APPENDIX F

MITIGATION AND RELOCATION PLANS

PORT EVERGLADES, FLORIDA PROJECT

This page intentionally left blank

Table of Contents

F MITIGATION AND RELOCATION PLANS F-1
F.1 Overview of the Seagrass Mitigation Plan F-1
F.2 Overview of the Mangrove Mitigation Plan F-2
F.3 Overview of the Coral Reef and Hardbottom Mitigation Plan F-2
F.3.1 Background F-3
F.3.2 Mitigation strategies proposed F-4
F.3.3 Natural Reef Enhancement F-7
F.3.4 Enhancement of Impacted Reefs F-7
F.3.5 Artificial Reef Creation F-21
F.3.6 Mitigation Monitoring F-23
F.3.7 Selection of Mitigation Sites F-26
F.3.8 Timing for Mitigation Activities F-30
F.4 Relocation Plan of Corals and Other Organisms F-31
F.4.1 Impact Avoidance/Minimization and Additional Relocation Actions F-31
F.4.2 Collection, Transportation, and Transplanting Methods F-35
F.4.3 Monitoring F-37
F.4.4 Reporting F-39
F.5 References F-41

List of Tables

Table F-1. Considerable declines in coral populations recorded in southeast Florida between 2004 to 2018 (Source: Walker, 2018). F-4
Table F-2. Summary of mitigation strategies proposed for this project for natural reef enhancement of impacted and degraded sites or artificial reef creation with biological enhancement. F-6
Table F-3. Overview of coral propagation target species. The goal is to conduct mixed-species propagation and subsequent outplanting. These percentages were developed in coordination with NMFS Habitat Conservation Division (HCD). Species were selected based on (1) known presence near the project area, (2) likelihood of success, and (3) most current information regarding coral species known to be propagated in Florida in either in-situ nurseries (based on personal communication with local practitioners), or land-based facilities for sexual propagation (L. Gregg, FWC, personal communication). F-15
Table F-4. Proposed recipient areas for outplanted corals, by project timing (pre-, during, post-construction) and level of effort expected. These percentages were developed in coordination with NMFS HCD. F-15
Table F-5. Assumptions and proposed monitoring events and success criteria for each mitigation strategy. F-23

Table F-6. Proposed mitigation activities by timing of project construction (pre-, during, or post-construction). F-30
Table F-7. Relocation actions by project area. F-32
Table F-8. Proposed recipient places for relocated corals, octocorals and sponges. F-34

List of Figures

Figure F-1. Florida's Coral Reef, which stretches for over 350 miles. Southeast Florida Coral ECA boundaries are denoted in turquoise color. (Source: https://floridadep.gov/rcp/coral/content/coral-eca-southeast-florida-coral-reef-ecosystem-conservation-area). F-3
Figure F-2. Reef restoration activities over time (Source: Adam Smith and Ian Mcleod, The Conversation). F-5
Figure F-3. Photos of impacted areas and adjacent reef needing primary restoration at the T/V Margara grounding site in Puerto Rico (Source: NOAA's Restoration Center). F-9
Figure F-4. Sand Bypass project features, including proposed location of the 0.2-acre nearshore mitigation coral nursery site. (Source: Broward County) F-10
Figure F-5. Spillage model sediment depositions for Scenario 2 (Cutterhead with no overflow) depicting areas of potential project-related sedimentation (denoted by different sediment deposition values), along with boundaries of the Sand Bypass project (areas denoted in light green), and location of the 0.2 acre nearshore mitigation coral nursery site (denoted by orange rectangle polygon). F-11
Figure F-6. Micro-fragmented *O. faveolata* colonies fusing after being outplanted in the field for 5 months (Source: Forsman et al. 2015). F-18
Figure F-7. Reef Cell artificial reef module with Coral Lok fasteners to facilitate coral attachment (i.e. no epoxy or cement needed) (Source: reefcells.com) F-23
Figure F-8. Potential reef enhancement sites near the project area which have been impacted by grounding or anchoring events and that are being assessed for suitability (Source: Pinnacle Ecological) F-27
Figure F-9. Potential natural reef enhancement sites near the project area which have been naturally degraded and that are being assessed for suitability (Source: Pinnacle Ecological) F-28
Figure F-10. Potential mitigation sites for artificial reef creation near the project area which have are being assessed for suitability (Source: Pinnacle Ecological) F-29

This page intentionally left blank

F MITIGATION AND RELOCATION PLANS

The proposed mitigation plan for the Port Everglades, Florida (PEV) Project will fully compensate for all project-related impacts associated with construction. Please see **Appendix D** for a full description of the proposed impacts to related resources, along with a detailed depiction of the two functional assessments utilized to calculate the mitigation necessary to fully compensate for project-related impacts. The Corps proposes to utilize credits at West Lake Park (WLP) to mitigate impacts to seagrasses and mangroves. An additional seagrass creation opportunity is described below (Section F.1) if further mitigation is necessary for the project. Finally, the Coral Reef and Hardbottom mitigation (Section F.3) will consist of three scenarios expanding on the 2016 EIS plan of artificial reef and coral propagation as described below.

The Relocation plan for corals and other organisms contained in this document provides the biological monitoring protocols and avoidance/minimization requirements specific to the project relocation activities, as well as additional relocation actions proposed for compensatory mitigation. The activities described in this plan are based upon the Corps' determinations provided to Florida Department of Environmental Protection (FDEP) via memo dated September 11, 2020.

F.1 Overview of the Seagrass Mitigation Plan

The Corps proposes to fully compensate for project related seagrass impacts, the removal of approximately 7.475 acres of seagrasses, at an on-going habitat enhancement and restoration project at West Lake Park (WLP) Broward County, Florida. WLP does not comprise a mitigation bank, and its use for mitigation is not available for purchase by the public or private entities. Credits (units of increased ecological functional value) compiled in association with the existing WLP permits (for restoration/enhancement activities) are specifically limited for use as mitigation for Broward County projects (and further, specifically the Port and airport expansions). Broward County (the local sponsor) will bear the responsibility for construction, monitoring, and success of mitigation at WLP. See Figure 87 and 88 from the original EIS. Following the receipt of the 2020 seagrass survey, the Corps conducted the required functional assessment to determine mitigation needs. The same functional assessment applied to generate the credits at WLP was utilized to determine the mitigation amount or compensation required to offset project related impacts. This ensured a consistent methodology through the process. The Uniform Mitigation Assessment Method (UMAM) required 1.84 units to compensate for project impacts to seagrasses. WLP currently has a total of 2.14 units which is sufficient to offset project impacts.

If, through further evaluation and consideration additional seagrass mitigation is required, a new creation opportunity has been identified and is located near the entrance to the harbor. The proposed creation area would be constructed inside Port Everglades Harbor within a man-made sand trap along the north side of the channel just west of the north jetty. Quarried or dredged rock material will be placed adjacent to the channel within the proposed mitigation area to act as a wave break reducing the wave energy produced by passing vessels and natural storm events.

Behind the wave break there is the potential to create up to an approximate 6.5 acres of seagrass mitigation. The typical factors for seagrass creation, projected density, species composition and success criteria will be determined through additional analysis and evaluating the additional need. In water construction will be required to match bottom elevations to seagrass beds directly west along the north side of the channel. These beds will serve as reference beds and donor sites to increase the likelihood for

success by mimicking the natural conditions of currently growing seagrasses. If increasing the elevation is required, clean sand from the dredging project would be utilized. The Corps will seek to utilize existing grass species in the harbor but may require looking outside the harbor depending on the overall likelihood for success of the effort.

F.2 Overview of the Mangrove Mitigation Plan

The construction of the project would remove approximately 2.32 acres of mangroves and 0.05-acre of wetlands. A UMAM was conducted following the results of the 2020 mangrove survey indicating that 0.83 units necessary to fully compensate for project impacts. Like the proposed seagrass mitigation, the Corps propose to offset these mangrove impacts at WLP. WLP currently has a total of 13.58 units available.

The new creation area detailed in the seagrass mitigation plan (Section F.1) may also provide additional mangrove habitat and serve as a buffer to adjacent uplands. The new creation area would require an additional coastal engineering analysis, biological analyses, and design, while consideration given to cost, and the recipient site conditions prior to implementation. Navigational warning signs would be installed and past use of the existing "beach" for sea turtle nesting will require consideration. Final design of the wave break will have considered issues like flushing and passage for marine turtles attempting to nest on the adjacent beach.

F.3 Overview of the Coral Reef and Hardbottom Mitigation Plan

The mitigation plan to compensate for impacts to coral reef and hardbottom habitats has expanded to include multiple opportunities along with the capability to "stack" or perform multiple beneficial actions providing additional ecosystem functions while allowing for an increase to the overall mitigation credit realized through their use. Two functional assessments were conducted which include UMAM for the FDEP and Habitat Equivalency Analysis (HEA) for National Marine Fisheries Service (NMFS). The proposed project would remove 28.92 acres of reef habitat by direct impacts and negatively affect, to some degree, approximately 128.86 acres of adjacent reef habitat which is considered indirect impacts (see Appendix D of the DSEIS). The outcome of the functional assessments requires the Corps to produce mitigation to offset 15.10 units through UMAM and 4,161.74 SUYs under HEA.

The Corps proposes a plan which includes multiple strategies combined to total the necessary mitigation amount. Three Mitigation Scenarios will be utilized to replace the functions lost. Scenario 1 is Artificial Reef Mitigation which includes two options involving Artificial Reef with Biological Enhancement and Artificial Reef creation where natural recruitment to bare substrate is expected. The combination of these activities will result in 5 acres of artificial reef creation (3 acres Artificial Reef and 2 acres Artificial Reef with Biological Enhancement). Scenario 1 results in an approximate functional lift of 97.9 SUYs and 1.366 UMAM units. This is like the boulder-based mitigation proposed in the 2016 EIS.

The remaining mitigation options focus on enhancement of existing reefs that are currently not providing a high level of ecological function due to: (1) physical damage (e.g., vessel grounding sites), (2) overgrowth of undesirable algal communities, including algal turfs that entrap sediments and coral competitors, (3) the presence of marine debris (e.g. rubble), and/or (4) low population levels of corals susceptible to Stony Coral Tissue Loss Disease (SCTLD), including corals listed as threatened under the Endangered Species Act (ESA) that may preclude natural reproduction. Mitigation Scenario 2 proposes to restore damaged and degraded sites with actions including rubble removal (15 acres), active cleaning and herbivore

replenishment (15 acres), relocating or transplanting corals above required for minimization needs (15 acres) and relocating or transplanting other desirable species (15 acres). Scenario 2 activities will generate approximately 909 SUYs and 3.5 UMAM units. Scenario 3 proposes reef enhancement with a focus on assisted reproduction and includes activities like assisted reproduction or propagation of species for transplanting offshore (79 acres) along with active site cleaning and herbivore enhancement (79 acres). Scenario 3 will provide approximately 3,219.25 SUYs and 13.167 UMAM units.

F.3.1 Background

The Southeast Florida Coral Reef Ecosystem Conservation Area (ECA) was officially established on July 1, 2018 to protect and manage the offshore reef habitats within the area. The ECA includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward, and Miami-Dade Counties from the northern boundary of the Biscayne National Park to the St. Lucie Inlet (**Figure F-1**). While the Florida Keys portion of the reef is protected by management plans of Florida Keys National Marine Sanctuary (FKNMS), National Parks, and National Wildlife Refuges, the northern portion of the reef was unprotected (prior to the designation of the Coral ECA), and lacking a state-adopted management plan for its future sustainability and conservation. Further, the Southeast Florida Coral ECA is affected by high usage year-round (e.g. diving, fishing), water quality degradation, coastal development, and other direct threats that led to the creation of five focus areas in the DEP Coral Reef Conservation Program, as well as the creation of the Southeast Florida Coral Reef Initiative (SEFCRI).

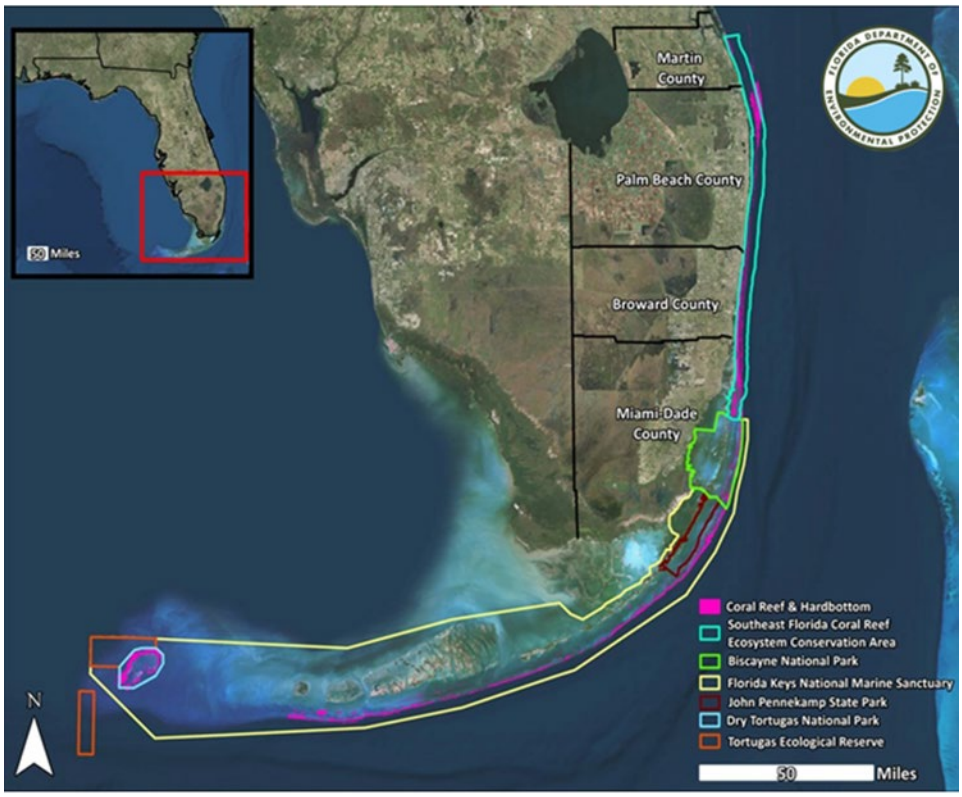

Figure F-1. Florida's Coral Reef, which stretches for over 350 miles. Southeast Florida Coral ECA boundaries are denoted in turquoise color. (Source: https://floridadep.gov/rcp/coral/content/coral-eca-southeast-florida-coral-reef-ecosystem-conservation-area).

Historically, southeast Florida coral populations could recover after natural disturbances through sexual reproduction and the production of coral recruits that could replenish depleted reefs (through larval dispersal and connectivity). However, the condition and resilience of the southeast Florida coral reef ecosystem has been declining for decades due to many anthropogenic and natural stressors. In recent years, the SCTLD has significantly declined susceptible stony coral abundance (see **Table F-1**). Specifically, the abundance of corals has been reduced by at least 30% and has caused the loss of 60% of their live tissue (Walton et al. 2018). Mean density and richness at sites with previous relatively high values are considerably lower than their historic values (with a 57.2% and 42.2% decrease respectively), indicating profound changes in the coral populations. Furthermore, this disease event contradicts the previous notion of Burman et al. (2013) that the present coral assemblages are stable because they have "withstood a number of recent perturbations, including thermal stress and disease".

Table F-1. Considerable declines in coral populations recorded in southeast Florida between 2004 to 2018 (Source: Walker, 2018).

Species	2004 % total coral population	2018 % total coral population
Montastraea cavernosa	18.8	6.9
Siderastrea spp.	31.8	23.8
Solenastrea bournoni	6.0	1.2
Meandrina meandrites	3.1	0.2
Dichocoenia stokesii	2.3	0.8
Colpophyllia natans	0.5	0.1

Due to these substantial declines, the likelihood of eggs and sperm from different colonies naturally encountering each other is currently considerably reduced, thereby limiting successful recruitment that is essential to reef recovery through natural processes. However, reef recovery can be accelerated by increasing stony coral density through restoration processes (as shown in **Figure F-2)**. For example, one way to achieve this is by increasing coral size and density in an area through asexual (e.g. propagation) and sexual forms of reproduction ("assisted reproduction").

F.3.2 Mitigation strategies proposed

A common approach for coral reef mitigation of coastal construction projects in southeast Florida has typically been the creation of artificial reefs, particularly limestone boulders (Lindeberg and Seaman, 2011; Ladd, 2012). However, artificial reefs have not demonstrated to be effective in replacing both the structural loss and the ecological functions of a natural reef over time (Miller et al. 2009; Moulding, 2011; Ladd, 2012), and a suite of other mitigation options is now available which warrant further consideration. Ladd (2012) assessed 11 alternative mitigation options for southeast Florida (other than limestone boulders) through a review of best available literature and discussions with local coral reef scientists and resource trustees. One of the options that was recognized as a higher priority action in this review was the use of coral nurseries and propagation efforts. Though this option was considered as a logistically-practicable and scientifically-feasible mitigation strategy in the 2016 Final Environmental Impact Statement, recent advances in the field of coral restoration suggest that many other strategies are also feasible (see **Figure F-2**) and may be appropriate to help mitigate the potential loss of ecological services associated with project-related impacts, particularly to the middle and outer reefs.

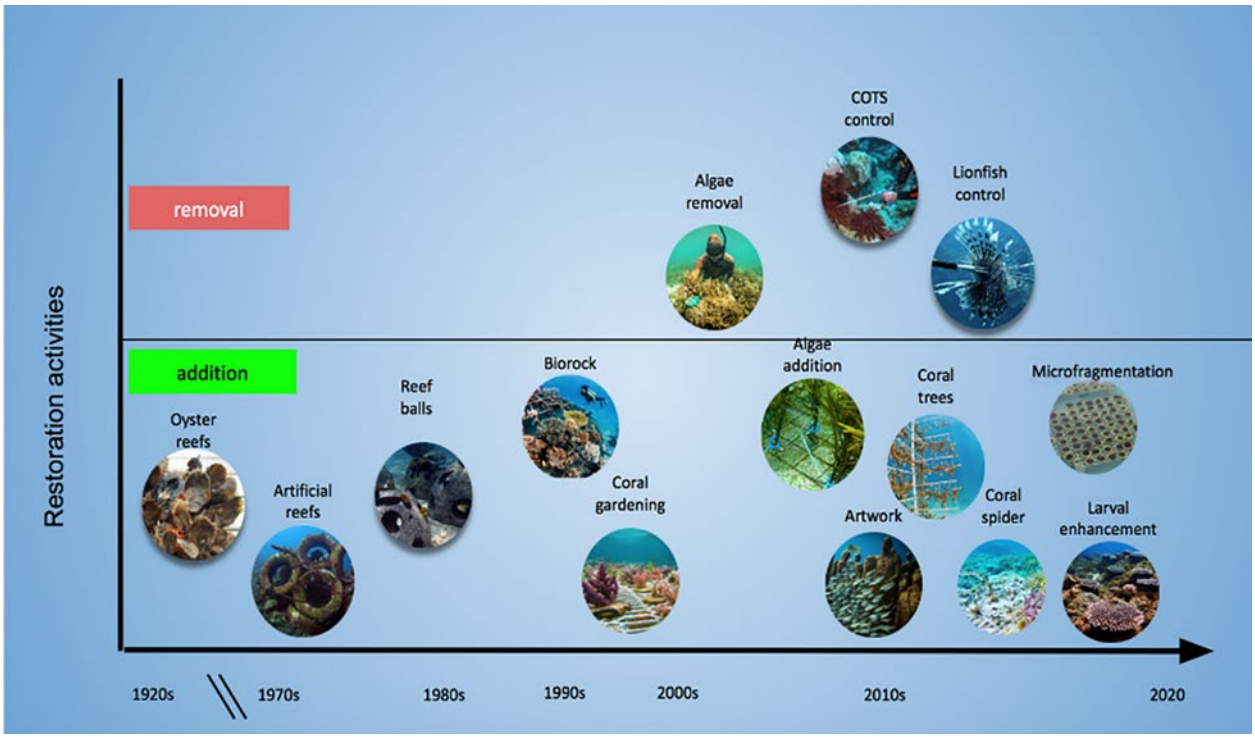

Figure F-2. Reef restoration activities over time (Source: Adam Smith and Ian Mcleod, The Conversation).

The mitigation plan here proposed has been divided into two main categories: (1) natural reef enhancement of impacted and degraded reefs, and (2) artificial reef creation (with natural recruitment or "bare" substrate), or with biological enhancement. Several of the mitigation strategies proposed to be used in natural reef enhancement can also be implemented for artificial reefs (summarized in **Table F-2**). These strategies include the active cleaning and removal of macroalgae and other coral competitors (described in **Section F.3.4.3.1**), herbivore replenishment (described in **Section F.3.4.3.2**), relocation of corals, octocorals, and sponges (described in detail in the Relocation Plan, **Section F.4**), assisted reproduction (described in **Section F.3.4.3.5**), and disease intervention and minimization (described in **Section F.3.4.3.6**). Additional strategies which are relevant just for natural reef enhancement include rubble stabilization / removal (described in **Section F.3.4.1**), coral propagation and outplanting (described in **Section F.3.4.3.3**), including microfragmentation techniques for propagation of massive coral species (described in **Section F.3.4.3.4**).

The following sections describe in more detail each of the mitigation strategies proposed for this project, expected benefits, and potential risks, as well as strategies to help minimize or mitigate risks. In general, these mitigation strategies vary in their viability and applicability based on factors such as location (e.g. proximity to the project), appropriate timing (pre-, during or post-project construction), costs, and likelihood of success. However, when done properly (i.e. in accordance to best management practices of the restoration community), these mitigation strategies are expected to serve as a unique opportunity to "jumpstart" reef recovery of mitigation reefs and increase the likelihood of meeting success in a shorter period (see **Table F-2**). The Corps will continue coordination with the Interagency Working Group (IWG) to develop a more detailed mitigation plan (e.g. specific sites, timing, success criteria, etc.) as more information is obtained. It is anticipated that for mitigation activities related to natural reef enhancement or artificial reef creation with biological enhancement will follow best practices management from the

restoration community, including the newly released Manager's Guide to Coral Reef Restoration Planning and Design (Shaver et al. 2020).

Table F-2. Summary of mitigation strategies proposed for this project for natural reef enhancement of impacted and degraded sites or artificial reef creation with biological enhancement.

Mitigation option	Strategies proposed for biological enhancement	Justification
Natural enhancement of impacted and degraded reefs	Rubble stabilization / removal	This is a widely accepted practice by the NOAA Restoration Center to help restore impacted sites (e.g. vessel groundings) (Jaap, 2000).
	Active cleaning, removal of macroalgae and other coral competitors	Provides available substrate for natural recruitment almost immediately, reducing time-lag. Prevents excessive macroalgal growth which can outcompete corals (Ceccarelli et al. 2018). The removal of the zoanthid *Palythoa cari-baeorum* (an aggressive coral competitor) may also be necessary.
	Herbivore replenishment	Reintroduction of herbivores (e.g. seeding with sea urchins *Diadema antillarum* and the Caribbean king crab *Mithrax Spinossisimus*) has been identified as one mechanism to increase the resilience of coral reefs by the National Academy of Sciences (NAS, 2018).
	Relocation of corals, octocorals and sponges	Organisms are moved out of harm's way and help jumpstart reef recovery of mitigation reefs by reducing time-lag (Jaap, 2000).
	Coral propagation and outplanting	Widely used restoration practice in South Florida, especially for fast-growing species. Consistent with Acropora Recovery Plan (NMFS, 2015) and FKNMS's Restoration Guidelines for Coral Reefs and Associated Habitats in FKNMS (2019). Helps jumpstart reef recovery of mitigation reefs by reducing time-lag. Helps replace structural complexity and restore genetic diversity.
	Microfragmentation and outplanting	Helps jumpstart reef recovery of mitigation reefs by reducing time-lag. Sexual maturity of colonies may be achieved in a few years. Can help restore genetic diversity.
	Assisted reproduction	Assisted reproduction (e.g. creation of spawning hubs and outplanting sexually produced coral recruits) has been identified as one mechanism to increase the resilience of coral reefs by the National Academy of Sciences (NAS, 2018). This strategy can also help expand the diversity of species used in mitigation.
	Disease intervention and minimization	Strategy identified to help control and/or prevent further outbreaks of Stony Coral Tissue Loss Disease (SCTLD), e.g., treatment with beneficial microorganisms such as probiotics. Serves as an adaptive management strategy for the long-term success of other strategies (e.g. relocation, outplanting) (Vardi et al. 2020).
Artificial reef creation with biological enhancement	Active cleaning, removal of macroalgae and other coral competitors	Provides available substrate for natural recruitment almost immediately, reducing time-lag. Prevents excessive macroagal growth which can outcompete corals (Ceccarelli et al. 2018). The removal of the zoanthid *Palythoa*

		caribaeorum (an aggressive coral competitor) may also be necessary.
	Herbivore replenishment	Reintroduction of herbivores (e.g. seeding with sea urchins *Diadema antillarum* and the Caribbean king crab *Mithrax Spinossisimus*) has been identified as one mechanism to increase the resilience of coral reefs by the National Academy of Sciences (NAS, 2018).
	Relocation of corals, octocorals and sponges	Organisms are moved out of harm's way and help jumpstart reef recovery of mitigation reefs by reducing time-lag (Jaap, 2000).
	Assisted reproduction	Assisted reproduction (e.g. creation of spawning hubs and outplanting sexually produced coral recruits) has been identified as one mechanism to increase the resilience of coral reefs by the National Academy of Sciences (NAS, 2018). This strategy can also help expand the diversity of species used in mitigation.
	Disease intervention and minimization	Strategy identified to help control and/or prevent further outbreaks of Stony Coral Tissue Loss Disease (SCTLD), e.g., treatment with beneficial microorganisms such as probiotics. Serves as an adaptive management strategy for the long-term success of other strategies (e.g. relocation, outplanting) (Vardi et al. 2020).

F.3.3 Natural Reef Enhancement

Natural reef enhancement has the potential to reverse population decline and accelerate the recovery of a reef after a disturbance (or multiple disturbances). By building on the success of previous and planned restoration work in southeast Florida and the Florida Keys National Marine Sanctuary (e.g. NOAA's Restoring Seven Iconic Reefs: A Mission to Recover the Coral Reefs of the Florida Keys), and partnering with local restoration practitioners and coral reef management agencies, we expect to replicate the success observed and help enhance reefs near the project area that have been affected by either anthropogenic impacts (e.g. ship groundings, anchoring damage) or that have experienced natural degradation as a result of stressors such as storm damage, climate-change induced bleaching, and disease.

Sites that will be considered for natural reef enhancement will represent similar habitats and reef zones to those that may be impacted by project-related activities or associated sedimentation. Successful mitigation will include the restoration of ecosystem functions (or ecological services) to help compensate for losses resulting from unavoidable project-related impacts to hardbottom habitats. Natural reef enhancement sites will include (1) impacted reef sites such as vessel grounding or anchoring events, and sites which may potentially be affected by the project as a result of sedimentation (considered for post-project mitigation) such as areas near the Sand Bypass project, and (2) known degraded reef sites near the project area.

F.3.4 Enhancement of Impacted Reefs

This section has been divided to include two types of impacted reefs: (1) grounding and anchoring sites in the vicinity of the project area (Broward county), and (2) areas of the spoil shoal north of the channel (east of the areas designated by the Sand Bypass project) which will be targeted for continued re-exposure of hardbottom (i.e. rubble removal) post-construction. Because of the slow recovery rate for many

Caribbean coral species, impacted sites will need physical repair in addition to post-repair active biological enhancement. The latter would accelerate the biological recovery of the site ahead of the time full recovery would occur if recovery relied entirely on natural recruitment, as many benthic species may take years (or even decades) to recruit and grow to a size capable of reproducing. The interval required to reach substantial functional productivity after repair is complete is estimated to be ~30 years. However, this is expected to be shortened to 10-20 years with active biological enhancement.

A two-phase approach will be used for enhancing impacted reefs. Phase 1 will include the repair phase, using a combination of strategies such as rubble stabilization, restoration of the reef structure and topographic complexity, and/or filling and sealing reef fractures. In addition, rubble and small rocks from the grounding sites can be used to fill holes in the seabed. Phase I may also include incorporating results from larval dispersal and connectivity modeling (e.g. Figueiredo, 2019) to help support site selection of candidate sites and maximize potential connectivity among enhancement sites. This information can also help the decision-making process for selecting enhancement sites which more effectively maximize the spatial impact of mitigation actions, while minimizing costs and effort (e.g. spillover effects). Phase 2 will include biological enhancements at the site to jumpstart the natural recovery process after repair (as described in **Table F-2** and **Section F.3.2**) and help restore ecological functions lost such as species and genetic diversity, reef health, and increased recruitment and connectivity. For example, outplanting fast-growing coral species (e.g. *Acropora cervicornis*) to impacted sites can help replace the 3D structure of the reef in a relatively short period of time compared to outplanting massive coral species, in addition to providing additional benefits associated with storm risk and coastal protection through wave and energy dissipation, if outplanted in shallow-water (e.g. Storlazzi et al. 2019; Ghiasan et al. 2020).

F.3.4.1 Repair of Grounding and Anchoring Sites

Best practices for achieving enhancement of these sites will be guided by the NOAA's Restoration Center, who has conducted this type of work at groundings sites in Caribbean locations (e.g. T/V Margara grounding in Puerto Rico, see **Figure F-3**). Currently known grounding sites in southeast Florida that are not recovering naturally are recommended for active biological enhancement (Ladd, 2012). The increased amount of rubble (compared to non-impacted sites) is suggested to be a limiting recovery factor for the survival and growth of stony corals and octocorals (Gilliam and Moulding, 2011). Incorporating additional actions (e.g., relocation of stony corals, octocorals, and sponges, and herbivore replenishment as discussed in **Table F-2**) can further facilitate coral reef recovery towards a more natural reef community.

Some of the ecological benefits of this mitigation alternative include the following:

- Stabilization of rubble and fractured hardbottom that could otherwise damage surrounding coral reef / hardbottom habitats
- Increased relief provided to flattened reef structure
- Impacted sites can serve as great recipient sites for relocated corals, octocorals and/or sponges to help jumpstart recovery.
- Creation of enhanced habitat that is expected to be more similar to adjacent natural reef communities over time
- Integration of enhanced areas into existing natural reef structure (i.e. more substrate available for natural recruitment), increasing connectivity among habitats over time.
- Increased species and genetic diversity of species at these sites, promoting reef health

- High functional value expected to be reached after a short-time interval, especially if genetically diverse organisms are relocated and/or fast-growing species are outplanted to these sites. Current time-lag for recovery of these sites could be very slow or nonexistent without active biological enhancement.

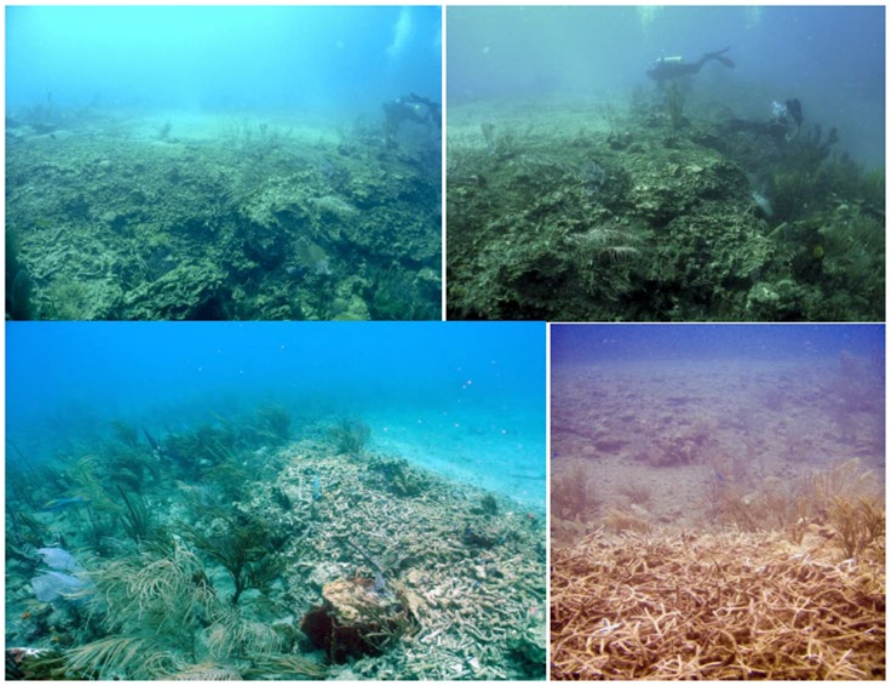

Figure F-3. Photos of impacted areas and adjacent reef needing primary restoration at the T/V Margara grounding site in Puerto Rico (Source: NOAA's Restoration Center).

F.3.4.2 Re-exposure of Hardbottom from Areas of the Spoil Shoal

The artificial material north of the entrance channel is comprised of dredged spoil that was constructed during the 1961-1963 deepening for the Outer Entrance Channel (OEC) with sidecast disposal of material north of the Port. This area is part of the Broward County's Sand Bypass project, which will include the construction of a "sand trap" and the removal of a portion of the rubble spoil shoal in the area as depicted in **Figure F-4**. The mitigation plan for this project will include the re-exposure of natural hardbottom by removal of rubble from rubble sand and rubble spoil shoal crest, enhancement and expansion of the Broward County's Stony Coral Nursery Program, construction of a 0.2-acre boulder reef coral nursery in the nearshore area just south of the rock rubble barrier (see **Figure F-4**), and construction of a 0.3-acre boulder reef coral nursery off Ft. Lauderdale (not depicted in Figure). Stony corals, octocorals, queen conch (*Strombus gigas*), and long-spined sea urchins (*Diadema antillarum*) will also be relocated out of the direct impact areas prior to initial construction of the sand trap to help minimize impacts.

The Corps is aware of the mitigation efforts for the Sand Bypass project (as described above) and does not intend to interfere with the Sand Bypass mitigation plan. Negotiations with the County are ongoing to avoid potential deepening-related sedimentation on this area, especially in the location of the 0.2 acre nearshore nursery boulder reef, which appears to be within the area predicted to receive up to 1 cm of sedimentation according to the spillage model (see **Figure F-5** for Scenario 2).

The Corps plans to expand current Sand Bypass mitigation efforts by proposing the enhancement of natural reef areas east of the rubble barrier and nearshore coral nursery mitigation site (**Figure F-4**) as a post-project mitigation alternative, using the array of mitigation strategies discussed in **Table F-2**. Priority areas to be targeted (e.g. deeper areas of the spoil shoal) for enhancement will be coordinated with the IWG. The ecological benefits of this proposed mitigation are very similar to those described for the repair of grounding and anchoring impacted sites with the additional benefit of providing additional enhanced habitat near the project area which may help offset project-related ecological losses in Broward County.

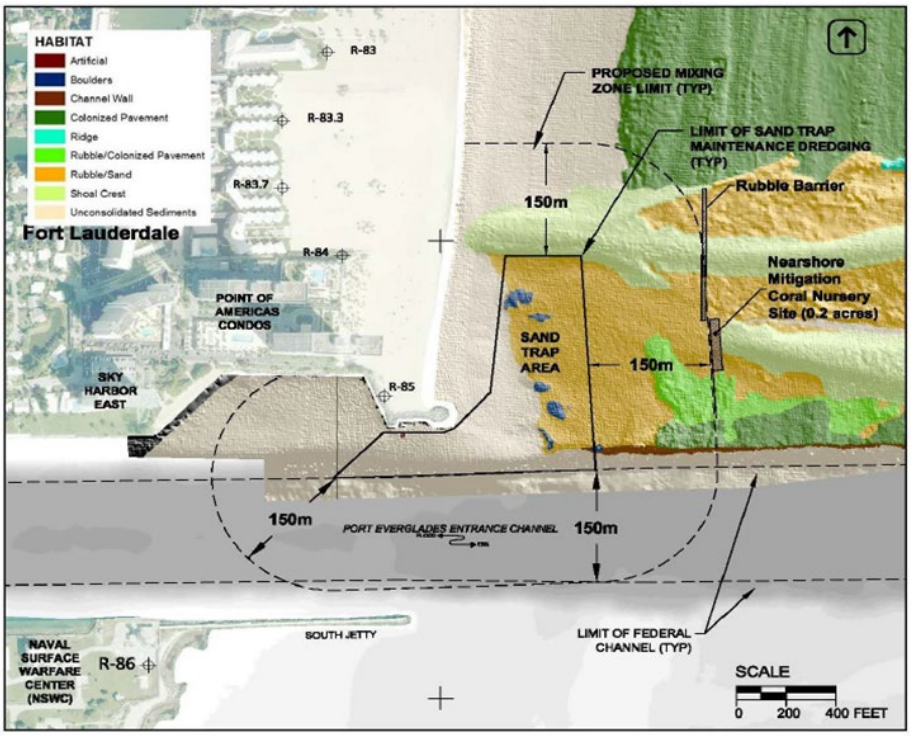

Figure F-4. Sand Bypass project features, including proposed location of the 0.2-acre nearshore mitigation coral nursery site. (Source: Broward County)

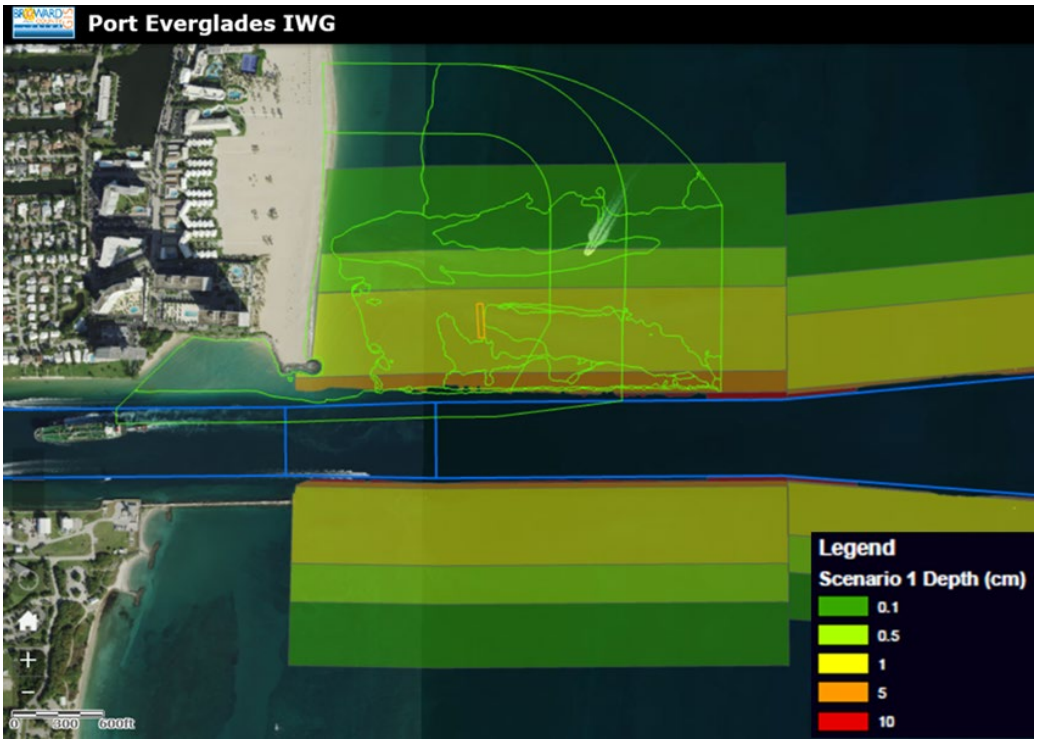

Figure F-5. Spillage model sediment depositions for Scenario 2 (Cutterhead with no overflow) depicting areas of potential project-related sedimentation (denoted by different sediment deposition values), along with boundaries of the Sand Bypass project (areas denoted in light green), and location of the 0.2 acre nearshore mitigation coral nursery site (denoted by orange rectangle polygon).

F.3.4.3 Enhancement of Degraded Reefs

Enhancement of natural degraded reefs is expected to consist primarily of biological enhancements to help jumpstart the natural recovery process (as described in **Table F-2**), though some sites may need an additional repair phase (e.g. rubble stabilization and removal) as described above for impacted reefs. The interval required to reach substantial functional productivity varies depending on the mitigation strategies used but is estimated to be much shorter (e.g. 10-20 years) than leaving these sites to be naturally recruited, especially since many coral species are not even naturally recruiting to reefs (particularly ESA-listed coral species, e.g. NMFS, 2015).

Below we describe in more detail each of the strategies proposed for the biological enhancement aspect of this mitigation plan (summarized in **Table F-2**). Proposed relocation efforts by the Corps are described separately in the Relocation Plan of corals and other organisms (**Section F.4** below).

F.3.4.3.1 Active Cleaning and Removal of Macroalgae and Other Coral Competitors

Excessive macroalgal growth is known to overgrow and outcompete stony corals, especially in the presence of increased nutrient levels (Diaz-Pulido and McCook, 2003; Burkepile and Hay, 2006; Ladd, 2012). Though this is considered a site preparation or corrective mitigation action, sites (artificial or natural reef enhancement sites) can be actively managed to promote colonization (i.e. recruitment of corals and other benthic invertebrates) and coral relocation success. The advantage of this mitigation

alternative is that it provides available substrate for natural recruitment almost immediately, helping community species be similar to other natural reefs over time, as well as helping recruit species which may be suffering from poor recruitment. Many of these ecological gains can be achieved within 10-20 years.

At each mitigation site, various tasks will be performed initially (prior to beginning biological enhancement or prior to outplanting corals), and each year prior to coral spawning events that generally occur in August/September. Tasks will include (1) clearing excessive macroalgae and other coral competitors (e.g. Palythoa) from reef surfaces to promote larval settlement and (2) addition of sea urchins and/or Caribbean king crab as a natural source of continuous algal control (herbivore replenishment, see **Section F.3.4.3.2**).

Some of the ecological benefits of this mitigation alternative include the following:

- Provides available substrate for settlement almost immediately
- Restoration of habitat structure/critical habitat
- Increases connectivity among habitats
- Reduces time-lag for recovery
- Enhances recruitment and available substrate for beneficial algae (e.g. crustose coralline algae) known to serve as cue for settlement for coral larvae (e.g. Erwin et al. 2008).
- High value mitigation alternative with low risk if best practices from restoration practitioners are applied.

F.3.4.3.2 Herbivore Replenishment

Herbivores are critical components of healthy, resilient coral reef ecosystems, providing a top-down control which can help promote growth and success of reef-building corals (Diaz-Pulido and McCook, 2003; Burkepile and Hay, 2006; Littler et al. 2006; Ladd, 2012). Long-spined sea urchins (*Diadema antillarum*) and Caribbean king crab (*Mithrax Spinossisimus*), once abundant on Florida reefs, have suffered significant declines in recent decades. In the case of *D. antillarum*, significant declines in population numbers were the result of a mass-mortality event in the 1980s (Lessios, 1988; Ladd, 2012). The presence of *D. antillarum* has been shown to decrease macroalgal abundance, increase juvenile coral density and diversity (Edmunds and Carpenter, 2001; Carpenter and Edmunds, 2006), decrease coral disease incidence, and increase coral survival (Jordán-Garza et al. 2008; Ladd, 2012).

To help jumpstart the recovery of mitigation reefs, each degraded site will be seeded with herbivores for three consecutive years, as part of an active management and natural source of continuous algal control. Sites will be initially seeded with herbivores through opportunistic availability in areas targeted for relocation (first year) but subsequent seedings (years) will depend on availability from commercial production (if this option is viable at the time mitigation begins). Current knowledge regarding propagation of long-spined sea urchins and king crab is limited, and as such, this activity is proposed only if commercial production proves successful. However, recent advancements have been made towards the successful commercial production of *D. antillarum* in Florida (K. O'Neill, pers. comm.). Currently, the estimated costs per grazer (urchin or crab) added are ~$35 (Source: Restoring Seven Iconic Reefs: A Mission to Recover the Coral Reefs of the Florida Keys).

Some of the ecological benefits of this mitigation alternative include the following:

- Re-introducing grazers can help maintain a coral-dominated state by reducing competition with macroalgae (top-down herbivory, e.g. Littler et al. 2006).
- Increases available substrate for natural recruitment, serves as a continuous source of algal control.
- Demonstrated to increase coral growth and decrease macroalgal cover on reefs, at least on a small-scale.
- Increases non-coral species diversity at mitigation sites
- Lowers time-lag for recovery
- Can be used in combination with active cleaning and removal of macroalgae and other competitors (see **Section F.3.4.3.1**), to help maintain a healthier reef community

F.3.4.3.3 Coral Propagation and Outplanting

In May 2013, NMFS recommended that the Corps mitigate project-related impacts to corals and hardbottom habitats by propagating coral colonies at in-situ and land-based nurseries and then outplanted the colonies to suitable recipient sites on the reef tracts. NMFS estimated that this approach requires ~20 years to complete and would cost approximately $35.6M to $42.3M, including risk contingencies (see 2016 EIS sub-Appendix E). NMFS's recommendation was based on successes of coral propagation and enhancement programs in Atlantic and Caribbean waters, using scientifically-vetted practices developed and used by coral nursery managers in the Florida Keys, Broward County, Puerto Rico, U.S. Virgin Islands, and other Caribbean islands to reproduce Acropora species asexually (e.g., Johnson et. al 2011).

The proposed coral propagation and outplanting mitigation option is based on utilizing existing NMFS programs to support the implementation of the project in partnership with local resource agencies (e.g., FDEP), academic institutions, and other coral restoration practitioners in the area. This alternative is designed to maximize the chances of successful natural coral reproduction, larval transport, settling and colonization into new areas, and genetic mixing required for survival and recovery of the species. Furthermore, this mitigation option is consistent with the Acropora Recovery Plan (NMFS, 2015) and FKNMS's Restoration Guidelines for Coral Reefs and Associated Habitats in FKNMS (2019). Many of the actions described in this section are considered "green light" actions under FKNMS's Restoration guidelines, and as such are likely to be approved in the FKNMS without significant review.

Completion of this aspect of the mitigation plan will include activities to "ramp-up" propagation, outplanting to natural reef sites targeted for enhancement, and monitoring/contingency plans in case success criteria is not met. "Ramp-up" activities will include expansion or creation of in-situ and land-based nurseries, and outplanting site selection. Once coral fragments have grown to a size where the probability of survival on natural reefs has increased to an acceptable level (usually between 12 to 18 months, but much less for fast-growing species like *Acropora cervicornis*), the corals are outplanted. Protocols and methods to propagate and outplant corals onto natural reefs have been successfully established for fast-growing species (e.g. Johnson et al., 2011; Lirman and Schopmeyer, 2016; Schopmeyer et al. 2017), and massive (brain) coral species are also being currently propagated and showing success (e.g. *Orbicella faveolata* and *Montastraea cavernosa*; Page et al. 2018), making active coral population enhancement a viable, realistic, and important mitigation option for southeast Florida. To our knowledge,

no propagation nurseries in Florida exist for large-scale propagation of other reef organisms besides stony corals, urchins, and Caribbean king crab.

Some of the ecological benefits of this mitigation alternative include the following:

- Faster coral growth can be achieved in nurseries (propagation phase)
- Increase abundance and diversity of species once corals are outplanted
- Spawning "hubs" can be created if fragments from the same species are outplanted in proximity and factors such as larval dispersal and connectivity are taken into consideration (see **Section F.3.4.3.5**). Appropriate outplanting densities can be targeted to resemble historic densities, instead of status quo.
- Outplanting fast-growing species (*A. cervicornis*) first can help replace the reef structural complexity sooner (in 3-4 years) compared to slow-growing species. Fast-growing species can also be outplanted in thickets (vs. individual fragments) to increase resistance to storm impacts.
- Lowers time-lag for recovery of mitigation sites. How much depends on various factors (e.g., species targeted, coral growth in land-based vs in-situ nurseries, outplant frequency, outplant site physical characteristics, etc.).
- This is considered a high value, low risk mitigation alternative, especially for fast-growing species.
- When coupled with advanced genetics, propagated corals with high survivorship potential can be outplanted to natural reefs to increase the genetic diversity and population size of remnant coral populations. Including multiple genotypes in outplanting efforts also increases reef resilience as some genotypes are more prone to stressors (bleaching, disease) than others (e.g. Pausch et al. 2018; Miller et al. 2019).

At the moment, risks exist of potentially spreading Stony Coral Tissue Loss (SCTLD) disease or creating new flares or outbreaks when outplanting disease-suceptible coral species. However, this risk can be mitigated by (1) avoiding outplanting any propagated corals which show signs of disease, (2) following appropriate SCTLD dive gear decontamination procedures when conducting in-water work (e.g. AGRRA protocol), (3) propagating highly-disease susceptible species in land-based nurseries with closed-recirculating systems (i.e. genetic rescue) until it is appropriate to outplant these species to natural reefs, (4) monitoring and actively mitigating for disease after outplanting, including actions such as quarantine, lesion treatments with antibiotics, and/or use of probiotics (if proven successful and is permitted by regulatory agencies) (see **Section F.3.4.3.6**), and (5) adaptively managing the mitigation program by incorporating lessons learned from existing and planned studies (FWC is currently leading a large-scale study to examine the potential disease risks and survival related to outplanting SCTLD-disease susceptible corals to help define appropriate timeframes for outplanting). The Corps will continue coordination with the Interagency Working Group (IWG) to develop a more detailed coral propagation and outplanting plan as more information become available.

F.3.4.3.3.1 Mixed-Species Approach to Propagation

As part of the proposed mitigation, a mixed-species approach to propagation will be used, focusing on stony coral species present in the project area, and prioritizing reef-building, broadcast-spawning species (see **Table F-3**). In addition, propagation and subsequent outplanting will be conducted in a phased approach by type of species (fast-growing vs. slow-growing), at appropriate distances and timing with

regards to project construction (>2 km from project area during the project vs. >500 m – 2 km post-project mitigation, see **Table F-4**). Final decisions regarding which species will be propagated and outplanted will be based on how successful these activities are for each target species at the time mitigation begins.

Table F-3. Overview of coral propagation target species. The goal is to conduct mixed-species propagation and subsequent outplanting. These percentages were developed in coordination with NMFS Habitat Conservation Division (HCD). Species were selected based on (1) known presence near the project area, (2) likelihood of success, and (3) most current information regarding coral species known to be propagated in Florida in either in-situ nurseries (based on personal communication with local practitioners), or land-based facilities for sexual propagation (L. Gregg, FWC, personal communication).

Coral species	% allocation (ESA species)	% allocation (non-ESA species)	Justification & Benefits	Risks	Land-based vs. *in-situ* nurseries
Acropora cervicornis	50%	N/A	ESA-listed species, reef-builder, grows fast, not susceptible to SCTLD, less susceptible to sedimentation	Susceptible to storm impacts and fragmentation but risk can be partially mitigated by outplanting in thickets	*in-situ*
Orbicella faveolata, O. annularis and O. franski	25%	N/A	ESA-listed species, reef-builder, good for microfragmentation, candidate for genetic rescue	Intermediate disease susceptible species, grows slow	both
Montastraea cavernosa	N/A	25%	Reef-builder, good for microfragmentation, candidate for genetic rescue	Intermediate disease susceptible species, grows slow	both
Pseudodiploria strigosa	N/A		Reef-builder, candidate for genetic rescue	Highly disease susceptible species, grows slow	Land-based
Diploria labyrinthiformis	N/A		Reef-builder, candidate for genetic rescue	Highly disease susceptible species, grows slow	Land-based
Meandrina meandrites	N/A		Reef-builder, candidate for genetic rescue	Highly disease susceptible species, grows slow	Land-based
Colphophyllia natans	N/A		Reef-builder, candidate for genetic rescue	Highly disease susceptible species, grows slow	Land-based

Table F-4. Proposed recipient areas for outplanted corals, by project timing (pre-, during, post-construction) and level of effort expected. These percentages were developed in coordination with NMFS HCD.

Timing	Distance from the channel	Artificial Reefs	Purpose	Natural Reef Enhancement sites	Purpose	Total effort
Pre-	N/A	0%	N/A	0%	N/A	0%

Timing	Distance from the channel	Artificial Reefs	Purpose	Natural Reef Enhancement sites	Purpose	Total effort
During-	> 2 km	5%	Contingency plan	45%	Meet target densities. All ESA-listed corals go to natural reefs.	50%
Post-	>500 m – 2 km (except for mitigation activities in spoil shoal)	5%	Contingency plan	45%	Meet target densities. All ESA-listed corals go to natural reefs.	50%
						100%

The propagation and outplanting approach will use a combination of two types of reef organisms: (1) fast-growing and (2) slow-growing coral species.

Phase 1 – Fast-growing coral species propagation

The faster growing reef species are primarily composed of *A. cervicornis*, because this species exhibits faster growth rates than other Atlantic/Caribbean coral species, reproduces predominantly via asexual fragmentation, and can be propagated efficiently both in-situ and land-based nurseries. While replacing coral colonies is an essential component of the reef mitigation, replacing the three-dimensional structure of the reef is also important. Corals will be outplanted onto natural reefs in Broward County using the methods successfully developed by restoration practitioners (e.g. Johnson et al. 2011; Lirman and Schopmeyer, 2016; Schopmeyer et al. 2017).

Phase 2 – Slow-growing coral species propagation

Slow-growing corals are composed of massive (brain) corals currently being successfully propagated by local restoration practitioners (see **Table F-3**). It will take longer for mitigation sites to reach full ecological services using slow-growing species, but they are essential to ensuring the mitigation sites are composed of an appropriate fully functional suite of species. Both phases may be implemented concurrently, sequentially, or both.

For both phases, propagation of corals will be conducted via in-situ nurseries (good for fast-growing species or relocated massive coral species known to be not susceptible or moderately-susceptible to SCTLD) and land-based nurseries (more appropriate for species candidates for microfragmentation or for relocation and propagation of highly-disease susceptible species). Each type of nursery functions in a different capacity and provides distinctive products; therefore, each type has different advantages and disadvantages. Both land-based and in-situ nurseries are needed to hold the coral broodstock to use for propagation activities (sexual and asexual), as well as rear coral offspring. Nurseries can also serve as repository of genetic diversity (i.e. genetic “bank”). The Corps will assess options for expanding existing infrastructure (e.g. additional in-situ nurseries or land-based facilities) to scale-up the production of corals necessary to achieve the goals in this mitigation plan. In addition, redundancy will be built for outplanted corals to ensure success criteria is met.

F.3.4.3.3.2 *In-situ* and Land-Based Nurseries

In Florida and the Caribbean, the most common in-situ nurseries are Acroporid coral propagation nurseries due to the high growth rates and ability to reproduce through fragmentation of these species (Ladd, 2012). In-situ coral nurseries can be a cost-effective tool for coral reef restoration; these operations do not occupy land-based space and if correctly positioned require minimal transportation costs from the nursery to the mitigation site (Ladd, 2012). Furthermore, in-situ nurseries require relatively low maintenance and protocols have been successfully developed by restoration practitioners (e.g. Johnson et al. 2011; Lirman and Schopmeyer, 2016; Schopmeyer et al. 2017). Disadvantages of in-situ coral nurseries include the ability to scale-up (large number of corals needed especially for large-scale projects than may be currently available), and exposure to storm impacts, diseases, extreme weather events, and/or damage by fishermen and boaters. However, careful planning, appropriate site-selection and monitoring can help decrease some of these risks (Ladd, 2012).

Land-based propagation nurseries can employ the same methods as those used by in-situ nurseries (fragmentation and propagation) using regulated tank setups. Owing to the increased control of water conditions offered and easier monitoring by land-based nurseries, these operations can take advantage of different propagation methods that cannot be accomplished or are much more difficult in-situ (Ladd, 2012). Land-based nurseries can also serve as a safeguard against extreme hot/cold water events or storm impacts which may otherwise cause high mortality in in-situ nurseries. In addition, early life stages of coral have high mortality rates in the wild, thus sexual propagation in controlled environments can help increase the amount of sexually produced coral juveniles that would be available for enhancement efforts (outplanted at a time when survival rates are expected to be higher). The main disadvantage of land-based nurseries is the ability to scale-up (additional resources and infrastructure needed), leading to potentially higher costs compared to in-situ nurseries.

F.3.4.3.4 Microfragmentation

Massive stony coral species have often been overlooked in propagation and outplanting activities because of their slow growth, and because developing the appropriate techniques to effectively propagate and outplant these species have proven challenging (Page et al. 2018). However, recent advancements show increase rates of success, especially through microfragmentation efforts (Page and Vaughan, 2014; Page et al. 2018). When coral colonies are micro-fragmented, fragments are cut to ~1 cm2 or less and grown to ~6 cm2 prior to outplanting, at which stage fragments can show comparable survival compared to larger fragments (at least for the coral species *Montastraea cavernosa* and *Orbicella faveolata*, see Page et al. 2018). When grown in close proximity, smaller pieces of the same initial colony can eventually fuse and form a larger, reproductive-size colony in a much shorter period (a process called micro-colony fusion) (Forsman et al. 2015, see **Figure F-6**). Microfragmentation has even been shown to increase growth in *A. cervicornis* without causing mortality (Lohr et al. 2015). Recent observations show microfragmented *O. faveolata* colonies began to reproduce in the field within 5 years after being outplanted (see press release: https://mote.org/news/article/mote-marine-laboratory-documents-another-first-for-massive-corals-in-florid). Microfragmentation of reef-building species impacted by the SCTLD can considerably enhance coral density on the reef, enhance fertilization success, and ultimately promote recruitment success.

Some of the ecological benefits of this mitigation alternative include the following:

- Microfragmentation can help expand the mix and genetic diversity of species used in propagation and outplanting.

- Asexually reproducing corals through microfragmentation has the advantage of quickly increasing coral tissue growth and biomass to provide habitat for reef-associated species and prevent reef substrate erosion.
- Lowers time-lag for recovery.
- Known degraded reefs in Broward County with large ecologically important coral colonies (>2 m) can be targeted for microfragmentation (B. Walker, pers. comm.).
- Microfragmentation can accelerate coral cover by growing corals faster and larger.
- This is considered a high value mitigation strategy, especially given slow coral growth rates for massive coral species and bottlenecks for successful sexual reproduction.

Despite recent advances in coral microfragmentation, some risks of this alternative include high predation of newly-outplanted fragments (Page et al. 2018; Koval et al. 2020). However, this risk can be mitigated by (1) caging corals the first weeks after outplanting, and/or (2) outplanting additional fragments to compensate for the tissue biomass lost due to predation. In addition, including rare coral species (e.g., Dendrogyra cylindrus) at the moment is still considered very risky due to low survival. Therefore, propagation and outplanting efforts through fragmentation should be targeted for species shown to be successful to date (see **Table F-3**).

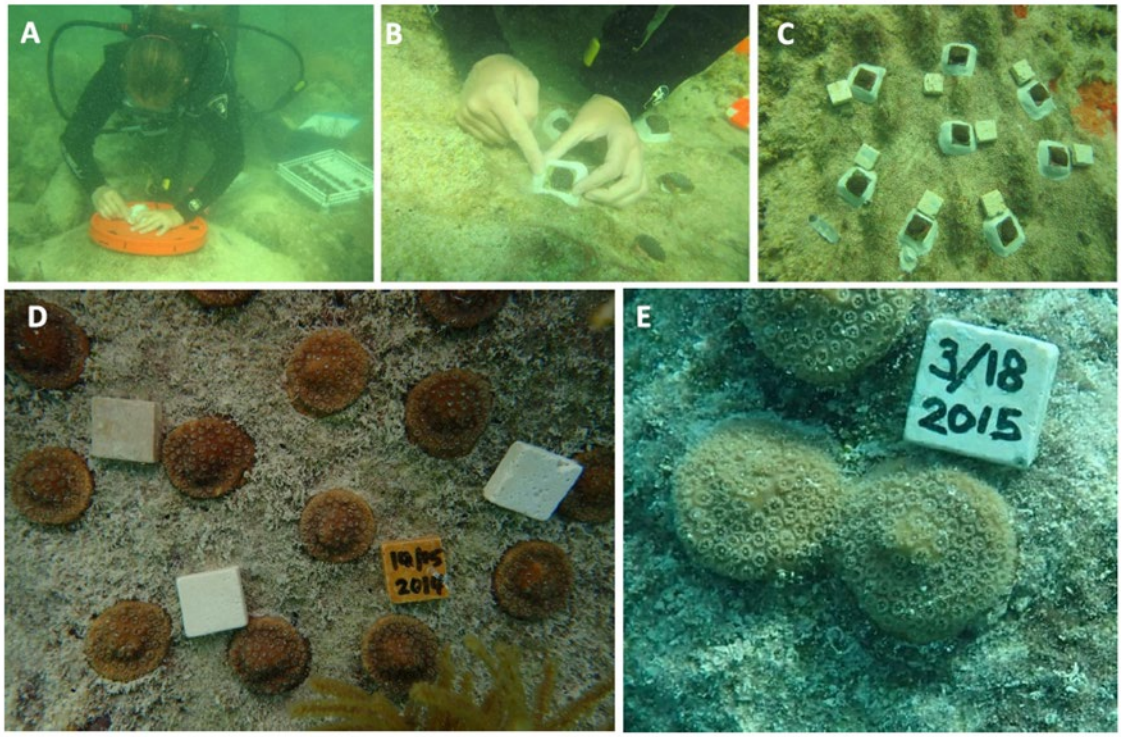

Figure F-6. Micro-fragmented *O. faveolata* colonies fusing after being outplanted in the field for 5 months (Source: Forsman et al. 2015).

F.3.4.3.5 Assisted Reproduction

Assisted reproduction is a broad term that can entail collecting coral gametes, performing fertilization, rearing embryos to the larval stage for settlement, and growing the recruits until they reach a size suitable for outplanting. The collection of gametes can be made in the field during the annual coral spawning event and/or in land-based nurseries by bringing in sexually mature colonies to outdoor tanks right before spawning is projected to occur. Coral gametes can also be acquired by maintaining corals year-round in outdoors tanks exposed to natural moon and light cues under a natural annual temperature cycle, or even by replicating those same conditions in indoors aquaria (Craggs et al. 2017).

Though this mitigation alternative may be considered part of the relocation and outplanting planning efforts, assisted reproduction (e.g. managed breeding) has been identified as one mechanism to help increase the resilience of coral reefs by the National Academy of Sciences (NAS, 2018). Assisted sexual reproduction of corals can considerably increase the number of genetically unique corals available for restoration and increase the genetic diversity of existing populations. On a local-scale, coral density can be managed by relocating colonies to specific sites in an attempt to bring sexually mature colonies close enough together to increase the likelihood that eggs and sperm from these colonies will come into contact during spawning events, essentially creating a spawning "hub" for select species. Larval dispersal and modeling results would need to be incorporated to optimize site selection (e.g. Figueiredo, 2019) and the ecological services that result from this activity. This reef enhancement activity not only promotes species recovery through supporting recruitment driven by natural sexual reproduction but also promotes recovery through providing sites where efficient spawning observations and gamete capture can occur.

In this mitigation plan, assisted reproduction can be achieved via numerous ways, including: (1) outplanting corals of same species in close proximity (see **Section F.3.4.3.4**), (2) rearing and outplanting sexually-produced coral recruits (considered part of the strategies under managed breeding, NAS, 2018), (3) growing corals to sexual maturity faster via microfragmentation, and (4) creating "spawning hubs" (also called "spawning nurseries" or "artificial spawning hotspots") with consideration of currents, larval dispersal and connectivity. Zayasu and Suzuki (2019) showed that theoretically, even a small "artificial spawning hotspot" can help supply enough coral larvae to restore a large area for the arborescent Acropora corals. Their work also suggests that to enhance larval supply, it is important to enhance both population density and genetic diversity of adult corals by using at least ~15 genotypes from each species targeted.

Some of the ecological benefits of this mitigation alternative include the following:

- The establishment of a spawning hub can contribute to natural ecosystem processes by increasing the likelihood that eggs and sperm from coral colonies fertilize and facilitating the collection of gametes by restoration practitioners for propagation purposes (part of FWC's Coral Reef Restoration Priorities, L. Gregg, pers. comm.).
- This strategy can help expand the diversity of species used in mitigation.
- This is a highly advocated strategy among local restoration practitioners.
- Helps rebuild population diversity by augmenting local genotypes and increasing population size.
- Outplanting in proximity allows easier introduction of additional genetic diversity, resulting in individuals with higher fitness than the parental population.

- This is considered a high value mitigation strategy. Could help mitigate the failed coral recruitment corals are experiencing in the Atlantic/Caribbean, especially massive reef building corals.
- This strategy is considered feasible at local scales

Some of the risks associated with assisted reproduction, particularly rearing and outplanting sexually produced juveniles, include potentially high mortality. However, this risk can be mitigated by (1) growing coral recruits/juveniles in land-based nurseries to the point where they would be expected to have higher survival rates (at least 1 year; current work by local practitioners is aimed at determining optimal size for coral offspring prior to outplanting), (2) building redundancy in propagation efforts to ensure success criteria is met, (3) only allocating a small portion of the mitigation plan to this strategy (minimizing risk), and (4) caging during the first weeks after outplanting to minimize predation. Finally, though a longer time-lag for recovery is expected for this strategy compared to other strategies describes in this plan, the ecological gains from implementing this strategy are significantly greater than other mitigation options.

F.3.4.3.6 Disease Intervention and Minimization

In Florida, the condition and resilience of the coral reef ecosystem have been imperiled for decades due to chronic, widespread coral bleaching, various diseases, physical impacts from natural (e.g., hurricanes), anthropogenic sources, and most recently by the severe impacts of the Stony Coral Tissue Loss Disease (SCTLD) outbreak (Walton et al. 2018). Since 2014, SCTLD has been affecting roughly half of the coral species found in Florida, including all the major coral reef framework-building species, species that contribute significantly to coral cover, coral reefs that are federally designated as Habitat Areas of Particular Concern within Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act, and five ESA-listed coral species. In response to SCTLD, DEP, in partnership with other local state and federal agencies, developed a coral disease response network consisting of 10 response teams, a steering committee, and two dedicated staff members.

Extensive coral mortality related to SCTLD can result in failure to meet success criteria and failure to offset impacts resulting from the project. One of the concerns related to the mitigation activities here proposed is that introducing disease susceptible corals to an area experiencing SCTLD infections (i.e. via relocation or outplanting) may result in high levels of mortality from disease. This is a concern for corals being held in in-situ nurseries as well as those directly relocated or outplanted onto artificial or natural reefs. There is also the potential that outplanting susceptible corals may increase coral disease incidence in an area by introducing new biological material open to SCTLD infection and increasing local pathogen load via new infections. As such, disease intervention and minimization techniques may be considered under contingency planning of this mitigation plan, and may include a variety of methods (as available and permitted by regulatory agencies), which include: quarantine procedures for coral colonies, lesion treatments with antibiotics (currently shown to be effective at minimizing or stopping the spread of disease at least for some species), and/or whole-colony prophylactic treatments such as probiotics to maintain coral health prior to relocation or outplanting. Identifying the beneficial microorganisms, such as probiotics, is a species-specific task and recent progress has been made towards isolating probiotic strains that can stop or slow SCTLD lesion progression in diseased *Montastraea cavernosa* colonies and prevent SCTLD transmission (V. Paul, unpublished data). It is possible the state of the science will advance considerably and there will be a desire to include probiotic application in the mitigation plan to increase the ecological services at enhancement sites (as new information on SCTLD and restoration best practices are developed). These are considered “yellow light” actions under by FKNMS (2019) that will require additional information and analysis to address appropriate timing. FWC is currently leading a large-scale

study to examine the potential disease risks and survival related to outplanting SCTLD-disease susceptible corals and this information will be used to define appropriate timeframes for outplanting these species (see **Section F.3.4.3.3**). The Corps will continue coordination with the Interagency Working Group (IWG) to develop a more detailed coral propagation and outplanting plan as more information become available.

Some of the ecological benefits of this mitigation alternative include the following:

- Serves as an adaptive management strategy for the long-term success of other strategies (e.g. relocation, outplanting).
- Increases survival rates of disease-susceptible species
- Lowers time-lag for recovery by minimizing mortality of relocated or outplanted corals which may be affected by disease.
- If used in conjunction with propagation, it may help assess genotypes which may be disease resistant (e.g. Miller et al. 2019) as best candidates for outplanting.
- This strategy aligns well with best coral restoration practices in Florida and goals from SCTLD response teams.

Some of the known risks associated with this mitigation alternative include: the potential need for re-treatment of large colonies, sometimes requiring multiple interventions (e.g. SCTLD efforts from K. Neely and B. Walker), and risks associated with applying antibiotics on a large-scale (vs. and aquarium setting). The Corps will follow best management practices and coordinate with local state and federal agencies regarding current investigations aimed at guiding the specificity and effective dosages necessary to reduce the risk of antibiotic resistance and implement this strategy.

F.3.5 Artificial Reef Creation

Artificial reefs will be used as a mitigation option by itself (i.e. bare substrate), or in conjunction with other options for biological enhancement as described in previous sections and summarized in **Table F-2**.

Some of the ecological benefits of this mitigation alternative include the following:

- Potential to create new substrate and habitat for coral reef communities to develop, or upon which coral nurseries can be created and developed.
- Help divert anthropogenic pressures from natural reef sites (e.g. through diving and fishing activities), as well as increase revenue from these activities (Leeworthy et al. 2006; Ladd, 2012).
- Artificial reefs can support comparable levels of fish assemblages to those of natural reefs (Paxton et al. 2020a). Furthermore, large reef-associated transient predators were shown to be denser in artificial reefs compared to nearby natural reefs (Paxton et al. 2020b). These patterns were more evident for taller artificial reefs, highlighting the importance of vertical relief.
- Artificial reefs can serve to increase user and public awareness as well as participation regarding coral reef resource and conservation issues.
- Opportunities for experimental design and “hybrid approaches” which integrate both the gray and green infrastructure have the potential for stronger wave energy dissipation, with benefits for coastal resilience and shoreline protection (Ghiasian et al. 2020).

Some of the risks or disadvantages associated with this mitigation alternative include the following:

- Artificial substrate has not demonstrated to act like natural consolidated substrate, in terms of restoring lost ecological functions (Miller et al. 2009; Moulding, 2011).
- Artificial substrate does not provide the same ecological functions as habitat suitable for coral recruitment and larval attachment for ESA-listed corals (NMFS, pers. comm.). Furthermore, southeast Florida reefs are not substrate limited (Ladd, 2012).
- Habitat where artificial reef is deployed may be altered or destroyed.
- Artificial reef creation as a sole mitigation alternative does not address the overall mitigation needs to offset project-related losses as a result of project construction and/or associated sedimentation, particularly to the middle and outer reefs.

Some of the issues described above related to artificial reefs have been associated with lack of implementation with proper planning and site evaluation, insufficient monitoring or lack of contingency plans to ensure success criteria is met, and inadequate ecological compensation for the loss of ecological services as a result of destruction of the natural habitat (Ladd, 2012). The Corps will continue coordination with the Interagency Working Group (IWG) to develop a more detailed plan for artificial reefs siting and construction to ensure goals and success criteria are met and will follow best management practices from the restoration community to implement this strategy.

F.3.5.1 Artificial Reef Construction Materials and/or Methodology

The Corps will coordinate with local state and federal agencies and follow best management practices regarding construction and siting of artificial reefs including those described in the Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida (Lindberg, 2011). It is anticipated that construction of high-relief, high complexity (HRHC) and low-relief, low complexity (LRLC) artificial reefs would occur to mitigate for impacts to high relief habitat and lower relief reef. The artificial reef creation would be “type-for-type” to reflect the differences in the habitat structure of the hardbottom/reef habitat to be impacted; therefore, two types would be constructed: LRLC reefs would be constructed inshore of, and shallower than, HRHC reefs.

Limestone rock will be used in the artificial reef construction as it provides an ideal substrate for the establishment of a fouling community and colonization by the common reef community species. Limestone for the artificial reefs could be excavated from the project, depending on the size and quantity available, or it could be mined and truck-hauled from upland sites. The material would be deployed in a shore-parallel orientation typical of natural reefs. Buoys delineating the proposed artificial reef site would mark areas for deployment.

Rocks would be deployed to provide the maximum structural complexity and to provide refugia for cryptic and reclusive species. Interstitial sand patches associated with reef habitat would be incorporated into the design to create open sand surface. Construction of artificial reefs in the vicinity of the nearshore placement area may also provide storm risk protection to this area by reducing the wave height and wave energy (Ghiasian et al. 2020). The main constraint for this benefit to be realized is to construct the artificial reef at a depth where the waves passing over the artificial reef “feel” the structure. This can be accomplished by decreasing the water depth over the structure and/or by increasing the frictional dissipation between the waves and the structure by adding corals (e.g. via biological enhancement).

F.3.5.2 Alternative Construction Methods Under Consideration

Construction or artificial reefs may also include the use of reef cells (or modules) which can be built to look similar to natural reefs (or coral colonies), and/or which may facilitate plugging outplanted corals through the use of built-in coral fasteners (e.g. Coral Loks, see **Figure F-7**).

Figure F-7. Reef Cell artificial reef module with Coral Lok fasteners to facilitate coral attachment (i.e. no epoxy or cement needed) (Source: reefcells.com)

F.3.6 Mitigation Monitoring

Monitoring the success of the mitigation strategies proposed is a very important component of this plan. The proposed monitoring will include both mitigation sites and a subset of control sites to compare them against. Monitoring will include multiple events for each mitigation activity (see **Table F-5)**, which may be conducted concurrently at any given mitigation site.

Table F-5. Assumptions and proposed monitoring events and success criteria for each mitigation strategy.

Mitigation strategy	Assumptions and proposed success criteria	Monitoring events proposed
Rubble removal / stabilization	The Corps will use similar success criteria as the Sand Bypass project for re-exposed hardbottom based on completing a target area (e.g. 90%). The Corps will consider using species diversity instead of functional group similarity as a metric for success criteria.	One event yearly for 5 years
Active cleaning, removal of macroalgae	The Corps will consider success criteria based on completing a target area (e.g. 90%).	One event yearly for 3 years

Mitigation strategy	Assumptions and proposed success criteria	Monitoring events proposed
Herbivore replenishment	There may not be a way to monitor success, but the Corps will consider success criteria based on adding a % target (i.e. pre-defined number of herbivores to each mitigation site).	One event yearly for 3 years
Disease intervention and minimization	This is considered a corrective action / contingency, but the Corps will consider success criteria based on completing a target area / number of treatment lesions, if/as disease is observed in mitigation sites.	Multiple events per year for up to 3 years
Traditional propagation / outplanting (fast-growing species)	Will use regional restoration benchmarks from the literature (e.g. Schopmeyer et al. 2017) for success criteria. In the 2016 EIS, a 85% success criteria (after 3 years) was used.	Multiple events per year for up to 3 years
Slow growing species propagation /ouplanting	The 2016 EIS had a placeholder for certain % for other species (not *A. cervicornis*). The Corps will use best practices from the restoration community for the Phased approach which may include adding the fast-growing species first, then the slow growing species (similar to the Iconic Reefs Mission). The 2016 EIS described using photo-mosaics in addition to fate-tracking individual colonies. However, the Corps will consider alternative options including digital video and/or photographs for quantitative data collection.	Multiple events per year for up to 3 years
Microfragmentation	This mitigation strategy can be considered in itself or under assisted reproduction or propagation /outplanting since it can help grow faster to maturity. The Corps will use similar success criteria and performance measures as for outplanting adults. In addition, the Corps will consider documenting the reproductive status of a subset of corals from each cohort outplanted (e.g. 10% of the colonies through histological analysis at the time of collection (baseline) and at Year 3 after outplanting.	Multiple events per year for up to 3 years
Creation of “spawning hubs”	The Corps will coordinate with the IWG the best metrics for monitoring success criteria and will follow best practices from the restoration community. The Corps will consider documenting the reproductive status of a subset of corals from each cohort outplanted [e.g. 10% of the colonies through histological analysis at the time of collection (baseline) and at Year 3 after outplanting].	Multiple events per year for up to 3 years
Rearing and outplanting sexually produced juveniles	Coral juveniles are expected to have lower survival rates compared to adults, but they will be grown in land-based nurseries until out-planted at a time when survival rates are expected to be higher. The Corps will consider similar metrics for verification monitoring as for relocated corals (see **Section F.4.3.2**). This may include monitoring at: 1 week (to ensure corals are still securely attached), 1 month (assessment for predation and disease), and 6 months and 1 year (assessment of survival or no net tissue loss).	Immediately post and multiple events for up to 1 year
Artificial reef creation (natural recruitment / bare substrate)	The Corps will use performance measures and success criteria as identified in the 2016 EIS.	Monitoring as proposed in the 2016 EIS

The final monitoring plan for mitigation activities will be developed after appropriate sites have been identified and characterized / groundtruthed (see **Section F.3.7**) and will include information needs, indicators for success and methods, spatial scale and locations, timeframe, and roles and responsibilities for collecting data. The Corps will follow best management practices and coordinate with local state and federal agencies regarding appropriate monitoring protocols, metrics to assess, and monitoring events for each mitigation activity proposed. It is anticipated that for mitigation activities related to natural reef enhancement or artificial reefs with biological enhancement will follow the newly-released Coral Reef Restoration Monitoring Guide – Methods to evaluate restoration success from local to ecosystem scales (Goergen et al. 2020). This may include using the 5-universal metrics for coral reef restoration (landscape/reef – level, population level, colony level, genetic and genotypic diversity and environmental metrics), as well as goal-based performance metrics (see Goergen et al. 2020) as applicable, depending on the mitigation strategy.

The monitoring program for artificial reefs would consist of both physical and biological components. Physical monitoring would assess the degree of settling of the reef materials, and biological monitoring would assess populations of algae, invertebrates, and fishes, as compared with concurrent control sampling of natural reefs. It is anticipated that methods outlined in the 2016 EIS for assessing success criteria will be used by the Corps for monitoring artificial reefs with natural recruitment (i.e. bare substrate) (see **Table F-5**).

F.3.6.1 Contingency Plan (corrective actions) if success criteria is not met

If proposed mitigation success criteria for each activity has not been met after the last monitoring event (survey), the Corps will meet with FDEP to discuss the performance of the mitigation and a path forward to complete the mitigation requirement. Typically, failure to meet established success criteria will require additional relocation or outplanting. Recommendations from NMFS will be followed for risk contingencies related to the coral propagation and outplanting option (see 2016 EIS sub-Appendix E). In addition, caging will be considered by the Corps for mitigation activities that are more prone to high predation (e.g. microfragmentation, see Page et al. 2018 and Koval et al. 2020), or the Corps may consider using alternate sites for outplanting or additional outplanting to account for tissue loss due to predation.

F.3.6.2 Reporting

The Corps will coordinate with the IWG the specific information (including statistical analysis) that will be included in each monitoring report. Commencement dates of monitoring events will be reported by the monitoring team via email to the FDEP JCP Compliance Officer (JCPCompliance@dep.state.fl) roughly seven (7) days prior to the start of in-water work and the day that work begins. Brief work progress summaries (e.g., which sites or tasks have been completed, weather delays, etc.) shall be submitted (emailed) weekly to the JCP Compliance Officer while monitoring is underway. The JCP Compliance Officer will also be notified when monitoring has been completed for each monitoring event.

F.3.6.3 Data Management

Given the large amount of data expected from this plan over the course of the project, the Corps will determine appropriate short- and long-term storage of the data. A Data Management team will be responsible for data storage, version control, accessibility of data, long-term storage, and management of

data throughout the project. The team shall be of sufficient size and capability to handle the amount of data expected from the monitoring efforts detailed in this plan.

F.3.7 Selection of Mitigation Sites

F.3.7.1 Site Selection of Natural Enhancement Sites (Impacted or Degraded)

The first step of this mitigation plan will be to select appropriate sites that are spread across the different habitats that could be impacted as a result of the project or associated sedimentation (i.e. Nearshore Ridge, Inner reef, Middle reef, and Outer reef). Site selection will drive other parts of the mitigation plan development, such as the identification of mitigation activities that are appropriate at each site, coral species that are appropriate to be outplanted at each enhancement site (depending on factors such as habitat, depth, and water flow), and prioritization of species that need to be propagated based on likelihood of success (see **Table F-3**).

Mitigation sites identified will be proportional in size to areas that are expected to be impacted by the project. Data collected by a Port's contractor will be used to assist in evaluating differences between sites and feasibility of mitigation options here proposed. The identification of viable sites for natural reef enhancement will occur in three (3) stages. Stage I will include the refinement (narrowing down) of potential sites to a reasonable number that can be further investigated through in-situ reconnaissance and habitat characterization. Stage II will include preliminary reconnaissance to document general suitability of the site for enhancement. Finally, Stage III will include a quantitative assessment of each potential mitigation site to determine appropriate mitigation strategies and expected ecological benefits from these. Site characteristics and data collection will include parameters such as: reef structural complexity, availability of substrate, water depth, water quality, location, coral resources, existing benthic community structure, and fish population dynamics. Ground-truthing these sites also allow estimating target percent cover and number of corals or non-coral species needed for appropriate enhancement (e.g. status quo or historic densities). Data collected will be summarized to assist in evaluating differences between sites and prioritize sites which best meet the mitigation plan recommendations and outplanting site selection criteria coordinated with the IWG.

Final decisions regarding which sites will be used for mitigation will be determined by the Corps through a ranking exercise based on the most important criteria coordinated with the IWG. A similar ranking to that conducted for the NOAA's Seven Iconic Reefs could be used, where sites targeted for restoration were evaluated based on different characteristics, and the most important criteria for selection was ranked. On this exercise, the five most important criteria identified were: (1) biodiversity and habitat, (2) ecological services (diversity), (3) sustainability and connectivity, (4) likelihood of success, and (5) genetic health/complexity. Sites were then selected based on having sufficient biogeographic representation (which in our case would be habitats within the Nearshore Ridge, Inner reef, Middle reef, and Outer reef).

F.3.7.2 Grounding and Anchoring Sites

FDEP and Broward County have already identified several impacted sites in coral reef habitat near the project's area and a Port's contractor is currently assessing these sites for suitability to perform mitigation. From these, Pinnacle Ecological has identified several sites near the project area which are currently being assessed for suitability (**Figure F-8**).

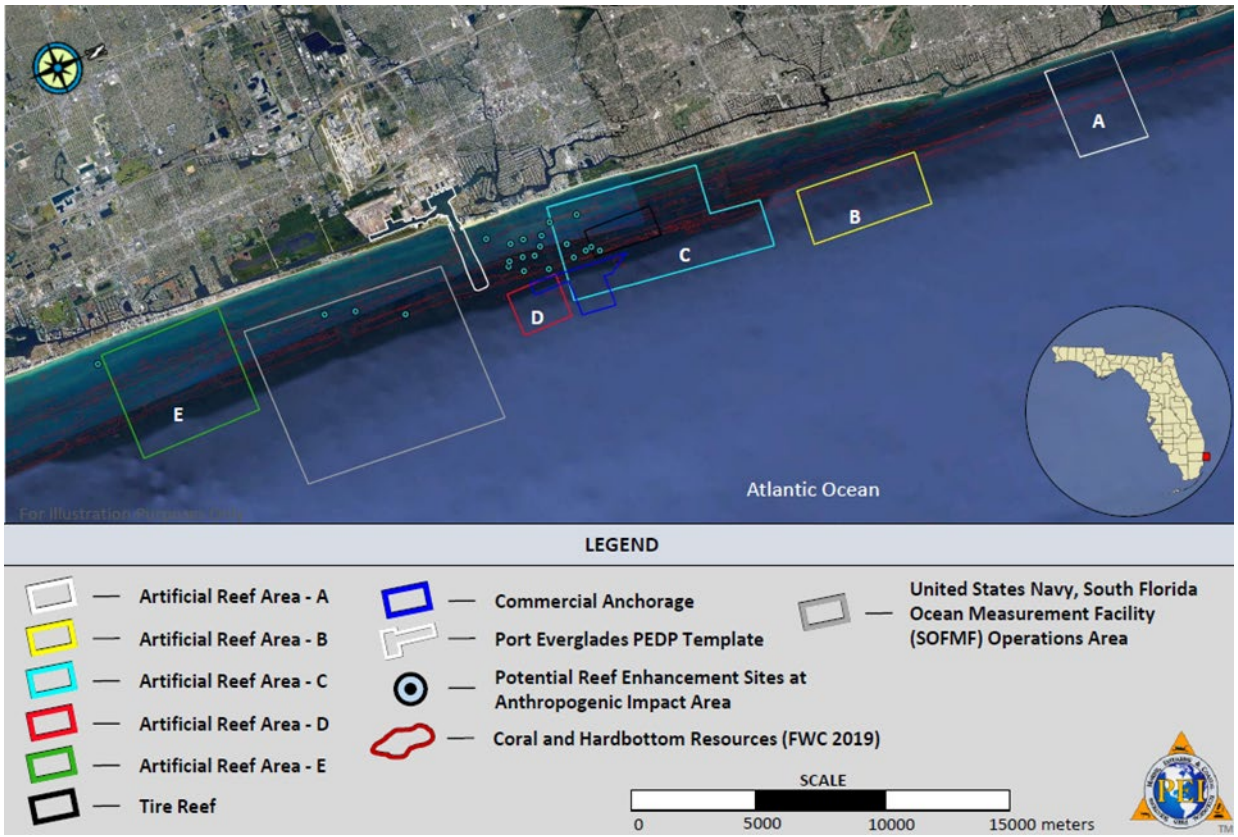

Figure F-8. Potential reef enhancement sites near the project area which have been impacted by grounding or anchoring events and that are being assessed for suitability (Source: Pinnacle Ecological)

F.3.7.3 Degraded Reef Sites

Pinnacle Ecological has identified several degraded sites as potential candidates for natural enhancement near the project area which are currently being assessed for suitability (**Figure F-9**). More information will be provided regarding the size, current conditions of sites, and type (source) of degradation for each proposed site. Understanding the type of degradation is important to assist with ranking/prioritization and determine appropriate mitigation strategies and expected ecological lift for each site. For example, some sites might require the removal of rubble and the stabilization of the substrate in addition to biological enhancement, and these sites may yield greater ecological lift than sites with just needing biological enhancement.

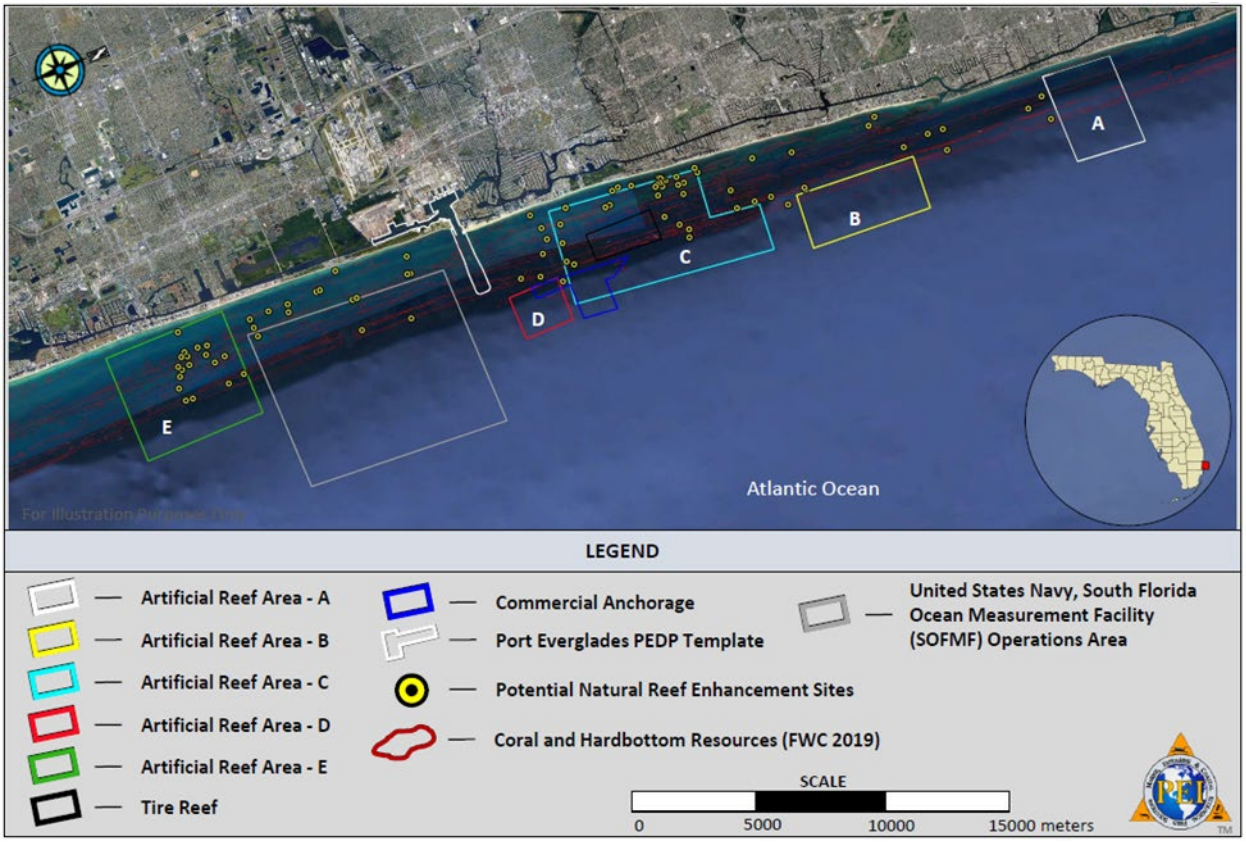

Figure F-9. Potential natural reef enhancement sites near the project area which have been naturally degraded and that are being assessed for suitability (Source: Pinnacle Ecological)

F.3.7.4 Site Selection of Artificial Reef Sites

Data collected by the contractor (Pinnacle Ecological) will be used to assist in evaluating the feasibility of constructing artificial reefs. So far, Pinnacle Ecological has identified several potential candidates for mitigation reef deployment near the project area which are currently being assessed for suitability (**Figure F-10**). Similar to the considerations and strategy being used for natural reef enhancement site selections, the identification of viable sites for artificial reef creation will include proposing potential locations followed by the refinement (narrowing down) of the potential sites to a reasonable number that can be further investigated. Refinement will include consideration of the general suitability of the site (e.g. site characteristics such as existing substrate, water depth, water quality, location, nearby coral resources and benthic community structure, and fish population dynamics), potential effects on coastal processes (e.g. littoral sediment transport), and appropriate buffers needed around construction areas to prevent additional impacts to nearby hardbottom habitats. This information will be summarized to assist in evaluating differences between proposed locations and prioritize which best meet the recommendations coordinated with the IWG.

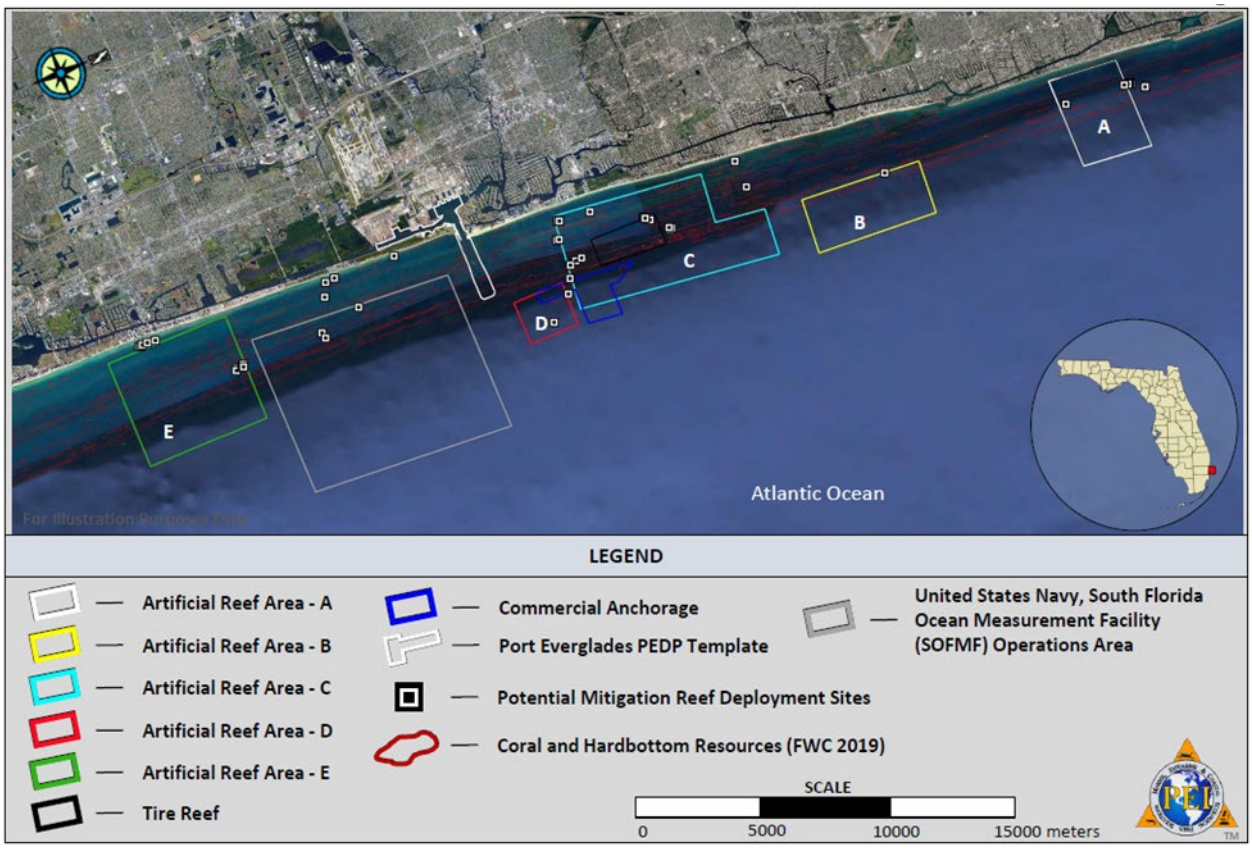

Figure F-10. Potential mitigation sites for artificial reef creation near the project area which have are being assessed for suitability (Source: Pinnacle Ecological)

F.3.7.5 Appropriate Sites for Coral Propagation

Offshore *in-situ* nurseries will be sited to balance different factors such as appropriate habitat and water quality conditions, decreased risk of future impacts, and permitting conditions. This option includes expanding existing nursery sites offshore Broward County from Nova Southeastern University, and/or the creation of new in-situ nurseries, preferably within Broward County.

The inclusion of land-based nurseries can help minimize the impacts from damage to offshore in-situ sites. In addition, land-based nurseries are great candidates for propagating disease susceptible species and prevent potential flares or additional outbreaks near the project area. The Corps will consider expansion of current facilities or creation of new facilities (if feasible), as appropriate.

F.3.7.6 Appropriate Sites for Outplanting

The outplanting process will require numerous natural reef sites to be accomplished successfully. Outplant recipient sites should be selected using a strategy that maximizes likelihood of outplant survival while minimizing risk from natural and human disturbances. Should a site perform poorly due to local environmental conditions, an alternate site can be identified. Additional considerations when selecting appropriate outplant recipient sites include the following:

- Incorporating results from larval dispersal and connectivity modeling (e.g. Figueiredo, 2019) can help identify reefs that when directly enhanced, can provide benefits to other surrounding areas without direct enhancement (i.e. spillover effects). This information can help the decision-making process for selecting enhancement sites which more effectively maximize the spatial impact of mitigation actions, while minimizing costs and effort.
- Recent work from the US Geological Survey (USGS) suggests that recipient sites for outplanting which may provide the best coastal storm risk protection include sites continuous alongshore on hardbottom, around the 3 m isobath or deeper, and at least ~25 m wide and 0.25 m high (C. Storlazzi, pers. comm.).
- Degraded reefs in Broward County with large ecologically important coral colonies (>2 m) are great candidates for propagation and outplanting via microfragmentation. Walker and Klug (2015) mapped the locations of large *Orbicella faveolata* colonies in southeast Florida which could be used to prioritize sites. These colonies can be hundreds of years old and likely have exponentially more reproductive capacity than smaller colonies of the same species. In addition, their age indicates that these colonies have persisted through many anthropogenic and natural stressors that have occurred in the region (Walker and Klug, 2015).

NMFS Protected Resources Division has expressed preference for selecting outplanting sites as suggested by USGS to target *A. cervicornis*, and sites with large dead colonies candidates for microfragmentation to target Orbicella species. A large portion of the mitigation plan in the 2014 Biological Opinion was focused on impacts to ESA-listed corals and designated critical habitat, and as such these two options are considered ideal to help address those issues

F.3.8 Timing for Mitigation Activities

The mitigation plan proposed requires many years to complete, and timing of activities is dependent on timing of project construction and on targeting appropriate distances from the project area to help minimize potential project-related impacts to mitigation sites (see **Table F-6)**. In general, sites appropriate for pre- and during construction mitigation will be located at least 2 km from the project area, whereas sites targeted for post-construction mitigation will be located between 500 m – 2 km from the project area (with the exception of areas in the spoil shoal targeted for natural enhancement).

Table F-6. Proposed mitigation activities by timing of project construction (pre-, during, or post-construction).

Pre-construction	During construction	Post-construction
Site-selection	Coral propagation	Coral propagation
Construction of artificial reefs	Coral outplanting (in phases) at distances >2 km	Coral outplanting (in phases) at distances >500 m – 2 km
Expansion of land-based facilities	Natural reef enhancement at distances >2 km	Coral outplanting of disease susceptible species
Creation or expansion of *in-situ* nurseries	Relocation and mitigation monitoring	Natural reef enhancement at distances >500 m – 2 km

Pre-construction	During construction	Post-construction
Cleaning or performing remedial actions to prepare natural degraded reefs for relocation	Cleaning and maintenance of mitigation reefs with biological enhancement	Spoil shoal mitigation activities
Relocation of corals, octocorals and sponges	Adaptive management (contingency plans if success criteria is not met)	Mitigation monitoring
N/A	Additional site-selection (as needed)	Cleaning and maintenance
N/A	N/A	Adaptive management (contingency plans if success criteria is not met)

F.4 Relocation Plan of Corals and Other Organisms

F.4.1 Impact Avoidance/Minimization and Additional Relocation Actions

Impact avoidance/minimization includes the relocation of stony corals from direct and indirect impact areas to mitigation reefs (natural and artificial reefs) located outside of the area potentially under the influence of the project. These activities will be conducted prior to project construction. Additional relocation actions are proposed in this plan for compensatory mitigation (as part of the biological enhancement of mitigation sites proposed in the Coral Reef and Hardbottom Mitigation plan, **Section F.3** above) and includes the relocation of smaller stony corals, octocorals, sponges, and major herbivores (sea urchins and Caribbean king crab).

Relocation actions within the direct impact areas and the indirect impact areas are described below (**Sections F.4.1.1 and F.4.1.2**, respectively) and summarized in **Table F-7**. The activities described in this plan are based upon the Corps' determinations provided to FDEP via memo dated September 11, 2020.

Table F-7. Relocation actions by project area.

Level of impact	Project area	Relocation proposed	Corals to be relocated as part of minimization efforts[1]	Additional relocation actions for compensatory mitigation (biological enhancement)[2]
Direct	Existing authorized channel	No, corals of opportunity	N/A	N/A
	Newly excavated material (OEC), including channel walls and side slopes	Yes	Listed coral species regardless of size; Stony corals ≥10 cm (as indicated in the 2016 EIS)*[β] based on priority needs	% of stony corals ≥5 cm based on priority needs[β]; % of octocorals ≥15 cm; % of sponges (species and sizes pending IWG discussion); Sea urchins (*Diadema antillarum*) and Caribbean king crab (*Mithrax Spinossisimus*) opportunistically
	Areas within the footprint that are below dredge depth	Yes	Listed coral species regardless of size; Stony corals ≥10 cm*[β] based on priority needs	% of stony corals ≥5 cm based on priority needs[β]; % of octocorals ≥15 cm; % of sponges (species and sizes pending IWG discussion); Sea urchins (*Diadema antillarum*) and Caribbean king crab (*Mithrax Spinossisimus*) opportunistically
Indirect	Areas with expected sediment deposition up to 5 or 10 cm from spillage model (see Appendix D of the DSEIS)	Yes	Listed coral species regardless of size; Stony corals ≥10 cm based on priority needs[β]	% of stony corals ≥5 cm based on priority needs[β]
	Artificial areas within turbidity mixing zone (0-150 m)	Yes	Listed coral species regardless of size and stony corals ≥10 cm located within breakwaters and spoil shoal[β]	% of stony corals ≥5 cm based on priority needs[β]
	Additional indirect areas near the PEV	If needed	N/A	*A. cervicornis* fragments collected from wild patches for nursery propagation & subsequent outplanting in mitigation sites

[1]Minimization is considered taking organisms out of harm's way. [2]Refer to the Coral Reef and Hardbottom Mitigation plan. Specific percentages for proposed relocation of different benthic groups will be coordinated with the IWG after mitigation sites have been identified. *Corals relocated from impact areas which will be fully mitigated for are intended to be placed on mitigation reefs (natural and artificial reefs). [β]A portion of the moderate and highly disease-susceptible corals relocated as part of the minimization requirements are intended to be placed in land-based nurseries for propagation and subsequent outplanting.

F.4.1.1 Relocation from Direct Impact Areas

The direct impact area is defined in the DSEIS as "…effects that are caused by the activity and occur at the same time and place". For the PEPD, that area is located within the dredging and construction footprint and is expected to result in a 100% loss of function of coral/hardbottom habitat. Potential direct impacts to hardbottom resources could occur in the expanded bottom, including the downslope areas below 57 feet within the channel footprint, and portions of the existing channel wall that fall within these areas. For additional information on benthic habitats in the project area and anticipated project effects to these habitats, see Section 3 "Affected Environment" and Section 4 "Environmental Consequences" of the DSEIS.

As part of the minimization efforts for this project, all ESA-listed corals (regardless of size) and non-ESA listed stony corals ≥ 10 cm in diameter will be relocated from the direct impact area (see **Table F-7**). Additional relocation actions for compensatory mitigation includes relocation of octocorals ≥ 15 cm, sponges (species and sizes pending IWG discussion), and/or opportunistic relocation of major herbivores (sea urchins and Caribbean king crab), as detailed in **Table F-7**. These additional actions are considered part of the biological enhancement of mitigation sites proposed in the Coral Reef and Hardbottom Mitigation plan.

F.4.1.2 Relocation from Indirect Impact Areas

The indirect impact area is defined in the DSEIS as "…effects caused by the activity and are later in time or farther removed in distance but are still reasonably foreseeable". Indirect impacts are effects caused by the project action but occur outside the direct footprint of the project; may or may not result in less than 100% loss of function; and the loss may be permanent or temporary. For the PEPD, examples of potential indirect impacts include impacts resulting from turbidity, sedimentation, rock rubble movement downslope as a result of the dredging activity, and changes to hydrology and ecological connectivity. Potential indirect impacts could occur in areas outside of the channel footprint affected by sedimentation and/or turbidity and downslope areas outside the footprint of the excavated channel, including portions of the existing channel wall. For additional information on benthic habitats in the project area and anticipated project effects to these habitats, see Section 3 "Affected Environment" and Section 4 "Environmental Consequences" of the DSEIS.

Impact avoidance measures will be implemented in this area to minimize potential adverse effects associated to sedimentation and/or turbidity during project construction. As part of these minimization efforts, all ESA-listed corals (regardless of size) and non-ESA listed stony corals ≥ 10 cm in diameter will be relocated from areas in the spillage model anticipated to receive up to 5 or 10 cm in sediment deposition (see **Table F-7** and Section 4 "Environmental Consequences" of the DSEIS). Additional relocation actions for compensatory mitigation includes relocation of stony corals ≥5 cm from these areas as detailed in **Table F-7**. These additional actions are considered part of the biological enhancement of mitigation sites proposed in the Coral Reef and Hardbottom Mitigation plan.

F.4.1.2.1 Artificial Areas Within the Project Vicinity

Artificial areas adjacent to the PEV footprint include two submerged breakwaters on the north and south side of the channel and an area designated as a spoil shoal. Based on coordination with the IWG during

the development of the Dredging-related Sedimentation Monitoring plan (Appendix G of the DSEIS), the Corps does not plan to monitor or mitigate in these areas (see Appendix D of the DSEIS). The Corps also excluded this area from the impact assessment as well as other areas of the federal navigation project that have been previously maintained including the existing channel bottom and channel walls where new widening is not proposed. However, the Corps plans to relocate all ESA-listed species regardless of size, as well as stony corals ≥10 cm from the breakwaters and spoil shoal areas as detailed in **Table F-7**. In addition, the Corps is aware of the hardbottom mitigation efforts proposed by the Broward County as a part of the Sand Bypass project. Discussions with the County to address this issue are ongoing. The Corps is aware that should the County's mitigation site be in place prior to the deepening project construction, impacts to the Sand Bypass mitigation site would need to be considered as part of the deepening project impacts.

F.4.1.3 Recipient Sites

Additional details on the mitigation efforts and recipient sites proposed by the Corps are described in detail in the Coral Reef and Hardbottom Mitigation Plan (Section F.3). Recipient sites will be identified to include those listed in **Table F-8**. It is expected that prior to construction, all octocoral and sponges identified for relocation will be transplanted to either natural or artificial reefs. ESA-listed corals identified for relocation will be transplanted to natural reefs, with a portion going to in-situ or land-based nurseries for propagation and subsequent outplanting. A portion of the moderate and highly-disease susceptible species to Stony Coral Tissue Loss Disease (SCTLD) identified for relocation will go to land-based nurseries (i.e. genetic rescue) for propagation and subsequent outplanting, while coral species considered not disease-susceptible will be relocated to natural and artificial mitigation sites, with a portion going to in-situ or land-based nurseries for propagation and subsequent outplanting. Finally, any herbivores relocated opportunistically will be placed in mitigation sites (natural and artificial reefs) as described in the Coral Reef and Hardbottom Mitigation Plan.

Table F-8. Proposed recipient places for relocated corals, octocorals and sponges.

Location	ESA-listed corals	Not disease susceptible corals	Moderate and highly-disease susceptible corals	Octocorals	Sponges
Natural reefs	X	X	X	X	X
Artificial reefs		X		X	X
Land-based nurseries	X	X	X[1]	N/A	N/A
In-situ nurseries	X	X	N/A	N/A	N/A

[1] Considered genetic rescue of disease susceptible coral species.

F.4.2 Collection, Transportation, and Transplanting Methods

F.4.2.1 Locating and Collecting

Locating and collecting species of interest will be conducted in accordance with the Florida Fish and Wildlife Conservation Commission (FWC) 2020 Coral and Octocoral Mitigation Relocation Recommendations and as further described in this Section.

F.4.2.1.1 Direct Impact Area: Stony Corals and Octocoral Colonies

All hardbottom habitats within the direct impact area shall be included in the coral colony search and removal area. Within this area, a series of 50 m diameter plots will be used to define smaller, more manageable collection areas. Prior to in-water work, the project's GIS database will be used to overlay 50 m diameter plots on the benthic habitat map to ensure the entire search area is covered. The center point for each plot shall be recorded and used to define each in situ collection site. At each collection site, divers will swim survey tapes 25 m out from the center point on north, east, south, and west compass headings to further subdivide each collection site into quadrants. A diver will be assigned to each quadrant.

At each site, divers will locate colonies in their quadrant that meet the requirement for relocation. The FWC has prioritized coral species for removal and relocation based on susceptibility to Stony Coral Tissue Loss Disease (SCTLD) and conservation value. Only stony coral and octocoral colonies that are visibly free of disease and meet the FWC recommended relocation sizes as listed in the 2020 FWC Coral and Octocoral Mitigation Relocation Recommendations (see Appendix A) are required to be collected and relocated.

Once located, divers will manually dislodge colonies from the substratum. Colonies on loose rubble that can be easily carried by divers will be left on rubble. Colonies which are on consolidated pavement or larger pieces of rubble will be removed from their substratum. Colonies shall be dislodged gently using hammers and chisels. Extreme care shall be taken to minimize impacts to colonies. Every effort shall be made to remove colonies from their substratum without fragmenting them. Some fragmentation is expected, particularly for colonies with flat growth forms. If a colony fragments during dislodgement, viable fragments shall be collected and re-attached at the receiver site.

Prior to removal, divers will note whether the colony is attached or not, and if attached, whether the colony is attached to rubble, consolidated pavement, or to large rubble/boulders. Once dislodged, divers will swim colonies to the center point of the site. Colonies that are removed from consolidated substrata will be collected separately from colonies on mobile rubble. After all quadrants at each site have been surveyed, the dislodged colonies will be lifted to the boat using buoyed baskets. Care shall be taken to minimize impact to colonies while in the baskets (e.g., colonies shall not be layered within the baskets). Colony collection shall occur in the beginning (morning) of each field day. Only as many colonies as can be transplanted the same field day shall be collected.

F.4.2.1.2 Long-spined Sea Urchins and Caribbean King Crab

In consideration of the low density and potential direct impacts to long-spined sea urchins (*Diadema antillarum*) and/or Caribbean king crab (*Mithrax Spinossisimus*), the Corps is committed to opportunistically relocating these organisms from direct impact areas immediately prior to dredging (as

detailed in **Table F-7**). Individuals shall be collected in conjunction with coral collection at the 50 m diameter plots (see **Section F.4.2.1.1**).

F.4.2.1.3 Sponges

The Corps is committed to relocate sponges (species and sizes pending IWG discussion) from direct impact areas immediately prior to dredging. The Corps has not previously conducted relocation for sponges; therefore, the Corps will continue to work with the Interagency Working Group (IWG), specifically FDEP, to develop the requirements for the safe transplantation of sponges.

F.4.2.1.4 Indirect Impact Area: Stony Coral Colonies

The colony search and removal area within the indirect impact area will be determined based on the dredging methodology used and the potential indirect impact area. The survey will be conducted using the NMFS protocol as recommended in the 2020 South Atlantic Regional Biological Opinion (SARBO) for Dredging and Material Placement Activities in the Southeast United States (NMFS, 2020). A 50 m diameter plot shall be established around the center point (location coordinates) of each of the sites. The area within each of the 50 m diameter plots shall define the colony collection area for the indirect impact area. At each of the collection sites, divers will swim survey tapes 25 m out from the center point on north, east, south, and west compass headings to further subdivide each collection site into quadrants. A diver will be assigned to each quadrant.

F.4.2.2 Transporting

Care shall be taken to prevent injury while transporting corals/octocorals, sea urchins, and sponges to their respective transplantation sites. Transporting species of interest will be conducted in accordance with the FWC 2020 Coral and Octocoral Mitigation Relocation Recommendations and as further described in this Section.

F.4.2.2.1 Stony Corals and Octocoral Colonies

Prior to transport, each colony shall be wrapped in bubble wrap packing material to prevent abrasion, and then stowed in a cooler on board the vessel to keep them cool, damp, and out of the sun. Colonies shall only be kept in coolers (out of the water) for a few hours. Colonies shall be transported to their respective transplantation sites each field day following collection. The aim shall be to transplant all colonies the same day they were collected. If conditions (e.g., weather and sea state) do not allow for same day transplantation, then colonies will be transported to the transplantation site and cached in a safe, secure location. Attachment of the cached colonies shall be the priority for the next available field day.

F.4.2.2.2 Long-spined Sea Urchins and Caribbean King Crab

Care shall be taken to prevent injury while transporting herbivores to mitigation sites (natural or artificial reefs). Organisms shall be collected in baskets and relocated on the day of collection.

F.4.2.2.3 Sponges

The Corps has not previously conducted relocation for sponges; therefore, the Corps will continue to work with the IWG, FDEP specifically, to develop the requirements for safe transportation for sponges.

F.4.2.3 Transplanting

Care shall be taken to prevent injury to species of interest while conducting transplantation activities. Transplanting corals/octocorals will be conducted in accordance with the FWC 2020 Coral and Octocoral Mitigation Relocation Recommendations and as further described in this Section.

F.4.2.3.1 Stony Corals and Octocoral Colonies

The transplantation area to which the corals are relocated shall be of similar characteristics from which they were collected. Collected colonies shall be attached to the substratum using Portland cement, or by using epoxy, nails, and zipties. Before attachment, both the substratum and the coral (underside of the colony or rubble) will be prepared. Fouling organisms (mostly algae) and sediment will be removed from contact surfaces. Care will be taken to avoid injury to living coral tissue during surface preparation.

F.4.2.3.2 Long-spined Sea Urchins and Caribbean King Crab

Any herbivores encountered opportunistically will be released to concentrate densities in mitigation sites (natural or artificial reefs).

F.4.2.3.3 Sponges

The Corps has not previously conducted relocation for sponges; therefore, the Corps will continue to work with the IWG, FDEP specifically, to develop the requirements for safe transplantation of sponges.

F.4.3 Monitoring

F.4.3.1 Qualifications

The Corps will require that all field personnel conducting coral surveying, monitoring, and transplanting activities shall be qualified relocation contractors by FWC or have sufficient documentation to demonstrate that they have successfully conducted relocation of corals in Florida. The names and qualifications of the individuals performing the activities shall be submitted to the Corps for review and approval prior to the start of work. If additional team(s) are subcontracted, or if new staff are added to the team, proposed changes and qualifications shall be submitted to the Corps' for review. The Contractor's selected hardbottom monitoring firm is fully responsible for training of new staff members and subcontractors on the required procedures, as well as the QA/QC verification of their work.

F.4.3.2 Verification of Relocated Organism Monitoring

The following describes the proposed verification monitoring to occur post-transplantation, which was developed with NMFS HCD for relocation of corals, octocorals, and sponges:

- Relocation of corals[2]:
  - 1 week: verify that corals remain securely attached
  - 1 month: verify potential predation and disease
  - 6 months and 1 year: verify no net tissue loss by considering multiple individuals from same species

- Relocation of octocorals:
  - 1 week: verify that octocorals remain securely attached
  - 1 year: verify net positive tissue growth by subsampling individuals from different species

- Relocation of sponges[3]:
  - 1 week: verify that sponges remain securely attached
  - 1 year: verify net positive tissue growth by subsampling individuals from different species

F.4.3.3 Monitoring Transplanted Corals

Monitoring of corals/octocorals will be conducted in accordance with the FWC 2020 Coral and Octocoral Mitigation Relocation Recommendations and as further described in this Section.

F.4.3.3.1 Stony Corals and Octocoral Colonies

If the total quantity of corals or octocorals to be relocated is less than 4,000 colonies, an appropriate representative subset of the total number of colonies relocated to be monitored is 25% (1,000 colonies maximum). If the total quantity exceeds 4,000, the Corps will coordinate with the IWG to determine the appropriate monitoring quantity. The subset to be monitored will be representative of the species in the composition and size classes of the total relocated corals/octocorals. Individual colonies will not be tagged; instead, each circular plot will be tagged, and the colonies contained therein will be monitored.

Monitoring shall occur on 4 occasions: immediately following transplantation (baseline), and then at 6 months, 12 months (1 year), and 36 months (3 years) post-transplantation. During the baseline survey (immediately following transplantation), colonies at each of the monitored sites shall be identified (to species for stony corals, to genus for octocorals), measured (diameter for stony corals, height for octocorals), and have their condition recorded. Whether a colony was relocated from rubble shall also be noted during the baseline survey. During each subsequent monitoring event, colonies within each of the monitored plots will be measured and have their condition recorded. The following shall be noted for colony condition: percent bleaching; percent old and recent mortality (respectively); and presence of disease, obvious signs of predation, and signs of sedimentation (e.g. accumulation, burial of colony base, etc.). The same monitoring procedures shall be used during each monitoring event (baseline through to

[2] High levels of success are expected (>85%, e.g. Monty et al. 2006; Thornton et al. 2000; Stephens, 2007). Monitoring does not apply to corals relocated to land-based or in-situ nurseries. For corals relocated to nurseries an inventory with general status/condition would be established.

[3] The Corps has not previously conducted monitoring for sponges; therefore, the Corps will continue to work with the IWG, FDEP specifically, to determine the best course of action for verification monitoring of sponges.

Year 3). After each monitoring event, the status of the colonies within the plots will be compared to previous events. Any changes in status from previous events will be discussed.

F.4.3.4 Contingency Plan

If post-transplantation monitoring identifies that success criteria is not being met, the Corps will conduct additional relocation or outplanting. If algae or predation is found to be the cause, additional strategies may include cleaning algae or caging or consideration of alternate sites to deter or reduce predation.

F.4.4 Reporting

For each submission event, notifications and/or data shall be provided as specified in this Section.

F.4.4.1 Notification of Commencement, Progress, and Completion of Work

Commencement dates of activities (e.g. minimization/avoidance activities, monitoring events, etc.) shall be reported via email to the IWG. Work progress summaries shall be emailed weekly until the completion of activity. Notification of the completion of work shall be emailed within seven (7) days of the work being completed.

F.4.4.2 Data Submission

Raw data to be provided shall consist of photographs, monitoring data, and field data sheets. Any video that is opportunistically captured shall also be provided.

F.4.4.2.1 Photographs

Still photographs shall be submitted using portable, large capacity hard drives. Main folders will be identified by a descriptive name, so data may be easily differentiated. Each main folder will contain separate labelled subfolder when multiple data sets are submitted. Any video captured opportunistically shall also be submitted. Videos and still photographs shall appear in separate folders on the hard drive.

F.4.4.2.2 Monitoring Data

Data collected during each monitoring event shall be supplied in Excel format. Separate Excel workbooks shall be supplied for multiple, disparate data sets. Each workbook submitted shall have a descriptive name so data can be easily differentiated.

F.4.4.2.3 Field Data Sheets and Survey Logs

Copies (e.g. photographs or scans) of field datasheets shall be submitted in pdf format.

F.4.4.3 Relocation Report Submissions

Monitoring reports shall be provided for all permit required monitoring. Along with each monitoring report, the data analyzed to produce the report shall be submitted along with tables used in the analysis

of data, tables used to construct figures, and tables and figures provided in the report (in Excel format). Each monitoring report shall clearly describe methods used in monitoring and data analysis and explain any deviations from the monitoring plan or conditions of the permit. Reports shall also provide results in appropriate graphical, tabular, and text formats.

The reports will be provided within 90 days of completing each required monitoring event (see **Sections F.4.3.2 and F.4.3.3**) and will be shared with the IWG.

F.5 References

Burkepile, D.E. and Hay, M.E. 2006. Herbivore vs. nutrient control of marine primary producers: Context-dependent effects. Ecology. 87:3128-3139.

Burman, S., Aronson, R., and van Woesik, R. 2012. Biotic homogenization of coral assemblages along the Florida reef tract. Marine Ecology Progress Series, 467, 89-96.

Carpenter, R.C and Edmunds, P.J. 2006. Local and regional scale recovery of Diadema promotes recruitment of scleractinian corals. Ecology Letters. 9:271-280.

Ceccarelli, D. M.; Z. Loffler, D.G. Bourne, G.S. Al Moajil-Cole, L. Boström-Einarsson; E. Evans-Illidge, K. Fabricius, B. Glasl, P. Marshall, I. McLeod, M., Read, B. Schaffelke, A. K. Smith, G. T. Jorda, D.H. Williamson and L. Bay. 2018. Rehabilitation of coral reefs through removal of macroalgae: state of knowledge and considerations for management and implementation. Restoration Ecology 26(5): 827-838.

Craggs J, Guest JR, Davis M, Simmons J, Dashti E, Sweet M. 2017. Inducing broadcast coral spawning ex situ: closed system mesocosm design and husbandry protocol. Ecology and Evolution 7:11066-11078.

Diaz-Pulido, G. and McCook. L.J. 2003. Relative roles of herbivory and nutrients in the recruitment of coral-reef seaweeds. Ecology. 84:2026-2033.

Edmunds, P.J. and Carpenter, R.C. 2001. Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. PNAS. 98(9):5067-5071.

Figueiredo, J. 2019. Final Report to NOAA CRCP. Optimal placement of coral restoration projects to enhance reef resilience: a management tool. 74 pp.

Florida Fish and Wildlife Conservation Commission (FWC). 2020. Coral and Octocoral Mitigation Relocation Recommendations.

Forsman, ZH, Page, CA, Toonen, RK and Vaughan, D. 2015. Growing coral larger and faster: micro-colony-fusion and a strategy for accelerating coral cover. PeerJ 3: e1313

Ghiasian, M, Carrick, J, Rhode-Barbarigos, L, Haus, B, Baker, A, and Lirman, D. 2020. Dissipation of wave energy by a hybrid artificial reef in a wave simulator: implications for coastal resiliency and shoreline protection.

Gilliam, D.S. and Moulding, A.L. 2011. A Study to Evaluate Reef Recovery Following Injury and Mitigation Structures Offshore Southeast Florida: Phase I. Nova Southeastern University Oceanographic Center. Dania Beach, Florida. 60 pp.

Goergen, E.A., S. Schopmeyer, A.L. Moulding, A. Moura, P. Kramer, and T.S. Viehman. 2020. Coral reef restoration monitoring guide: Methods to evaluate restoration success from local to ecosystem scales. NOAA Technical Memorandum NOS NCCOS 279. Silver Spring, MD. 145 pp. doi: 10.25923/xndz-h538

Jaap, W.C. 2000. Coral reef restoration. Ecological Engineering 15 (2000) 345–364

Johnson, M.E., Lustic, C., Bartels, E., Baums, I.B., Gilliam, D.S., Larson, L., Lirman, D., Miller, M.W., Nedimyer, K., and Schopmeyer, S. 2011. Caribbean Acropora Restoration Guide: Best Practices for Propagation and Population Enhancement. The Nature Conservancy, Arlington, VA. 64 pp.

Jordán-Garza, A.G., Maldonado, M.A., Baker, D.M., and Rodríguez-Martínez, R.E. 2008. High abundance of *Diadema antillarum* on a Mexican Reef. Coral Reefs. 27(2):295. doi:10.1007/s00338-007-0338-3.

Koval G, Rivas N, D'Alessandro M, Hesley D, Santos R, and Lirman D. 2020. Fish predation hinders the success of coral restoration efforts using fragmented massive corals. PeerJ 8:e9978 https://doi.org/10.7717/peerj.9978

Ladd, M. 2012. Coral Reef Restoration and Mitigation Options in Southeast Florida. 77pp.

Leeworthy, V.R., Maher, T., and Stone, E.A. 2006. Can artificial reefs alter user pressure on adjacent natural reefs? Bulletin of Marine Science. 78(1):29-37.

Lessios, H.A. 1988. Mass mortality of *Diadema antillarum* in the Caribbean: what have we learned? Annual Review of Ecology and Systematics. 19:371-393.

Lindberg, W.J. and Seaman, W. (eds). 2011. Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida. Florida Department of Environmental Protection. Miami, FL. 150 pp.

Lirman, D, and Schopmeyer, S. 2016. Ecological solutions to reef degradation: optimizing coral reef restoration in the Caribbean and Western Atlantic. PeerJ 4:e2597

Littler, MM, Littler, DS and Brooks, BL. 2006. Harmful algae on tropical coral reefs: Bottom-up eutrophication and top-down herbivory. Harmful Algae 5: 565–585

Lohr KE, Bejarano S, Lirman D, Schopmeyer S, and Manfrino C. 2015. Optimizing the productivity of a coral nursery focused on staghorn coral *Acropora cervicornis*. Endanger Species Res 27:243–250

Miller, MW, Valdivia, A, Kramer, KL, Mason. B, Williams, DE and Johnston, L. Alternate benthic assemblages on reef restoration structures and cascading effects on coral settlement. Marine Ecology Progress Series 387: 147-156.

Miller MW, Colburn PJ, Pontes E, Williams DE, Bright AJ, Serrano XM, and Peters EC. 2019. Genotypic variation in disease susceptibility among cultured stocks of elkhorn and staghorn corals. PeerJ 7:e6751 DOI 10.7717/peerj.6751

Monty J, Gilliam, DS, Banks, KW, Stout, DK, and RE Dodge. 2006. Corals of opportunity survivorship and the use of coral nurseries in coral reef restoration. Proc 10th ICRS: 1665-1673.

Moulding, A.L. 2011. Evaluation of Past Coastal Construction Project Monitoring in Southeast Florida and Recommendations to Improve Future Monitoring. Nova Southeastern University Oceanographic Center. Dania Beach, Florida. 92pp.

National Academies of Sciences, Engineering, and Medicine (NAS). 2018. A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs. Washington, DC: The National Academies Press. doi: https://doi.org/10.17226/25279

National Marine Fisheries Service (NMFS). 2020. South Atlantic Regional Biological Opinion for Dredging and Material Placement Activities in the Southeast United States (SARBO).

National Marine Fisheries Service (NMFS). 2015. Recovery Plan for Elkhorn (*Acropora palmata*) and Staghorn (*A. cervicornis*) Corals. Prepared by the Acropora Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

Florida Keys National Marine Sanctuary (FKNMS). 2019. Restoration Guidelines for Coral Reefs and Associated Habitats in FKNMS. 5 pp.

Page, C.A., and Vaughan, D.E., 2014. The Cultivation of Massive Corals using "Micro-fragmentation" for the "Reskinning" of Degraded Coral Reefs.

Page, CA, Muller, EM and Vaughan, DE. 2018. Microfragmenting for the successful restoration of slow growing massive corals. Ecological Engineering 123: 86-94.

Pausch RW, Williams, DE and Miller MW. 2018. Impacts of fragment genotype, habitat, and size on outplanted elkhorn coral success under thermal stress. Marine Ecology Progress Series 592: 109–117.

Paxton AB, Shertzer KW, Bacheler NM, Kellison GT, Riley KL and Taylor JC. 2020a. Meta-Analysis Reveals Artificial Reefs Can Be Effective Tools for Fish Community Enhancement but Are Not One-Size-Fits-All. Front. Mar. Sci. doi: 10.3389/fmars.2020.00282 7:282.

Paxton AB, Newton EA, Adler AM, Van Hoeck RV, Iversen ES, Jr., Taylor JC, et al. 2020b. Artificial habitats host elevated densities of large reef-associated predators. PLoS ONE 15(9):e0237374. https://doi.org/10.1371/journal.pone.0237374

Restoring Seven Iconic Reefs: A Mission to Recover the Coral Reefs of the Florida Keys. https://www.fisheries.noaa.gov/southeast/habitat-conservation/restoring-seven-iconic-reefs-mission-recover-coral-reefs-florida-keys

Schopmeyer, S.A., Lirman, D., Bartels, E. et al. 2017. Regional restoration benchmarks for *Acropora cervicornis*. Coral Reefs 36, 1047–1057 (2017). https://doi.org/10.1007/s00338-017-1596-3

Shaver E C, Courtney C A, West J M, Maynard J, Hein M, Wagner C, Philibotte J, MacGowan P, McLeod I, Boström-Einarsson L, Bucchianeri K, Johnston L, Koss J. 2020. A Manager's Guide to Coral Reef Restoration Planning and Design. NOAA Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 36, 128 pp.

Storlazzi, C.D., Reguero, B.G., Cole, A.D., Lowe, E., Shope, J.B., Gibbs, A.E., Nickel, B.A., McCall, R.T., van Dongeren, A.R., and Beck, M.W. 2019. Rigorously valuing the role of U.S. coral reefs in coastal hazard risk reduction: U.S. Geological Survey Open-File Report 2019–1027, 42 p., https://doi.org/10.3133/ofr20191027

U.S. Army Corps of Engineers (Corps). 2016. Final Environmental Impact Statement. Port Everglades Harbor Navigation Study, Broward County, Florida. 345 pp.

Vardi T.; T.Rankin; T. Oliver; A. L. Moulding; F. Parrish; T. Moore; I. C. Enochs; T. Shay Viehman and J.L. Koss 2020. NOAA Action Plan on Coral Interventions. U.S. Department of Commerce National Oceanic and Atmospheric Administration National Marine Fisheries Service NOAA Technical Memorandum NMFS-F/SPO-208October 2020.

Walker, B. 2018. Southeast Florida reef-wide Post-Irma coral disease surveys. Florida DEP. Miami, FL. Pp. 1-37.

Walker, B and Klug, K. 2015. Southeast Florida Large Coral Assessment 2015: 1 -151. https://nsuworks.nova.edu/occ_facreports/125.

Walton CJ, Hayes NK and Gilliam D. 2018. Impacts of a regional, multi-year, multi-species coral disease outbreak in Southeast Florida. Frontiers in Marine Science 5: 323.

Zayasi, Y and Suzuki G. 2019. Comparisons of population density and genetic diversity in artificial and wild populations of an arborescent coral, *Acropora yongei*: implications for the efficacy of “artificial spawning hotspots”. Restoration Ecology 27:2, 440–446.