Fishery Ecosystem Plan II
Live/Hardbottom Habitat
Draft
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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 nearshore zone (0-5m) followed by 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, Miami Terrace, and Pourtales Terrace. Deep offshore and deep areas occur in depths greater than 400 m (1,312 ft.).

To facilitate development of a regional mapping strategy for SAFMC Fishery Ecosystem Plan II (FEP II), a Managed Species Writing Team provided input on the spatial partitioning of offshore habitat identified in Table 1 to allow general evaluations of existing mapping efforts and further develop the Strategy in cooperation with the Southeast Area Monitoring and Assessment Program (SEAMAP) Species Habitat Characterization and Assessment Workgroup, the SAFMC Habitat Protection and Ecosystem Based Management Advisory Panel and other regional partners. (Note: An overview of the developing strategy can be viewed in the Research and Monitoring Page of FEP II Dashboard http://safmc.net/fishery-ecosystem-plan-ii-research-and-monitoring/. This effort builds on the Council’s Habitat and Ecosystem Atlas (http://safmc.net/habitat-and-ecosystems/safmc-habitat-and-ecosystematlas/) and provides an evolving prioritization to facilitate regional collaborative acquisition of data on the physical and biological characteristics of the South Atlantic region. The Strategy is being developed as a living online functional tool highlighted in the Digital Dashboard (http://ocean.floridamarine.org/safmc_dashboard/) and accessible through the Services presented in the SAFMC Habitat and Ecosystem Atlas.)

Table 1. Approximate depth distribution of bottom habitat zones in the South Atlantic region.

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 2009) 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 likely spawning location for multiple 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 1), and additional sites have been identified in the Snapper-Grouper Amendment 36 as Spawning Special Management Zones to further protect spawning reef fishes (Figure 2). In the Amendment 14 MPAs and Spawning SMZs, fish in spawning condition have been observed in the area or have been reported anecdotally (SAFMC 2007, SAFMC 2016, Farmer et al. 2017). Regulations for Spawning SMZs became effective 2017.

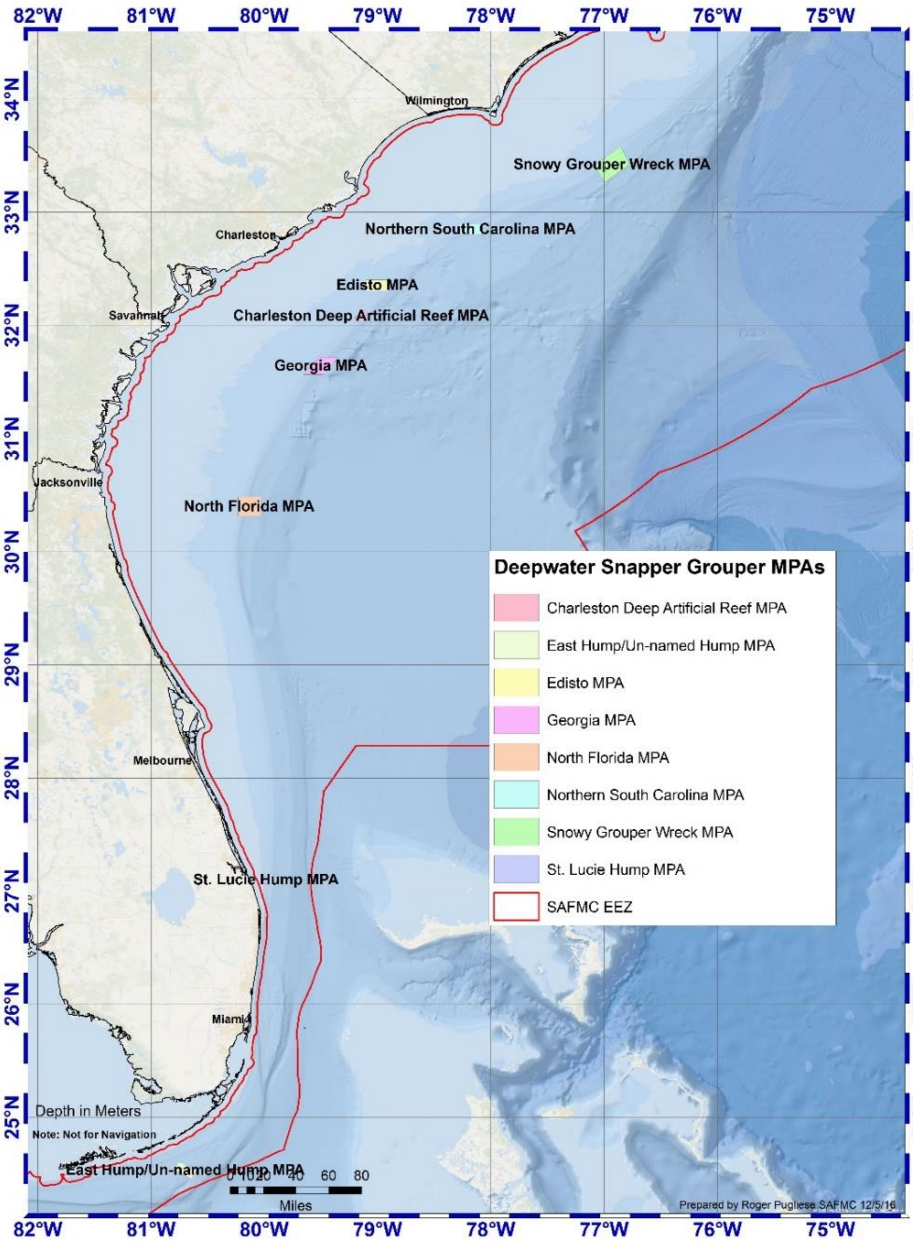

Figure 1. Map of the South Atlantic Region's Deepwater Marine Protected Areas (MPAs) (Source: Roger Pugliese, SAFMC Staff). Link: http://safmc.net/fishery-ecosystem-plan-ii-safmc-managed-areas/.

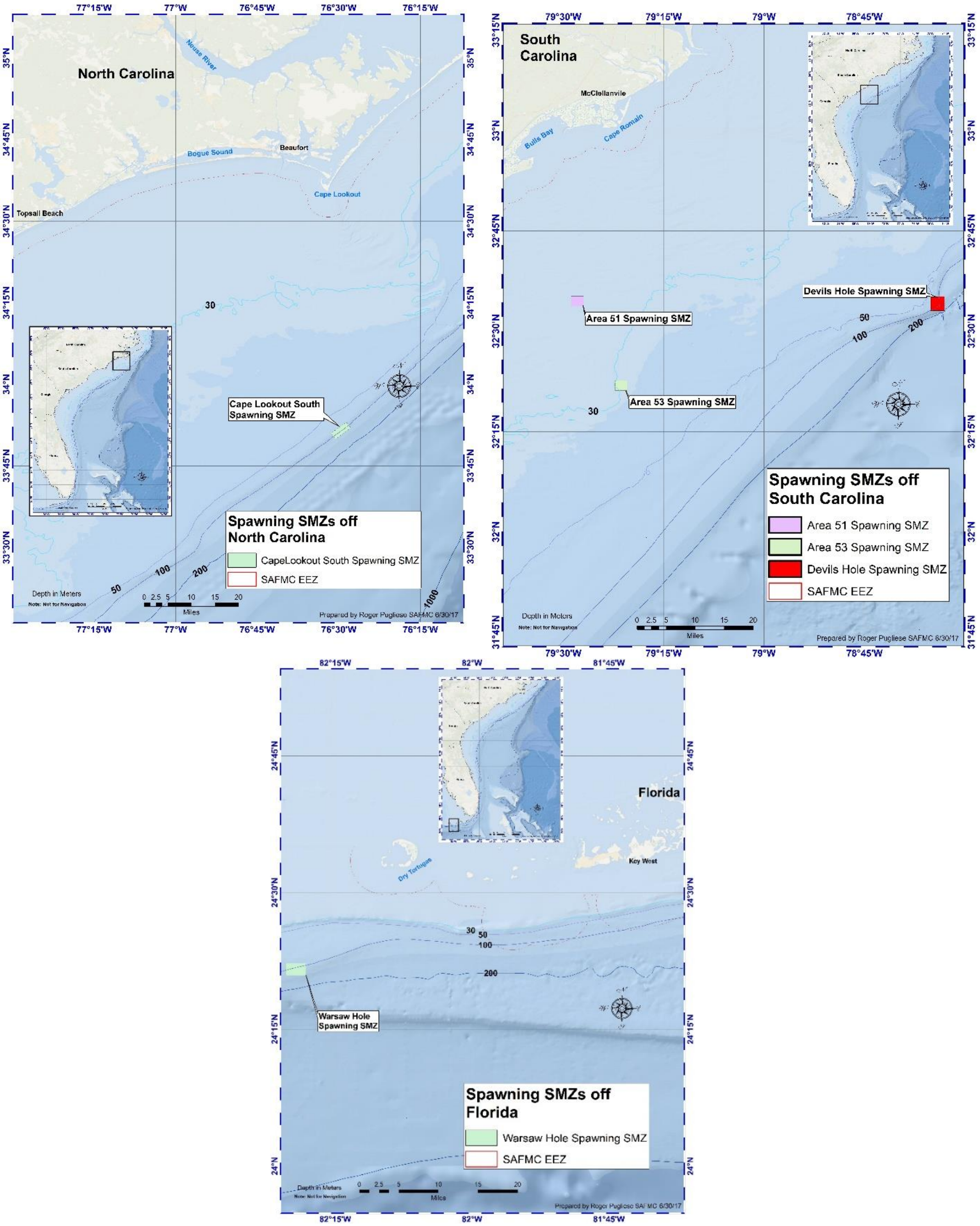

Figure 2. Maps of Spawning Special Management Zones off North Carolina, South Carolina and Florida East Coast (Source: Roger Pugliese, SAFMC, Staff). Link: http://safmc.net/fishery-ecosystem-plan-ii-safmc-managed-areas/

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). 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 use nearshore hardbottom habitats are utilized in recreational, commercial, bait, or aquaria fisheries. Some of the more abundant 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 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 and snappers over the entire survey (Ferro et al. 2005).

A fishery independent baseline assessment was recently completed for the southeast Florida segment of the Florida reef tract consisting of the northern 105 miles of the ~360 mile Florida reef tract. Comparisons of reef fish relative abundance, species assemblage composition, species diversity and in depth analyses including length frequency distributions of eight recreationally and commercially important species were made to fishery independent datasets collected in the Florida Keys and Dry Tortugas portions of the Florida reef tract (Kilfoyle et al. 2018). The report provides a synoptic overview of a five-year dataset that encompasses the collective sampling effort from all partner agencies, and includes survey results from 1,360 sites sampled during the 2012-2016 time period off southeast Florida

(Kilfoyle et al. 2018). Comparisons of data from all subregions of the FRT showed a pattern of increasing percent occurrence and density, and similar Lbar, for most but not all target species from southeast Florida through the Florida Keys and into the Dry Tortugas (Kilfoyle et al. 2018). Likewise, this comparison leads to the finding that many species of fisheries interest are depleted in the northern portion of the FRT as they are in the Florida Keys (Kilfoyle et al. 2018). These results validate assertions that many target species are being locally depleted, with large reproductively mature adults being the prime targets (Kilfoyle et al. 2018). Some species are affected more critically than others due to the combination of slow growth, complex life histories, and behavioral tendencies that have resulted in severely reduced abundance and truncated size class distributions. Protection from exploitation is also playing a part in the regional differences, as demonstrated by higher relative abundance and size of fish observed in data from the Dry Tortugas (Kilfoyle et al. 2018). The southeast Florida fishery-independent dataset does not depict a pristine condition that provides a target for preservation. Rather, the dataset provides a picture of fish assemblages that have already experienced substantial anthropogenic impacts; it provides a critical baseline for management strategies aimed at improvement of valuable and heavily utilized fisheries resources (Kilfoyle et al. 2018).

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

In more temperate regions, the inner shelf has 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 is covered by a vast plain of sand and mud (Newton et al. 1971) underlain at depths of less than a meter (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 (1979), Grimes et al. (1982), Lindquist et al. (1989), Potts and Hulbert (1994), Parker and Dixon (1998), Ojeda et al. (2001), and Whitfield et al. (2014).

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 Shallow Coral Chapter of the Fishery Ecosystem Plan II (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. 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 South Atlantic region most live hardbottom habitats 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 bottom areas from North Carolina to northern Florida (CSA, 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 Shallow Coral Chapter of the Fishery Ecosystem Plan II 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

Miller and Richards (1980) and Sedberry et al. (2005) noted that there is a stable temperature on the outer shelf or the area between 26 and 51 m (85 to 167 ft) where the temperature does not drop below 15°C (59° F). Fisco (2016) identified a linear, often shore-parallel, low-relief feature, present in four of the five reef ecoregions off Florida east coast mostly occurring deeper than 20 m and consisting of hardbottom with sparse benthic assemblages likely due to variable and shifting rubble and sand cover. Some of the hard bottom contained exposed ledges where large fish like Goliath Grouper (*Epinephelus itajara*) and Nurse Shark (*Ginglymostoma cirratum*) may have aggregated. A deep complex of hardbottom ridges occurs off North Palm Beach and Martin ecoregions in depths of 20 m to 35 m (Fisco 2016) consisting of primarily low cover, deep assemblages dominated by small gorgonians, sponges and macroalgae, with denser areas existing near areas of higher relief with large areas of shifting unconsolidated sediments between ridges.

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 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 live hard bottoms may represent the remnants of ancient reefs that existed when the sea level was lowered during the last glacial period. Fish 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 live hard bottom 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 (Schobernd and Sedberry 2009, 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 and Deep Offshore

While there are extensive hardbottom habitats offshore this section focuses on 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 2006; Partyka et al. 2007). 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 1989; Bane et al. 2001; 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 in the South Atlantic 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) and 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 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 hardbottom habitat loss” (Kilfoyle et al. 2013). The impacts of elevated sedimentation from dredging are likely negative across many variables (e.g. coral abundance and condition (Miller et al. 2016 and Fournay and Figuardo 2017)) that indirectly and directly influence fishes (CSA, 2009, Jordan et al. 2010), yet are not addressed by reef mitigation.

Additional detailed information on Artificial Reef Habitat is available on the South Atlantic Habitats Page of the FEP II Dashboard (http://safmc.net/fishery-ecosystem-plan-ii-south-atlantic-habitats/).

Essential Fish Habitat

Live hardbottom habitat constitute essential fish habitat for a high number of species of warm-temperate and tropical species of snappers, groupers, and associated fishes (SAFMC, 1998, SAFMC 2009). Fautin et al. (2011) reported 1200 species of fish from the entire South Atlantic region, including the Florida Keys. Designations of live hardbottom as EFH or as EFH Habitat Areas of Particular Concern for Council managed species in various Fishery Management Plans are presented in the SAFMC EFH User Guide (http://safmc.net/download/SAFMCEFHUsersGuideFinalRevAug17_2.pdf.) Detailed information on designation, spatial distribution, threats and SAFMC EFH Policy Statements can be viewed online on the EFH Page of the FEP II Dashboard (http://safmc.net/fishery-ecosystem-plan-ii-essential-fish-habitat-and-habitat-conservation-essential-fish-habitat/.)

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.

During sampling for the fishery independent baseline assessment off southeast Florida, 1,238,951 fish representing 305 species from 70 families were recorded from 2012 to 2016. (Kilfoyle et al. 2018). Out of those 305 species, 184 were recorded every year. Of the 121 species that were seen less frequently, 50 were small cryptic or nocturnal species, 10 were solitarily occurring elasmobranchs, 10 were large sportfishes, 7 were temperate-associated species, and many of the rest are considered as uncommonly or infrequently encountered. By comparison, there were 347 species recorded in fishery independent reef fish surveys in the Florida Keys and 370 species in the Dry Tortugas during the same 2012-2016 time-frame (Kilfoyle et al. 2018).

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 2009). 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.

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 1986), 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. 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, 1967) for those species under management.

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