reported from beds in eastern Pamlico Sound (DMF 1990). ASMFC compiled a list of ASMFC managed species that utilize SAV for some portion of their life cycle. Over 30 species were documented potentially using SAV as larvae, juveniles, or adults for various functions (Table 3.2-5).

While there have been few studies dealing with larval fish settlement and use of seagrass habitats, there have been numerous publications listing juvenile and adult fishes collected in seagrass meadows. The same ecological characteristics of seagrass beds that make the habitat favorable for juveniles should also benefit larval fish and invertebrates. 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 hentzi*), and halfbeaks are present and use seagrass beds.

Table 3.2-5. Ecological functions provided by seagrass habitat for various life stage(s) of ASMFC fishery species (Source: ASFMC 1997). **Life stage documented to use SAV for function listed 1**

SPECIES	**REFUGE/ ATTACHMENT2**	**SPAWNING3**	**FOOD4**	**PREY5**
Atlantic croaker	L,J,A	J?	J,A	
Atlantic menhaden	L,J,A	J,A		
Red drum	L,J	A?	J,A	
Spanish mackerel	J?	J?,A?		
Spot	L,J,A	J,A		
Spotted seatrout	J,A	A	L,J,A	
Striped bass	J?	J?,A?		
American eel	J	J,A?		
Black sea bass	J	J,A?		
Scup	L,J,A?	A?	L?,J,A?	
Tautog	J, E2	E,A	L?,J,A	
American lobster	J?	J?,A?	J?,A?	
Atlantic herring	L?,J?	L?,J?,A?		
Atlantic sturgeon	J?	J?		
Bluefin	J	L?,J,A?		
Northern shrimp	E?,L?2,J?,A?	A?	J?,A?	L?,J?,A?
American shad	J?	J?,A?		
Hickory shad	J?	J?,A?		
Alewife	J?	J?,A?		
Blueback herring	J?	J?,A?		
Summer flounder	J,A	J,A		
Weakfish	L,J,A	A?	L,J,A	
Winter flounder	J?,A?	J?,A?		

<table>
<tr><td colspan="3">Southern flounder</td><td colspan="4">J,A</td><td colspan="3">J,A?</td></tr>
<tr><td colspan="2">Striped mullet</td><td colspan="3">J,A</td><td colspan="3">J?,A?</td><td colspan="2">L?,J?,A?</td></tr>
<tr><td>White mullet</td><td colspan="3">L,J,A</td><td colspan="2">A?</td><td colspan="3">J?,A?</td><td>L?,J?,A?</td></tr>
<tr><td colspan="3">Rainbow smelt</td><td colspan="4">J,A?</td><td colspan="3">J?,A?</td></tr>
<tr><td>Black drum</td><td colspan="3">L?,J?,A?</td><td colspan="2">A?</td><td colspan="3">J?,A?</td><td>J?,A?</td></tr>
<tr><td>Bay scallop</td><td colspan="3">E?$_2$,L?,J$_2$,A</td><td colspan="2">A?</td><td colspan="3">J?,A?</td><td>J,A</td></tr>
<tr><td colspan="2">Brown shrimp</td><td colspan="3">J,A</td><td colspan="3">J,A</td><td colspan="2">J,A</td></tr>
<tr><td colspan="2">Pink shrimp</td><td colspan="3">J,A</td><td colspan="3">J,A</td><td colspan="2">J,A</td></tr>
<tr><td colspan="2">White shrimp</td><td colspan="3">J?,A?</td><td colspan="3">J,A</td><td colspan="2">J?,A?</td></tr>
<tr><td colspan="2">Blue crab</td><td colspan="3">J,A</td><td colspan="3">J,A</td><td colspan="2">J,A</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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3.2 Estuarine/inshore systems

3.2.1 Estuarine Emergent (salt marsh and brackish marsh)

Description and Distribution

One of the dominant features of the Coastal Plain of the southeastern U.S. is its extensive saltmarshes. Saltmarshes are transitional areas between land and water, occurring along the intertidal estuarine shorelines where salinity ranges from near ocean strength to near fresh in upriver marshes. The saltmarsh is a type of wetland. Wetlands are classified on the basis of their hydrology, vegetation, and substrate. The most widely used classification system, that proposed by Cowardin et al. (1979), classifies wetlands into five ecological systems, one of which is the Estuarine System. The Estuarine System is further divided into the Subtidal and Intertidal subsystems. Emergent Wetland is one of eight classes of wetlands within the Estuarine Intertidal Subsystem. Estuarine emergent wetlands are characterized by the presence of erect, rooted, herbaceous hydrophytes dominated by salt-tolerant perennial plants. In the southeastern U.S., saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*S. patens*), big cordgrass (*S. cynosuroides*), needlerush (*Juncus roemerianus*), salt grass (*Distichlis spicata*) and narrow-leaved cattail (*Typha angustifolia*) are major components of the estuarine emergent plant community.

In this section, the term saltmarsh encompasses brackish marsh, as well. Although there is no clear distinction between the commonly used terms saltmarsh and brackish marsh, the latter typically refers to estuarine emergent wetlands with salinities near the lower end of the mixohaline range, which includes oligohaline (0.5-5.0 ppt), mesohaline (5.0-18.0 ppt), and polyhaline (18.0-30.0 ppt) salinity regimes. By contrast, saltmarshes can also occur in salinity regimes that are fully marine or euhaline (30.0-40.0 ppt), as well as in hyperhaline (>40 ppt) environments. Characteristic plant species vary along a continuum from high salinity saltmarshes, which are typically dominated by *S. alterniflora* in the southeast, to lower salinity brackish marshes,‖ where species such as *S. cynosuroides* and *J. romerianus* achieve greater dominance. Because tidal brackish marshes are transitional areas between saltmarshes and tidal freshwater marshes, brackish marshes include species from both habitats, and, therefore, have relatively high plant diversity.

Saltmarshes occur in each of the states in the South Atlantic Region. The total area of saltmarshes in this region is approximately 894,200 acres (Field et al. 1991). It is estimated that saltmarshes in the South Atlantic account for 21% of the nation‘s total salt marshes (Field et al. 1992). Unlike the Gulf Coast states, particularly Louisiana, which have lost thousands of acres of estuarine emergent marsh due to a variety of causes including erosion, saltwater intrusion, subsidence sea-level rise, sediment deprivation and physical alteration, the acreage of estuarine emergent marsh throughout the remainder of the southeastern U.S. has remained relatively stable from the mid-1970s to mid-1980s (Hefner et al. 1994).

In the southeastern U.S., South Carolina has the greatest saltmarsh acreage (365,900 acres), followed by North Carolina (212,800 acres) and Georgia (351,236 acres). Florida (east coast) has the least saltmarsh 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.

Note--There needs to be a better assessment of emergent marsh totals for the different states within the SAFMC area. It is hard to manage something you do not have relatively accurate data on how much it is you have and what kind it is. There is also a need to better assess the managed species that rely on these habitats at some point in their life-histories and the forage species they rely upon, better linking salt marshes to EFH. Here and in other sections it is necessary to partner with Federal Agencies, each state, with non-government organizations (NGO's), and NOAA Sea Grant to obtain funds to acquire this fundamental information. This should be a priority issue for the Council.

Table 3.2-1 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 3.2-1 shows the estuarine drainage areas in the South Atlantic Region for which the estimates have been compiled.

Table 3.2-1. 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.

Saltmarshes 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 of 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 . Salt marshes persist longest in low-energy protected areas where the rate of sediment accretion is greater than or equal to the rate of subsidence (Mitsch and Gosselink 1986).

Figure 3.2-1. Estuarine drainage areas in the South Atlantic Region (Source: NOAA 1991a).

Ecological Role and Function

Structure and function of a saltmarsh are influenced by marsh habitat size, landscape setting, 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 vary widely among salt marshes , 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 throughout the estuary from the marsh, provides the base of the food chain supporting many marine organisms.
Few aquatic species feed directly on living plant tissue in salt/brackish marsh (i.e., periwinkle), and their productivity is very low compared to that of detritivores and consumers of microalgae (Wiegert and Freeman 1990; Steel 1991; SAFMC 1998a). However, biotic interactions with primary consumers can result in degradation or loss of wetlands. Recent study results from the southeastern United States suggest that blue crab predation on snails may prevent the snail from overgrazing the marsh grass (Silliman and Bertness 2002).

Detrital and bacterial production from salt/brackish marsh exhibits some of the highest recorded values per unit area of any ecosystem in the world (Wiegert and Evans 1967). Slow-moving or sessile species residing in salt/brackish marsh and contributing to secondary production include fiddler crabs, mud snails, amphipods, oysters, clams, and ribbed mussels (Wiegert and Freeman 1990). Based on data from Georgia marshes, biomass of these resident species exceeded 15 g carbon/m2, and consisted of 80-200 fiddler crabs, 400-700 periwinkle snails or mud snails, and 7-8 mussels (Wiegert and Freeman 1990). The resident estuarine fishes (i.e., killifish, grass shrimp, sheepshead minnow) are an important link between estuarine production and transient predatory fish populations (Wiegert and Freeman 1990; Kneib 1997). Salt-brackish marsh edge also provides important feeding areas for blue crabs, red drum, flounder, seatrout and other large predators searching the edge of complex structure near deeper water, as illustrated by greater predation on grass shrimp with increasing depth in shallow-estuarine water (Clark et al. 2003).

It has been estimated that 45% of salt marsh production is exported to the estuarine system in the form of detritus, dissolved organic matter, and transient nekton (i.e., grass shrimp and killifish; Teal

1962). The biomass of secondary production going in and out with the tide (fish, shrimp) is less well known than resident species biomass (Kneib and Wagner 1994). The exported production of brown and white shrimp is probably the best known and most significant to coastal fisheries (Turner 1977; Wiegert and Freeman 1990). The estimated yield of shrimp from North Carolina was 107 lb per acre of intertidal vegetated bottom (Turner 1977), where intertidal vegetation included salt marsh macrophytes, *Spartina* spp. [and] *Juncus* spp. However, recent research suggests that wetlands vary greatly in their role as exporters or importers of organic matter (Wiegert and Freeman 1990). This variation could be the result of variable erosion or deposition rates among seasons or wetland areas.

Primary production in salt/brackish marshes is converted into fish production through several pathways. Using sulfur, carbon, and nitrogen isotopes to trace organic matter flow in the salt marsh estuaries of Sapelo Island, Georgia, Peterson and Howarth (1987) found two major sources of organic matter used in fish production: *Spartina* (detritus) and algae. The relative importance of each source is determined by the feeding mode, size, location, and trophic position of the marsh and estuarine consumers (Peterson and Howarth 1987). For example, benthic microalgae probably support herbivorous snails, whereas detritus supports sheepshead minnows, mummichogs, and their prey. Attached algae can be found on the marsh grass itself, the intertidal mudflats, and the shallow subtidal bottom near the marsh. Pinckney and Zingmark (1993) compared production rates of benthic microalgae in various bottom types in an estuarine system (North Inlet, South Carolina). Short *Spartina* marsh accounted for the greatest amount of microalgal productivity (44.6%) in the system, followed by intertidal mudflats (22%), tall *Spartina* marsh (18%), and shallow subtidal bottom (<1 m mean low water) (13%). Sand flats accounted for only 3% of the total annual microalgal production (Pinckney and Zingmark 1993). 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 95% of the commercial species in the United States are estuarine dependent species (Feierabend and Zelazny 1987 as cited in Mitsch and Gosselink 1993). Most of the juveniles of fishery species found in salt/brackish marsh nurseries were spawned offshore during winter. The larvae were transported through inlets and into estuarine waters where they settled in the upper (low salinity) or lowermost (high salinity) reaches of estuarine creek systems (Ross 2003). The peak of juvenile settlement generally occurs in spring through early summer, although the peak is correlated more with water temperature (Ross and Epperly 1985). Settlement in upper reaches is particularly beneficial to spot and croaker, where growth and survivorship are enhanced compared to lower reaches (Ross 2003). If movement to general regions of the estuary is largely passive (Pietrafesa et al. 1986; Pietrafesa and Janowitz 1988), the viability of spot and croaker stocks could be reduced by hydrodynamic conditions resulting in more settlement to lower regions of the estuary (Ross 2003). This settlement pattern could also occur in other 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 the shoreline and for storing floodwaters during coastal storms.

Species composition and community structure

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 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. Because salt marshes in the southeastern U.S. are influenced by the twice daily rise and fall of tides, they can be subject to rapid changes in salinity, temperature and water depth. Salinity, flood frequency and extent, marsh size and landscape setting can influence the types and densities of flora and fauna occuring in the salt marshes. The low marsh zone typically floods twice daily, while the high marsh floods only during storms and unusually high tides. One plant species, *S. alterniflora*, dominates the regularly flooded low marsh. *S. alterniflora* is the most abundant plant in southeastern marshes and is responsible for much of the marsh‘s productivity. *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 to 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 *J. roemerianus*, like *S. alterniflora*, is found in all of the estuaries of the ? South Atlantic Basin?. 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, *S. 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 *S. 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 inhabits 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.

Fauna

Estuarine intertidal marshes provide habitat for Council-managed species, other fish, shellfish, and 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 additional managed species such as coastal migratory pelagics (i.e., mackerels) and species in the snapper grouper complex.

In contrast to freshwater marshes, salt marshes typically have low species diversity of the higher vertebrates, higher species diversity of invertebrates. The invertebrate community in salt marshes is composed of various macrofaunal and mesofaunal species. The macrofaunal community is dominated by various species of crabs (e.g., fiddler and blue crabs), gastropod molluscs (such as *Littorina irrorata*), polychaetes, and amphipods. The protection afforded by marsh grass stem structure and the abundant food supply of salt marshes make them important nursery habitats for larval and juvenile stages of decapod species such as blue crab (*Callinectes sapidus*), white shrimp

(*Penaeus setiferus*), and grass shrimp (*Palaemonetes* spp.). Subadult stages move into intertidal marshes along the creek edge on incoming tides and penetrate the interior marshes during flood tide (Kneib and Wagner 1994). Resident species such as fiddler crabs (*Uca* spp.) burrow preferentially in sediments with intermediate densities of *Spartina* root mats (Bertness and Miller 1984). *Uca* spp. and *Palaemonetes* spp. are important prey of piscine, avian, and mammalian marsh inhabitants. These are the primary foragers of marsh vegetation, detritus, and mesofauna. The mesofaunal community consists of protozoa, nematodes, copepods, annelids, and rotifers. These organisms primarily feed on the microbial population, which chiefly consists of various species of bacteria and fungi. *S. alterniflora* supports a large number of epiphytic fungi, which not only contribute carbon and nutrients, but also participate in decomposition of standing biomass.

Table 3.2-2 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.

Table 3.2-2. 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 ocellatus 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
DECAPODS --
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. penaeid shrimp M Sp, Sc, Ty, Ju R/C/P
Uca spp. fiddler crabs R Sp, Ju R/C/P
Letter codes for the Resident Status 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.

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.

Marshes as Essential Fish Habitat

It is estimated that over 95% of the finfish and shellfish species harvested commercially in the United States are wetland-dependent (Feierabend and Zelanzy 1987). Coastal wetlands are implicated when you consider that a large majority of commercial fishing occurs in estuarine and marine systems. Within the coastal wetlands category, there are a relative small number of anadromous species that are dependent on riverine forested wetlands for spawning and nursery habitat rather than estuarine marsh. But they only account for a small fraction of species in the commercial catch. The vast majority of finfish and shellfish could thus be considered dependent on estuarine wetlands.

The detritus and attached microalgae made available to secondary consumers by the presence of marsh grass forms the contribution of estuarine marsh production to commercial fisheries production. However, the environment creating individual salt marshes can differ such that more or less production is exported and available for consumption. Species associated with adjacent mud flats and channels benefit more from the presence of marsh plants as more production is exported. There are also species that use marsh grass more directly as refuge and/or foraging areas. Of all the SAFMC managed species, red drum and shrimp are considered most dependent on salt marsh habitat (SAFMC 1998).

Turner (1977) demonstrated the association between shrimp and intertidal habitat (defined as salt marsh or mangroves) at a regional scale. The study compared the commercial harvest of shrimp in various locations with areal estimates of salt/brackish marsh coverage. The results indicated a strong correlation between shrimp yield and area of estuarine vegetation, with little correlation between yield and estuarine area, average depth, and volume. The relationship between shrimp harvest (y) and area of estuarine marsh (e) was quantified in the following equation (where x is degrees latitude):
$Y = 159e-0.070(x)$

However, it should be noted that annual shrimp abundance is highly dependent on weather conditions, in addition to fishing mortality and habitat changes (??? shrimp management plan – draft 2005).

The relationship between red drum production and estuarine marsh areas has not been quantified to the same level as that of shrimp. Juvenile red drum are found year-round over a wide array of salinity and habitats, although they seem to prefer sheltered, nearshore areas of coastal rivers and submerged aquatic vegetation (SAV) growing near marsh grass behind barrier islands (Ross and Stevens 1992). However, there is substantial evidence for the association of red drum with salt marsh habitat from diet studies. A summary of study results in DMF (2000) found the diet of juvenile red drum was comprised of predominantly mud crabs and fiddler crabs, the latter being closely associated with marsh habitat (Weigert and Freeman 1990).

Suggested by D. Meyer. It seems to me we need some new sections related to:

Linkages to adjacent habitats-- In this section we could discuss the important linkage of salt marsh to terrestrial habitat: the importance of oyster reefs to maintain the integrity of the salt marsh and reduce erosion of it, the importance of oyster reef and sub-aquatic vegetation (SAV) as low tide refuge habitats and the importance of the combination with salt marsh to increase habitat heterogeneity and maintain a shallow water wedge restrict predation on forage and juvenile game fishes. The linkage to upland habitats related to marshes acting as transition zones for freshwater inputs and how uplands are important a sediment sources to maintain marsh elevation relative to sea-level changes, a refuge for marsh migration during sea-level rise periods, and increasing the salinity regime profile (especially in creek feed salt marshes), which increases the heterogeneity of the marsh and increases rare species accumulation…. Etc.

Threats to salt marsh habitats—Too much fresh water input as freshets from storm water, road building causing impoundment of existing salt marsh causing salinity changes and poor hydrologic circulation patterns [this can enhance the eventual change in vegetation dominance and potentially lead to nuisance plant species, including the non-native form of the common reed (Phragmites australis) to invade disturbed areas], coastal development (bulk-heads, sea walls, revetments, etc.) causing no retreat for the salt marsh as sea-level changes occur, eutrophication, etc.

Policy for management—We need to have a coherent policy as to how the SAFMC will participate in the management of these habitats. Help direct research that is conducted at the federal, state and local level to obtain the information necessary for managing the habitats outlined in the Habitat Management Plan. There needs to be a link with federal agencies and state and local governments to proceed with best management practices to put these ideas into action and not just come out with documents to distribute and read.

3.2.2 Mangroves (formerly Estuarine Shrub/Scrub Mangrove)

Description and Distribution

I would add Buttonwood Conocarpus erectus to the discussion of mangroves.

It is in the family Combretaceae along with white mangrove Laguncularia racemosa.In the book:Ecosystems of Florida. Eds. Ronald J. Myers and John J. Ewel. 1990. Chapter 15 Mangroves By William Odum and Carol McIvor under the heading mangrove species the authors state: A fourth species, the button-wood (Conocarpus erectus L.) is classified only as a "mangrove associate" since it does not have any degree of root modification for saturated, saline soils or viviparity of propagules.Because it constitutes an important upland fringe of many Florida mangrove ecosystems (Tomlinson 1980), button-wood will be discussed occasionally in this chapter. Me: Buttonwood can found on the shoreline particularly in lower salinity areas and where shorelines have eroded.

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. In the southeastern U.S., collectively three species comprise true ―mangrove‖ forest: the red (*Rhizophora mangle* L), black (*Avicennia germinans* L. Stearn), and white (*Laguncularia racemosa* L. Gaertn.f.) (Figure 3.2-2); the buttonwood (*Conocarpus erectus* L.), although frequently referred to as a mangrove, does not meet the definition proposed by Tomlinson (1986). The growth of mangroves appears limited by inter-specific competition to coastal and estuarine systems and more inland areas subject to saline intrusions. 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: Miami-Dade, Monroe, Collier, and Lee Counties (Gilmore and Snedaker 1993; Figure 3.2-3).

The three mangrove species of the southeastern U.S. exhibit unique productivity maxima that vary with local soil salinity and flooding regimes. Consequently the composition, and even growth forms of mangrove forests are a function of the interplay between static topography and dynamic hydrology. In recognition of this interplay, several classification systems for mangrove forests have been proposed. While the first such systems were based on differences in mean water depth (Provost 1973, Tabb et al. 1974), that of Lugo and Snedaker (1974) was based on physiogamy. The classification scheme originally proposed by Lugo and Snedaker (1974) has undergone several revisions (i.e., Snedaker 1989, Gilmore and Snedaker 1993) and is the most widely cited mangrove classification system today. A brief description of these types follows.

Mangrove fringe forests occur along sheltered coastlines with exposure to open water of lagoons and bays and are almost exclusively dominated by red mangrove. The tree canopy foliage forms a vertical wall. 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. In some locations, these fringe forests have a shoreline berm or an interior wrack line (i.e., build up of detritus). Elsewhere, mangrove prop roots create subtidal or intertidal structure that supports both attached and mobile estuarine organisms, including small forage fish, estuarine fish, and, in some places, fish from nearby reefs..

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 development of a shoreline berm. Riverine mangrove forests occur in riverine areas that have estuarine water exchange and are the most productive of the forest types (Table 3.2-3). The high productivity is attributed to reduced salinity and the fact that nutrients in freshwater runoff from land mix with minerals in seawater to provide the complete mineral complex required for growth. Mangrove production contributes organic detrital material to adjoining systems.

Table 3.2-3. Characteristics of mangrove forest types of southern Florida (Source: Gilmore and Snedaker, 1993).
Mangrove Types
Fringe Overwash Riverine Basin Dwarf

	Fringe	Overwash	Riverine	Basin	Dwarf
Characteristics					
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					
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

Basin mangrove forests exist in inland topographic depressions 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. Black mangroves normally dominate, but invasion by Australian pine (*Casuarina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*) is very common.

Dwarf mangrove forests occur in areas where nutrients, freshwater inflow and tidal activity limit tree growth. Although all of the species can exist in a dwarf form, in southeast Florida large areas of the southeastern Everglades are dominated by dwarf red mangrove forest, and this area has increased in recent years (Ross et al. 2000).

Black Mangrove White Mangrove Red Mangrove

Figure 3.2-2. Illustrations of red mangroves, black mangroves, and white mangroves with propagules, flowers, and leaves (Source: Odum et al. 1982).

25 N 30N Florida Keys Biscayne Bay Indian River Ponce de Leon Inlet Red and White Mangroves Black Mangrove Cape Canaveral

Figure 3.2-3. Approximate northern limits for the red mangrove, black mangrove, and white mangrove in Florida (in Odum et al. 1982 based on Savage 1972).

Ecological Role and Function

Odum et al. (1982) provided a detailed account of the ecology of mangroves in South Florida. More recent publications provide updated summaries of ecology, fishery value, and research information from the limited literature that exists on mangrove habitat (Baran & Hambrey 1998, Alongi 2002, Manson et al. 2005a, Manson et al. 2005b, Faunce & Serafy 2006). Cintron-Molero (1992) provided a succinct summary of the functional values of mangrove ecosystems. Mangrove ecosystems provide many goods and services beneficial to humans. 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 juvenile and adult fish and invertebrates. In addition, they contribute dissolved and particulate organic detritus to adjacent waters in support of estuarine food webs. Because they are occupied by high proportions of juveniles belonging to fishery species, and these individuals eventually leave mangroves to join the exploited adult phase inhabiting adjacent estuaries or coral reefs, mangroves possibly enhance secondary production in fishes. Mangroves also support the secondary production of birds. For example, the foraging and reproductive success of wading birds such as Roseate Spoonbills (*Ajaia ajaia*) greatly depends on the availability, quantity, and quality of mangrove forests and their associated fauna (Lorenz 2001). In addition to their direct biological value, mangroves help shape the geomorphology of the coastline, retard land loss from erosion, and contribute to the heterogeneity of landforms that provide shelter, foraging grounds and nursery areas for terrestrial organisms. The structure of the mangrove forest buffers interior coastal areas from gale winds and storm surge, protecting human settlements (UNEP 2006).

Species composition and community structure

Gilmore and Snedaker (1993) divided mangrove faunal communities into seven spatial guilds that are defined by microhabitat associations. These are dynamic groupings with species often moving from one guild to another during ontogeny or with changes in environmental conditions (Table 3.2-4). The aquatic components of the community, both fish and invertebrates, are contained in fish and invertebrate use; spatial guilds I, III, IV and V are most relevant, but Guilds II, VI and VII cannot be discounted because they contain the arboreal and terrestrial components of the community, many of which are predators or scavengers on the fish and invertebrate fauna. Various life stages of fish and invertebrates are found in mangrove habitat, with occurrence determined by accessibility and body depth relative to water depth. Fishery species, both fish and invertebrates, are primarily represented as transients commonly using the fringe, riverine, and overwash island mangrove forests (Guild I). Adults of the same species are, in most cases, found in adjacent seagrass meadows, in reef structures, or elsewhere offshore. In Florida, spiny lobsters (*Panulirus argus*) and pink shrimp (*Farfantepenaeus duorarum*) are the most important commercial and recreational invertebrates commonly found among the prop-roots of red mangroves. Fish species listed as mangrove transients in Table 5 that are important in Florida recreational or commercial fisheries include common snook (*Centropomus undecimalis*), sheepshead (*Archosargus probatocephalus*), black drum (*Pogonias cromis*), red drum (*Sciaenops ocellatus*), gray snapper (*Lutjanus griseus*), and dog snapper (*Lutjanus jocu*). Tarpon (*Megalops atlanticus*) is found in mangrove creek habitat. Many small species make up the rest of the fish and invertebrate communities found in mangrove areas of the southeastern U.S. This list also includes the goliath grouper, *Epinephelus itajara*; presently under ―no-take/protected status. Other protected species found in one or more type of mangrove habitat include the West Indian manatee (*Trichechus manatus*), American crocodile (*Crocodyllus acutus*) American alligator (*Alligator mississippiensis*), juvenile bull shark (*Carcharhinus leucas*), lemon shark (*Negaprion brevirostris*), Atlantic stingray (*Dasyatis sabina*), and smalltooth sawfish (*Prisis pectinata*).

Mangroves as Essential Fish Habitat

For economically important fishery species in the U.S., flooded mangrove habitats provide feeding opportunities and increased refuge from predation relative to open habitat. A quantitative understanding of the use of mangroves by fish and invertebrates is still being developed, hampered by difficulties in quantitative sampling in mangroves, where red mangrove prop roots and black mangrove pneumatophores pose formidable obstacles to most quantitative sampling approaches (Faunce and Serafy 2006).

In a review of the pertinent literature, Faunce and Serafy (2006) found that roughly one in five purported ―mangrove-fish surveys failed to sample this habitat per se. Lack of complete sampling has undoubtedly produced unrepresentative data in specific cases and has probably led to unfounded conclusions about the nature and extent of fish utilization of mangroves in general. It may, for example, have led to inclusion of a few species on the Gilmore and Snedaker (1993) (Table 3.2-4) list that do not belong there. Despite these drawbacks, generalizations can be made regarding the importance of U.S. mangrove habitat to fisheries.

Evidence linking mangrove habitat to fisheries production mainly has been based on a simple correlative approach relating fisheries to mangroves (Manson et al. 2005, and references therein). Fishery production is appreciably higher in coastal areas off estuarine mangrove forests than off non-mangrove coasts (Marshall 1994). Similarly, greater densities of several species have been recorded adjacent to bays containing mangroves than those without them (Nagelkerken et al. 2001, Dorenbosch et al. 2004, Mumby et al. 2004). Heald and Odum (1968) may have been the first to propose the role of fringe and overwash mangrove forests as nurseries for a variety of economically valuable species in the U.S. This paradigm has been largely based on repeated observations that mangroves contain greater densities of juvenile fishes compared to adjacent habitats. However, the mangrove fringe typically occupies a smaller area than those habitats to which it is often compared (e.g. seagrass beds or mud flats), and the differences may not reflect overall abundance. Furthermore, few studies have been made comparing faunal density in mangrove habitat to that in adjacent habitat, and some of these have used different sampling methods in the two habitats, making the comparison somewhat questionable. On the other hand, the same gear may differ in efficiency when applied to different habitats, so this also is an issue.

Nurseries have been defined as habitats whose inhabitants exhibit greater growth, survival, density, and successful export to adult populations than surrounding habitats (Beck et al. 2001, Adams et al. 2006). By this definition, despite decades of work, there is little empirical evidence that mangroves are nursery habitats for fishery species. Manson et al. (2005) noted a deficiency in survival and growth information worldwide. Studies of growth of individual species in U.S. mangroves may be limited to the work of Robertson and Duke (1990) and Faunce (2005). A meta-analysis of comparative data on density in mangrove and alternative habitat by Sheridan and Hays (2003) suggested that faunal density was significantly higher in alternative habitats than in mangrove habitat, but survival was significantly higher in mangrove habitat. They considered these results preliminary because of the small number of data sets covered.

Food availability may be enhanced within mangrove habitat. Experimental manipulations have found that structure with attached epibionts attracted significantly more fish than bare stakes (Laegdsgaard and Johnson 2001), suggesting that structure may increase the availability of potential food items. Greater densities of a planktonic crab larvae actively selected by predatory fishes have been found in Queensland mangroves (Robertson et al. 1988). The work of Odum and Heald (1975) provided convincing evidence that nutrient export from estuarine mangroves supports a detrital food web that propagates to forage items for juveniles of exploited species. Species such as common snook (*Centropomus undecimalis*), goliath grouper (*Epinephelus itajara*), sheepshead (*Archosargus probatocephalus*), black drum (*Pogonias cromis*) and red drum (*Sciaenops ocellatus*) likely benefit from the presence of large expanses of mangrove forests (Lewis et al. 1985). A recent study reports that juvenile Goliath grouper prefer well-developed fringing red mangrove shorelines with high spatial complexity (Frias-Torres 2006).

The mangrove-forage association of other exploited species in South Florida is more tenuous. Species such as gray snapper (*Lutjanus griseus*), schoolmaster snapper (*L. apodus*), bluestriped grunt

(*Haemulon sciurus*), and sailors choice (*H. parra*) occupy reefs as adults and also occur in those mangroves that frequently experience clear, marine waters (Ley and McIvor 2001). Stable-isotope and observational data have demonstrated that the majority of food items for these species is derived from foraging on adjacent seagrass beds at night (e.g. Rooker and Dennis 1991, Loneragan et al. 1997, de la Moriniere et al. 2003, Kieckbusch et al. 2004). Therefore, any observed growth of these species occupying mangroves during daylight hours is a result of foraging on adjacent habitats and not the mangrove habitat per se.

Assimilation of mangrove products into food webs has been shown to be minimal in a number of stable isotope studies (Sheridan and Hays 2003). For example, Fry and Smith (2002) examined stable isotopes of carbon, nitrogen, and sulfur along a salinity gradient in a riverine mangrove forest, the Shark River estuary of South Florida. Looking at mussels and barnacles, they found the strongest influence of mangrove in the food web in the middle estuary, where mixing models based on sulfur isotopes suggested that as much as 60% of filter-feeder production was mangrove-based. They concluded, however, that, overall, the food web of mangrove estuaries is based primarily on phytoplankton and benthic microalgae. In another South Florida study, Fry et al. (1999) found evidence of a mangrove diet in some pink shrimp newly recruited to the Tortugas fishing grounds; however the predominant stable isotope signature indicated a seagrass food base. While the export of dissolved and particulate materials to coastal areas may be substantial (Lee 1995), evidence of its incorporation and use in coastal waters is lacking.

The repeated observation that mangroves harbor more individuals during the day than at night is strong evidence that mangroves serve as daytime refuges from predation, and thus act as a nursery in this sense, even though some species may not feed there. It has been experimentally demonstrated that the structurally heterogeneous root habitat of mangroves reduces the effectiveness of larger-bodied predators (Primavera 1997, Laegdsgaard and Johnson 2001). Mangroves also produce shade, allowing inhabitants greater visual range than they would have in more brightly lit areas (Helfman 1981). Frias-Torres (2006) noted that shade is an important characteristic in habitat selection by goliath grouper. Because the degree of predation is dependent on light levels, the combination of root structure and inherent low light levels is an additional benefit with regard to avoiding predation (Chittaro et al. 2005).

Not all mangrove stands—even those of the same type, as defined by Gilmore and Snedaker (1993)—are the same in terms of support for fauna. Three Florida studies have compared the associated fauna of mangrove stands and found differences. In the first study, conducted in the upper reaches of northeastern Florida Bay, several distinct fish assemblages were evident within mangroves bordering basins of varying distance from freshwater and saltwater sources (Ley et al. 1999). In the second study, the fringing mangroves of the Biscayne Bay (Florida) mainland contained a significantly lower overall taxonomic richness and density of four out of five reef fishes compared to fringing forests located across the bay on the leeward side of oceanic barrier islands (Serafy et al. 2003). In the third study, density and frequency of occurrence of five reef fishes declined precipitously as a function of increasing distance from oceanic inlets, and distinct shoreline selection was exhibited (Faunce 2005). The availability of certain types of structure as microhabitat might also influence mangrove usage. For example, Frias-Torres (2006) found that juvenile goliath grouper were associated with erosional, concave shorelines of sufficient water depth (i.e., > 80 cm) containing overhangs and undercuts, as opposed to depositional shorelines without these features. Lee (2004) concluded that tidal amplitude and extent of intertidal area, rather than amount of mangrove area per se, influenced prawn catch in tropical nearshore environments across 37 countries. These results point out that the use of mangrove shorelines will be species, season, and location dependent.

Several physical features of mangroves make them especially favorable as fish habitats. Mangrove creeks and ditches, although not as well studied as fringing mangroves, are widely used by fishes. Because creek edges within fringe mangrove habitat are flooded most of the time, they provide low-water refugia during periodic dry-downs. Not surprisingly, the largest-bodied aquatic organisms, e.g., the West Indian manatee (*Trichechus manatus*), American crocodile (*Crocodyllus acutus*) American alligator (*Alligator mississippiensis*), juvenile bull sharks (*Carcharhinus leucas*), lemon sharks (*Negaprion brevirostris*), Atlantic stingray (*Dasyatis sabina*), tarpon (*Megalops atlanticus*), common snook (*Centropomus undecimalis*), and goliath grouper (*Epinephalus itajara*) have been observed within mangrove creeks and ditches (Tabb 1974, sources within Odum et al. 1982). Ley and McIvor (2001) and Faunce et al. (2004) reported a positive relationship between water depth in mangrove forests and the density of gray snapper in southeast Florida.

Mangrove creeks are important conduits between expansive coastal marshes and downstream embayments. Faunce et al. (2004) linked hydrologic regime to change in density of 12 taxonomic groups of fishes and found that the nature of the response was linked to body-size. Small bodied (< 10 cm total length) resident fishes were negatively correlated with changes in water levels within 90 days, while larger fishes, including predatory species, were positively correlated with changes over this and longer time periods (Faunce et al. 2004). The authors concluded that these results represented the concentration of small fish into the creek and their resulting exploitation by larger predators. These results highlight the importance of deepwater habitats as refugia from desiccation for forage species and as feeding areas for larger species. For prey-predator interactions to occur, both groups of fishes must have access to the same habitat.

Just as the area and depth of the creeks influence the degree to which fishes are concentrated during low water events, the flooding of basin mangrove habitats influences the amount of forage fish produced. The mangrove basin habitat (Spatial Guild V) is characterized by separation from tidal water by a berm and seasonal changes in water level and thus availability to fishery resources. The more abundant fishes found in this habitat are cyprinodontiform species such as killifish, mosquitofish, and mollies, which grow and reproduce rapidly. These —r-type species are able to quickly colonize newly flooded mangrove basin habitat, and their growing season is directly related to hydroperiod. In a unique long-term study, Lorenz (1999) demonstrated that basin forests that underwent longer hydroperiods possessed a greater density of demersal prey-base fishes than locations that experienced a shorter hydroperiod. The Lorenz (1999) findings echoed those of similar studies conducted within the adjacent freshwater Everglades (Loftus and Eklund 1994, Trexler 2001). Because basin habitats typically cover great spatial areas, relative to other mangrove forest types, and are occupied by numerous r-type species, they have the potential to support immense biological production (biomass= area x time). The time period that adjacent basins are flooded determines the quantity of forage items that potentially can become available to higher consumers, and the rate of decline in water levels relative to the local topography (especially the slope of creek banks) enables the production to be realized by these consumers, including predatory fishes and wading birds. For this reason, both Lorenz (1999) and Faunce et al. (2004) advocated a hydroperiod of ca. 240 days followed by a dry-down of ca. 90 days.

Mangrove stands and seagrass beds and/or coral reefs may play supporting roles in providing nursery habitat for fishery species and other fish and invertebrates, and the documentation and quantification of linkages among these habitats is an emerging avenue of investigation for mangrove researchers. Approaches range from correlative analyses to elemental signatures and tagging (Gillanders et al. 2003). Skilliter et al. (2005) found that the abundance of *Penaeus plebejus* and *Metapenaeus bennettae* was significantly and consistently greater in dense seagrass proximal to mangroves than in other types of habitat. Additionally, sparse seagrass close to mangroves supported more of these species than dense seagrass farther away, indicating that the spatial arrangement of habitats was more important than structural complexity alone. Mumby et al. (2004) found that the community structure of coral reefs off Belize was influenced by the presence of mangroves in the vicinity, and the total adult biomass of several species was higher. In acknowledgement of the linkage between mangroves and adjacent habitats, research is now evolving to focus on which mangrove systems contribute most to offshore fisheries production. For example, Mumby (2006) prepared algorithms identifying the relative importance of mangrove nursery sites, the connectivity of individual reefs to mangrove nurseries, areas of nursery habitat that have unusually large importance to specific reefs, and priority sites for mangrove reforestation projects. These four algorithms should be considered for use in coastal ecosystem and fishery management and planning.

The first international symposium on mangrove habitat, organized by Joseph Serafy, NOAA, National Marine Fisheries Service, Miami, was held in Miami in spring of 2006, and peer-reviewed papers from that conference were published, providing further information on mangroves as nurseries. The conference website is: http://www.rsmas.miami.edu/conference/mangrove-fish-habitat/

A special issue of the Bulletin of Marine Science (Volume 80, Number 3, May 2007) devoted to the symposium contains keynote papers by Stephen J. M. Blaber and Ivan Nagelkerken, 19 full articles, and 4 notes. Guest editors of this special issue were Joseph E. Serafy and Rafael J. Araujo. Papers were not available for review in time for development of this mangrove section of the FEP, therefore the volume advances the science of mangrove importance to fisheries beyond that discussed above.