A Species Action Plan for the Pillar Coral *Dendrogyra cylindrus*

Final Draft
November 1, 2013

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Cover photograph by the Florida Fish and Wildlife Conservation Commission

Recommended citation:
Florida Fish and Wildlife Conservation Commission. 2013. A species action plan for the pillar coral. Tallahassee, Florida.

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) developed this plan in response to the determination that the pillar coral (*Dendrogyra cylindrus*) be recommended for listing as Threatened on the Florida Endangered and Threatened Species List. Although the pillar coral is widely distributed on coral reefs throughout the Caribbean Sea and tropical Western Atlantic, the species is considered rare on many reefs. In Florida, its occurrence is uncommon and its population size is small and relatively unknown. Because the pillar coral is vulnerable to many threats including climate change; ocean acidification; coral bleaching; disease; hurricanes; sedimentation; poor water quality; coastal construction activities; and physical damage caused by boats, anchors, and abandoned fishing gear, its population has likely been steadily decreasing in Florida. In addition to anthropogenic threats, the pillar coral is constrained by its own reproductive biology. A broadcast spawning species, pillar coral's successful reproduction has been extremely limited, as evidenced by a lack of juvenile corals observed in Florida. As a result, the Biological Status Review report concluded that the pillar coral met several criteria that warrant listing it as a Threatened species. These criteria include: 1) a 30% projected decline in population size within the next 100 years, 2) a restricted area of occupancy less than 2,000 km^2 (772mi^2), 3) the current area of occupancy is highly fragmented and all areas are subjected to threats, and 4) a continuing decline of mature individuals, which may constitute 1 subpopulation that is less than 1,000 individuals in size. This species is also a candidate for the Federal Endangered listing under the Endangered Species Act. The FWC Marine Life Rule (Rule 68B-42.009, Florida Administrative Code [F.A.C.]) prohibits the take, destruction, and sale of marine corals, sea fans, and encrusting octocorals. While this rule prohibits intentional take and harvest of pillar corals, it does not guard against the many threats that are slowly diminishing the population.

The goal of this plan is to improve the status of the species so that a population continues to exist within its historical range in Florida. Objectives of this plan include stabilizing or increasing the existing population, the current area of occupancy, and the number of sexually mature individuals; and evaluating the reproductive potential of the population over the next decade. In order to meet these objectives, conservation actions must focus on protecting the overall coral reef habitat. This includes management actions that reduce physical impacts to reef habitat from offshore construction activities and anchor damage (e.g., installation of mooring buoys) or prevent entanglement or destruction by fishing gear. Research priorities are to identify the current size and status of the population, assess genetic diversity, and determine reproductive potential. Restoration activities include rearing juvenile pillar corals in nurseries through active propagation or through the collection of corals of opportunity. Restoration activities should also include the enhancement of beneficial organisms that maintain optimal conditions on coral reefs (e.g., long-spined urchins [*Diadema antillarum*]). Outreach and education programs can continue to promote the benefits of the Coral Reef Protection Act and new programs should be developed that actively encourage the public to report the location and condition of pillar corals. These management, research, and education priorities can assist in meeting the goals and objectives set forth in this plan.

This plan details the actions necessary to improve the conservation status of the pillar coral. A summary of this plan will be included in the Imperiled Species Management Plan (ISMP), in

satisfaction of the management plan requirements in Chapter 68A-27, F.A.C., Rules Relating to Endangered and Threatened Species. The ISMP will address comprehensive management needs for 60 of Florida's imperiled species and will include an implementation plan, rule recommendations, permitting standards and exempt activities, anticipated economic, ecological, and social impacts, projected costs of implementation and identification of funding sources, and a revision schedule. The imperiled species management planning process relies heavily on stakeholder input and partner support. This level of involvement and support is also critical to the successful implementation of the ISMP. Any significant changes to this plan will be made with the continued involvement of stakeholders.

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GLOSSARY OF TERMS AND ACRONYMS

Acroporid: Corals of the family Acroporidae, such as *Acropora palmata* and *Acropora cervicornis.*

Allee effect: Anything that causes a reduction in population growth when said population occurs at a low density (e.g., broadcast spawning by nature would induce an Allee effect if the pillar coral's sexually mature individuals in Florida were too far apart from each other).

Anomalous: Deviating from what is standard, normal, or expected.

Aragonite: A carbonate mineral, 1 of the 2 common, naturally occurring, crystal forms of calcium carbonate, $CaCO_3$ (the other form being the mineral calcite). It is formed by biological and physical processes, including precipitation from marine and freshwater environments.

Area of Occupancy: The area within its extent of occurrence (see Extent of Occurrence), which is occupied by a taxon, excluding cases of vagrancy. This reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats (as defined by the International Union for Conservation of Nature [IUCN]).

Autotrophic: Nutrition derived from self-synthesized organic compounds.

Bioerosion: Erosion of hard ocean substrates by living organisms.

Bleaching: A stress response by the coral host in which symbiotic zooxanthellae are expelled.

BRG: Biological review group, a group of taxa experts convened to assess the biological status of taxa using criteria specified in Rule 68A-27, Florida Administrative Code, and following the protocols in the Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0) and Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1).

Broadcast Spawner: A method of sexual reproduction employed by some species of scleractinian corals whereby gametes are simultaneously or sequentially released into the water column, where fertilization and larval development occur.

BSR: Biological status review report, the summary of the biological review group's findings. Includes a Florida Fish and Wildlife Conservation Commission (FWC) staff recommendation on whether or not the species status meets the listing criteria in Rule 68A-27.001, Florida Administrative Code. These criteria, based on IUCN criteria and IUCN guidelines, are used to help decide if a species should be added or removed from the Florida Endangered and Threatened Species List. In addition, FWC staff may provide within the report a biologically justified opinion that differs from the criteria-based finding.

Cnidarian: Any of various invertebrate animals of the phylum Cnidaria, characterized by a radially symmetrical body with a saclike internal cavity, and including the jellyfishes, hydras, sea anemones, and corals.

CO_2: Carbon dioxide, a gas at standard temperature and pressure that is involved in the carbon cycle, ocean acidification, and climate change. Specifically, large concentrations act to warm the earth's surface, and acidify ocean waters by dissolving and dissociating to carbonic acid.

Coral Polyp: A cnidarian in its sedentary stage. Polyps have hollow, tube-shaped bodies with a central mouth on top surrounded by tentacles. Some cnidarians, such as corals and sea anemones, only exist as polyps after their larval stage, while others turn into medusas as adults or lack a polyp stage completely.

Corals of Opportunity: Unattached corals or recent fragments created by natural (e.g., storms or waves) or anthropogenic (e.g., boat strikes, diver kicks) forces.

Corallite: The skeleton of a coral polyp.

Corallivore: Any animal that eats coral polyps.

CRPA: Coral Reef Protection Act enacted by the State of Florida legislature in 2009, which aims to increase protection of coral reef resources on sovereign submerged lands off the coasts of Martin, Palm Beach, Broward, Miami-Dade, and Monroe counties.

Demographic Survey: An ecological survey which aims to determine specific population parameters (e.g., mortality rate, growth rate, size structure, recruitment rate), which occurs at fixed sites visited over time or via synoptic sampling.

DEP: Florida Department of Environmental Protection

Dinoflagellate: Flagellated protist, for corals, dinoflagellates are autotrophic organisms involved in a mutually-beneficial symbiotic relationship.

El Niño/La Niña–Southern Oscillation: A band of anomalously warm ocean water temperatures that occasionally develops off the western coast of South America and can cause climatic changes across the Pacific Ocean.

Extent of Occurrence: The geographic area encompassing all observations of individuals of a species, including intervening areas of unoccupied habitat. Synonymous with range. See also Area of Occupancy (as defined by IUCN).

Fecundity: Potential reproductive capacity of an individual or population.

F.A.C.: Florida Administrative Code. The Department of State's Administrative Code, Register and Laws Section is the filing point for rules promulgated by state regulatory agencies. Agency rulemaking is governed by Chapter 120, Florida Statutes, the Administrative Procedures Act. Rules are published in the Florida Administrative Code.

FKNMS: Florida Keys National Marine Sanctuary, created in 1990, protects 9,946 km^2 (2,900 nautical mi^2) of waters surrounding the Florida Keys, from south of Miami to the Dry Tortugas, excluding Dry Tortugas National Park. Administered by the National Oceanic and Atmospheric Administration (NOAA) and jointly managed with the State of Florida.

FKNMS Advisory Council: Sanctuary advisory councils are community-based advisory groups established to provide advice and recommendations to the superintendents of the national marine sanctuaries.

FRRP: Florida Reef Resilience Program, managed by The Nature Conservancy and based in the Florida Keys, seeks to develop strategies to improve the health of Florida's reefs and enhance the sustainability of reef-dependent commercial enterprises and recreational activities.

FRT: Florida Reef Tract, a reef system stretching 567 km (358 mi) from Martin County to the Dry Tortugas.

F.S.: Florida Statute

FWC: The Florida Fish and Wildlife Conservation Commission, the state agency constitutionally mandated to protect and manage Florida's native wildlife species.

FWRI: The Florida Fish and Wildlife Research Institute, the fish and wildlife research branch of the FWC.

Gametes: Sex cells, or eggs and sperm, that fuse during fertilization.

Gametogenesis: The process by which cells undergo meiosis to form gametes.

Gemmae: Modified buds of tissue that detach from the parent to form new colonies.

Gonochoric: Possessing at least 2 distinct sexes.

Groundtruthing: The process of gathering data to test the accuracy of a scientific model.

Hard corals: Hermatypic corals (see "hermatypic" below).

Hardbottom: Low-relief benthic habitat the shorewhich houses many coral reef species.

Hermatypic: A coral capable of depositing calcium carbonate (aragonite) to form reef structure.

Heterotrophic: Nutrition derived from externally-obtained organic compounds that are unable to be synthesized.

In situ: "In place," or for corals, research that is conducted underwater on a reef, as opposed to in a mesocosm (aquarium).

ISMP: Imperiled Species Management Plan

IUCN: International Union for Conservation of Nature, a professional global conservation network

IUCN Red List (IUCN Red List of Threatened Species): An objective, global approach for evaluating the conservation status of plant and animal species, the goals of which are to: Identify and document those species most in need of conservation attention if global extinction rates are to be reduced; and provide a global index of the state of change of biodiversity.

Meandroid: Describes a coral colony composed of corallites forming linear series or groups of series within the same ridges that results in a "whirling" pattern.

Meiosis: Cell division needed for sexual reproduction.

Mote: Mote Marine Laboratory, a private marine research laboratory and nonprofit organization in Sarasota, Florida.

Mounding Species: Slow growing corals that have mound or boulder growth forms.

Multi-Satellite Altimetry: Combining several satellites to conduct altimetry (height) measurements, which are determined by determining the time taken by a radar pulse to travel from satellite antennas to the surface and back to the satellite receiver.

Mutualism: A symbiotic relationship in which both organisms benefit.

NMFS: National Marine Fisheries Service, a unit of NOAA

NOAA: National Oceanographic and Atmospheric Association

NSUOC: Nova Southeastern Oceanographic Center, a division of Nova Southeastern University, located in Dania Beach, Florida and home of the National Coral Reef Institute.

Octocoral: Also known as Alcyonaria or soft corals, they are comprised of soft corals, sea fans, sea whips, and sea plumes.

Patchy Distribution: A population which is spatially distributed in a clumped fashion

Propagation: For corals, the process of creating fragments or larval recruits that are then reared in a nursery setting.

PSU: Pennsylvania State University

Reef Accretion: The process by which calcifying organisms develop a 3-dimensional reef structure.

Relict Population: A small isolated population disconnected from the greater population (i.e., from pillar corals in the Caribbean) that is no longer contributing recruits and unable to sustain itself.

Resilience: The ability of a system to absorb disturbances and bounce back.

Scleractinian: A hard coral of the order Scleractinia

SEFCRI: Southeast Florida Coral Reef Initiative, an interagency and non-agency team of marine resource professionals, scientists, resources users, and other stakeholders.

SEFCRI Region: The northern third of the FRT, encompassing the St Lucie Inlet of Martin County southward to the northern border of Biscayne National Park.

Sovereign submerged lands: Natural or historically submerged lands owned by the State of Florida, either by right of statehood or by deed or grants.

Spur and Groove Reefs: Bank reef type composed of ridges of corals (spurs) separated by sandy bottom channels (grooves).

SWG: State Wildlife Grant

Synoptic Survey: An ecological survey of specified population parameters (e.g., size structure) that occurs at stratified, random locations, similar to a stock assessment.

Take: As defined in Rule 68A-27.001(4), F.A.C. “To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in such conduct.”

TNC: The Nature Conservancy

Substratum: Underlying hard surface on which corals settle, attach, and grow.

Symbiotic: a relationship between 2 organisms that may or may not be beneficial, or exert no influence on one organism.

Viable Population: A self-sustaining population capable of sexually reproducing and contributing recruits.

Zooxanthellae: Symbiotic dinoflagellate algae that live in coral tissue and give coral their color and most or all of their energy requirement.

INTRODUCTION

This plan was developed in response to a determination by the Florida Fish and Wildlife Conservation Commission (FWC) that the pillar coral (*Dendrogyra cylindrus*) be recommended for listing as Threatened in Florida. This plan was developed through the cooperative efforts of FWC staff, researchers, and stakeholders.

Biological Background

The pillar coral is a member of the family Meandrinidae (Linnaeus 1758). The genus *Dendrogyra* (Ehrenberg 1834) contains only 1 species. Corallites are meandroid with a "whirling" pillar growth pattern that grow in clumps of columns. The polyps tend to be emergent in the daytime giving a "fuzzy" appearance (Figure 1) to the brownish, tan, or gray colonies.

Pillar corals are hermatypic, gonochoric, broadcast spawners. Additionally, they can reproduce through asexual fragmentation and gemmae (Weil et al. 2000). Colonies are found on flat or gently sloping back-reef and fore-reef environments from 1 to 25 m (3 to 82 ft) deep, most commonly from 5 to 15 m (16 to 50 ft) (Goreau and Wells 1967, Carpenter et al. 2008). Colonies rarely occur in extremely exposed locations. The species can be locally abundant in shallower, well-circulated areas due to propagation by fragmentation (i.e., the species' dispersion can be defined as *patchy distribution*), and relatively small (i.e., < 1 m [3.3 ft] in diameter) colonies that are not the result of partial colony mortality are seldom observed. This species is resistant to heavy wave surge and can substantially contribute to reef accretion in high-density areas; however, colonies will occasionally topple due to bioerosion at the bases. Upper portions of the colonies generally survive, and the colony produces multiple new pillars which continue to grow upward (K. Lunz, Florida Fish and Wildlife Research Institute [FWRI], personal communication). This species feeds heterotrophically on small zooplankton and also receives energy from its mutuallistic autotrophic zooxanthellae. Corallivorous fishes and snails are known to prey on it.

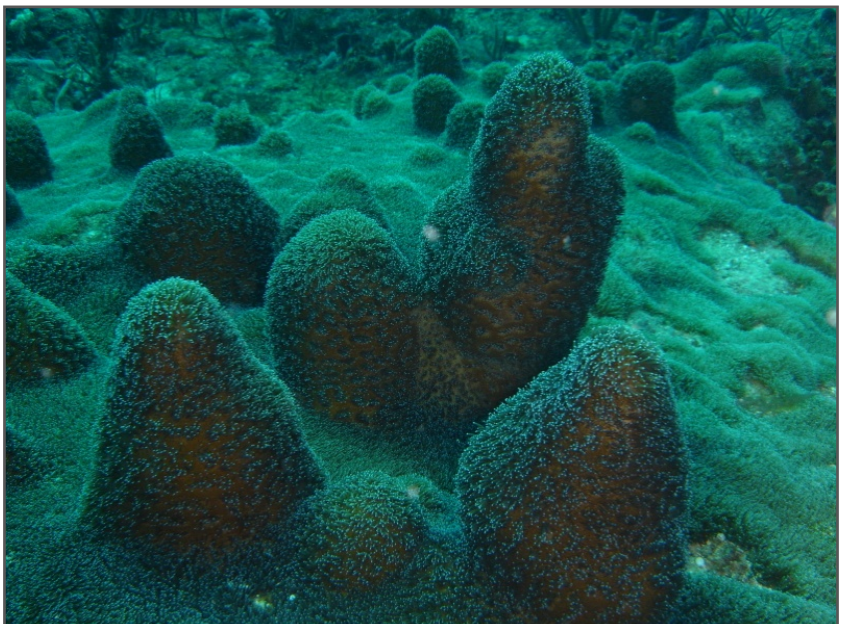

Figure 1. Pillar coral colony. Emergent "fuzzy" polyps are evident in this photo. FWC photograph.

The age of first maturity of most reef building corals is typically 3 to 8 years (Wallace 1999). As such, the average age of mature pillar corals is likely greater than 8 years. Pillar corals are known to spawn approximately 1 to 3 days after each August full moon (Szmant 1986, Neely et al. 2013). Total longevity is not known, but it likely to be more than 10 years and may be as long as

100 to 200 years. Reports from Curacao indicate that pillar corals have an average mean linear growth of 8 mm (0.31 in) annually (R. Bak, Netherlands Institute for Sea Research, University of Amsterdam, personal communication). Annual growth in the northern Keys has been reported to range between 14.3 mm (0.56 in) and 23 mm (0.9 in) per year (Hudson et al. 1997).

Pillar coral are widely distributed throughout coral reefs of the Caribbean Sea and the subtropical and tropical Western Atlantic, ranging from the northern coast of South America (Colombia) to southern Florida (Smith 1971, Veron 2000) (Figure 2). This species is reported to have been eliminated from Panama, even though recent fossils (< 1,000 years old) have been found. Although conspicuous, the species has been described as uncommon or rare on many Caribbean reefs (Szmant 1986).Within Florida, reports of geographic distribution range from Palm Beach County to the Dry Tortugas (Figure 3). This species is most frequently encountered at high-relief spur and groove reefs of the Florida Keys, and very rarely on mid-channel patch reefs and deep fore-reefs (M. Chiappone, Nova Southeastern Oceanographic Center [NSUOC], unpublished data; see Coral Reef Quick Looks). Most colonies are fused solidly to the underlying substratum. Pillar corals also occur in patch reef and hardbottom habitats.

Figure 2. *Dendrogyra cylindrus* global distribution. Map source: International Union for Conservation of Nature (IUCN).

No specific data to discern population trends are available, but monitoring programs have reported low colony density and infrequent encounter rates (M. Chiappone, unpublished data; R. Ruzicka, FWRI, unpublished data). The species reportedly has low juvenile survivorship throughout its range (Aronson et al. 2008). No juvenile pillar corals have been identified in surveys of Florida Keys reefs from 1999 through 2009 (M. Chiappone, personal communication). A lack of juvenile corals can be attributed to fertilization failure, recruitment failure (whereby larval corals do not settle on substrate), or low post-recruitment survival. Florida's pillar corals are thought to be a relict population, as historical accounts suggest it was originally more abundant throughout the Florida Reef Tract (FRT) (Colin 1978).

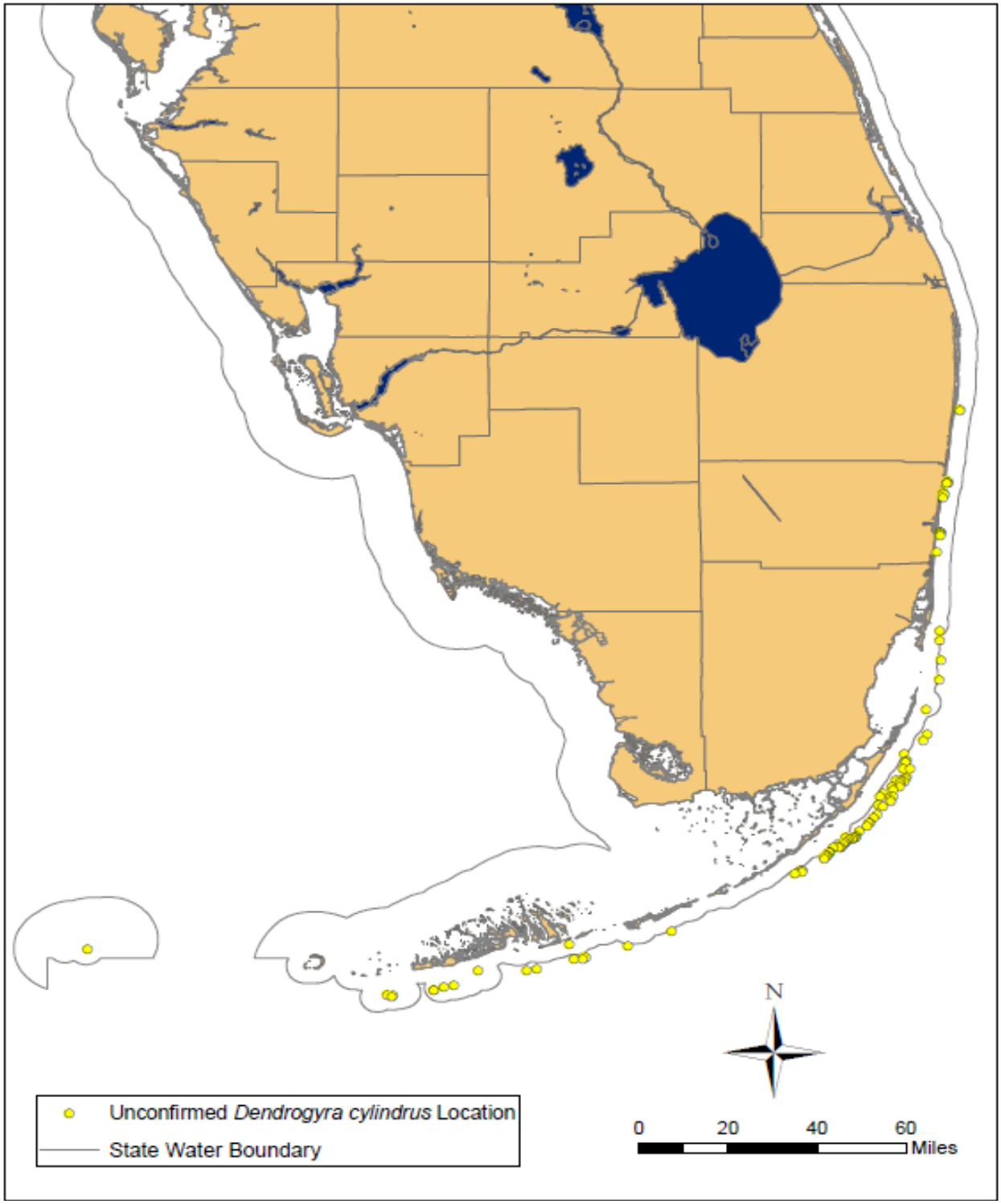

Figure 3. Overview of southeastern Florida showing reported, but unconfirmed, pillar coral colony locations. Map provided by Nicole D'Antonio, NSUOC.

A major threat to corals is global climate change, in particular, temperature extremes that lead to bleaching and increased susceptibility to disease, ocean acidification, and severe El Niño/La Niña-Southern Oscillation events and storms. Pillar coral is susceptible to bleaching, a general stress response process in which corals expel their symbiotic zooxanthellae, which can cause mortality. Bleaching is induced by anomalous water temperatures, low dissolved oxygen levels, excessive sedimentation, and high pollutant or nutrient levels. Due to this species' sensitivity to bleaching, disease, and extensive reduction of coral reef habitat due to a combination of threats, population decline may be inferred by both the percentage of destroyed reefs and critical reefs that are likely to be destroyed within 20 years (Wilkinson 2004). Its threat susceptibility increases the likelihood of being lost within 1 generation in the future from reefs at a critical stage. In the event of extreme weather (e.g., hurricanes) it is assumed that most mature individuals will be removed from a destroyed reef. This has the potential to decimate the entire population. Therefore, the estimated habitat degradation and loss of 38% over 3 generations is the best inference of population reduction (Aronson et al. 2008). Although the pillar coral may propagate through fragmentation, due to reproductive pattern (gonochoric), low juvenile survivorship, and the hypothesized, frequent occurrence of clones in localized areas (highly clonal populations are likely to have less fertilization and lower larval production), this species may be slow to recover after disturbance events.

Taxonomic distinctness also raises the conservation priority, as the genus *Dendrogyra* contains a single species. When contributions to the gene pool of that genus are considered, a genus with a single species has a higher conservation value than a genus with multiple species (Clarke and Warwick 1998, 2001).

No population viability analyses exist for Florida pillar corals to date, and its current population size is unknown.

Conservation History

The majority of the pillar coral in Florida exist within the Florida Keys National Marine Sanctuary (FKNMS) (Figure 4). In 1990, FKNMS was designated 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 km^2 (2,900 nautical mi^2) 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).

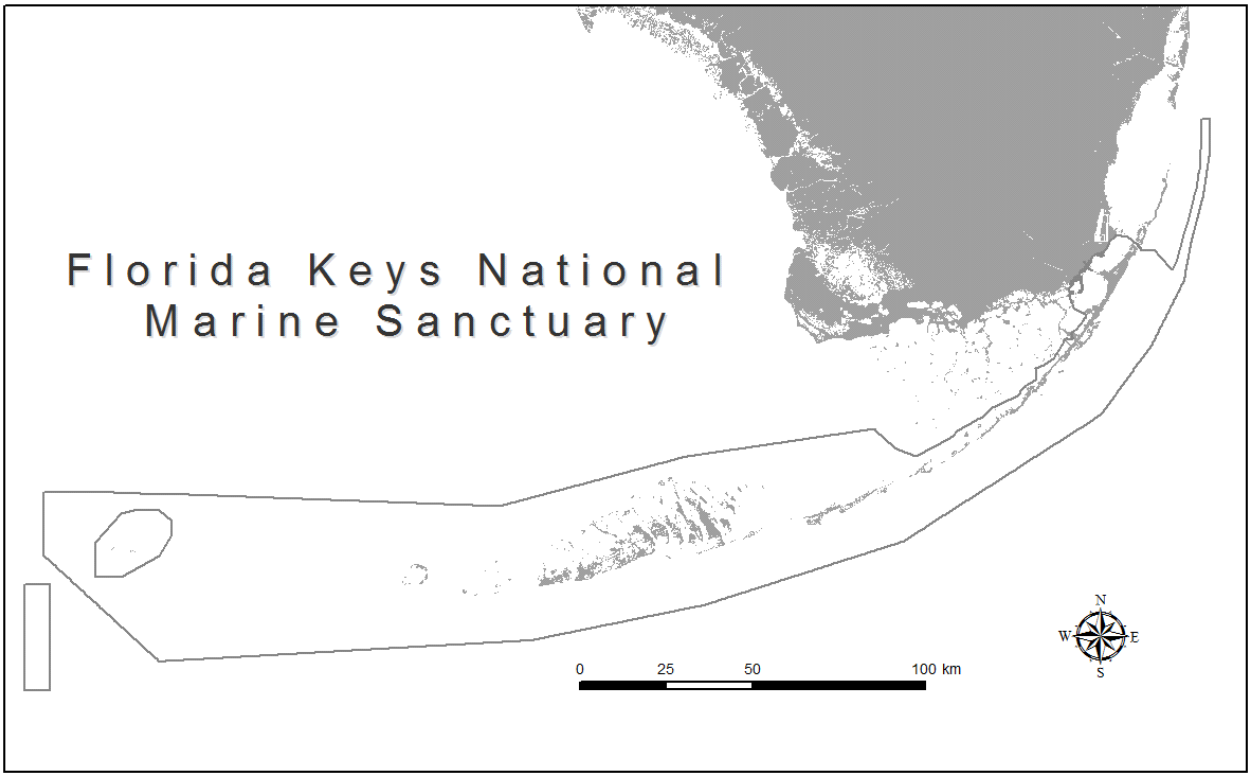

Figure 4. Overview of the Florida Keys National Marine Sanctuary. Map provided by FWRI.

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 is intended to provide protection for corals, including the pillar coral, and its habitat throughout its range from injury or destruction caused by commercial and recreational vessels that are operated, anchored, or moored in a reckless or wanton manner.

The CRPA authorizes the Florida Department of Environmental Protection (DEP), as the state's lead trustee for coral reef resources, to protect coral reefs through timely and efficient assessment and recovery of coral reefs from damage. To carry out the intent of the Act, the DEP also has the authority to enter into delegation agreements with state and local government agencies with coral reefs in their jurisdictions.

The CRPA is enforced by the DEP's Coral Reef Conservation Program but not by any other state or local law enforcement entities. The CRPA includes language that would provide for other law enforcement entities to support enforcement of the Act by entering into an agreement with the DEP; at this time, no other law enforcement entities have entered into such an agreement.

The FWC's Marine Life Rule (Rule 68B-42.009, F.A.C.) prohibits the take, destruction, and sale of marine corals, sea fans, and encrusting octocorals. This rule, enforced by FWC officers, prohibits intentional take and harvest of coral species, including the pillar coral.

Threats and Recommended Listing Status

Threats

Pillar corals are rare in Florida and vulnerable to many threats with disease a major contributor to tissue mortality.. The pillar coral is highly susceptible to white plague disease (Bruckner and Bruckner 1997, Porter et al. 2001, Santavy et al. 2001, Miller et al. 2003, Weil 2004), protozoan parasites (Upton and Peters 1986; E. Peters, George Mason University, personal communication), and other unknown or undescribed conditions. For example, the FWC is currently collaborating with the University of South Carolina to identify a recently observed condition affecting pillar corals in the Upper Keys (Figure 5). Other threats include hurricanes, which can topple colonies (Rogers et al. 1991), predation by damselfish, physical abrasion and damage caused by collisions with boats or anchors, damage from abandoned lobster traps, bioerosion by sponges, and sedimentation associated with dredging or coastal construction activities (Bak and Elgershuizen 1976). Prior to its ban, collection of coral for curios was once widespread off the coast of Florida (Colin 1978). Throughout pillar coral's range in Florida, direct impacts to reef habitat from permitted offshore construction projects (e.g., beach nourishment, port dredging, and cable deployments) can impact known colonies and critical habitat for this species.

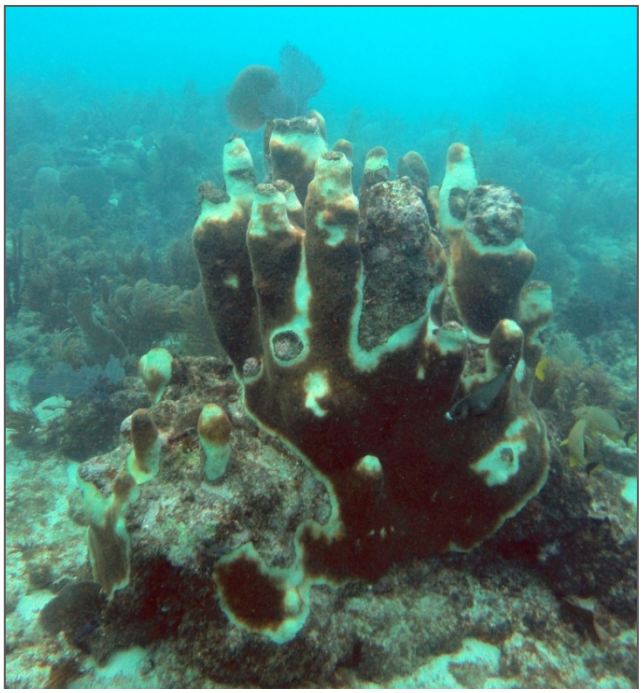

Figure 5**.** A pillar coral colony suffering extensive tissue loss from an unidentified disease**.** FWC photograph.

Impacts from climate change have been identified as one of the greatest global threats to coral reef ecosystems. As temperatures rise, outbreaks of mass bleaching and infectious disease are likely to be more frequent. Additionally, carbon dioxide (CO_2) absorbed into the ocean from the atmosphere has already begun to reduce calcification rates in reef-building and reef-associated organisms by altering seawater chemistry through decreases in pH (ocean acidification). In the long term, the impacts of rising temperatures and ocean acidification could challenge the effectiveness of other management efforts.

Climate change poses direct threats to pillar corals and coral reefs in general. Climate change triggers prolonged periods of high surface temperatures in the ocean, which induce mass-bleaching events. Elevated water temperatures stress corals, leading them to expel their zooxanthellae (the symbiotic algae that live inside the coral tissue and give corals their color) in a process referred to as coral bleaching (Glynn 1996). During a bleaching event, after corals lose their zooxanthellae, the white of the coral skeleton becomes readily visible as it shows through the translucent coral tissue. Without these symbionts, the coral slowly starves. Although small-scale bleaching episodes were noted during the last century, in the 1980s, regional and global

mass-bleaching events increased in regularity. Mass-bleaching events, like the one from 1997 to 1998, affected numerous reefs worldwide and caused catastrophic mortality. Many scientists now believe that the greatest threat to the long-term survival of coral reefs is warming sea temperatures and the increased potential of coral bleaching (Hoegh-Guldberg et al. 2007). Debilitating effects of bleaching include reduced skeletal growth and reproductive activity, a lowered capacity to shed sediments, and a decreased resistance to invasion by competing species and diseases (Glynn 1996). Prolonged bleaching can cause partial or total colony death. If the bleaching is not too severe, and stressful conditions decrease after a short time, affected colonies can regain their symbiotic algae within several weeks or months (Glynn 1996). However, prolonged bleaching can leave corals in a weakened condition, increasing their susceptibility to disease (Muller et al. 2008).

Another threat posed by climate change is ocean acidification. Ocean acidification leads to a reduction in coral calcification. Normally, the oceans have the capacity to absorb ~30% of the CO_2 contained in the atmosphere, but the rising amount of CO_2 emissions has surpassed the limit of what oceans normally absorb, changing ocean chemistry and making them more acidic. For corals to grow, they require appropriate amounts of aragonite saturation, which is altered by the amount of CO_2 absorbed by the ocean. Aragonite saturation is decreasing globally, due to ocean acidification. Prior to the Industrial Revolution, around 98% of coral reefs were surrounded by waters in an adequate or optimal state of aragonite saturation. This has rapidly changed with increasing ocean acidification. Under present and future ocean acidification scenarios, corals will grow more slowly and produce weaker skeletons. This makes them more vulnerable to bioerosion and susceptible to breakage during hurricanes and storms. Under optimal scenarios, net reef accretion occurs on the healthiest reefs. Under more acidic conditions, reefs may not be able to overcome normal rates of bioerosion and there will be net loss in reef framework. The potential effects of ocean acidification on fertilization and settlement (likely due to ocean acidification-induced changes in reef cues rather than physiological effects of altered pH) may be more profound from a species/population stance than merely a reduction in calcification potential (Albright et al. 2010, Albright et al. 2011, Doropoulos et al. 2012, Webster et al. 2012).

Locally or regionally, changes in storm frequency, intensity, and pattern may directly impact coral reef ecosystems, and changes in rainfall may affect sedimentation, salinity, and nutrient and pollutant inputs (Rogers 1990). Additionally, the frequency of documented coral disease outbreaks has dramatically risen over the last several decades. An increase in disease prevalence has been connected to deteriorating water quality and increased sea surface temperatures (Peters 1997, Bruno et al. 2007).

Sea level rise may also affect the growth of coral reefs. As a low-elevation coastal region, sea level rise is of great concern for southeastern Florida. Measured (multi-satellite altimetry) global sea level rise averaged 2.4 mm (0.09 in) per year between 1992 and 2003 (Trimble et al. 2006). Wanless (1989) reported that since 1932, sea level rise in south Florida has accelerated, and more recent rates are 2 to 4 mm (0.08 to 0.16 in) per year. Others estimate probable rates of 15 ± 3 mm (0.59 ± 0.12 in) per year over the next century (Buddemeier and Smith 1988). These rates could directly impact corals by shifting them to a deeper, lower light position in the water column. However, secondary impacts, such as increased sedimentation and turbidity from coastal flooding and erosion, could degrade water quality and inhibit reef growth.

Many tropical reefs live near their lethal temperature limits (Edwards 1995). High-latitude reefs in southeastern Florida have likely adapted to lower temperatures, but their ability to adapt to higher temperatures is unknown. El Niño events can cause increases in water temperature on an annual scale, and increases on a longer scale are widely predicted by scientists. In general, exposure for only a few days to temperatures of 3 to 4 degrees Celsius above normal summer ambient maxima, or for several weeks to elevations of only 1 to 2 degrees Celsius above maxima, can cause coral bleaching. Recovery depends on exposure time and magnitude of elevation. Coral bleaching reduces growth and impairs reproduction, and even sub-lethal bleaching temperature rise can affect growth, recovery from injury, and reproduction (Goreau and MacFarlane 1990, Leder et al. 1991, Meesters and Bak 1993, Szmant and Gassman 1990, Baird and Marshall 2002).

The pillar coral's life history traits and biology also threaten its local persistence. Because the population is so small and fragmented across the FRT, reproduction is constrained by an Allee effect. The pillar coral is a gonochoristic broadcast spawner, with separate male and female colonies. The pillar coral may be experiencing recruitment failure in Florida because there is a low probability that gametes of resident colonies are successfully fertilizing in the water column and then settling to produce new individuals (Szmant 1986; M. Chiappone, unpublished data). There is no evidence that substantiates the recruitment of new individuals (e.g., recently settled or juvenile corals) in the Florida Keys. Evidence strongly suggests that the pillar coral is currently undergoing recruitment failure (Miller et al. 2000, Miller 2011).

There are greater threats to pillar corals than can be addressed in this plan. Water quality and climate change are among these threats. Working with state and federal managers to create large-scale habitat management plans may effectively address these issues. The pillar coral may potentially be federally listed as an Endangered Species by NOAA's National Marine Fisheries Service (NMFS) by mid2014, which may result in a Coral Reef Habitat Management Plan. The Southeast Florida Coral Reef Initiative (SEFCRI) is embarking on a process to create a habitat-based management plan for the SEFCRI region, the Our Florida Reefs initiative, and the FKNMS is currently in a public re-zoning process. These efforts are comprehensive and can potentially provide actions to address larger threats.

Recommended Listing Status

In 2010, FWC directed staff to evaluate the status of all species listed as Threatened or Species of Special Concern that had not undergone a status review in the past decade. To address this charge, staff conducted a literature review and solicited information from the public on the status of the pillar coral. The FWC convened a biological review group (BRG) of experts on the pillar coral to assess the biological status of the species using criteria specified in Chapter 68A-27.001, F.A.C. This rule includes a requirement for BRGs to follow the Guidelines for Application of the International Union for Conservation of Nature (IUCN) Red List Criteria at Regional Levels (Version 3.0) and Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1). FWC staff developed an initial draft Biological Status Review report (BSR), which included the BRG's findings and a preliminary listing recommendation from staff. The draft was sent out for peer review, and the reviewers' input was incorporated into a final report..

The FWC BRG for the pillar coral concluded from the Biological Status Review report (BSR; FWC 2011) that pillar coral met several of the BSR criteria necessary to warrant listing by FWC as a Threatened species. Criteria met included historical population decline (long term, i.e., 50 years or more), low area of occupancy, continued declines in population and areas of occupancy, fragmented populations, and very few mature individuals. Based on the low reproductive potential of the current population and the high level of accelerated threats (including climate change and disease), it is highly likely that the population will decline at least a 30% over the next 100 years. Currently, biological information regarding this species' population, reproductive status, and its recruitment success in Florida is extremely limited.

The pillar coral met these listing criteria during the BSR

- Criteria A(3) and C(1) of the BSR: population size reduction of at least 30% projected or suspected to be met within the next 100 years and estimated continuing decline of at least 10% in 10 years.
- Criteria B(2)a, B(2)b, and D(2) of the BSR: area of occupancy is less than 2,000 km^2 (772 mi^2) and is severely fragmented and declining and the population has a very restricted area of occupancy.
- Based on the IUCN Red List Guidelines, the current area of occupancy is likely less than 2,000 km^2 (772 mi^2). Criteria B(2)b, C(2), C(2)aii, and D(1) of the BSR: area of occupancy is declining, continuing decline of mature individuals, all mature individuals are in 1 subpopulation, and the population is estimated to be less than 1,000 mature individuals.
- The BSR predicts a continued decline of at least 30% over the next 100 years. Additionally, it is inferred from other broadcast spawning corals in Florida that Florida pillar coral may constitute 1 subpopulation. Censused colonies are at such low densities that fertilization potential approaches 0, and thus the current number of mature individuals would be 0. This suggests that the Florida pillar coral population may be a relict population.

In addition to its current state listing status as Threatened, this species is proposed for Federal Endangered listing under the Endangered Species Act (NOAA 2012*a*). The NOAA/NMFS is anticipated to make this determination by June 2014.

CONSERVATION GOALS AND OBJECTIVES

Goal

The conservation status of the pillar coral is improved to the point that the species is secure within its historical range.

Objectives

I. Determine the distribution and status of, stabilize, and increase the existing population of the pillar coral within the next 10 years.

Rationale

This objective addresses listing Criteria A(3) and C(1) of the BSR: population size reduction of at least 30% projected to be met within the next 100 years. Apparent low resilience, fertilization rates and recruitment, as evidenced by lack of recruits and juveniles (Miller et al. 2000, Miller 2011), have contributed to this species' decline and anticipated continued decline. Historical and current population sizes are largely unknown and targets will be defined in the future as data are gathered.

To secure the population (i.e., maintain it at its current level) within its current range, it is necessary to map and groundtruth reported pillar coral colonies to establish baseline data for the size and extent of the existing population. Demographic and synoptic surveys are needed to determine the existing population structure, the range and abundance of this species, mortality rates, growth rates, and recruitment rates.

Additionally, it is not currently known if the existing colonies are sexually reproducing. Documentation and observation of spawning events will confirm whether colonies are releasing gametes. Fertilization assays will provide information regarding the pillar coral's potential to sexually reproduce within its current range. Results of a current recruitment study by FWRI through the Coral Reef Evaluation and Monitoring Project will assist in determining recruitment potential.

After conducting surveys and determining locations of existing pillar coral colonies, protections can be implemented to help these colonies persist. Mooring buoys are a tool used throughout the Florida Keys and southeastern Florida to protect corals from physical damage from anchors. Placing mooring buoys at popular recreational dive locations which have pillar coral colonies should aid in reducing damage to colonies from anchors. Setting up zones that restrict commercial lobster traps, anchoring, or both will further protect existing pillar coral colonies from physical damage. Educating boaters and divers to properly identify colonies so that they can avoid placing traps and anchors in close proximity will further reduce damage to colonies. Effective enforcement of the CRPA will also provide protection.

II. Maintain and increase area of occupancy of the pillar coral over the next 10 years.

Rationale

This objective addresses listing Criteria B(2)a, B(2)b, and D(2) of the BSR: area of occupancy is less than 2,000 km^2 (772 mi^2) and the population is severely restricted, fragmented and

declining,. Based on IUCN Red List Guidelines, the current area of occupancy is likely less than 2,000 km^2 (772 mi^2), all of which is subjected to threats. Increasing the population of long-spined urchins (*Diadema antillarum*) may indirectly assist in increasing the pillar coral population. Long-spined urchins are grazers that assist corals in successful recruitment by increasing available settlement substrate. Relocating nursery-reared urchins to the natural reefs could improve settlement habitat quality for pillar corals.

III. Stabilize and increase the number of mature pillar coral individuals and the reproductive success of these individuals over the next 10 years.

Rationale

This addresses listing Criteria B(2)b, C(2), C(2)aii, and D(1) of the BSR: area of occupancy is declining, continuing decline of mature individuals, all mature individuals are in 1 subpopulation, and the population is estimated to be less than 1,000 mature individuals.

The BSR predicts a continued decline of at least 10% over the next 100 years. Additionally, it is inferred from other broadcast spawning corals in Florida that Florida pillar corals may constitute 1 subpopulation. Censused colonies occur at such low densities that fertilization potential likely approaches 0, thus the current number of mature individuals would be 0. This rationale suggests that the Florida pillar coral population may be a relict population.

Active restoration of pillar coral colonies will require knowledge of rearing techniques. In order to rear pillar coral colonies in an *in situ* nursery, corals of opportunity need to be collected and grow-out and maintenance techniques need to be developed. Gametes can also be collected for settlement experiments and to develop genotyping techniques. Following this research, the existing population can be genotyped. This information will be useful for selecting appropriate colony outplanting locations after successful nursery methods are developed.

CONSERVATION ACTIONS

The following sections describe the conservation actions that will make the greatest contribution toward achieving the conservation objectives. Actions are grouped by category (e.g., Habitat Conservation and Management, Population Management). Action priority, urgency, potential funding sources, likely effectiveness, identified partners and leads for implementation are identified in the Conservation Action Table (Table 1).

Habitat Conservation and Management

Action 1 To reduce anchor damage, install mooring buoys in locations that support pillar coral colonies and are popular diving, snorkeling, and fishing locations.

One of the greatest challenges to protecting corals is to protect the overall coral reef habitat. The pillar coral, a species that also serves as a habitat, is vulnerable to physical damage from anchors (Actions 3 and 12). Buoys should only be installed in locations that are currently frequented by divers, snorkelers, or fishers as installation of buoys in locations not currently frequently used may serve to increase use in that area. Installing mooring buoys is a feasible action provided there is an entity willing to commit to long-term maintenance of the buoys. Mooring buoys are used throughout the FRT to provide convenient access to the reefs by boaters without the need for deploying an anchor. Installation of mooring buoys may effectively protect coral reef habitat, including pillar coral colonies. This action was not declared urgent (in Table 1) because there are many mooring buoys currently installed in state and federal waters and because anchor damage is not the greatest threat to pillar coral survival.

Action 2 Support establishment of long-spined urchin nurseries and outplant urchins at pillar coral locations.

Long-spined urchins are herbivores important to maintaining conditions favorable for settlement of scleractinian corals, including the pillar coral. As corals need algae-free substrate in order to settle, adding grazers like long-spined urchins to the reefs should increase the amount of habitat available for pillar coral recruitment. Long-spined urchin populations suffered a severe die-off in the 1980s (Lessios 1988) and populations have not yet rebounded. Current research on rearing and outplanting them looks promising, but is still in its infancy. Although long-spined urchin relocation is potentially feasible in the future, it is not an urgent action, as there are many other factors impacting successful settlement and recruitment of pillar coral larvae.

Research led by the FWRI in the Keys is currently underway to gain information on how urchins interact with artificial structures under natural conditions and to test whether these structures enhance their survival rates. These results will serve as a guide for resource managers seeking to develop and implement a comprehensive ecosystem-based coral reef restoration strategy that includes re-establishing a stable long-spined urchin population along the FRT. The FKNMS has identified long-spined sea urchin research as an essential component of restoring the health and resiliency of Florida's reef ecosystem (B. Sharp, FWRI, personal communication). This research will provide information beneficial to future long-spined urchin outplanting efforts. Increasing these grazer populations will increase the potential of settlement success for pillar coral by maintaining suitable settlement habitat.

Actions 7 and 8 also are related to Habitat Conservation and Management but are included below in other sections.

Action 3 Implement actions to protect the pillar coral from anchor damage in vulnerable locations.

Coordination is needed with the DEP and potentially the FKNMS, Biscayne National Park, Biscayne Bay Aquatic Preserve, the Dry Tortugas National Park, and other stakeholders to identify areas where pillar coral colonies are most vulnerable to damage from anchors and to devise an action plan to protect these colonies. This collaborative effort could be done in combination with the installation of mooring buoys (Action 1) and targeted outreach and education (Action 12).

Action 4 Implement actions to protect pillar coral from fishing gear.

Some abandoned fishing gear, such as lobster and crab traps, can cause damage to pillar corals if the traps are deployed on or near pillar coral or are abandoned. Trap movement during storms poses a great threat to pillar coral colonies because of coral's fragile columnar growth. Pillar coral colonies of any size are susceptible to fragmentation, breakage, and abrasion from traps and trap lines. Even traps initially placed in locations devoid of corals can be moved by storms into reef habitats and cause damage. Even non-tropical storm systems can move traps 30.48 m (100 ft) from their original locations (Lewis et al. 2009). Abrasion can scour tissue away, leaving the colony vulnerable to disease. Implementation of Action 10 would require a stakeholder scoping process to identify actions to protect the pillar coral without impeding the commercial lobster fishery.

Population Management

Action 5 Map and groundtruth the existing population of pillar coral.

In order to effectively manage the population, it is necessary to define the population. Identifying and mapping existing populations will provide information critical to developing effective management strategies. Mapping and groundtruthing of existing colonies of the population are feasible research activities that are of utmost urgency.

The current population size of pillar coral is unknown in Florida. A database has been compiled of unconfirmed locations reported by stakeholders (Figure 3). The FWC is coordinating a project to groundtruth and quantify these points (commenced July 2013). The results of this project will provide valuable information regarding the extent and health of pillar coral on the FRT. Acquiring a population baseline will provide the necessary information to develop further strategies to stabilize and increase the population.

Action 6 Research genetic structure and assess genotypic diversity.

Different management and restoration actions will be taken depending on the genetic diversity (or lack thereof) of the existing population. No research has been conducted on the genetic

diversity of pillar coral within the greater Caribbean (a collaborative Pennsylvania State University [PSU] and FWC-granted project focusing on the FRT commenced July 2013). However, given the low population size, it is assumed that there is little genetic diversity throughout the FRT. Researching genetic structure and assessing genotypic diversity is necessary to determine the stability of the current population and to assist in ensuring that multiple genotypes are eventually represented in Florida nurseries (Actions 7 and 8). Documentation of sex ratios and gametogenesis will determine sexual reproductive capacity of the population. This action may ultimately enable researchers to manipulate and increase genetic diversity and potential larval production of the population.

Action 7 Acquire rearing techniques through coordination with other nurseries that work with mounding coral species.

Mote Marine Laboratory (Mote) and The Nature Conservancy (TNC) have preliminary experience in raising mounding coral species. Currently, mounding species are not commonly reared (as opposed to branching species of corals) as they are considered more difficult to rear, and because they are slow growing (8 to 23 mm [0.31 to 0.90 in] per year).

Action 8 Collect pillar coral gametes and corals of opportunity, rear them, and outplant them in wild sites (sites to be determined after further research).

Collecting corals of opportunity for nurseries, developing rearing techniques, and eventual outplanting is the next step after establishing the population baseline. Collecting gametes for genetic and larval rearing studies and collecting corals of opportunity to build a nursery is a feasible activity that is currently being successfully conducted for another species of coral (i.e., staghorn coral [*Acropora cervicornis*]).

The successful propagation and outplanting of corals, particularly those under threat, can increase populations and restore ecosystems. Improved survival of nursery and outplanted corals maximizes recovery efforts for these Threatened species and the return on nursery-based restoration projects for the time and money spent.

State Wildlife Grants (SWGs) have been awarded to the FWRI Coral Program in partnership with NSUOC and PSU that will begin to fund Actions 5 and 6.

Monitoring and Research

Action 9 Conduct synoptic and demographic surveys and include disease and health assessments.

To assess population status and trends, synoptic and demographic surveys should include assessments of current disease and health status.

General coral reef demographic surveys are currently being conducted by a number of research groups including the FWRI Coral Program, as well as targeted pillar coral demographic surveys (funded by FWC's SWG program). Synoptic surveys have been done along the FRT in the past

by the Coral Reef Monitoring a Assessment team, led by Dr. Steven Miller of NSUOC. Since 2005, TNC has implemented the Florida Reef Resilience Program (FRRP) to provide a unified method of dividing up and looking at the reef tract to assess long-term resiliency. The sampling design was created by reviewing existing maps, data, and biophysical information and by conducting workshops and acquiring expert input. The goal of the program is to monitor coral reef health after disturbances. The focus of this program has been on climate change disturbances, such as coral bleaching. Trained experts survey corals and bleaching on the FRT during peak annual temperatures. Follow-up surveys are conducted after moderate and severe bleaching years. The survey methodology is also used to assess other disturbances such as hurricanes, cold-water events, and oil spills. This program provides a general baseline of coral condition across the FRT, provides valuable data regarding species diversity, and will assist in identifying pillar coral colonies and their conditions on the FRT (Johnson and Lustic 2011). The FWC currently participates in annual and event surveys in cooperation with TNC's FRRP.

Action 10 Observe and document spawning annually and determine sexual reproduction potential.

Little is known about the reproductive strategies of pillar coral and if the Florida population is a viable population or a relict population. Conducting a census of population status and trends, identifying sex ratios, and determining sexual reproduction potential will fill crucial data gaps. A census can provide information on current population status and will facilitate successful restoration efforts to be designed specifically for the species' biology, reproductive capacity, ecological habitat requirements, and historical range.

While pillar coral spawning has recently been observed on one reef (Figure 6), it is unknown if pillar coral are successfully sexually reproducing throughout the FRT. Broadcast spawning, employed by some species of scleractinian corals, is often timed when conditions are ideal to increase the success rate of reproduction. This mode of sexual reproduction can be highly successful when a sufficiently large and genetically diverse population exists. However, when a population is severely fragmented, lacking genotypic diversity, or skewed towards 1 sex, reproduction will fail Documenting spawning pillar coral will assist in establishing sex ratios of the population. Harvesting of gametes will assist in determining the compatibility of broadcasted gametes and fertilization success. Fecundity studies will assist in determining the overall reproductive potential of the population.

Figure 6. Pillar coral releasing gametes into the water column in the Keys, August 2012. FWC photograph.

Rule and Permitting Intent

The FKNMS, the CRPA, and FWC's Marine Life Rule as described above (Conservation History), are the only protections in place that affect the pillar coral. These management actions are not, however, written specific to pillar coral but rather apply to coral reefs in general. Actions 3 and 4 included in Habitat Conservation and Management are management actions that may be effectively implemented through Rule or Permitting changes.

Law Enforcement

Action 11 Collaborate with DEP and Law Enforcement entities to enforce the CRPA.

The CRPA authorizes DEP, as the state's lead trustee for coral reef resources, to protect coral reefs through timely and efficient assessment and recovery of damages to coral reefs. DEP may enter into delegation agreements with other state or local government agencies with coral reefs in their jurisdiction to carry out the intent of the CRPA. The CRPA includes language that would provide for other law enforcement entities, such as the FWC, to support enforcement of the Act by entering into an agreement with the DEP, but at this time no other law enforcement entities

have entered into such an agreement. Facilitating agreements between DEP and other law enforcement agencies, including FWC, to allow other enforce the CRPA would strengthen the effectiveness of Act at reducing anchor damage to corals.

Incentives and Influencing

The pillar coral occurs exclusively on sovereign submerged lands managed by the federal government or the State of Florida. Incentive programs are not currently applicable for this species. However, through education and outreach, reef users can be encouraged to conserve and protect reef resources (Actions 12 and 13).

Education and Outreach

Action 12 In collaboration with pertinent agencies and non-profit organizations, design education and outreach programs to inform the boating public about the CRPA, as well as the harm inflicted by, and safe alternatives to anchoring on hardbottom communities.

The FWC partners with DEP's Coral Reef Conservation Program and other agencies in coral outreach efforts. It is feasible that the FWC could continue these partnerships, develop additional materials, and implement outreach programs. Expanding outreach efforts is not a high priority as there are many programs already in existence. However, new and expanded programs could have great value in furthering coral reef awareness. One example is the FKNMS Blue Star Program to reduce the impact of divers and snorkelers on the coral reef ecosystem by forming a partnership with commercial operators to educate their customers about the coral reef ecosystem, the FKMNS, and diving and snorkeling etiquette. The Blue Star program recognizes dive and snorkel operators in the Florida Keys who meet set criteria designed to ensure that their customers are receiving information about coral protection. Participation in the Blue Star Program is voluntary, and the program has no regulatory component.

Action 13 Educate recreational divers, dive operators, and snorkelers to identify pillar corals and encourage them to report observed colonies to a website (this may be an existing website, such as Mote's Marine Ecosystem Event Response and Assessment program or the DEP's Southeast Florida Action Network .

Incorporating stakeholders in identifying existing pillar coral colonies can be of great assistance in determining its current population and range. Establishment of a public sightings database will help researchers in establishing the population baseline. Additionally, involving the public will give them a sense of ownership, influencing them to take action to help conserve the species (e.g., no touching, no anchoring, etc.). This is feasible but requires groundtruthing by trained researchers.

Coordination with Other Entities

Action 14 Coordinate with NOAA and NMFS to develop a critical habitat designation and a federal management plan for the pillar coral.

The most effective management of the pillar coral will likely result from comprehensive plans. Pillar coral is currently a candidate for federal Endangered Species status (NOAA 2012*a*). If listed, NOAA/NMFS protocol is to first identify critical habitat, and then develop a Recovery Plan to include recovery criteria and actions for pillar coral. A comprehensive plan involving multiple, listed coral species would allow for management actions that address large-scale threats (e.g., water quality and climate change) that cannot be addressed by single-species plans.

The FWC will coordinate with NOAA/NMFS to ensure that the conservation actions identified in this plan are represented in the federal plan.

Action 15 Participate in regional research and scoping plans.

The SEFCRI is embarking on an initiative called "Our Florida Reefs" aimed at drafting a comprehensive management plan for the SEFCRI region. The FWC is involved in this process. The SEFCRI is focused on the northern third of the FRT, which stretches more than 160 km (100 mi) from the border of Biscayne National Park to the St. Lucie Inlet and includes the water adjacent to the 4 southeastern counties of Martin, Palm Beach, Broward, and Miami-Dade. Since 2003, over 70 partners representing county, state, and federal government agencies, non-governmental organizations, and academic institutions have been working through the SEFCRI to implement 140 projects to reduce threats to coral reef resources in this area. The outcomes and information from these projects will help the SEFCRI to achieve its mission: to develop an effective strategy to preserve and protect southeastern Florida's coral reefs and associated reef resources, emphasizing balance between resource use and protection in cooperation with all interested parties.

DEP is coordinating a SEFCRI effort to develop and implement a transparent and inclusive process where coral reef stakeholders in the region consider the outcomes from almost a decade of effort. The goal is to identify potential management actions that could reduce negative impacts to and to better conserve and manage southeastern Florida coral reefs. These management recommendations may be targeted at the various local, state, and federal resource management agencies that have jurisdiction in southeast Florida.

The FWC and other federal and state agencies and stakeholders are participating in review of FKNMS management. In response to requests by the public, shifting environmental conditions and threats in the Florida Keys, better scientific information, and legal requirements, the FKNMS Advisory Council is conducting a review of sanctuary regulations, including the rules and boundaries for marine zones in the FKMNS and surrounding national wildlife refuges. The review is an ongoing process (NOAA 2012*b*).

The FWC has an initiative through the SWG program to develop a comprehensive coral reef restoration plan for Florida that will outline the essential strategies necessary to effect a well-coordinated, comprehensive coral reef restoration effort in Florida. The document will identify the research and conservation actions necessary for this effort based upon the consensus recommendations of scientists and conservation managers across the region. The lack of a unified restoration strategy has resulted in duplication of effort in some restoration activities

while vital gaps in others remain. The identified research needs and prioritization of activities provided by the plan will help to focus projects considered for future funding.

Action 16: Review offshore construction permits and recommend actions to reduce or eliminate impacts to pillar coral and its habitat.

Throughout pillar coral's range in Florida, direct impacts to reef habitat from permitted offshore construction projects (e.g., beach nourishment, port dredging, and cable deployments) can potentially impact known colonies and critical habitat for this species. FWC provides recommendations to permitting agencies, and does have an opportunity to review most coastal construction permit applications; however, there is often a lack of time and staff resources to complete thorough reviews of many of these large and complex projects. Adequate time must be allowed for appropriate FWC staff to review these applications and coordinate with the appropriate state or federal agencies to provide recommendations to avoid and minimize impacts, to assist in designing appropriate pre- and post-construction survey and monitoring programs, and to help design mitigation when necessary. Subsequent monitoring reports should be submitted to FWC in order to track the fate of temporarily impacted corals and habitats and the success of mitigation projects.

Table 1. Pillar Coral (*Dendrogyra cylindrus*) Conservation Action Table

NOTE: An explanation of acronyms used is below the table.

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
1	2	1	To reduce anchor damage, install mooring buoys in locations that support pillar coral colonies and are popular diving, snorkeling, and fishing locations.	Habitat Conservation & Mgmt, Education & Outreach, Coordination with Other Entities	EXPANDED	YES	NO	TBD	Grant	HSC, FWRI, LE	FKNMS, Miami-Dade County, Broward County, DEP	Mooring buoys are currently widely used throughout southeast Florida. Current programs exist to educate boaters about the benefits of mooring buoys and how to properly use them. Pillar coral colonies in areas with mooring buoys will have high likelihood of being protected from physical damage from anchors.	Mooring buoys are practical and already used widely throughout southeast Florida. Mooring buoys require frequent maintenance by a licensed contractor. For a program to be successful, there must be funding available to perform the required maintenance. Feasibility of a mooring buoy program will be based on the availability of funding for maintenance.	No. Some mooring buoys already exist in close proximity to pillar coral colonies. Anchors are a threat to pillar coral but are not the most serious threat to this species' survival.
2	4	2	Support establishment of long-spined urchin nurseries and outplant urchins at pillar coral locations.	Habitat Conservation & Mgmt	NEW	YES	NO	TBD	Grant	HSC, FWRI, MFM	FKNMS, Mote Marine Lab, UCF	In theory, relocating nursery reared urchins to the natural reefs could improve settlement rates for pillar coral. However, this still requires research and monitoring to determine potential success.	This is a new area of research and there are no publications or studies to refer to predict feasibility.	No. While urchins may increase viable settlement areas for larvae, there are many other factors impacting successful settlement and recruitment of pillar coral larvae.
1	2	3	Implement actions to protect the pillar coral from anchor damage in vulnerable locations.	Protections & Permitting, Habitat Conservation & Mgmt	NEW	NO	NO	TBD	Unknown	HSC, FWRI, MFM, LE	FKNMS, DEP, local Law Enforcement agencies	Pillar coral colonies in protected areas will have high likelihood of being protected from physical damage from anchors. Enforcement of no anchor zones is more feasible than enforcement of the CRPA as it is currently written.	This action would need to be enacted by the DEP as they are the State Trustees for Sovereign Submerged Lands. Feasibility is unknown as no anchor areas currently do not exist anywhere on the FRT other than research only areas in the FKNMS.	No. Anchors are a threat to pillar coral but are not the most serious threat to this species' survival.
1	2	4	Implement actions to protect pillar coral from fishing gear.	Protections & Permitting, Habitat Conservation & Mgmt	NEW	YES	NO	TBD	Unknown	HSC, FWRI, MFM, LE	FKNMS, SAFMC, local Law Enforcement agencies	Pillar coral colonies in protected areas will have high likelihood of being protected from physical damage from traps. This rule would be modeled on a federal rule which has successfully protected corals in the FKNMS.	This action would require a stakeholder process and rulemaking by the FWC.	Yes. Some fishing gear, when abandoned, has the potential to be very damaging to all corals and especially pillar corals due to their columnar growth pattern.
1	1	5	Map and groundtruth the existing population of pillar coral.	Population Mgmt	NEW	YES	NO	$100k+	Grant	HSC, FWRI	FKNMS, NSUOC, Broward County, NPS, NMFS	This research will achieve the desired result of establishing a baseline of the population.	This research has been awarded a SWG grant. The project will begin in summer of 2013.	Yes. It is necessary to establish the existing population in order to monitor success of conservation actions. Establishing the baseline will assist in identifying other threats and developing additional conservation actions.
3	1	6	Research genetic structure and assess genotypic diversity.	Population Mgmt, Monitoring & Research	NEW	YES	NO	$100k+	Grant	HSC, FWRI, MFM	NSUOC, PSU, FKNMS, NPS, NMFS	This research will achieve the desired result of establishing a baseline of population genetics.	This research has been awarded a SWG grant. The project will begin in summer of 2013.	Yes. It is urgent to learn the genetic composition of the population. Different management/restoration actions will be taken depending on the genetic diversity (or lack thereof) of the existing population.

Table 1. Pillar Coral (*Dendrogyra cylindrus*) Conservation Action Table

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
3	2	7	Acquire rearing techniques through coordination with other nurseries that work with mounding coral species.	Habitat Conservation & Mgmt, Population Mgmt, Monitoring & Research	NEW	YES	NO	$100k+	Grant	HSC, FWRI, MFM	NSUOC, Coral Restoration Foundation, TNC, NMFS	This research will establish if nursery rearing and outplanting of pillar coral will be a feasible restoration technique.	Currently unfunded.	No. It will be important to establish effective techniques to enhance the existing population, however, the current priority should be to gather information to allow better protection of the existing population.
3	2	8	Collect pillar coral gametes and corals of opportunity, rear them, and outplant them in wild sites (sites to be determined after further research).	Habitat Conservation & Mgmt, Population Mgmt, Monitoring & Research	NEW	YES	NO	$100k+	Grant	HSC, FWRI, MFM	NSUOC, Coral Restoration Foundation, TNC, NMFS	This research will establish if nursery rearing and outplanting of pillar coral will be a feasible restoration technique.	Currently unfunded.	No. It will be important to establish effective techniques to enhance the existing population, however, the current priority should be to gather information to allow better protection of the existing population.
1	1	9	Conduct synoptic and demographic surveys and include disease and health assessments.	Population Mgmt, Monitoring & Research	NEW	YES	NO	$100k+	Grant	HSC, FWRI, MFM	FKNMS, NSUOC, Broward County, NPS, NMFS	This research will achieve the desired result of establishing a baseline of the population.	This research has been awarded a SWG grant. The project will begin in summer of 2013.	Yes. It is necessary to establish the existing population in order to monitor success of conservation actions. Establishing the baseline will assist in identifying other threats and developing additional conservation actions.
1	1	10	Observe and document spawning annually and determine sexual reproduction potential.	Population Mgmt, Monitoring & Research	NEW	YES	NO	$100k+	Grant	HSC, FWRI	FKNMS, NSUOC, Broward County, DEP, NMFS	This research will achieve the desired result of establishing a baseline of the population.	The impetus for this research was a pilot study in the summer of 2012. A SWG grant for focused research has been awarded. The project will begin in summer of 2013.	Yes. It is necessary to establish reproductive capacity of the existing population in order to monitor success of conservation actions. Establishing the baseline will assist in identifying other threats and developing additional conservation actions.
1	3	11	Collaborate with DEP and Law Enforcement entities to enforce the CRPA.	Protections & Permitting, Coordination with Other Entities	EXPANDED	YES	YES	TBD	Existing Budget	LE, MFM	DEP, FKNMS, NPS	This action would improve protection from anchor damage for all pillar coral colonies. The aspects of this action that make feasibility questionable are the ability of LE to implement due to their limited resources.	It is unlikely that FWC and NPS would commit to enforcing the CRPA as it is currently written.	No. Anchors are a threat to pillar coral but are not the most serious threat to this species' survival.
1	5	12	In collaboration with pertinent agencies and non-profit organizations, design education and outreach programs to inform the boating public about the CRPA, as well as the harm inflicted by, and safe alternatives to anchoring on hardbottom communities.	Education & Outreach	ONGOING	YES	YES	TBD	Existing Budget	FWRI	DEP, FKNMS, NPS	DEP currently has an outreach program (brochures and website) to aimed at educating boaters about CRPA. The program is still too new to assess its success.	Currently, FWC staff does partner with DEP CRCP on this program in southeast Florida (FKNMS and NPS are excluded). It is highly feasible that FWC could assist in identifying gaps in this program and lend resources to fill those gaps.	No. Reaching out to the public about anchoring is not urgent as anchors are a threat to pillar coral but are not the most serious threat to this species' survival.
1	3	13	Educate recreational divers, dive operators, and snorkelers to identify pillar corals and encourage them to report observed colonies to a website (this may be an existing website, such as Mote's Marine Ecosystem Event Response and Assessment program or the DEP's Southeast Florida Action Network .	Education & Outreach	EXPANDED	YES	YES	TBD	Existing Budget	FWRI, HSC	Mote Marine Lab, FKNMS, NPS, DEP	This action could be highly effective at gathering baseline information regarding pillar coral distribution on the FRT. Mote and DEP have programs in place that allow reef users to report damage, marine debris, etc on a website. These programs could be expanded to include reporting observation of listed species (i.e., pillar coral).	This action is very feasible as it would only require expanding upon existing programs (Mote's MEERA program and DEP's SeaFan program).	Yes. It is necessary to establish the existing population in order to monitor success of conservation actions. Establishing the baseline will assist in identifying other threats and developing additional conservation actions.

Table 1. Pillar Coral (*Dendrogyra cylindrus*) Conservation Action Table

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
2	1	14	Coordinate with NOAA and NMFS to develop a critical habitat designation and a federal management plan for pillar coral.	Coordination with Other Entities	NEW	YES	YES	TBD	Existing Budget	FWRI, HSC, MFM, LE	NOAA/NMFS	'NOAA/NMFS has proposed listing pillar coral as Endangered under the ESA with the final determination due in June 2014. It is unknown what effect any resultant critical habitat designation and recovery plan will have in conserving and expanding pillar coral distribution in Florida.	This coordination is feasible and the relationship already exists.	Yes. It is possible that an effective federal management plan could greatly contribute to the conservation of pillar coral.
2	2	15	Participate in regional research and scoping plans.	Coordination with Other Entities	NEW	YES	YES	TBD	Existing Budget	FWRI, HSC, MFM, LE	DEP/SEFCRI and NOAA	Development of effective comprehensive management plans in the FKNMS and northern FRT are instrumental in the conservation and survival of pillar coral.	This coordination is feasible and the relationship already exists.	No. It is possible that effective comprehensive management plans could greatly contribute to the conservation of pillar coral. However, most pillar coral is in the Florida Keys, not the SEFCRI region so this action is not urgent for survival of the species.
1, 2	3	16	Review offshore construction permits and recommend actions to reduce or eliminate impacts to pillar coral and its habitat.	Coordination with Other Entities	EXPANDED	YES	YES	TBD	Existing Budget	FWRI, HSC, MFM	DEP, SFWMD, USACE, NOAA	If able to effectively influence regulatory agencies to implement conditions in permits that will avoid or minimize impacts, this will reduce loss of pillar coral colonies and habitats.	This coordination is feasible and the relationship already exists.	No. Reducing construction related impacts to pillar coral and habitats will be beneficial, however, because all remaining pillar coral colonies are offshore, construction activities generally don't directly impact pillar coral habitats as much as they do other species of corals.

Acronyms used in this table:

CRPA:	Coral Reef Protection Act
DEP:	Florida Department of Environmental Protection
ESA:	Endangered Species Act
FKNMS:	Florida Keys National Marine Sanctuary
FRT:	Florida Reef Tract
FWC:	Florida Fish and Wildlife Conservation Commission
FWRI:	Fish and Wildlife Research Institute, the research branch of the Florida Fish and Wildlife Conservation Commission
GIS:	Geographic information system
HSC:	Habitat and Species Conservation, a Division of the Florida Fish and Wildlife Conservation Commission
LE:	Law enforcement
MEERA:	Marine Ecosystem Event Response and Assessment program
MFM:	Marine Fisheries Management, a Division of the Florida Fish and Wildlife Conservation Commission
NMFS:	National Marine Fisheries Service
NOAA:	National Oceanic and Atmospheric Administration
NSUOC:	Nova Southeastern University Oceanographic Center
NPS:	National Park Service
PSU:	Pennsylvania State University
SAFMC:	South Atlantic Fishery Management Council
SeaFan:	Southeast Florida Action Network
SEFCRI:	Southeast Florida Coral Reef Initiative
SFWMD:	South Florida Water Management District
SWG:	State wildlife grant
TBD:	To be determined
TNC:	The Nature Conservancy
UCF:	University of Central Florida
USACE:	United States Army Corps of Engineers

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