Fishery Ecosystem Plan II
Shallow Coral Reef Habitat
Draft
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Shallow Coral Reef Habitat

Description and distribution

Shallow water coral reefs and coral communities exist within the southern geographical areas under Council jurisdiction and in state waters where the Council has authority to designate essential fish habitat (EFH). 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 ecosystem 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 addressed in the Live/Hardbottom Habitat section of this document.

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 the deep water coral Section 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 see Section XXX.

Southeast 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 one 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 et al. 2012) In this area, this habitat also contains perhaps the most abundant population of staghorn coral, *Acropora cervicornis*, in the U.S. South Atlantic (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.

2. Ecological Functions

Coral reefs and hardbottom have many functional roles for species under the Council's 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 and Birkeland (2015).

3. Use

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.

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 55 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 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

In the State of Florida, many state parks and aquatic preserves include marine and/or estuarine waters (Chapter 258, F.S.). FDEP's Division of Recreation and Parks administers the state park system and it is their policy, in part, "to promote the state park system for the use, enjoyment, and benefit of the people of Florida and visitors" and to "conserve the natural values" of the parks (258.037, F.S.). The Florida Legislature established aquatic preserves to "set aside forever" the "state-owned submerged lands in areas which have exceptional biological, aesthetic, and scientific value…for the benefit of future generations" (258.36, F.S.).

When a state park or aquatic preserve's boundary extends into the nearshore marine environment, FDEP manages submerged lands within these boundaries while FWC manages fisheries resources.

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

In 1998, Presidential Executive Order #13089 established the United States Coral Reef Task Force (USCRTF) to lead U.S. efforts to preserve and protect coral reef ecosystems. In 2002, the USCRTF 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 that identify and implement priority actions needed to reduce key threats to coral reef resources. The goals and objectives of a LAS are closely linked to those found in the U.S. National Action Plan to Conserve Coral Reefs, adopted by the USCRTF in 2000.

With guidance from the USCRTF, the FDEP coordinated the formation an LAS known as the Southeast Florida Coral Reef Initiative (SEFCRI) in 2004. SEFCRI is a team of interagency marine resource professionals (state, regional, local, and federal), scientists, and reef resource stakeholders. It is a non-regulatory body coordinated and chaired by FDEP. Their mission is "to develop an effective strategy to preserve and protect southeast Florida's coral reefs and associated reef resources, emphasizing the balance between resource use and protection, in cooperation with all interested parties" (FDEP SEFCRI Charter art. 2).

SEFCRI identified the state waters containing reefs from St. Lucie Inlet in Martin County to the northern boundary of Biscayne National Park as their area of focus because these coral habitats are close to shore and co-exist with intensely urbanized areas that lack a coordinated multi-agency management plan like that of the Florida Keys National Marine Sanctuary. SEFCRI identified issues and threats to southeast Florida's coral reef resources and developed projects and actions to address causes of coral reef degradation and provide a road map for conservation and management.

Between 2013 and 2016, FDEP staff and the SEFCRI team developed and implemented a community planning process known as Our Florida Reefs. Our Florida Reefs brought together local residents, reef users, business owners, and visitors in Miami-Dade, Broward, Palm Beach, and Martin counties to discuss the future of coral reefs in this region. The process was designed to encourage public input from a broad range of community members and reef stakeholders and to identify potential management strategies for southeast Florida's reefs.

The Our Florida Reefs process developed recommended management actions (RMAs) to address issues ranging 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 Our Florida Reef Community Working Groups broadly supported the majority of these RMAs; however, the fishing representatives and larger fishing community strongly opposed the place-based and some other fishing-related RMAs. (Note: During the development and the first approval of the RMAs, the majority of the Our Florida Reefs participant slots reserved for representatives from the fishing community were vacant and not filled until later in the process. This limited the fishing community's engagement and input in the RMAs.)

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 on-going 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).

Coral disease is both a local and global threat to coral reef ecosystems. Disease has been identified as the main culprit for reductions in Acropora abundance in the Caribbean, including Florida (Precht and Miller 2007). Loss of Acropora, a major reef-building coral, reduced the complex structure of reefs. In the 1980s and 1990s, diseases such as white-band disease led to declines in Acropora abundance by nearly 100% in many areas (Precht and Miller 2007). Currently, a white-plague disease outbreak is affecting at least 13 coral species in southeast Florida, with reductions of some species to less than 3% or their initial population densities (Precht et al. 2016). This current disease outbreak has been called "one of the most lethal ever recorded on a contemporary reef" (Precht et al. 2016).

Disease also affects species that help maintain the reefs, such as long-spine sea urchins. In 1983, a waterborne pathogen caused mass mortality amongst long-spine sea urchin (*Diadema antillarum*), which was one of the main herbivores on Caribbean reefs (Lessios 2016). On average, this mass mortality event reduced the abundance of this species by 98% throughout the Caribbean (Lessios 2016).

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. In recent years, harvest of parrotfish in the Florida Keys has occurred at low-levels (approximately 3,000 fish per year) and has been stable (M. Smith, personal communication, July 3, 2017). 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 3 Threats). 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).

6.– Summary 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. Barbour et al, 2011 developed a model which predicted an annual exploitation rate between 35 and 65% would be required to cause recruitment overfishing on lionfish populations. Research is needed to further 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). Usseglio et al. 2017, has developed a framework that allows managers to predict the removal effort required to achieve specific targets (represented as the percent of lionfish remaining on the reef). Green et al. 2014 found that reductions in density of 25-92%, depending on the reef, were required to suppress lionfish below levels predicted to overconsume prey. On reefs where lionfish were kept below threshold densities, native prey fish biomass increased by 50 70%. Additional research may be needed to refine (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.

Habitat and Use Characterization of Reefs:

- 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.

Summary Management Recommendations:

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

- Mitigate key habitat issues by implementing focused removal of submerged trap debris from especially vulnerable habitats such as reefs and hardbottom where trap debris density is high (Uhrin et al 2014)

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

- 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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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).

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 1. 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.

2. Abundance and Trends of coral populations

Scleractinians

Southeast Florida

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).

Florida Keys

Following major losses to disease and bleaching throughout the past several decades, coral reefs are in a state of transition in the Florida Keys (FLK). 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 (FWC 2016). 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

Southeast Florida

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).

Florida Keys

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 (Fox et al. 2003, Stobart et al. 2005).

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 relativeimportance 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^{o}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).

Coral disease is both a local and global threat to coral reef ecosystems. Disease has been identified as the main culprit for reductions in *Acropora* abundance in the Caribbean, including Florida (Precht and Miller 2007). Loss of *Acropora*, a major reef-building coral, reduced the complex structure of reefs. In the 1980s and 1990s, diseases such as white-band disease led to declines in *Acropora* abundance by nearly 100% in many areas (Precht and Miller 2007). Currently, a white-plague disease outbreak is affecting at least 13 coral species in southeast Florida, with reductions of some species to less than 3% or their initial population densities (Precht et al. 2016). This current disease outbreak has been called “one of the most lethal ever recorded on a contemporary reef” (Precht et al. 2016).

Disease also affects species that help maintain the reefs, such as long-spine sea urchins. In 1983, a waterborne pathogen caused mass mortality amongst long-spine sea urchin (*Diadema antillarum*), which was one of the main herbivores on Caribbean reefs (Lessios 2016). On average, this mass mortality event reduced the abundance of this species by 98% throughout the Caribbean (Lessios 2016).

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.

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. Unlike scleractinians, some octocorals are also subject to harvest (Miller et al. 2014).

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.

5. Summary Recommendations

Coral Knowledge Gaps:

- Efficacy and improvement of coral (proactive) restoration strategies (Hunt and 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.
- Efficacy of disease remediation

Coral Summary Management Recommendations

- Coral population enhancement/gardening (Acropora Recovery Plan and Our Florida Reefs Recommended Management Action (OFR-RMA))
- Install mooring balls in sensitive areas (Florida Pillar Coral Aciton Plan; OFR-RMA)
- Enhance 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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