Miami Harbor Phase III
Federal Channel Expansion Project
Permit No. 0305721-001-BI

Impact Assessment for
Hardbottom Middle and Outer Reef
Benthic Communities at Cross Sites

DRAFT

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EXECUTIVE SUMMARY

The one-year post-construction impact assessment report contained herein used the Florida Department of Environmental Protection (FDEP)/ National Marine Fisheries Service (NMFS) recommended cross transect method (referred to as impact assessment throughout this report) to determine the permanence (persistence), extent (acreage) and level of severity (functional degradation/loss) or project related sedimentation impacts, if any. This report is responsive to Specific Condition 32 a ii. d of the Florida Department of Environmental Protection (FDEP) permit. In order to characterize permanent impacts, extent of impacts and functional loss associated with the dredging project in the hardbottom and reef habitat surrounding the PortMiami channel, 54 hardbottom, middle, and outer reef sites were surveyed at regular distance intervals from the channel-edge including established control sites. Sites were selected based on previous impact assessment surveys performed in 2015 (DCA 2015c) as the habitat most-likely to have experienced project-related impacts due to sedimentation.

Limitations of Study Design

A limitation of the one-year post-construction impact assessment survey is that both the locations and methods used in data collection were unique to the survey, preventing direct comparison of survey metrics to baseline data at any site. In addition, 2010 baseline surveys documented significant relationships with distance from the channel for corals, octocorals, and sponges prior to dredging. These data show that a channel-effect was present in all major benthic groups prior to construction activities in 2013 (DCA 2012). The presence of a channel-effect in the near-channel benthic resources in 2010 indicates that a traditional control-impact survey design would be in violation to the primary assumption that near-channel and control metrics are representative of one another in their natural state. In addition, since the data from 2010 was collected from different areas (sites) and using different methodologies than the 2016 impact assessment data, a Before-After-Control-Impact (BACI) design was not feasible for the near-channel PortMiami benthic resource data. As a result, the density and condition metrics collected in the 2016 impact assessment surveys are presented and discussed as qualitative information because no impact-control significance testing could be performed.

Baseline surveys conducted in 2010 (DCA 2012) documented the status of coral, octocoral and sponge communities within 500 m of the Miami entrance channel approximately three-years prior to the initiation of dredging associated with the Miami Harbor Phase III project. While no control data were collected during the 2010 surveys, these 2010 baseline as well as results from the permanent site impact assessment survey of 2016 were used as a point of qualitative comparison for the one-year post-construction impact assessment surveys. Trends in benthic communities between the two periods (2010 and 2016/17) were compared while considering other environmental and/or anthropogenic factors that may influence benthic resources in the area.

Permanent and Temporary Impact to Benthic Resources

Mortality of Scleractinians at Channel-side Sites: Permanent Impact

At potentially impacted permanent site locations where corals were followed over time, total coral mortality due to project-related sediment burial affected six out of 224 (2.7%) near-channel tagged corals. This represented the only permanent impact of the project. These effects may have extended beyond the near-channel habitat in the area of potential sedimentation. However, as a result of the presence of a regional disease event that caused significantly greater mortality than sediment burial (an estimated 72 out of 224; 32.1%) project-related mortality cannot be partitioned from other sources of mortality inherent to the coral density or coral mortality data metrics collected in the impact assessment survey (DCA 2017).

Partial Mortality of Scleractinian Bases: Temporary Impact

A temporary impact from construction activities was the increased proportion of near-channel sites affected by partial mortality due to sedimentation. At permanent monitoring sites in which the cause of partial mortality could be identified, 64.8% of near-channel corals had some level of partial mortality due to sedimentation compared with 19.4% at habitat control sites. In 2017, partial mortality at the base of the colony was found to be a poor indicator of dredge-related mortality. In the middle reef north ridge reef habitat where partial mortality of the base of the colony was highest for near-channel sites (97.1% of colonies at R2N1-RR had some level of partial mortality of the base), the corresponding habitat control had 81.6% of the corals with some level of partial mortality of the base. The fact that natural levels of coral mortality that included the base of the colony could reach 81.6% of the tagged coral population suggest this is a poor indicator of dredge-related mortality since no dredge impact occurred at this habitat control. The naturally high level of partial mortality at the base at habitat control sites is likely related to high levels of regional coral disease, multiple bleaching years and other factors that have influenced all sites. The inability to distinguish between partial mortality related to the project and natural sources of partial mortality is substantiated by planimetry analysis of tagged colonies between baseline and impact assessment surveys, at R2N1-RR, the permanent site with the highest proportion of corals with sediment-related partial mortality, and its habitat control. Although dredging affected channel-side corals as partial mortality, between baseline and impact assessment (-12.3%), there was no statistical difference in total tissue loss at R2N1-RR when compared to the paired control (-11.6%) (DCA 2017). In addition, since these organisms have persisted, they will continue to regenerate at their margins, therefore partial mortality of the bases is a temporary impact of the project.

Distribution of Sediments: Temporary Effect

In 2014-2015, impact assessment reports documented potential sediment effect areas within hardbottom, middle and outer reef habitats. Two qualitative indicators were used to identify areas of potential impact, the presence of "clay-like material" which was documented at channel-side sites during construction, and the presence of partial mortality around the base of corals, also documented at channel-side sites during construction compliance surveys. The areas in which the clay-like material and partial mortality around the base of the coral were documented varied by habitat and location. Estimates of potential acreage affected in the hardbottom, middle and outer reef included a total of 213.7 acres (DCA 2015d).

Impact assessments in 2014-2015 relied upon the qualitative assessment of "clay-like" material and coral colony partial mortality (DCA 2015c, d). While "clay-like" material was not documented in 2016-2017, fine sediments were still present in the survey area but made up a relatively small proportion of the total area delineated in 2014-2015 as the area of potential sedimentation effects. Out of 1,200 sample points spanning the 2014-2015 potential sedimentation affects areas only 123 (10.25%) were characterized as fine, 1,039 (86.5%) were characterized as mixed, 37 (3.1%) were characterized as coarse, and one point (0.08%) was characterized as rubble. Fine sediment was documented primarily in the northern middle and outer reef habitats, however fine sediment in and of itself is a natural part of the reef environment that is found at both control and near-channel locations. To represent a permanent impact to the site the fine sediment would have to prevent dense coral community establishment which has been linked to areas where mean sediment depth exceeds 5 cm in Florida Bay (Lirman et al. 2003) and 3 cm for areas of *Acropora* restoration efforts. Only one point out of 1,006 near-channel sediment assessment locations (0.09%) was characterized as fine sediment and exceeded the 3 cm guideline for restoration efforts. The dramatic decline in clay-like material and general reduction of fine and deep sediment to a single sediment assessment location show that the potential dredge-related sediment delineated in 2014-2015 was a temporary effect of the project. Percent cover analysis of sand at permanent sites related to the project corroborate the temporary nature of project sediment. At most sites percent sand cover increased as a result of the project but had declined towards baseline values during the one-year post-construction impact assessment (DCA 2017).

Distribution of Sediments 2016-2017

The distribution of sediments as recorded in the 2016-2017 impact assessment surveys suggest that the qualitatively documented "clay-like" material that was used to delineate the potential sedimentation effects areas of 2014-2015 were a temporary impact of the project. No "clay-like material" was recorded during these surveys. Given that over a year and a half passed since construction activities it is likely these sediments have been incorporated into naturally occurring reef sediments, or otherwise dispersed (Griffin 1974, Blair et al.1994, DCA 2015c, d). These sediments may have been incorporated into the FDEP approved category of "fine."

Did the project affect coral disease? No.

Despite the loss of six permanent tagged coral at near-channel sites there was no permanent loss of habitat function as a result of the project. Declines in coral density at most distances from the channel are consistent with regional losses due to white-plague disease experienced at all sites. This is corroborated by both the percent cover data at permanent monitoring sites in which coral declines in percent coral cover occurred at both near-channel and habitat control sites, and through species-susceptibility analysis of tagged coral mortality that found no increased disease-mortality at sites adjacent to dredge activity (DCA 2017). If declines in coral percent cover were specifically dredge-related, the decline would only have been documented at channel-side sites. In addition, if dredging had exacerbated white-plague disease there would have been increased coral mortality beyond that predicted due to species-susceptibility alone; neither of these patterns were observed. Percent coral cover declined at all sites and species-susceptibility analysis showed no increase in disease-related mortality at sites located adjacent to the PortMiami channel (DCA 2017). Furthermore no declines in octocoral or sponge density were documented in the 2016-2017 impact assessment surveys at any distance from the channel when compared to 2010 baseline data. These organisms were not affected by any additional regional mortality events and in many cases were found to have increased since 2010 surveys. The lack of decline in sponge and ocotocoral density corroborates the percent cover data at near channel sites in which documented declines in percent coral cover, consistent with disease loss, but the remaining categories of benthic invertebrates remained virtually unchanged from baseline to impact assessment surveys (DCA 2017).

Loss of Functional Habitat: No Impact

The benthic community of the hardbottom, middle and outer reef adjacent to the PortMiami entrance channel has the important ecological function of providing habitat for corals, octocorals, algae, fish, sponges, crustaceans, echinoderms, and other hardbottom and reef dwelling flora and fauna. To determine the degree to which a permanent loss of ecological value had occurred in potentially impacted areas as a result of the project, numerous monitoring results were considered. Organism density from the impact assessment was compared to densities prior to the project to identify areas in which project-related declines may have occurred. According to these results, the density of sponges and octocorals was equal to or greater than densities measured prior to dredging in 2010 baseline surveys, at all distances from the channel. These data indicate that no permanent negative impact to sponge and octocoral resources occurred as a result of the project. Also, permanent site functional cover data were compared between 2013 (pre-dredging) and 2016 (impact assessment) to document project-related declines in functional group cover. Although not available for areas away from the channel, these sites were adjacent to the channel and would have been the most affected communities based on proximity to the Project; these results support the 2010/2016 comparison from an independent data set for permanent sites. Functional group data from the permanent sites, which compared 2013 (pre-dredging) and 2016 (impact assessment) data, showed almost no change between pre- and post-dredging surveys for all major living groups: octocoral (9.27% to 9.97%), sponge (4.48% to 4.70%), zoanthids (0.54% to 0.46%) and sceractinians (0.88% to 0.62%). Scleractinians in the area suffered substantial mortality associated with a region-wide coral disease but this mortality was not associated with the project. While scleractinian corals were impacted at near-channel sites during the project (2.7% of channel-side corals died as a result of burial), this group represents less than 1% of living cover according to pre-dredging data. When considering a 2.7% loss of the hard coral functional group, which represents less than 1% of the living benthic cover, no permanent loss of ecological functions occurred as a result of this loss. Furthermore, partial mortality of corals documented during the project resulted in no net loss of tissue over the time period sampled. This was determined based on planimetry analysis of post-project comparisons of photographs of tagged corals before, during and after the project. When 2016/17 sediment data were considered, only one point out of 1,006 near-channel sediment assessment locations (0.09%) was characterized as fine sediment and exceeded the 3 cm guideline for restoration efforts. To represent a permanent impact to the site the fine sediment would have to prevent dense coral community establishment which has been linked to areas where mean sediment depth exceeds 5 cm in Florida Bay (Lirman et al. 2003) and 3 cm for areas of *Acropora* restoration efforts. Therefore, no permanent functional loss of habitat was documented in the 2016/17 cross site survey.

BEFORE THE PROJECT in 2013:
The mean percent cover of benthic invertebrates was approximately 15% of the bottom at the channel-side sites during baseline surveys: scleractinians (0.88%), octocorals (9.27%), sponges (4.48%) and zoanthids (0.54%), while CTB and sand comprised the remaining 84.1% of the benthic cover (DCA 2017).

AFTER THE PROJECT in 2016:
The mean percent cover of benthic invertebrates was approximately 16% of the bottom at channel-side sites: scleractinians (0.62%), octocorals (9.97%), sponges (4.7%) and zoanthids (0.46%), while CTB and sand comprised the remaining 84.09% of the bottom at channel-side sites (DCA 2017).

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1.0 INTRODUCTION

1.1 Study Context and Objectives

The Miami Harbor Phase III Deepening Project (Project) expanded the outer entrance channel to increase safe access to the Port Miami by larger class ships, including post-Panamax class ships. To accommodate these larger vessels, the outer entrance channel was widened at the outer reef and deepened to 52 (±1) feet Mean Lower Low Water (MLLW) (15.6 ± 0.3 m). Pre-construction avoidance and minimization of impacts to natural resources was conducted through the National Environmental Policy Act (NEPA) process and a Record of Decision was signed on May 22, 2006. The entire construction project was completed on September 17, 2015.

The one-year post-construction impact assessment report contained herein used theFlorida Department of Environmental Protection (FDEP)/ National Marine Fisheries Service (NMFS) recommended cross transect method (referred to as impact assessment throughout this report) to determine the permanence (persistence), extent (acreage) and level of severity (functional degradation/loss) or project related sedimentation impacts, if any. The project was permitted through the FDEP, under Permit No. 0305721-001-BI. Permit conditions provided methods on environmental monitoring required before, during, and after dredging activities. The FDEP permit stated in Specific Condition 32 a ii. d: “Impacted areas shall continue to be monitored monthly during the construction, one month post-construction, and two times during the next year in order to document results of the impact. Final monitoring results shall document permanent impacts, if any, to be used for estimates of additional mitigation using UMAM.” This report documents the second of two monitoring efforts in the one-year post-construction period. More specifically, this report documents the effects of the project on benthic resources within both permanent and non-permanent monitoring sites at increasing distances from the channel edge on hardbottom middle and outer reefs adjacent to the outer entrance channel.

<u>Cross Site Impact Assessment Survey 2016-2017</u>

In coordination with FDEP and NMFS, a total of 57 sites throughout the hardbottom, middle, and outer reefs were recommended by both FDEP and NMFS for monitoring, with an additional 11 sites added by NMFS as areas of potential concern. Due to time and budgetary constraints, and in coordination with the agencies, only 54 of the combined recommended 68 sites were surveyed. Those sites not surveyed included the 7 NMFS recommended sites at R2N-1050-RR, R2S-500 through R2S2200, NSHB North 7a-75 and NSHB South HBS3. R3N1-75 was eliminated because of potential overlap between R3N1-LR and R3N1-100-LR. R2N-50-RR and R2N-100-RR were combined for a site at R2N-75-RR and R2N-50-LR and R2N-100-LR were combined for a site at R2N-75-LR. See Figure 1 for all sites surveyed. Sites selected by FDEP and NMFS were sites with the greatest sedimentation related effects according to construction and post-construction period impact assessment surveys (DCA 2014b, DCA 2015c, d, Miller et al. 2016).

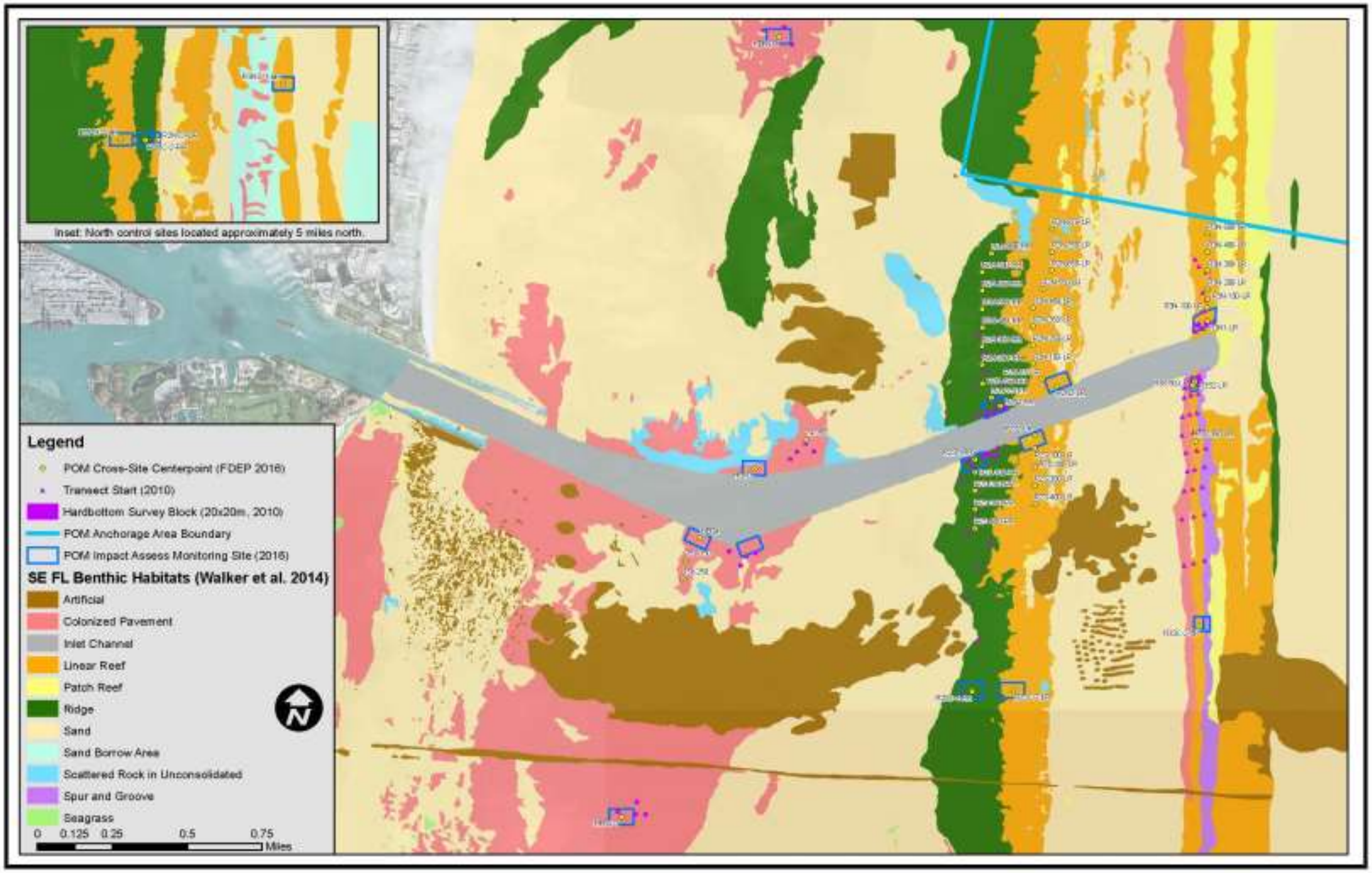


Figure 1. Miami Harbor Cuts 1 and 2 Entrance Channel hardbottom, middle, and outer reef monitoring stations surveyed during one-year post-construction impact assessment cross transect survey. Habitat maps were developed by Walker et al. 2014.

1.2 Previous Studies of Dredge-related Impacts to Coral Reef Resources

During dredging operations, if sediments are not contained, they may have a deleterious impact on coral reef fauna and flora. Thus, understanding the sedimentary dynamics of past dredging operations can serve as a guide to better understanding potential impacts from these projects.

The first paper to discuss the purported negative impacts of dredging on reefs in Florida was an opinion piece written in a trade journal that suggested the reefs in South Florida were being decimated by dredging projects and pollution (Straughan 1972). This paper, did not rely on monitoring data either before or after dredging had occurred, but was based on one-off observations and supposition. The unsubstantiated conclusions reached in this paper singlehandedly led to the abolition of dredging projects in the Florida Keys. Specifically, the reefs discussed in Straughan's paper were patch reefs known as "Hen and Chickens" and were located in the upper Florida Keys. Straughan (1972) cited a dredging project located more than a half-mile to the southwest as the culprit for the mass coral mortality observed on those reefs. Interestingly, this reef was also the focus of a USGS study that linked the coral mortality at the same reef to the lethal impacts of a cold-water event during the winter of 1970 (Hudson et al. 1976a, 1976b). Comparison of photos in Straughan (1972) with those recently published in Lirman et al. (2011) of a more recent cold-water coral mortality event, show a remarkably similarity in the resulting pattern of mortality in large *Orbicella faveolata* colonies, further substantiating the cold-water interpretation of Hudson et al. (1976a, 1976b) and not sedimentation from dredging.

The opinion piece by Straughan (1972) did, however, increase the interest in carefully detailing the scientific impacts of dredging projects on coral reefs. In addition, the passage of the Clean Water Act in November, 1971 led to increasing regulatory oversight of dredge-and-fill projects throughout the United States. Resulting studies, performed in the early 1970's, set a solid foundation upon which dredging impacts could be compared and contrasted in waters adjacent to coral reefs. In one resultant study, the Harbor Branch Foundation initiated a field research project to investigate the impact of dredge and fill operations on the Florida Keys reef ecosystem (Antonius 1974, Griffin 1974). The results suggested that little sediment is transported from nearshore dredging operations in the Keys out to the reefs (Dustan 1977). Some of the most important observations in the Griffin (1974) study include the following:

- The area of relatively intense plume, turbidity greater than 40 mg/l, rarely extended more than 100-200 m from the dredge.
- Concentration vs. distance plots show that the plume suspensate settles normally, with surface concentration declining in a logarithmetic manner and gradually fading into the background turbidity. In general, the area of plume influence rarely exceeds the limits of an area extending about 500 m down-current from the active dredge.
- Natural turbidity varied moderately in time and space. These natural variations are related to wind stress, resulting in higher turbidity especially during the winter and spring.
- Waves and currents wafted nearly all of the fine grained dredge effluent out of the project area within a few months following cessation of dredge operations.

- Considering the natural turbidity level and the measured spread of effluent from the dredge, it seems that the patch reef studied was too distant to have been affected by the dredging. In other words, a reef situated at least one-half mile from a dredge project in the Keys is not likely to be affected. This conclusion coincides with the results of the biological team (Antonius 1974). They monitored the health of the patch reef at the initiation of the project (November 1972) and after its termination (November 1973). Based on a quantitative quadrat surveys, they reported that no detectable changes had occurred and that the percentages of live and dead coral were identical before and after dredging.

More recently, mathematical model projections of turbidity plumes from cutter head suction dredges (Henriksen 2009) have validated the in situ observations of Antonius (1974) and Griffin (1974) (see Figure 2). These far-field turbidity models reveal that most sediment settles within the first 150-200 m and that essentially all of the suspended solids settle within 1000 m of the dredge operation.

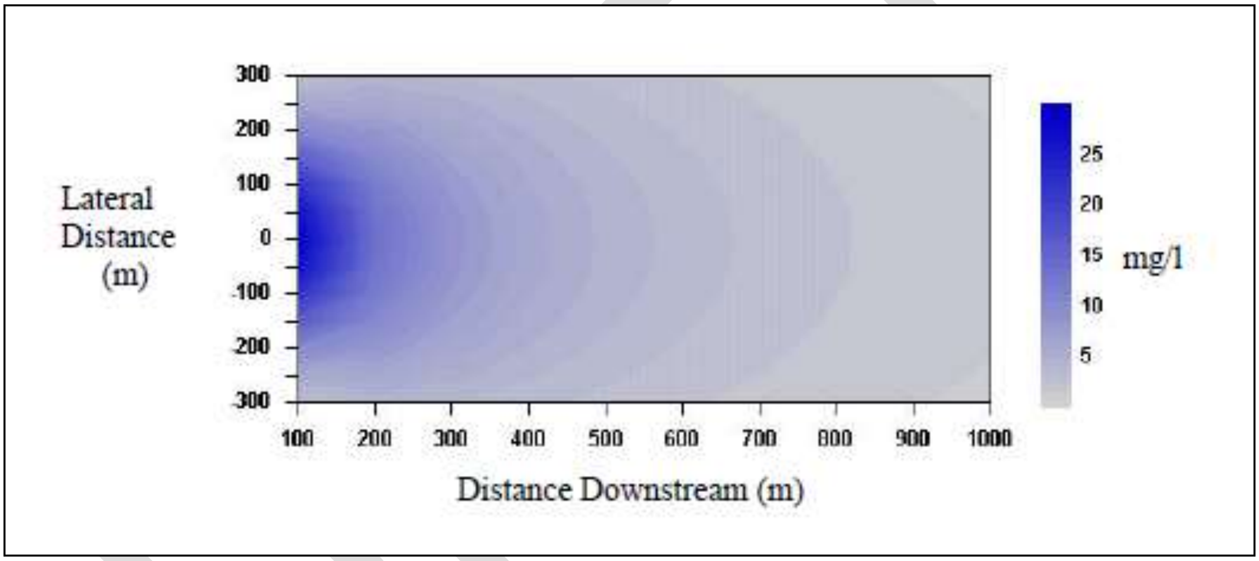


Figure 2. Model Projections of Far-Field Turbidity from Cutter-Head Dredge Operations (taken from Hendriksen, 2009).

Subsequently, additional studies from dredging projects in the region have replicated these previous results (Courtney et al. 1974, USACE 1975, Marszalek 1981). The key points raised by these studies include the following:

- Turbidity plumes visibly extend from the dredge in the direction of prevailing currents.
- Silt and sand settle rapidly from the turbidity plume forming a visible layer of sediment on the reef surface.
- Octocorals are the most tolerant of the reef macrofauna to sediment loading and dredging induced turbidity.
- Sponges that were covered in silt-sized particles eventually “sloughed-off” the sediment which appeared to be bound in a mucoid material.
- No permanent damage to sponges were observed.

- All coral species present in the study area (southeast Florida) showed similar tolerance to dredging.
- Tissue loss in stony corals (partial mortality) was generally confined to a rim around the base of the colony.
- The greatest impacts were found immediately adjacent to the cutter head dredge operations.
- Sediments from overflows could cause the partial mortality of corals up to 400 m from dredging operations.
- While scleractinian corals appeared the most impacted of the reef macrofauna – no mass mortality of corals occurred.

The results from the post-construction impact assessment associated with the PortMiami dredging Project (DCA 2015a, DCA 2015b) show a remarkable similarity to the projects described above. In fact, the results discussed in Griffin (1974) below are ironically just as valid today as they were more than 40 years ago.

- The problem mentioned most often in newspaper and magazine accounts was a supposed relationship between excess siltation produced by dredging and the decline in health of the coral reefs. It appeared from these popular accounts that the only living coral reefs in the continental United States were in imminent danger of extinction.
- Although the news stories concerning the decline of the reefs have been shown in our research to be more fictional than factual, they did serve the useful purpose of kindling scientific interest.

1.3 Study Area

The study area is located in central Miami–Dade County, within hardbottom and reef habitats east of the PortMiami entrance channel (Figure 1). The relict reefs of southeast Florida extend from Miami–Dade to Palm Beach County and were accretional reefs during the early to middle Holocene Epoch, approximately 10,000 – 6,000 years ago (Banks et al. 2007). Today, nearshore hardbottom areas (patch reefs) and parallel ridges or reefs lie offshore in a shore-parallel position, and are dominated by macroalgae, octocorals, sponges, and to a lesser extent hard corals (Moyer et al. 2003, Gilliam 2007). Throughout this report, these reef areas will be referred to as nearshore hardbottom or hardbottom, second or middle reef, and third or outer reef (after Moyer et al. 2003, but see Walker 2012).

The Holocene reefs in Miami–Dade County run almost continuously in a generally north-to-south trend along the coast to approximately 55th Street, Miami Beach. A break in the reef ridges occurs at approximately 55th Street. South of 55th Street, only two reef lines run parallel to the coast and are commonly referred to as the second (middle) and third (outer) reefs, with patchy nearshore hardbottom areas lying west of the second reef tract.

Pre-Project and during Project experience demonstrated that the channel-side environments were dynamic environments beginning in the pre-construction period. Water movement predictions by the U.S. Army Corps of Engineers (Corps) showed predominantly south to north flow with eddies over the middle reef and hardbottom north of the channel (Figure 1, USACE 2004). Tidal forces move water east or west along the channel at greater than 1 knot, twice per day. These tides caused deployed sediment blocks to remain clean at all sites, despite sedimentation. Additionally, in the baseline period burial of the nearshore hardbottom sites

HBN1-CR and HBN2-CP were documented. These sites were later naturally uncovered. Despite burial for months, no corals at these sites suffered mortality. These periods of burial and un-burial are related to the seasonal movements in nearshore sediments and are directly indicative of summer vs. winter beach profiles associated with changes in the fair-weather wave base (Figure 3).

> "The periods of (site) burial and un-burial are related to the seasonal movements in nearshore sediments and are directly indicative of summer vs. winter beach profiles associated with changes in the fair-weather wave base"

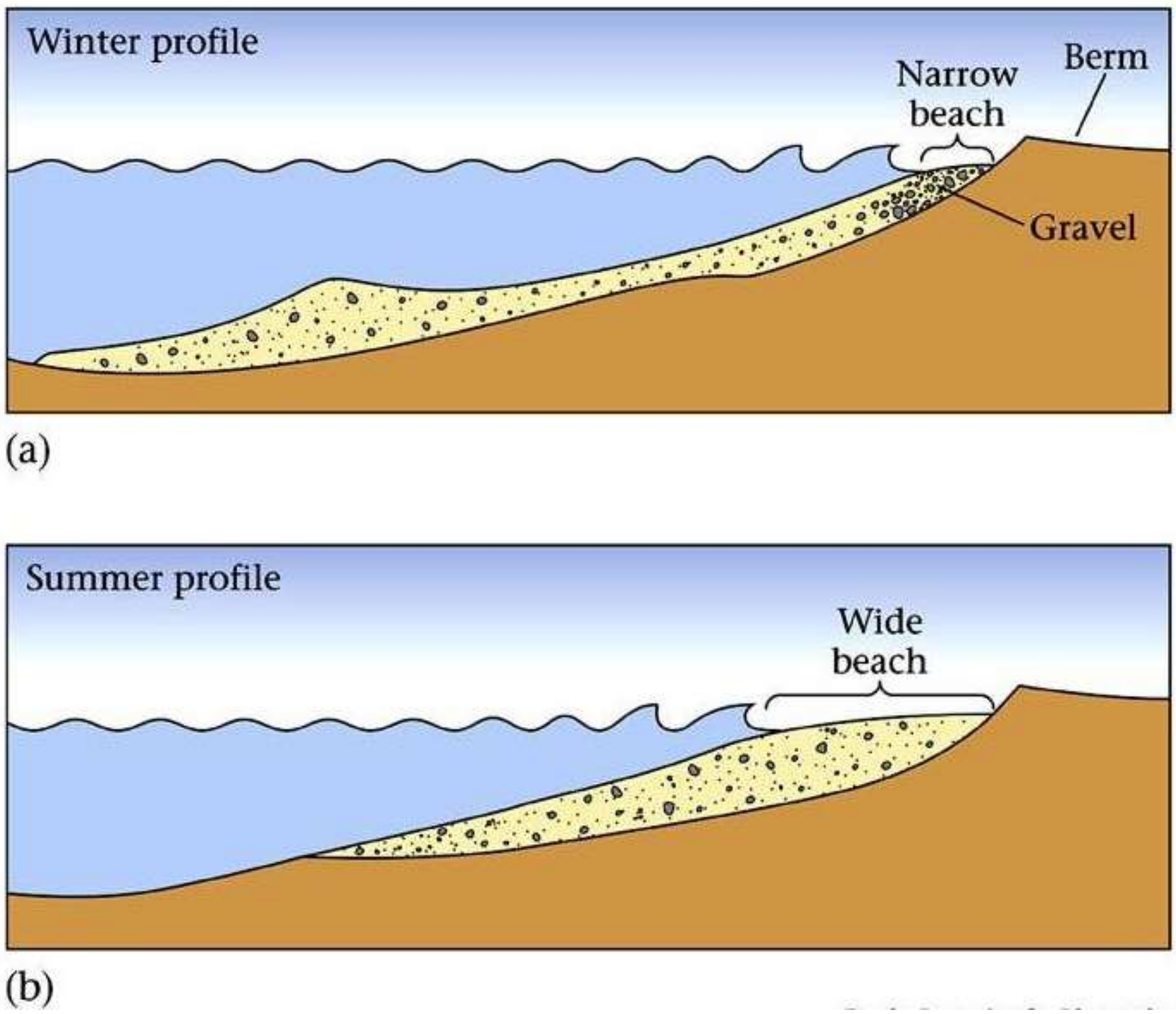


Figure 3. Cartoon depiction of winter versus summer beach profile. Note the abundance of sediment deposited offshore during the winter season. Modified from Figure 18.28 in *Earth: Portrait of a Planet*, 2nd Edition, W.W. Norton & Company.

1.4 FDEP, Permitted Impacts and Compensatory Mitigation

The FDEP permit authorized direct impact of 7.07 acres of outer reef, where widening of the channel was necessary to achieve the navigational goals of the Project. The FDEP permit required 9.28 acres of mitigation to offset these permitted impacts. Of the permitted direct impacts (7.07 acres), the actual impact was 6.88 acres. This represented 0.19 acres less impact than was permitted, which would have resulted in a lower total mitigation requirement. Compensatory mitigation deployment was conducted during Project construction and a portion of the compensatory mitigation was deployed prior to occurrence of the direct impact to the outer reef, representing a temporal benefit to the overall ecosystem prior to any impacts occurring. No up-front mitigation was built for expected temporary indirect effects associated with sediment accumulation.

1.4.1 Compensatory Mitigation

In order to mitigate for the direct impact to the outer reef, a total of 11.6 acres of artificial reef were constructed and accepted as complete by the Corps on April 22, 2015. This amount resulted in construction of 2.32 acres of artificial reef that can serve as advanced compensatory mitigation (9.28 acres were required) for other Project related impacts. When considering the actual direct impact of 6.88 acres, the 2.32 acre of surplus mitigation represents an even greater functional gain. The additional mitigation has been in the water as functional habitat for more than three years, as of October 2017.

1.5 Avoidance and Minimization

A number of avoidance and minimization measures were documented in the Environmental Impact Statement prepared under NEPA before Project construction. Avoidance and minimization was conducted during the Project to protect resources.

1.5.1 Avoidance

Through the contracting process, the Corps chose a Contractor to perform the work based on a number of criteria, including surpassing environmental requirements presented in the Request for Proposal. The Contractor was chosen in-part because of the ability to anchor within the existing channel, thereby avoiding direct impacts to resources associated with anchoring adjacent to the channel. Although these impacts were permitted, they were completely avoided as a result of the selection process. Similarly, blasting and the potential associated effects were completely avoided in the 2013-2015 Project, as no blasting occurred, due to the ability of the Contractor to use a large cutter-head suction dredge.

1.5.2 Minimization

1.5.2.1 Acropora cervicornis

Colonies of threatened species *Acropora cervicornis* that were identified within 33 m (100 feet) of the channel were moved prior to construction by Continental Shelf Associates (CSA) under contract through the dredge Contractor (CSA 2014a). As required under a Biological Opinion issued for the Project, thirty-eight (38) colonies were relocated, tagged and monitored during and after construction (CSI 2016). During the relocation effort, a fragment was collected from each of the colonies and provided to the University of Miami, RSMAS coral nursery for propagation and outplanting to ensure survival of the genetic diversity associated with these colonies. In October 2014, an additional 157 *A. cervicornis* colonies located within 150 m (450 feet) of the channel were relocated to the Rosenstiel School of Marine and Atmospheric Science (RSMAS) coral nursery by staff from the National Marine Fisheries Service (NMFS). From these colonies 3,191 fragments were collected, grown, outplanted and monitored (Lirman and Schopmeyer 2015, 2016).

1.5.2.2 Non-Acroporid Corals and Octocorals

The FDEP permit required all non-acroporid corals greater than 25 cm be relocated from within the direct impact area and up to 1,300 colonies between 10 cm and 25 cm be relocated to natural reefs (50%) and artificial reefs (50%). As a result, 827 colonies greater than 10 cm (all that were found) were moved to natural reef and artificial reef locations and 97 corals of opportunity less than 10 cm were also relocated. Monitoring of corals moved to natural hardbottom sites was conducted by Miami-Dade County (DERM 2016), corals that were moved to artificial reefs were monitored by Coastal Systems International (CSI) (CSI 2016).

1.5.2.3 Advanced Compensatory Mitigation

Advanced compensatory mitigation (ACM) was conducted by the Contractor. In coordination with the dredge Contractor, CSA relocated an additional 643 corals colonies less than 10 cm in diameter, as well as 50 large *Xestospongia muta* sponge colonies from within the direct impact area (CSA 2014b). Post-relocation monitoring of the *X. muta* sponges documented that 49 (98%) reattached after relocation (CSA pers. comm.). ACM was not required by permit.

1.5.2.4 Adaptive Management during Construction

During construction, a number of measures were taken to protect benthic resources. The following adaptive management measures were documented in weekly reports:

1. Turtle excluder devices (TEDs) removed on December 9, 2013 and removal was coordinated with NMFS as required under the South Atlantic Regional Biological Opinion (SARBO) for Dredge Terrapin Island.
2. Dredge movements and operations were closely coordinated with compliance monitoring dive team.
3. Spider Barge activity ceased from February 9, 2014 to March 6, 2014 to allow time for the southern hardbottom sites to recover from scow filling activity.
4. Dredging was relocated to the red side of the channel (inbound) away from the southern hardbottom sites.
5. The dredge was relocated several times to limit the immediate impacts to adjacent habitat between material preparation in Cut 3 and material removal in Cut 2 with the Spider Barge and scows.
6. Minimization of overflow from scows to the greatest extent practical by optimizing the slurry density and actively managing the material flow. Greater scow loads were achieved with less overflow volume required.
7. Liberty Island dredging with no overflow as of June 19, 2014. Liberty Island departed the Project site on July 3, 2014, and did not return to service on the Project.

8. An additional tug and scow were added to the scow package to allow the Spider Barge to load scows with minimal to no overflow, to help reduce possible sedimentation and turbidity as of Compliance Week 39.

1.6 Baseline Quantitative Study 2010 and Baseline Quantitative Study 2013

1.6.1 Baseline 2010

Baseline 2010 results revealed that nearshore hardbottom, middle and outer reef sites within 500 m of the Miami entrance channel, were colonized by sponges, octocorals and scleractinian corals.. The majority of scleractinians were smaller than 10 cm, and octocorals were generally smaller than 25 cm. Octocorals were more dominant in nearshore hardbottom and second reef areas, whereas sponges were similarly abundant on the second and third reefs. Sponge data were not collected for nearshore hardbottom sites in 2010, so their dominance at these sites was not documented. Scleractinians were low in abundance across nearshore hardbottom, second and third reefs. These reefs have little relief (rugosity); and the areas of highest rugosity lie adjacent to the channel or occur in isolated patches. Typical subtropical macroalgae, including *Dictyota*, cyanobacteria, and turf algae were common, although not quantified during this study.

Comparisons with other studies in the region show that these reefs are similarly depauperate in terms of scleractinian coral cover (Porter 1987; Blair and Flynn 1989; Moyer et al. 2003; Gilliam et al. 2006). The dominance of octocorals and sponges is a common feature of the reefs of southeast Florida (Goldberg 1973; Jaap 1983; Gililam et al. 2006; Moyer et al. 2003).

ANOVA results for nearshore hardbottom sites showed that scleractinian and octocoral density were significantly lower at HBS compared to HBSC, HBN, and HBNC. There were no significant differences in the densities of organisms between any other sites.

Linear regression results for middle and outer reef octocoral, scleractinian and sponge density per square meter were mixed, although most relationships were positive, with density increasing with distance from the channel. Coral colony condition were recorded during 2010, however, conditions were not comparable to condition data collected in 2013 and beyond because 2010 condition data was limited to bleaching, disease, fish bites and did not include information on sediment stress. The ANOVA and regression data from 2010 were used for qualitative comparison in this report. Appendix A provides a cross walk for site numbers from the DCA 2012 report and the distances from the channel, which are presented in the results section of this report.

1.6.2 Baseline 2013

The Project monitoring study design, as required by the FDEP permit, was developed using a repeated measures design, with three permanent transects established at each of 26 Project monitoring sites. Baseline surveys began in September 2013 and were conducted through December 2013 at hardbottom, middle and outer reef sites. For more information on the baseline reports, see DCA 2014a (hardbottom) and 2014b (middle and outer reef). Following the completion of construction at all areas, post-construction surveys were conducted at all 26 sites. For more information on post-construction survey results see DCA 2015a for hardbottom and DCA 2015b for middle and outer reef results.

1.7 Potential Impact Assessment Surveys

1.7.1 Potential Impact Assessment 2014

Gray or white, clay-like material was documented at channel-side sites, impacting corals during construction in early 2014. During and after construction, impact assessment surveys were conducted in order to outline areas of potential sedimentation effect in the hardbottom, middle and outer reefs. These surveys were initiated after corals at channel-side sites continued to exhibit "stress above normal," according to weekly compliance monitoring reports.

In July 2014, impact assessment surveys identified 38.7 acres of nearshore hardbottom habitat, affected by Project-related clay-like material (Figure 4). No Project-related sediment impacts were documented at control sites. During construction, impact assessment surveys for the nearshore hardbottom area consisted of 19 temporary 200 m transects running along a north-south orientation perpendicular to the channel on both the north and south sides of the channel. Monthly surveys were conducted between July 2014 and January 2015 in the hardbottom area as required by FDEP permit. Line intercept data were collected to document habitat type, qualitative sediment characteristic data and scleractinian presence and condition. By October 2014 the clay-like material was no longer visually distinguishable at surveyed transects (DCA 2015c).

1.7.2 Potential Impact Assessment 2015

Potential sedimentation effect surveys were conducted from April –May 2015 within middle and outer reef areas north and south of the Miami Harbor Channel, one month after the completion of offshore dredging activities.

According to the Potential Sedimentation effect report (DCA 2015c, d) 213.7 acres of middle and outer reef habitat area were estimated to be potentially impacted (Figure 5). The potentially impacted area on the middle and outer reefs were proportional to the influence of the hydrodynamics acting in the area of the Miami Harbor Channel. Estimated potential impacts were greatest on the north side of the middle reef and lowest on the south side of the outer reef. During surveys, pockets of clay-like material were observed within potentially impacted areas. The majority of potential impact was on the northern middle reef, with more than 60% of the total affected area located on the north side of the middle reef. Quantitative surveys focused on the documentation of partial mortality of scleractinian corals as the result of sedimentation, since this was the only dredge-related impact to organisms documented during construction at channel-side sites. It should be noted that partial mortality may be caused by several other factors, including disease, fish bites, and natural sedimentation processes. Since no pre-existing data were available for these factors, natural sedimentation effects could not be separated from Project related sedimentation effects using this post-hoc survey approach, which is why the phrase "potential sedimentation" was used as a modifier in this report.

A sedimentation impact study was conducted by NMFS staff, limited to the north middle reef in December 2015, and results were published in Miller et al. (2016). In that study, authors wrote that sedimentation impacts documented as partial mortality of hard corals were documented up to 700 m away from the channel on the northern middle reef, but their methods failed to take into consideration the region-wide disease event that began in 2014 (Precht et al. 2016) and the natural causes of partial mortality previously discussed.

> "In July 2014, 38.7 acres of nearshore habitat were affected by clay-like material… By October 2014 the clay-like material was no longer visually distinguishable at surveyed transects (DCA 2015c)."

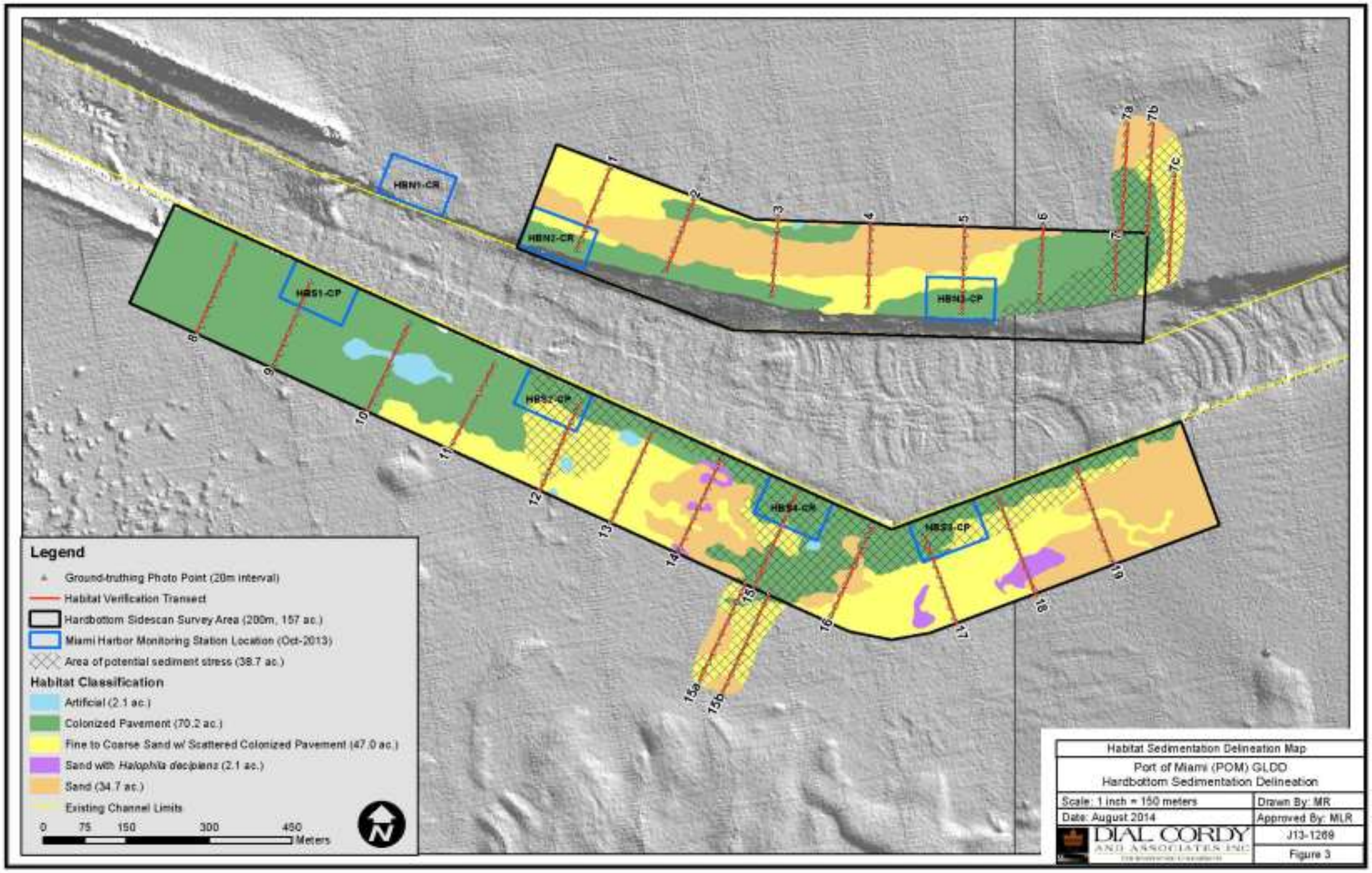


Figure 4. **Hardbottom habitat sedimentation delineation map (DCA 2014a).**

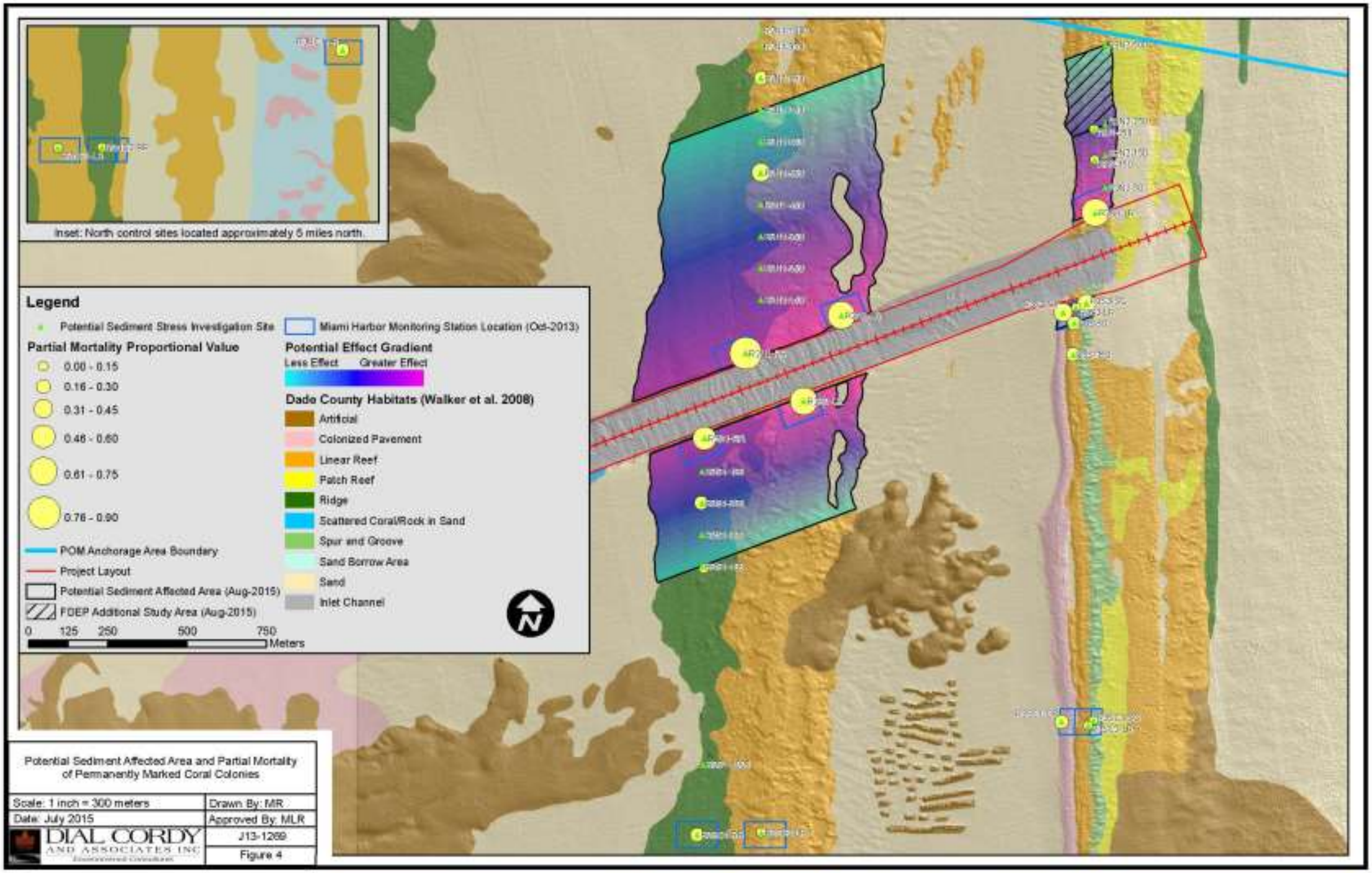


Figure 5. Middle and outer reef impact assessment map (DCA 2015d).

1.8 Regional Influences on Benthic Resources

During the project, a wide-spread thermally induced coral bleaching event during the summer of 2014 (NOAA 2014a, b, 2015a, b, c, Manzello 2015) preceded a white-plague disease outbreak that affected the Southeast Florida region (Figure 6 and 7, also see, CSI 2016, DERM 2016, Precht et al. 2016, Hayes et al 2017). Precht et al. (2016) documented region-wide species-specific rates of white-plague disease infection and estimates of species mortality that ranged from 0% for common coral species *Siderastrea siderea* and *Porites astreoides* to 100% infection and estimated mortality for *Eusmilia fastigiata*, 98% for *Meandrina meandrites,* and 97% for *Dichocoenia stokesi.*

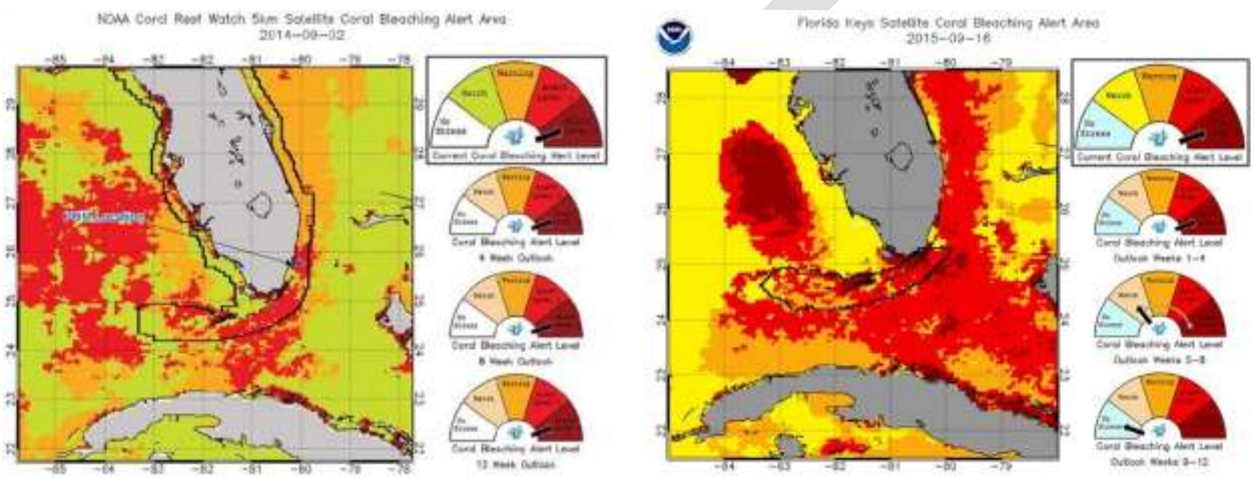


Figure 6. NOAA Coral Reef Watch 5 km Satellite Coral Bleaching Alert Area in 2014 (left) and 2015 (right) showing regional bleaching in South Florida and location of project area (NOAA 2014a). POM in the figure refers to the PortMiami. Bleaching alert levels are based on sea surface temperature data.

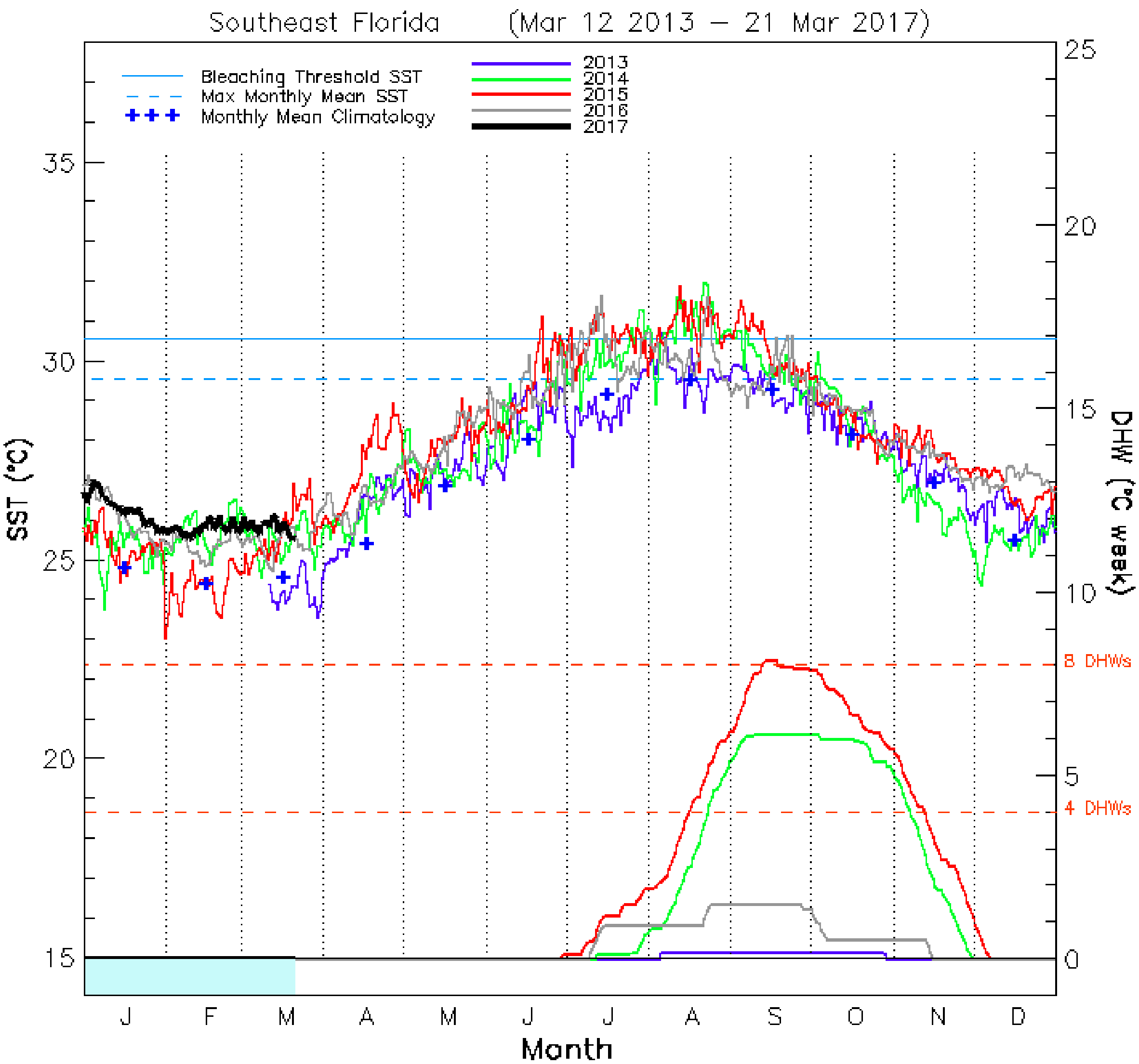


Figure 7. Annual Southeast Florida temperature data and degree heating weeks (DHW). Data from NOAA Coral Reef Watch Program (NOAA 2016).

The Florida Reef Resilience Program (FRRP) documented coral disease prevalence throughout the Florida Reef Tract during surveys in the summer of 2015 (August 7th- October 16th) and again in the summer 2016 (August 15th-October 21st). In the summer of 2015, during a second year of significant coral bleaching (Figure 7), high levels of coral disease were noted in Broward-Miami, Biscayne, Upper and Lower Keys subregions with the majority of high disease sites being located in the Biscayne-Miami sub region in 2015 (Florida Reef Resilience Program, 2015). High levels of coral disease (>10%) were also noted in the Broward-Miami sub region in the summer of 2016 along with Martin, the Upper Keys, Lower Keys, and Dry Tortugas sub regions (Florida Reef Resilience Program, 2016). Coral disease is present at lower levels (<5%) on Caribbean reefs (Muller and Van Woesik 2012, Ruiz et al. 2012). Recent data released from the Southeast Florida Coral Reef Environmental Monitoring Program (SECREMP) for Miami-Dade, Broward, and Martin County show a similar pattern of disease and disease-related mortality region-wide from their summer 2015 and 2016 coral monitoring surveys (Hayes et al. 2017). The white-plague disease continued to affect the region through the impact assessment sampling period in 2016 from the Florida Keys through Martin County (Figure 8, CSI 2016, DERM 2016, Precht et al. 2016 Hayes et al 2017, Aeby et al. 2017).

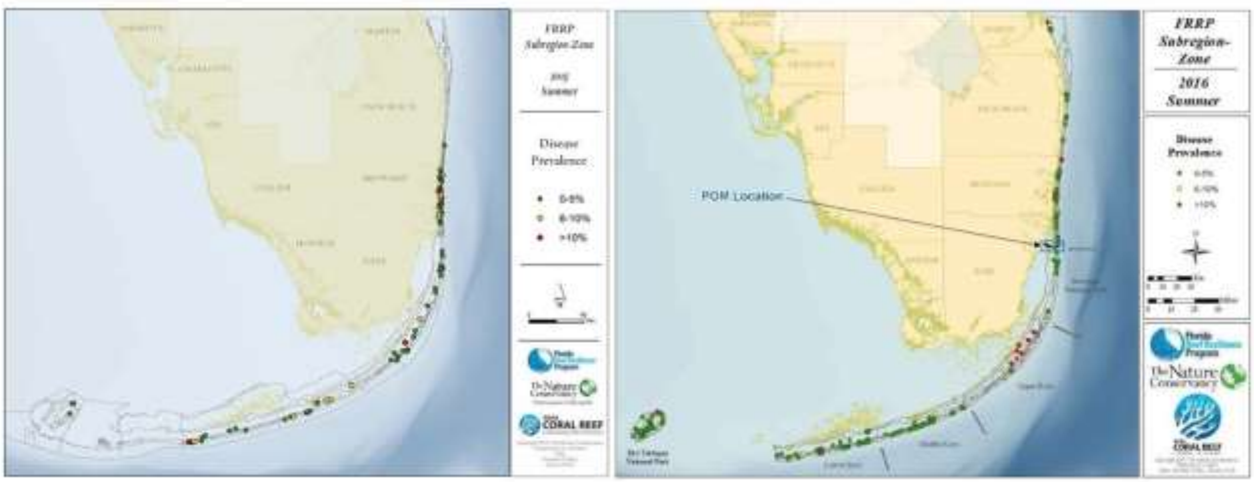


Figure 8. Disease presence as documented by the Florida Reef Resilience Program (FRRP) in 2015 (left) and 2016 (right). The Project area is shown as POM Location.

<u>White-plague and dredging</u>

A critical component of the permanent site impact assessment surveys and report (DCA 2017) was to examine the causes of coral mortality experienced during construction and post-construction periods and determine if the white-plague disease observed within the project corridor was caused, or exacerbated, by dredging activities. To accomplish this task, the disease susceptibility of the various species at each monitoring site needed to be taken into account. The species-level rates of white-plague disease infection and estimated mortality published in Precht et al. (2016) were used as an estimate of the species-level susceptibility to white-plague disease. The 10 sites visited by Precht et al. (2016) in which species-tallies of disease were calculated, spanned Miami-Dade County, and are an independent source of white-plague disease data. Other groups also documented species specificity of coral disease in Miami-Dade County, which corroborate the Precht et al. 2016 data (CSI 2016, DERM 2016, Hayes et al. 2017). Using these data, a mean estimated mortality and 95% CI for the mean was calculated for each permanent monitoring site based solely on the species-composition of the site. Hypothetical dredging effect hypotheses were evaluated based on the independent regional dataset on coral disease related mortality (Precht et al. 2016).

Hypothesis A: White-plague disease-related mortality proliferated as a *result* of dredging stress.

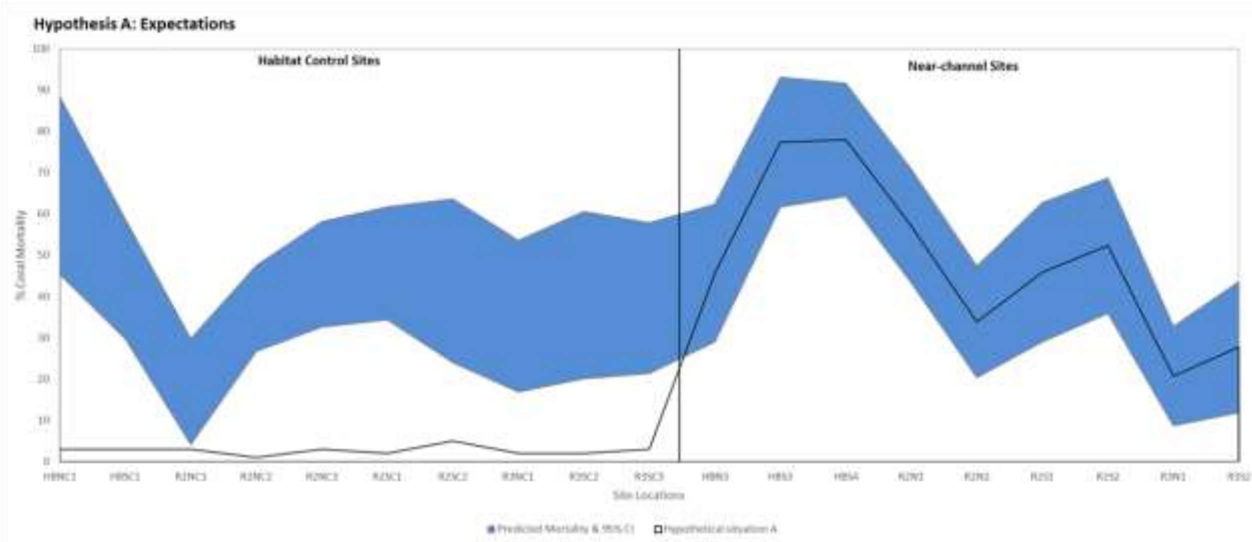
Expectation: If white-plague disease proliferated as a result of dredging stress, coral mortality at all control sites would be low, consistent with mortality at un-stressed sites, as corals at control sites were not impacted by dredge stress. Coral mortality at sites influenced by the dredge (near-channel permanent sites) would be within the range expected due to the species-specificity of the disease. A hypothetical depiction of this scenario is presented in Figure 9. The hypothetical depiction shows mortality rates at control sites that range between 1 and 5% and the mean estimated mortality predicted based on the species-susceptibility of the monitoring site is the depicted level of mortality at the near-channel sites (Figure 9).

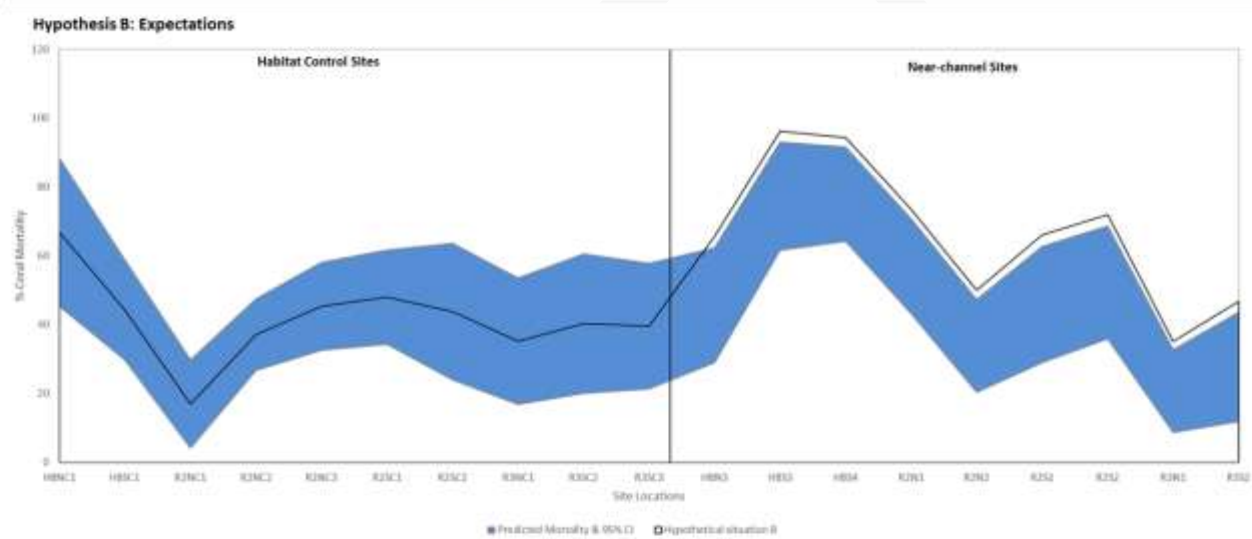
Hypothesis B: White-plague disease-related mortality was *exacerbated* as a result of dredging stress.

Expectation: If white-plague disease was exacerbated as a result of dredging stress, coral mortality at all control sites would be within the range predicted from regional levels of white-plague disease-related mortality. Disease-related mortality at near-channel sites would be expected to be higher than expected due to species-susceptibility alone. The hypothetical depiction of this scenario is presented in Figure 9. The levels of disease-related mortality for control sites depicted are the mean disease-susceptibility calculated for each site based on species-composition and rates of disease-related mortality presented in Precht et al. (2016). Exacerbated levels of disease-related mortality at near-channel sites show an increase of 20% of the 95% CI (Figure 9).

Hypothesis C: White-plague disease-related mortality was *not* affected by dredging stress.

Expectations: If rates of white-plague disease mortality were not affected by dredging, the expectation is that all monitored sites would have rates of disease-related mortality within the levels predicted from regional estimates of white-plague disease mortality. In this scenario the levels of disease-related mortality are presented as the estimated mean species mortality calculated based on community composition at each site (Figure 9).


Hypothesis A: Expectations
Habitat Control Sites
Near-channel Sites
% Coral Mortality
Site Locations


Hypothesis B: Expectations
Habitat Control Sites
Near-channel Sites
% Coral Mortality
Site Locations

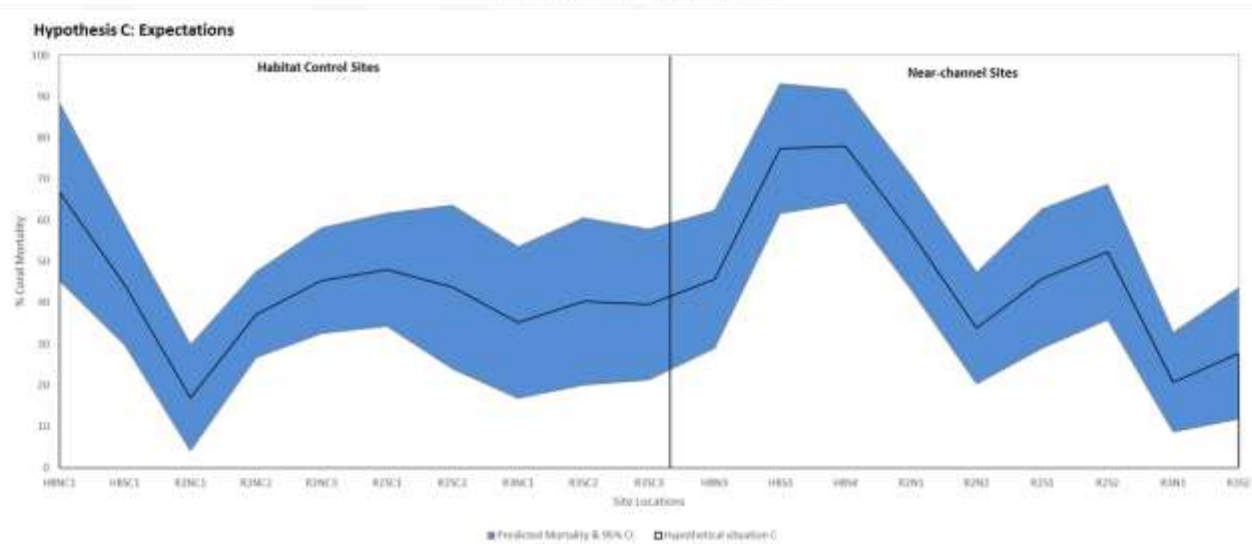

Hypothesis C: Expectations
Habitat Control Sites
Near-channel Sites
% Coral Mortality
Site Locations

Figure 9. Expectations for disease/dredging related hypotheses. Hypothesis A: disease was proliferated due to dredging stress. In this scenario the levels of disease-related mortality are presented as the estimated mean species mortality calculated based on community composition at each site. The hypothetical depiction shows mortality rates at control sites that range between 1 and 5% and the mean estimated mortality predicted based on the species-susceptibility of the monitoring site is the depicted level of mortality at the near-channel sites. Hypothesis B: disease was exacerbated due to dredging stress. In this scenario levels of disease-related mortality for control sites are the mean disease-susceptibility calculated for each site based on species-composition and rates of disease-related mortality presented in Precht et al. (2016). Exacerbated levels of disease-related mortality at near-channel sites are 20% greater than the calculated 95% CI. Hypothesis C: In this scenario the levels of disease-related mortality are presented as the estimated mean species mortality calculated based on community composition at each site.

The observed mortality at channel-side and control sites from the permanent monitoring sites recorded between baseline and the one-year post-construction impact assessment survey are shown in Figure 10. These data do not follow the pattern predicted by Hypothesis A in which dredging stress is responsible for disease-related mortality. Hypothesis A was rejected because rates of mortality and active disease documented at the control sites were within, *not below,* those predicted using regional estimates of disease. Instead, rates of control mortality were within the predicted 95% CI for white-plague disease at eight out of ten sites. Hypothesis B was rejected because none of the nine near-channel sites had levels of mortality that exceeded those predicted using regional species specific white-plague mortality estimates. Hypothesis C, in which white-plague disease was *not* affected by dredging stress is the only hypothesis that explains the observed data (Figure 8). Rates of coral mortality were predicted solely based on the species-composition and regional estimates of white-plague mortality at all near-channel sites and at all but two habitat controls.

The white-plague disease event had a devastating effect on Southeast Florida coral populations *including* those of the near-channel and habitat control sites of the PortMiami construction project. The effect of this disease has caused the mortality of many tagged near-channel and control corals, however, the rates of mortality are consistent with regional rates of disease and data collected at permanent sites does not support the hypotheses that dredging stress was responsible for or exacerbated levels of disease-related mortality. The loss of significant numbers of tagged corals as a result of the white-plague disease event has a direct effect on the results presented below. It is important to note that the ability to evaluate levels of disease-related mortality, as predicted by regional estimates of white-plague disease, requires that the species composition of the site be known prior to the disease event; a factor that was not possible at the cross site impact assessment locations. As a result, all estimates of coral mortality provided in this report cannot be partitioned into dredge, disease, or other causes of mortality.

> "(White-plague) disease caused the mortality of many tagged near-channel and control corals, however… the data collected at the permanent sites does not support the hypotheses that dredging stress was responsible for or exacerbated levels of disease-related mortality."

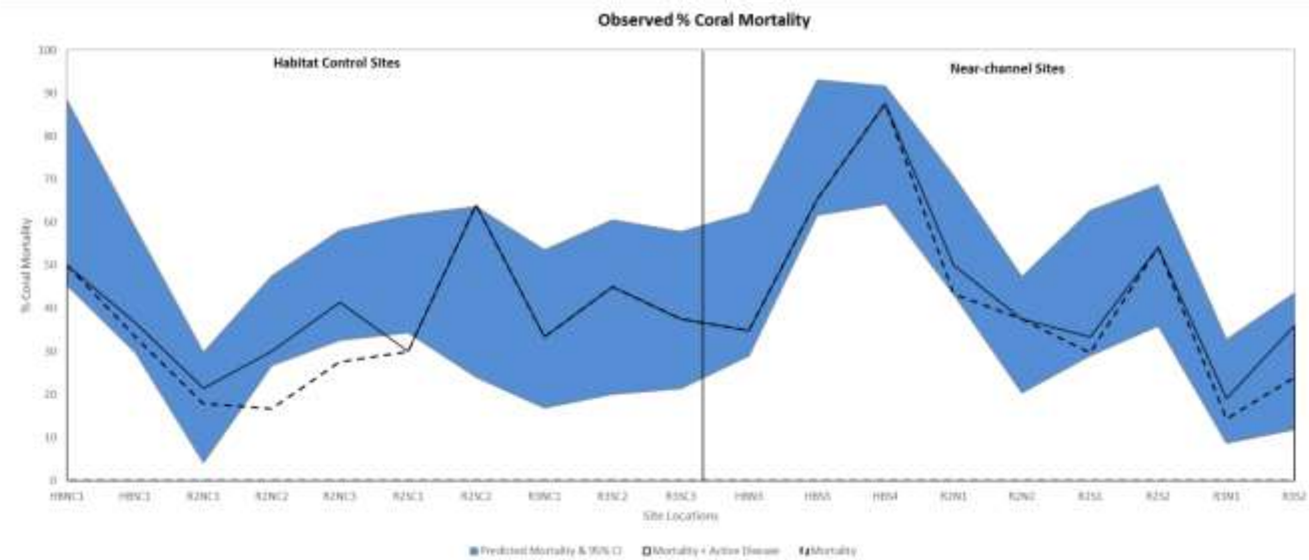


Figure 10. The predicted mortality and 95% CI for each permanent monitoring site based on white-plague disease prevalence/mortality estimates for observed and dead-in place corals published in Precht et al. (2016) (blue shaded region). Total observed mortality plus active disease documented during the impact assessment survey are depicted by the solid black line. Observed mortality total only is denoted by the black dotted line. Note that white plague disease affected coral species at different rates over time, so both corals observed with total mortality (dotted black line) and partial mortality and active disease (solid black like) are shown graphically (DCA 2017).

2.0 METHODS

2.1 Study Site Description

The study site includes the middle and outer reefs adjacent to the outer entrance channel at the PortMiami. Starting in the pre-construction period (2013), surveys were conducted at channel-side sites and associated control sites to document the population dynamics, condition, and sedimentation environment of the benthic communities adjacent to the PortMiami Phase III project area. Surveys were conducted immediately before commencement of construction activities, during construction, immediately post-construction and in the one-year post-construction period, as required by the FDEP permit. The one-year post-construction impact assessment consisted of two separate monitoring efforts, which could not be conducted simultaneously. The first effort focused on permanent sites. This second monitoring effort began after the field work for the first monitoring effort of select permanent sites was concluded.

This one-year post-construction impact assessment was conducted to document changes attributable to dredging while considering other environmental or anthropogenic factors that influenced hardbottom, middle, and outer reefs resources in the area. This impact assessment survey evaluated the most affected sites in the hardbottom, middle and outer reef, their controls, as well as additional sites in line with their respective channel-side sites at varying distances from the channel in order to delineate potential impacts using a cross methodology. This is the first use of this FDEP/NMFS cross site sampling methodology throughout the history of this project.

2.1.1 Study Site Selection

The location of previously established (channel-side and control) permanent monitoring stations were included in this survey protocol in addition to a number of new stations, that were added in order to assess the entire potential impact area (approximately 250 acres). A total of 68 sites were initially recommended by FDEP and NMFS; these sites were located throughout the hardbottom, middle, and outer reefs (Figure 1). Due to time, budgetary constraints, and site overlap, only 54 of the recommended initial 68 sites were surveyed (Table 1). In some cases, sites were consolidated due to potential overlap (*e.g.* a site at 75 meters from the channel was surveyed as opposed to one site at 50 meters and one site at 100 meters). Coordination and consultation with FDEP, NMFS and the Corps determined the priority of sites to be sampled with the available time and budget.

2.1.1.1 Study Site Nomenclature

Study sites were named by reef (HB – nearshore hardbottom, R2 – middle or second reef, R3 – outer or third reef), by orientation with respect to the channel (*i.e.* north (N) or south (S)), designated as a control (C), given a unique number from west to east by reef, and given a two letter code representing the habitat type based on the habitats described by Walker et al. (2008). For example, the site R2NC3-LR was the middle reef northern control at the third habitat type which is also known as "linear reef". For the additional non-permanent sites, FDEP-provided nomenclature defined sites by reef, distance in meters from the channel, and by habitat type (*e.g.* R2N-250-LR).

2.1.2 Permanent Sites

A total of nine control sites and eight channel-side sites were selected and surveyed during impact assessment surveys using the cross survey protocol. All control sites were located a considerable distance from the project area for comparison purposes to account for larger scale non-dredging (natural) conditions which could have affected benthic resources. The control and channel-side cross sites surveyed here were in the vicinity of the permanent sites surveyed before, during and after construction (DCA 2017). Northern control sites at middle and outer reef were placed further north due to the PortMiami anchorage area in order to avoid confounding effects due to non-project activities at the anchorage as well as diver safety issues. A list of all surveyed sites and their distances from the channel can be found in Table 1.

Table 1. Distances and directions from the channel of all permanent and non-permanent sites (54) monitored during impact assessment surveys.

Priority	Assessment Area	Site	Approximate Distance from Channel (m)	Priority	Assessment Area	Site	Approximate Distance from Channel (m)
1	Reef 2 North Ridge Reef (RR)	R2NC2-RR	9,380	2	Reef 2 North Linear Reef (LR)	R2NC1-LR	9,380
						R2NC3-LR	9,380
		R2N1-RR	28			R2N1-LR	18
		R2N-75-RR	75			R2N-75-LR	75
		R2N-150-RR	150			R2N-150-LR	150

Priority	Assessment Area	Site	Approximate Distance from Channel (m)	Priority	Assessment Area	Site	Approximate Distance from Channel (m)
		R2N-250-RR	250			R2N-250-LR	250
		R2N-350-RR	350			R2N-350-LR	350
		R2N-450-RR	450			R2N-450-LR	450
		R2N-550-RR	550			R2N-550-LR	550
		R2N-650-RR	650			R2N-650-LR	650
		R2N-750-RR	750			R2N-750-LR	750
3	Reef 2 South Ridge Reef (RR)	R2SC1-RR	1,270	4	Reef 2 South Linear Reef (LR)	R2SC2-LR	1,270
		R2S1-RR	23			R2S2-LR	21
		R2S-100-RR	100			R2S-100-LR	100
		R2S-200-RR	200			R2S-200-LR	200
		R2S-300-RR	300			R2S-300-LR	300
		R2S-400-RR	400			R2S-400-LR	400
5	Reef 3 North Linear Reef (LR)	R3NC1-LR	9,380	7	Hardbottom North Colonized Pavement (CP)	HBNC1-CP	2,350
		R3N1-LR	23			HBN3-CP	48
		R3N-100-LR	100			7a-150	150
		R3N-150-LR	150	8	Hardbottom South Colonized Pavement (CP)	HBSC1-CP	1,650
		R3N-200-LR	200			HBS4-CP	32
		R3N-300-LR	300			15b-150	150
		R3N-400-LR	400			15b-250	250
		R3N-500-LR	500	9	Reef 3 South Linear Reef (LR)	R3S-350-LR	350
6	Reef 3 South Linear Reef (LR)	R3SC2-LR	1,300	10	Reef 2 North Ridge Reef (RR)	R2N-850-RR	850
		R3S2-LR	21	11	Reef 2 North Linear Reef (LR)	R2N-875-LR	875
		R3S-50-LR	50				

2.1.3 Cross Sites

A total of 54 non-permanent sites (cross sites, named for transect layout) were selected and surveyed during impact assessment surveys. Non-permanent sites were placed at set distances from the channel edge in a north-south or south-north orientation depending on whether the sites were north or south of the channel. In some cases, cross sites were offset slightly to the west to prevent overlap between sites. Sites were generally placed in approximately 100 m intervals with some exceptions where the distance was reduced to 75 m. A list of all survey sites and their distances from the channel can be found in Table 1.

2.1.4 Site Layout

At each monitoring cross site, two intersecting 50 m pseudo-replicated transects were established in a north-south and east-west orientation to form a cross with the center placed at the FDEP-provided GPS coordinates for the site (Figure 11). Additional GPS coordinates were added using HYPACK software to mark the northern, southern, eastern, and western ends of each transect. In the field, a buoy with a small anchor was deployed at each of the five waypoints. An additional waypoint was collected in HYPACK when each anchor was deployed to mark the actual drop point with respect to the planned drop point.

The east-west transect at each site was always oriented from east (0 m) to west (50 m). The orientation of the north-south transect varied depending on orientation to the channel such that the north-south transect was established moving away from the channel (*i.e.* south (0 m) to north (50 m) on the north side of the channel and north (0 m) to south (50 m) on the south side of the channel). A system of colored buoys was used to mark the starts and ends of each transect so as to avoid confusion on the surface. Scientific divers laid the transect tapes using compass bearings for navigation taking care to establish transects as straight as possible while minimizing disturbance to benthic organisms and any sediments in the area. The locations of all buoys with respect to the transect tape and the location of the tape intersection were also recorded.

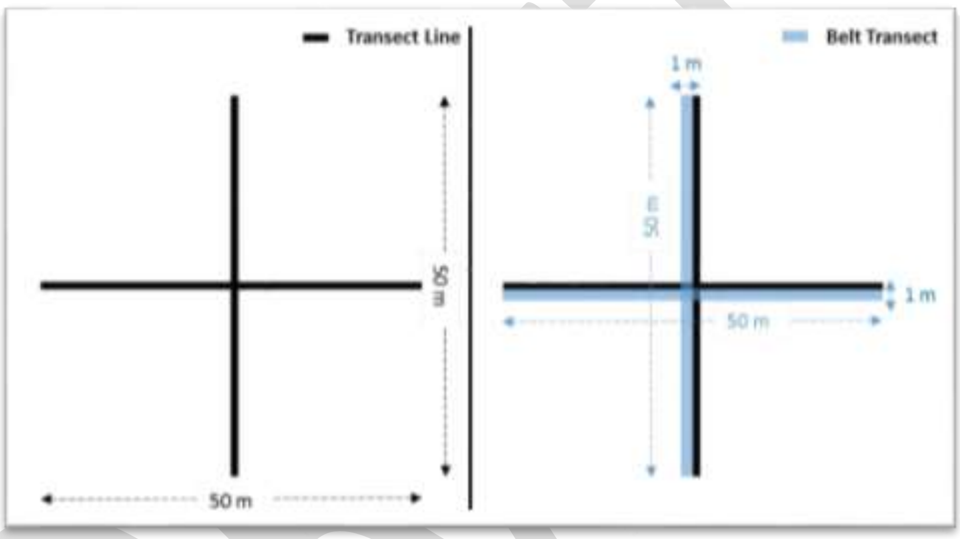


Figure 11. Pseudo-replicated cross transect site layout.

2.2 Data Collection

Per the FDEP and NMFS protocol, data collection at each site included: 1) downward-facing digital video of each 50 m transect, 2) 360^0 videos at the start, middle, and end of each transect, 3) sediment depth data (mm) at every meter for each transect, 4) qualitative sediment characterization every 5 m (fine, mixed, coarse), 5) coral, octocoral, and sponge data (maximum diameters in cm and condition) and corresponding photographs (FDEP 2016, also Appendix B).

Data were initially planned to be collected within a 1 m belt transect along the entire length of each 50 m transect for a total of 100 m^2 of data per site. The timing and budget of the impact assessment was based on the assumption that all the necessary data for a single site could be collected in a single day as stipulated in the protocol (each cross site was to be surveyed in one-day). After a practice run and initial attempts to complete data collection at one of the proposed sites, it was determined that it was not feasible to collect the proposed amount of data within one day, with the budgeted time, equipment and personnel. Per discussions with FDEP and NMFS, the protocol was revised to reduce the amount of data collected at each site. .

No changes were made to sediment data collection: sediment depth and qualitative characterization of substratum were collected along the entire length of each 50 m transect throughout the cross site surveys. The first modifications in the methods were made to the benthic community data only and were applied to all northern middle reef sites (Table 2). Portions of both north-south and east-west lines were omitted from benthic organism data collection as follows:

- NS Transect Data collection (0-10m and 40-50m)
  - Corals (data and photos for all sections)
  - Octocorals (data only, no photos)
  - Sponges (data only, no photos)
- EW Transect (0-10m, 20-30m, and 40-50m)
  - Corals (data and photos for all section)
  - Octocorals (data only for all sections, data and photos for 0-5m, 20-30m, 45-50m)
  - Sponges (data only for all sections, data and photos for 0-5m, 20-30m, 45-50m)

A second FDEP and NMFS approved modification was applied to the remaining sites (all sites except northern middle reef). The second modification was the omission of benthic invertebrate data collection (corals, octocorals, and sponges) along the north line only. A detailed breakdown of where data and photographs were collected for all data categories can be found in Table 2 and is further detailed by group in Sections 2.2.1.2 and 2.2.1.3.

Table 2. Breakdown of data and photograph collection at transect cross sites. x[1]: missing EW photos for sponges 20-25m, but have data at R2N1-RR; x[2]: missing 360º videos for NS at R2N1-RR; x[3]: missing NS photos for corals, but have data at R2N-150-RR; x[4]: missing 360º video at 0m on NS at R2S-300-RR; x[5]: missing 360º video at 0m on EW at R2S2-LR; x[6]: missing all 360º videos on NS at R2S-300-LR; x[7]: missing 360º video at 0m on NS at R3N-100-LR; x[8]: missing all 360º videos on NS at R3N-200-LR; x[9]: missing 360º videos at 0m and 25m on NS at R3N-400-LR; x[10]: missing 360º video at 0m on NS at R3N-500-LR; x[11]: missing 360º video at 0m on EW at R3N-500-LR; x[12]: missing photo of 50m on EW transect for sediment at HBN3-CP; x[13]: no photos for sponges between 45-50m because no sponges were present in this portion of the transect at HBN-7a-150; x[14]: missing 360º video at 0m on EW at HBS4-CP. Missing photos or video due to equipment malfunctions.

	Benthic Invertebrate Data					Sediment Data		Octocoral/Sponge Photos				Coral Photos					Quadrat Photos		Sediment Photos	
	NS		EW					NS	EW			NS		EW						
Site	0-10m	40-50m	0-10m	20-30m	40-50m	NS	EW	20-30m	0-5m	20-30m	45-50m	0-10m	40-50m	0-10m	20-30m	40-50m	NS	EW	NS	EW
R2NC2-RR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
R2N1-RR	x	x	x	x	x	x	x		x	x[1]	x	x	x	x	x	x	x	x	x	x
R2N-75-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-150-RR	x	x	x	x	x	x	x		x	x	x	x[3]	x[3]	x	x	x	x	x	x	x
R2N-250-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-350-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-450-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-550-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-650-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-750-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-850-RR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2NC1-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2NC3-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N2-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-75-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-150-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-250-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-350-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-450-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-550-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-650-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-750-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2N-875-LR	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
R2SC1-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S1-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-100-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-200-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-300-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-400-RR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2SC2-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S2-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-100-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-200-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-300-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R2S-400-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3NC1-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N1-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-100-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-150-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-200-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-300-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-400-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3N-500-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3SC2-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3S2-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3S-50-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
R3S-350-LR			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
HBNC1-CP			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
HBN3-CP			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x[12]
HBN-7a-150			x	x	x	x	x		x	x	x[13]			x	x	x	x	x	x	x
HBSC1-CP			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
HBS4-CP			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
HBS-15b-150			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x
HBS-15b-250			x	x	x	x	x		x	x	x			x	x	x	x	x	x	x

All scientific divers were trained and qualified to conduct benthic surveys in hardbottom, middle and outer reef environments, as required by the FDEP permit for the Project. Project specific training materials were developed and included coral species, octocoral genera, and sponge morphotype identification and stress indicator guides (DCA 2013). These training tools were provided to all Project personnel. In contrast to previous monitoring efforts, data on corals smaller than 3 cm were collected in this study. A site specific identification manual was developed and used as a training tool and reference in addition to the Humann (2002) reef identification guide book and on-line AGRRA (Atlantic Gulf Reef Rapid Assessment) coral identification keys (AGRRA 2013). A trained scientific diver from Coastal Systems International (CSI) provided Quality Assurance and Quality Control (QA/QC) oversight during 10% of diving operations. Each diver was equipped with a 20 or 50 cm scale bar in addition to a 1 m scale bar to ensure that the entire 1 m belt was surveyed.

Impact assessment surveys of the hardbottom, middle and outer reef sites were conducted between September 12, 2016 and May 30, 2017. In the month of October 2016, no scientific diving operations were conducted due to the passage of Hurricane Matthew and subsequent winter storms. Field staff used best professional judgment of wind and wave conditions to determine whether or not scientific dive operations could be conducted safely. Accordingly, no operations were conducted during small-craft boating advisories, when bottom visibility was less than one meter, or current velocities were in excess of one meter per second.

The FDEP-protocol initially stipulated that all data from a single site should be collected in a single day. However, despite the revised protocol, it was still not possible to collect all the necessary data at a site in a single day; the main limiting factor being the amount of dive tanks that could be safely transported onboard the dive vessel and remaining within budget. In order to avoid having to revisit a site and reestablish the transect lines, each sampling day would alternate between surveying two N-S transects and one EW transects.

2.2.1 In Situ Data

In situ data were collected along either specific sections of each transect (*i.e.* coral, octocoral, sponge data) or along the entirety of each belt transect (*i.e.* sediment data) at each hardbottom, middle and outer reef monitoring site. Scientific divers placed transect tapes, marked in metric and standard increments along the pre-established transects, securing the tape to the bottom as necessary to prevent it from moving due to waves, surge or currents. *In situ* post-construction data were collected using underwater data sheets, clipboards, and scale bars. Collection of *in situ* data were not conducted until after transect video was collected. In general, specific divers were assigned to complete a specific task on each survey site, but would assist others with data collection when finished with their assigned task (*i.e.* coral data collector assisted with sponge and octocoral data collection once all coral data were collected).

Coral stress condition codes were revised in coordination with FDEP with priority being given to codes which characterized varying degrees of sediment stress and mortality. Additional codes that described any additional organismal stress were recorded in a separate column. The organism condition codes used in data collection can be found in Table 3. A description of the codes required for data collection and their intended uses are provided below.

Sediment-based condition codes
The following sediment-associated condition codes were assessed for all corals, octocorals and sponges that were within a surveyed transect.

Unaffected (UN): Organism is healthy in appearance with no obvious signs of stress

> **Intended use:** To describe the proportion of organisms without signs of stress at a given site.
> **Limitations:** This number will vary depending on seasonality (i.e. the proportion of unaffected organisms at a site will be lower if sampled during regional bleaching or paling) or due to recent storm activity and can depend on the level of detail recorded by the observer.

Sediment dusting (SED): Low amount, a "dusting" of sediment on top of the colony/organism.

> **Intended use:** To indicate if the organism is encountering sediment that is settling out of the water column.
> **Limitations:** Settling sediment is a natural part of the reef ecosystem but can also be influenced by dredging. The percent of organisms affected by sediment dusting at a site can also vary due to weather conditions at the time of sampling. Sediment dusting is often elevated after the passage of storms.

Sediment accumulation (SA): Moderate sediment accumulation on top of colony/organism (more than dusting).

> **Intended use:** To indicate if an organism is experiencing stress from settling sediment.
> **Limitations:** Settling sediment is a natural part of the reef ecosystem but can also be influenced by dredging. The percent of organisms affected by sediment accumulation at a site can also vary due to the communities relative position in relation to sediment (i.e. low areas, or areas adjacent to naturally occurring sediment) or weather conditions at the time of sampling. Sediment accumulation is often elevated after the passage of storms. The proportion of corals with the appearance of sediment accumulation can also be related to community composition as some organisms rapidly remove sediment and others can take longer. Although sediment accumulation may lead to impact, sediment accumulation is an indicator of sediment stress and not a permanent impact in of itself.

Partial burial of the base (PBB): Portion(s) of the base of the colony/organism buried by sediment.

> **Intended use:** To indicate if an organism is experience stress from settled sediment located at the base of the organism. Prolonged partial burial can lead to organism mortality.
> **Limitations:** Partial burial of the base of an organism can occur in natural reef ecosystems particularly if the organism is located in or near a depression in the reef substrate; partial burial of an organism can also be influenced by dredging. Partial burial of the base is an indicator of sediment stress but is not a permanent impact in and of itself. Mortality due to partial burial may be an impact but can also occur in unaffected reef ecosystems.

Burial of the base (BBA): Entire base of the colony/organism buried by sediment.

> **Intended use:** To indicate if an organism is experiencing stress from settled sediment located at the base of the organism. Prolonged burial can lead to organism mortality.

Limitations: Burial of the base of an organism can occur in natural reef ecosystems particularly if the organism is located in or near a depression in the reef substrate; burial of the base of an organism can also be influenced by dredging. Burial of the base is an indicator of sediment stress but is not a permanent impact in of itself. Mortality due to burial of the base would be considered an impact and can also occur in unaffected reef ecosystems.

Burial (BUR): Entire colony/organism buried by sediment.

Intended use: To indicate if an organism is experiencing stress from sediment that is covering the organism. Prolonged burial can lead to organism mortality.
Limitations: Burial an organism can occur in natural reef ecosystems particularly if the organism is located in or near a depression in the reef substrate; burial can also be caused by dredging. Burial is an indicator of sediment stress but is not a permanent impact in of itself. Mortality due to burial may be considered an impact and can also occur in unaffected reef ecosystems and have been observed at sites near PortMiami channel due to the passage of natural sand waves (DCA 2015a).

Organism mortality condition codes
An important question posed by looking at corals throughout the region is "what is the impact of partial mortality on these colonies?" Clearly, the ability of these benthic organisms to survive and recover from disturbances is vital to the long-term persistence and biodiversity in these ecosystems. Specifically, the ability of bottom-dwelling marine epifauna to regenerate injured or lost body parts is critical to the survival of individuals from disturbances that inflict wounds and therefore is essential for community recovery. Throughout the region there are a number of processes, both natural and anthropogenic, that can cause lesions, wounds, and areas of dead tissue on coral skeletons. These include, but are not limited to the following disturbances:

- Predation (snails, urchins, fish, etc.)
- Coral disease (white-plague, black-band, dark-spot, etc.)
- Excessive sedimentation (burial, partial burial)
- Algal contact and overgrowth (both turf and macroalgae)
- Receding Margin Syndrome (RMS – an unknown condition leading to the slow progressive death of the colony)
- Sponge contact and overgrowth
- Mechanical damage - abrasion and/or impact (storms, fishing lines, lobster traps, etc.)
- Inter- and intraspecific competition between corals
- Coral bleaching (warm water stress)
- Cold-water stress
- Cyanobacterial blooms (*Lyngbya* spp.)

At PortMiami, the most commonly identified wound (area of partial mortality) associated with the project was a “halo” or rim of mortality found at the base of massive corals. While not all partial mortality halos are caused by sediment (Figures 12 and 13), this condition was used as a proxy indicator for potential impacts related to excessive sedimentation (DCA 2015d). Sediment does cause halos in natural settings as well, as demonstrated by project control corals (Figure 14). It should also be noted that halos were common features found on corals throughout the region prior to project initiation in 2013 (Figure 15).

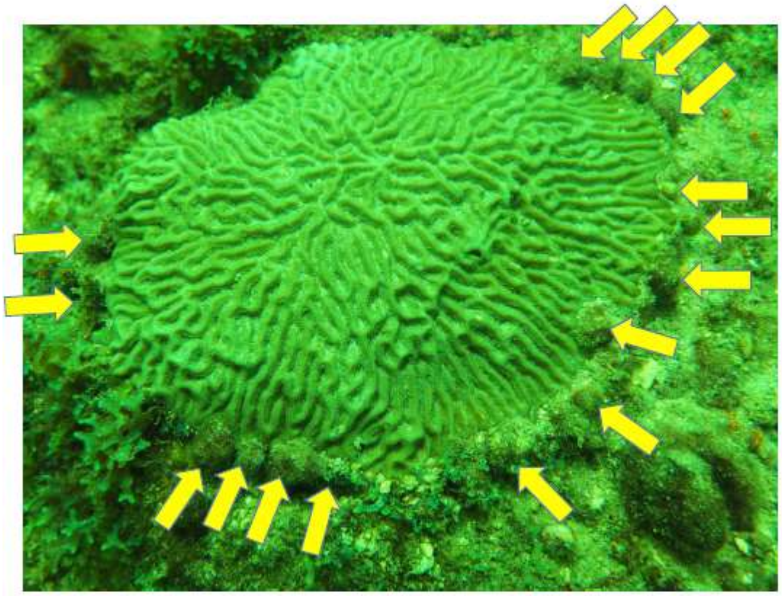


Figure 12. Rim of partial mortality (halo) caused by predation by the coralliferous gastropod, *Coralliophylla abbreviata*. Arrows point to well camouflaged snails along the interface of live coral tissue.

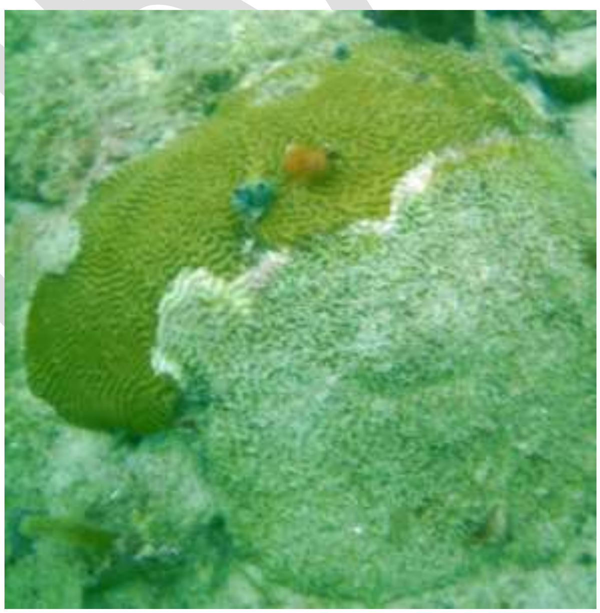


Figure 13. Large rim of partial mortality caused by active advance of white-plague disease from colony base.

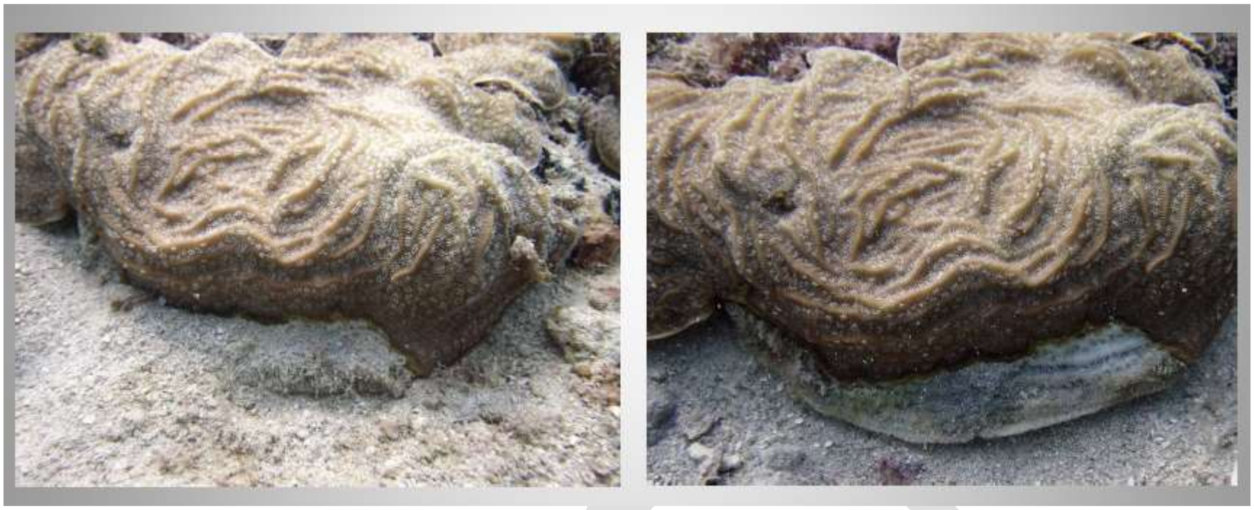


Figure 14. Colony of *Agaricia lamarcki* revealing partial mortality rim associated with accumulation of natural reef sediments around the base of the colony. Photo taken at R2 south control.

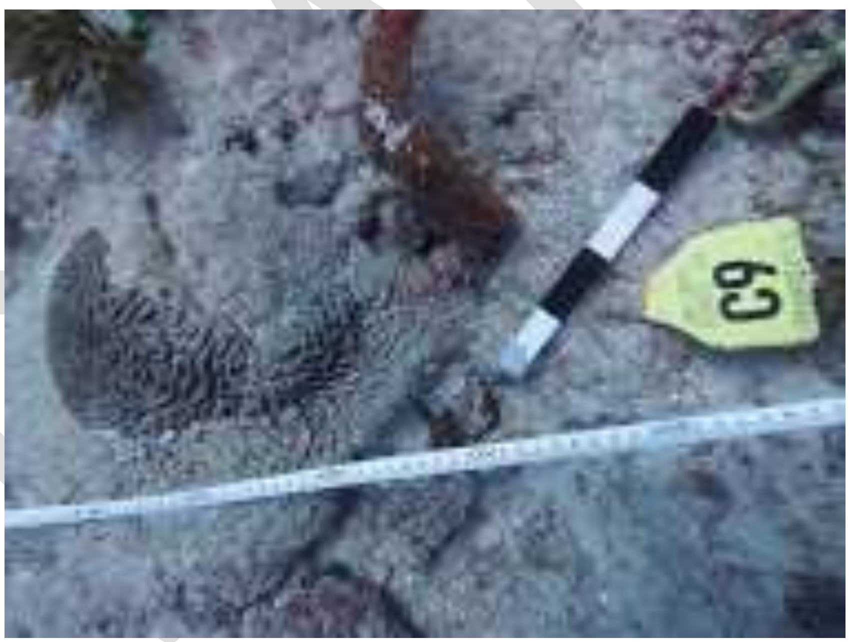


Figure 15. Partial mortality halo observed on tagged control coral R3SC3-T3-C9 during week 1 of pre-construction baseline surveys in 2013. The cause of this halo feature is unknown.

There are a number of factors that control the regenerative capacity of wounds, including the following intrinsic controls - coral size, age, shape (morphology), genotype, as well as the following extrinsic factors – type of wound, size of wound, perimeter (size and shape), depth of wound, and location (Henry and Hart 2005).

While no two coral colonies respond to wound healing in exactly the same fashion, Henry and Hart (2005) specifically noted that wounds near the colony base were sealed and calcified almost simultaneously. Tissue regeneration and calcification in these more proximal wounds were characterized by the random emergence of new polyps and calices with a slow-growing pigmented lip. This is typical of the wound regeneration observed in recovering corals throughout the region, including those area impacted by project-related sediments at PortMiami (Figure 16).

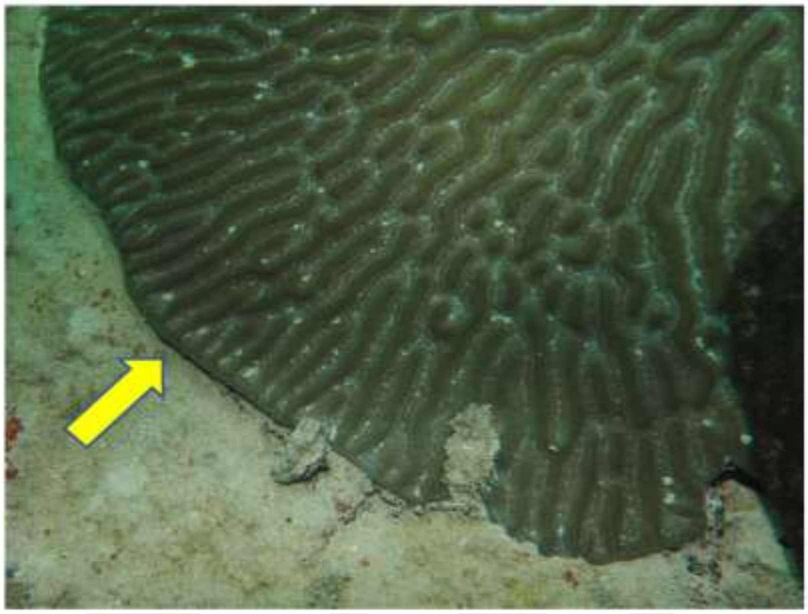


Figure 16. Regeneration and regrowth of coral margin on a colony of *Pseudodiplora clivosa* following sediment-related partial mortality around the base. Note the development of a lip or rim at base of colony typical of an advancing coral margin. Photo taken at R2N2-50m-EW on September 14, 2016.

In the case of partial mortality associated with excessive project sediments, the cessation of dredging caused an almost immediate amelioration of the sediment stress allowing the corals to continue to grow and regenerate. These observations, and those from fossil and sub-fossil examples, show that partial mortality caused by a number of disturbances are likely to heal once the cause if the disturbance is removed (Figure 17). Accordingly, most impacts that were recorded as partial mortality and attributed to project-related sediment burial should be classified as a temporary impact.

Figure 17. Photo of coral in the University of Miami Invertebrate Collection showing the regeneration and regrowth of coral margin on a colony of *Pseudodiplora clivosa* following sediment-related partial mortality around the base. Colony was collected in 1968. Note the development of a lip or rim at base of colony typical of an advancing coral margin. Photo taken by William Precht in April 2017.

The following mortality-associated condition codes were utilized to assess for all corals, octocorals and sponges that were within a surveyed transect.

Partial mortality (PM): Partial mortality of colony/organism appears white/denuded with no live tissue visible.

> **Intended use:** To indicate if an organism at a given site is experiencing mortality that does not include the base of the organism.
> **Limitations:** The partial mortality indicator can be affected by several causes including: old mortality that pre-dates construction activities, competition, disease, bleaching, predation, and potential dredge-related mortality. If organisms are not followed through time it is not possible to determine the cause of the organism mortality.

Partial mortality and base (PMB): Partial mortality of colony/organism that includes the base. Partial mortality of the base would include "halos".

> **Intended use:** To indicate if an organism at a given site is experiencing mortality that includes the base of the organism.
> **Limitations:** The partial mortality and base indicator can be affected by several causes including: old mortality that pre-dates construction activities, competition, disease, bleaching, predation, and potential dredge-related mortality. If organisms are not followed through time it is not possible to determine the cause of the organism partial

base mortality. Natural sediment can also cause partial mortality that includes the base of the colony, this was documented at many sites before the project began.

Complete mortality (DEAD): Death of the entire colony/organism; no live tissue remaining.

Intended use: To indicate of an organism is no longer living.
Limitations: Organism mortality can be caused by several causes including: natural mortality, old mortality that pre-dates construction activities, competition, disease, bleaching, predation, and potential dredge-related mortality. If organisms are not followed through time it is not possible to determine the cause of the organism mortality.

Basal attachment failure (BAF): Organism/colony completely detached from substrate (Octocorals/Sponges only).

Intended use: To indicate if an organism has become detached from the substrate.
Limitations: Organisms can become detached from the substrate for several reasons including: physical dislodgement from boat anchors, fishing activity, strong storms, or as a result of prolonged sediment exposure.

2.2.1.1 Quality Assurance and Control

Training on organism identification and code application were conducted prior to data collection to ensure all observers were collecting data using the same criteria. After *in situ* data collection was completed, scientific divers reviewed their results and discussed issues with the on-site scientific data manager and data were finalized. Underwater data sheets were washed, dried and quality controlled by trained staff, and then data were entered into a Microsoft Excel spreadsheet. QA/QC of data input was conducted by another scientist to ensure accurate data entry for analysis. Independent QA/QC of data input was also conducted by personnel from CSI and Esciences. Raw data, photos and video were provided to the FDEP in June 2017 for all cross sites.

2.2.1.2 Scleractinians

Per the revised-FDEP protocol, data were collected for scleractinian species occurring within specific sections of each 50 m x 1 m belt transects at all middle and outer reef sites. For the NS transect, coral data were collected for all corals between 0-10 and 40-50 meters. For the EW transect, coral data were collected for all corals between 0-10, 20-30, and 40-50 meters. Scleractinian NS data were only collected for middle reef north habitats. The 1 m belt was always on the left side of the transect tape. For each coral, divers recorded the species, size (max diameter), estimated percent mortality, and stress condition (if present). Stress conditions due to sediment were recorded separately from other stress conditions. A guide for estimating percent mortality can be found in Figure 18. In order to clearly see colony margins and estimate mortality, divers wafted away sediment from the base of each coral. Still photographs at multiple angles were taken for every colony with a ruler provided for scale both before and after wafting away sediment. This protocol was subsequently revised following the completion of all sites for Reef 2 North at which point data collection for corals on the NS transect was eliminated. Scleractinian corals are sensitive to environmental changes and therefore coral condition is commonly used as an indicator of reef “health” (Vargas-Angel et al. 2007). Coral condition is one of the metrics required by the FDEP permit, and coral health assessment parameters include any condition that may be expected to adversely affect coral “health”. Coral conditions are shown in Figure 19-23.

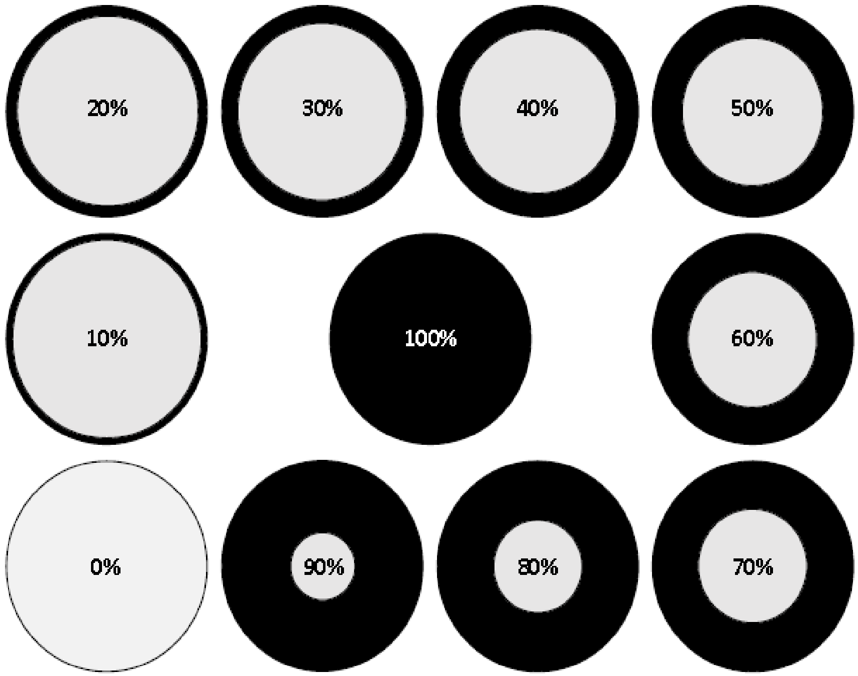


Figure 18. Guide for estimating percent mortality for scleractinians during impact assessment.

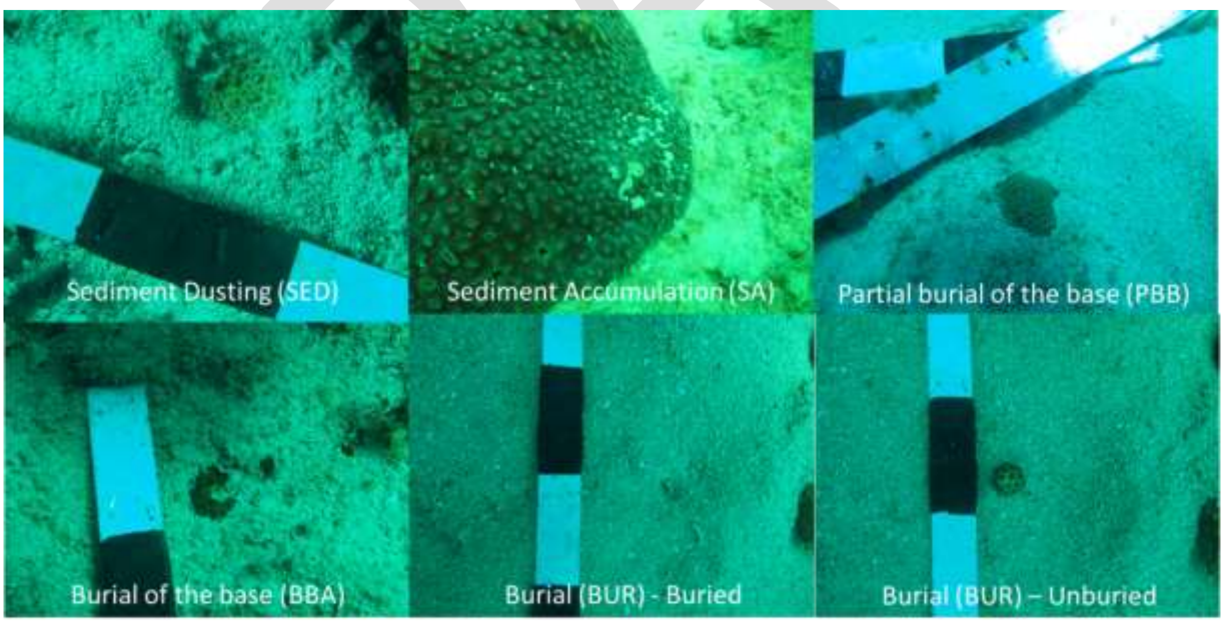


Figure 19. Photographs of sedimentation indicators documented during the one-year post-construction impact assessment surveys. Sediment dusting, burial of the base, and burial examples are from HBNC1-CP. The sediment accumulation example is from site R2N-450-LR and the partial burial of the base example was taken at R2SC2-LR.

Figure 20. Photographs of bleaching conditions documented during compliance and post-construction surveys.

Figure 21. Photographs of disease conditions documented during baseline through post-construction surveys.

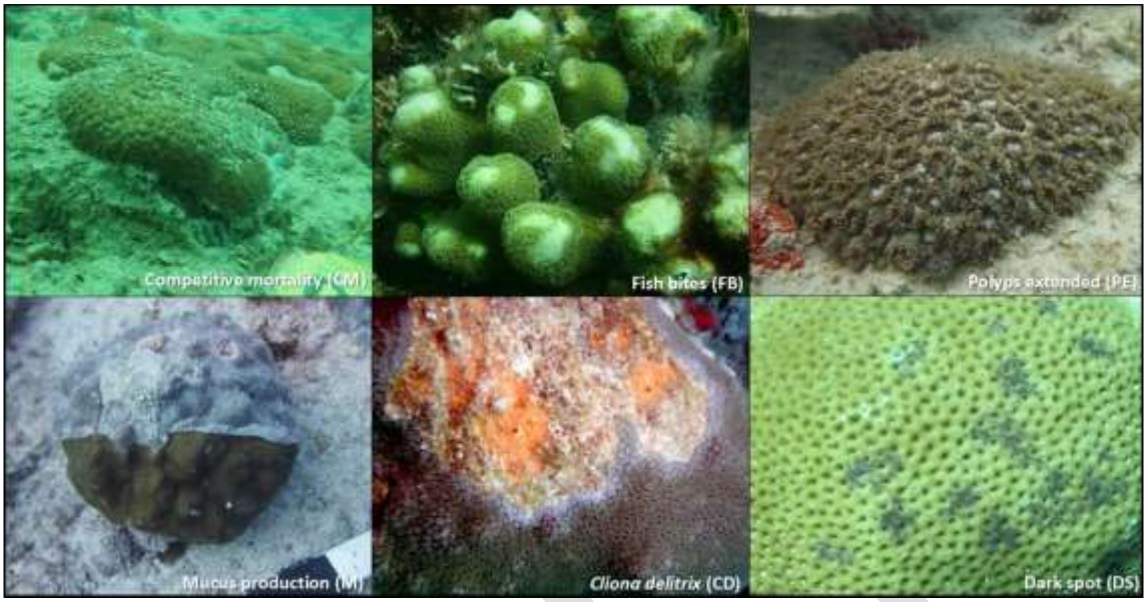


Figure 22. Photographs of stress indicators documented during compliance and post-construction surveys.

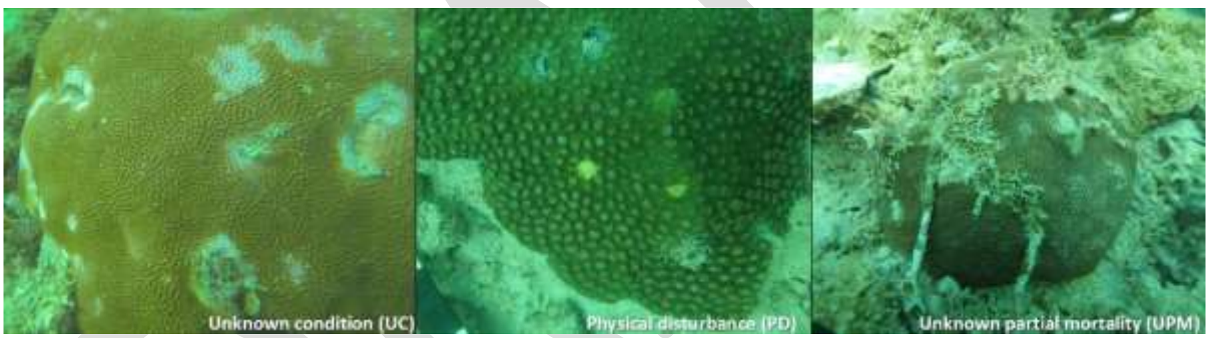


Figure 23. Photographs of stress indicators collected during compliance and post-construction surveys.

2.2.1.3 Octocorals and Sponges

In situ data were also collected on the abundance, condition, and maximum size (height or diameter as applicable) for all octocorals and sponges within specific sections of each 50 m x 1m belt transect. For the NS transect, octocoral and sponge data were collected for all individuals between 0-10 and 40-50 meters. For the EW transect, octocoral and sponge data were collected for each individual between 0-10, 20-30, and 40-50 meters. The 1 m belt was always on the left side of the transect tape. Octocorals were recorded by genera while sponges were recorded by morphotype. All sizes were recorded during impact assessment survey. Conditions for octocorals and sponges consisted of similar indicators used for scleractinian corals relating to sedimentation, mortality, stress, and disease (Table 3). Per the revised-FDEP protocol, photographs of octocorals and sponges were only required on the EW transect between 0-5, 20-30, and 45-50 meters. This protocol was subsequently revised again following the completion of all sites for Reef 2 North at which point data collection for octocorals and sponges on the NS transect was eliminated. Example of octocorals and sponges with conditions captured during impact assessment surveys are provided in Figures 24-27.

Table 3. Coral stress indicator categories for *in situ* data collection. Condition codes were revised by FDEP and NMFS to consolidate and include new condition codes to emphasize sediment impacts.

Condition	Cause	Appearance	Field Code	Applicable Organism(s)
Unaffected	N/A	Normal	UN	Coral, Octocoral, Sponge
Sediment	Sedimentation	Low amount, a "dusting" of sediment on top of the colony/organism.	SED	Coral, Octocoral, Sponge
Sediment Accumulation	Sedimentation	Moderate sediment accumulation on top of colony/organism (more than dusting).	SA	Coral, Octocoral, Sponge
Partial Burial of the Base	Sedimentation	Portion(s) of the base of the colony/organism buried by sediment.	PBB	Coral, Octocoral, Sponge
Burial of the Base	Sedimentation	Entire base of the colony/organism buried by sediment.	BBA	Coral, Octocoral, Sponge
Burial	Sedimentation	Entire colony/organism buried by sediment.	BUR	Coral, Octocoral, Sponge
Partial Mortality	Any	Partial mortality of colony/organism appears white/denuded with no live tissue visible.	PM	Coral, Octocoral, Sponge
Partial Mortality and Base	Any	Partial mortality of colony/organism that includes the base.	PMB	Coral, Octocoral, Sponge
Complete Mortality	Any	Death of the entire colony; no live tissue remaining.	DEAD	Coral, Octocoral, Sponge
Basal Attachment Failure	Any	Organism/colony completely detached from substrate.	BAF	Octocoral and Sponge
Additional condition codes				
Paling	Stressed/Elevated Irradiance/Temperature	Live tissue with some loss of color.	PA	Coral
Partial Bleaching	Stressed/Elevated Irradiance/Temperature	Patches of fully bleached or white tissue.	PB	Coral
Bleaching	Stressed/Elevated Irradiance/Temperature	Live tissue with complete loss of color across the entire colony.	BL	Coral
Black Band	Stress	Black band surrounds dead patch.	BBD	Coral
Yellow Band	Stress	Yellow band surrounds dead patch.	YB	Coral
White-Band (*Acropora* only)	Stress	White lines or bands of recently dead coral tissue found in species of the genus *Acropora.*	WB	Coral
White-Plague	Stress	White lines or bands of recently dead coral tissue affecting non-acroporid corals.	WP	Coral

Condition	Cause	Appearance	Field Code	Applicable Organism(s)
Unknown Band	Stress	Unknown band-like mortality around the base of the colony, later presumed to be white-plague on *Dichocoenia stokesii*	UB	Coral
Unknown *Solenastrea* Disease	Stress	Patchy discoloration of living tissue resulting in a mottled bleached appearance. Only noted for *Solenastrea* spp.	UD	Coral
Disease	Stress	Any indicator of disease.	DIS	Coral, Octocoral, Sponge
Polyp Extension	Stress and feeding	Tentacles are extended on 100% of polyps on the colony.	PE	Coral
Fish/Turtle Bite(s)	Grazing	Bites of live tissue removed.	FB	Coral, Octocoral, Sponge
Mucus Production	Sediment stress/Lunar cycle	Excessive mucus production results in a mucus film and/or sediment balled up in mucus.	MU	Coral, Sponge
Cliona spp.	Competition	Red boring sponge present on colony. Typically accompanied by tissue mortality radiating outward from the point of sponge emergence.	CD	Coral
Unknown Partial Mortality	Stress	Tissue mortality from an unknown cause.	UM	Coral, Octocoral, Sponge
Physical Disturbance	Abrasion	Abrasion or physical disturbance such as a gouge or a nick, not in a discernable pattern like fish bites.	PD	Coral, Octocoral, Sponge
Competitive Mortality	Competition	Recent partial mortality from a competition event. Typically the result of sponge or zoanthid overgrowth.	CM	Coral, Octocoral, Sponge
Dark Spot	Stress	Dark spots on otherwise normal *Siderastrea* spp.	DS	Coral
Unknown Condition	Stress	Discoloration of living tissue from an unknown cause. Not related to known bleaching or disease indicators.	UC	Coral, Octocoral, Sponge
Cyano	Natural	Cyano present on organism	CY	Coral, Octocoral, Sponge
Algae	Natural	Algae present on organism	AL	Coral, Octocoral, Sponge
Toppled Over	Physical Disturbance	Broken at base but still attached	TO	Octocoral and Sponge
Broken	Physical Disturbance	Portion(s) of organism/colony broken but still attached.	BR	Coral, Octocoral, Sponge

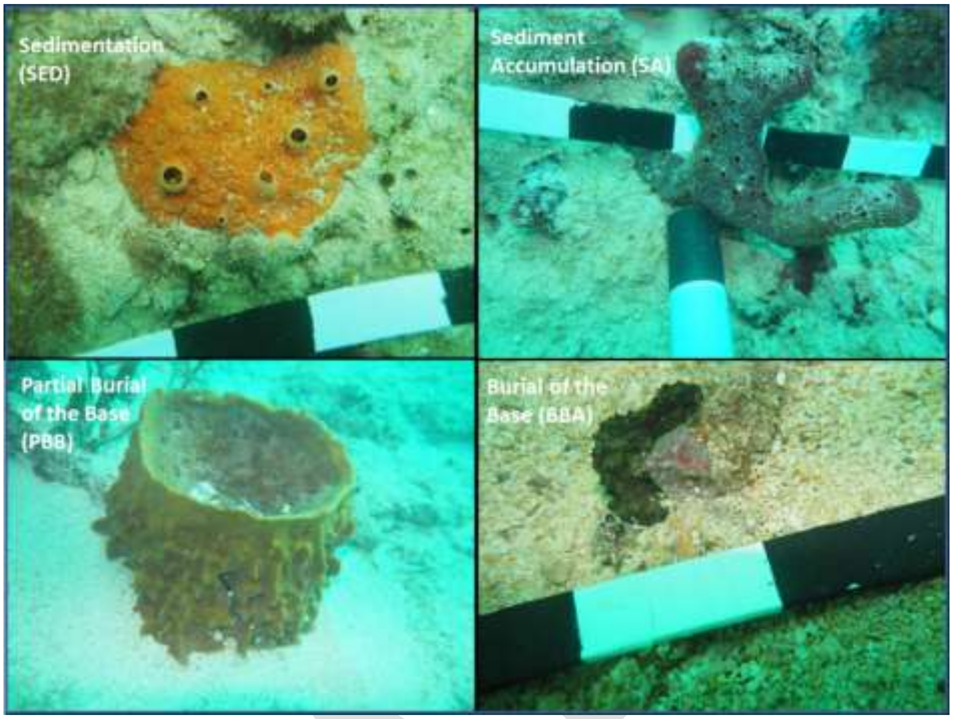


Figure 24. Photographs of sedimentation indicators on sponges documented during impact assessment surveys.

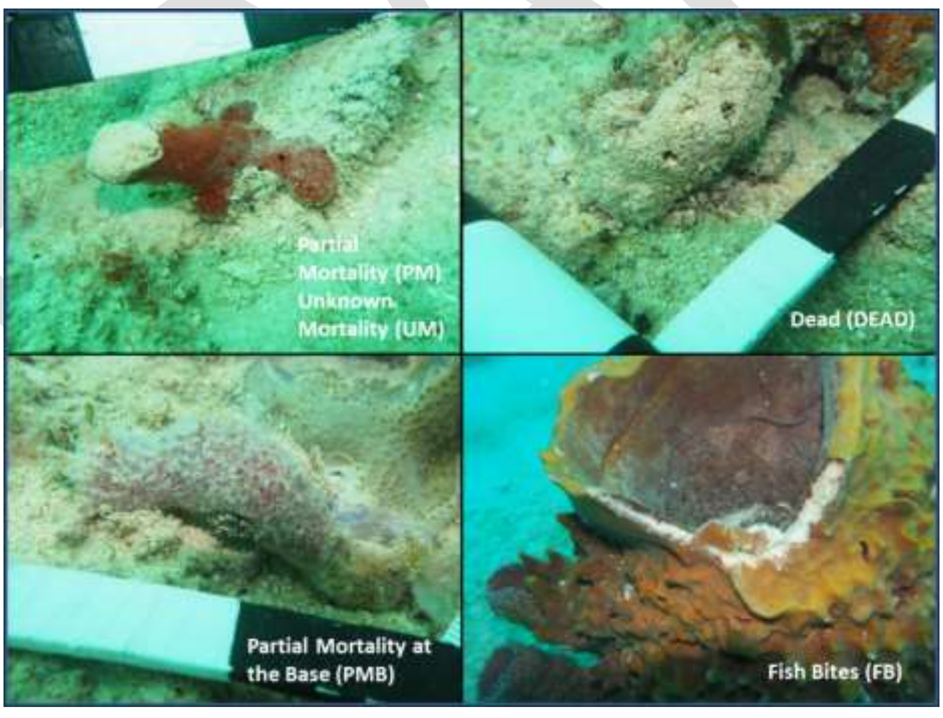


Figure 25. Photographs of partial or complete mortality on sponges documented during impact assessment surveys.

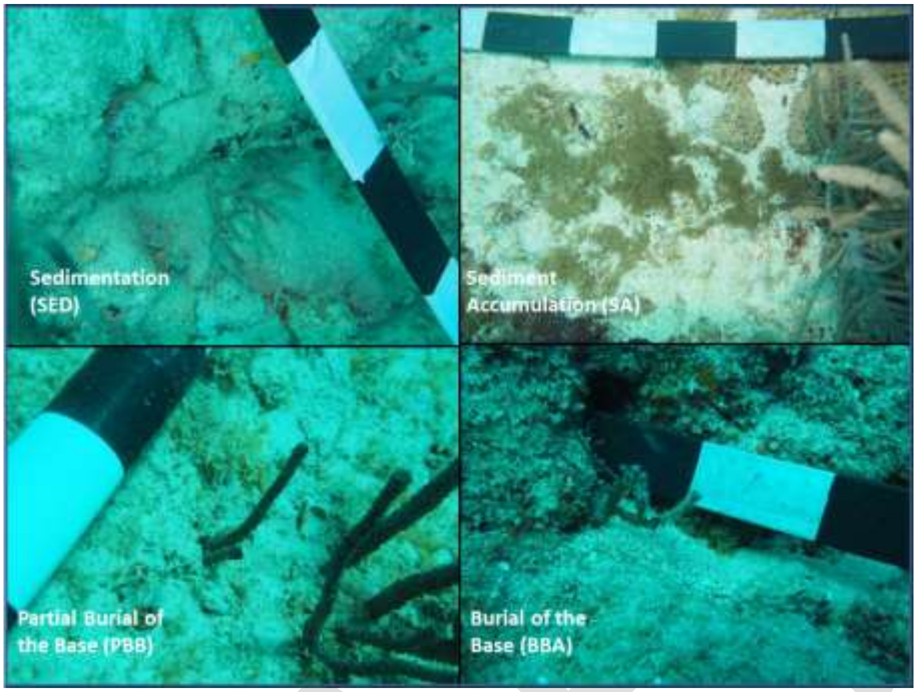


Figure 26. Photographs of sedimentation indicators on octocorals observed during impact assessment surveys.

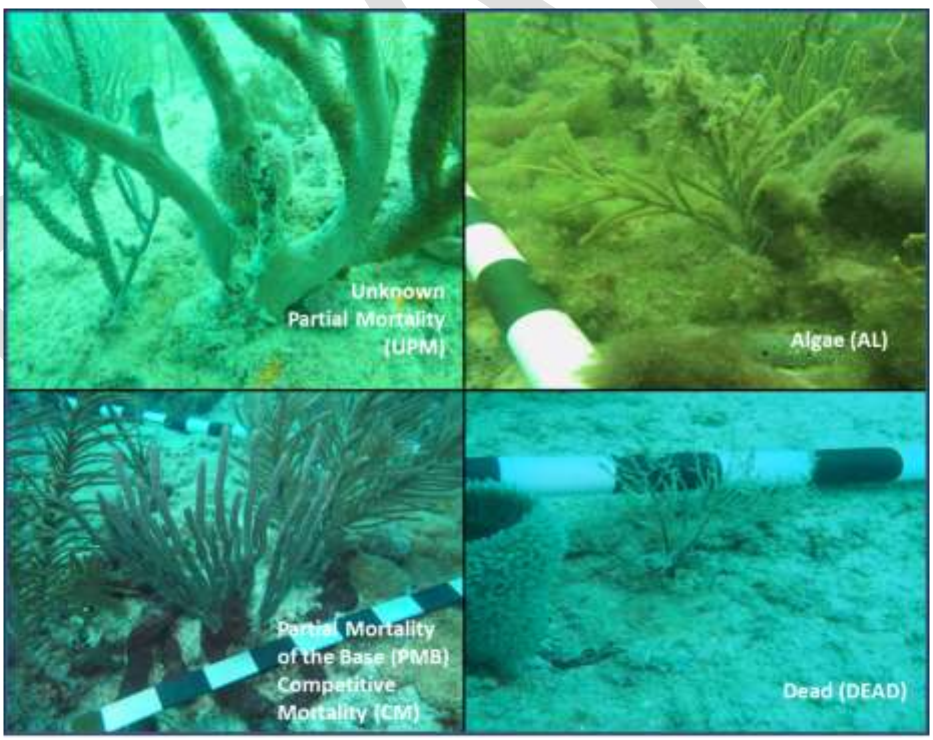


Figure 27. Photographs of various conditions affecting octocorals during impact assessment surveys.

2.2.1.4 Sediment Depth Measurement and Substratum Characterization

Per the FDEP/NMFS protocol sediment depth data were collected at 1 meter intervals along the entire length of both 50 m transects (102 total measurements, from 0 to 50 meters per transects. Sediment depth was collected on the right side of each transect immediately adjacent to the tape. Sampling excluded organisms blocking the sediment; a sediment measurement was taken at the nearest point past the organism when this occurred and a note was made on the datasheet for the actual location where the measurement was taken. Sediment depth was measure to the nearest millimeter (single decimal place).

Per the FDEP/NMFS protocol at every 5 meter interval, starting at 0, the substratum was qualitatively characterized. Substrate types included: hardbottom (no sediment present), sediment over hardbottom (< 30 cm of sediment), sediment (> 30 cm of sediment), and rubble. A point is considered deep sediment over hardbottom if the depth of sediment >4 cm. In order to determine whether sediment was covering hardbottom, the diver would perform an excavation (to at least 30 cm or until substrate was located). In the event of an excavation, characteristics of the sediment and documentation of any layers of different types of sediment were recorded. FDEP-approved sediment types included: fine, mixed, and coarse, which were determined using sediment comparator cards (Figure 28). Fine sediments are naturally occurring in the hardbottom, middle and outer reef habitats, and were present before the Project. The fine sediment category here is likely a mix of pre- and post-Project fine sediment. In the case of mixed sediments, if any portion of the sediment at a given meter was not homogenous, it was characterized as mixed (*e.g.* 95% coarse with 5% fine sediment would be classified as mixed). In addition, a photograph of the substratum and/or sediment at each 5 m interval was collected. Sediment characterizations were intended to delineate areas of potential dredge-sediment in the hardbottom, middle, and outer reef habitat. An example of the fine clay-like sediment that was characteristic of construction period dredge-sediment is shown in Figure 29. Voucher samples were collected at each site for all of the sediment types collected at a site. For example, if mixed sediment and fine sediment were encountered at a site, a sample of mixed sediment was collected in an empty water bottle and a separate sample of fine sediment was also collected in an empty bottle. All sediment voucher samples were collected by the person collecting sediment data.

Figure 28. Sediment comparator card used to determine sediment characterization.

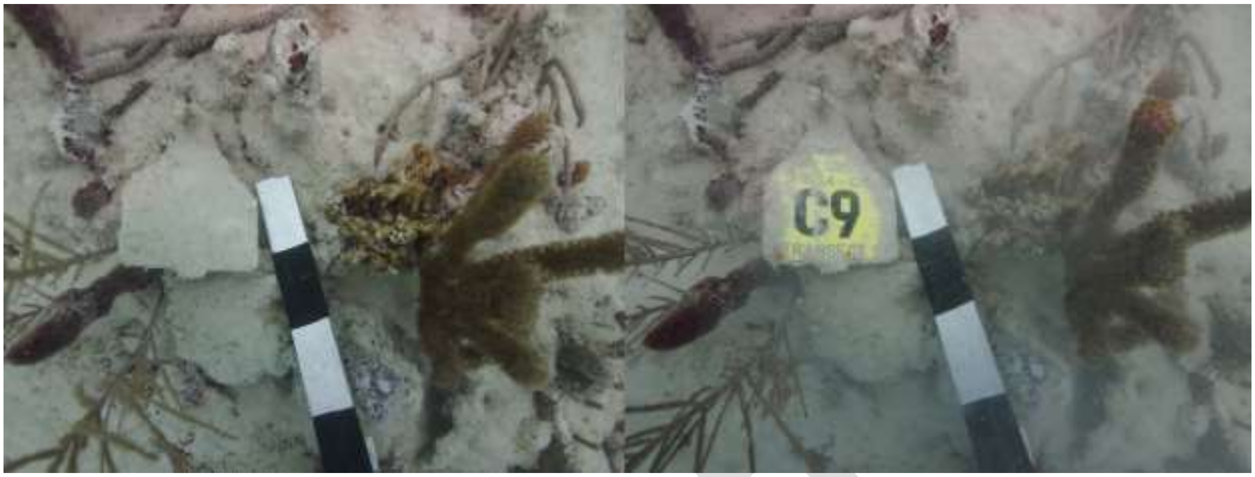


Figure 29. Example of fine "clay-like" sediment on hardbottom substrate that was observed during construction monitoring. Both photographs were taken in Compliance Week 16 visit 2 at permanent monitoring site HBS4-CR.

The purpose of collecting sediment depth and substratum characterization information was to document the extent and depth of potential dredge sediment throughout the hardbottom, middle and outer reef habitats near the PortMiami outer entrance channel. However, for this impact assessment there are several limitations of using sediment depth and type information as an indicator of dredging impact. The first limitation is that sedimentation metrics were not collected prior to dredge activity and it is therefore unknown if sediment depth and type found at control site locations is representative of the un-affected near-channel habitat. Rates of sedimentation were higher at near-channel sites when compared to habitat controls during the 2013 baseline survey (DCA 2015a, b) but sediment depth was not included in the baseline permitted monitoring protocols. A study by the USACE (Figure 30) documented current velocities and direction, demonstrating that eddies may concentrate material on the north side of the middle reef and hardbottom habitat, however no sediment depth measurements were collected in this study (USACE 2006). Greater deposition on the north side of the middle reef is also consistent with baseline sedimentation study results (DCA 2014c).

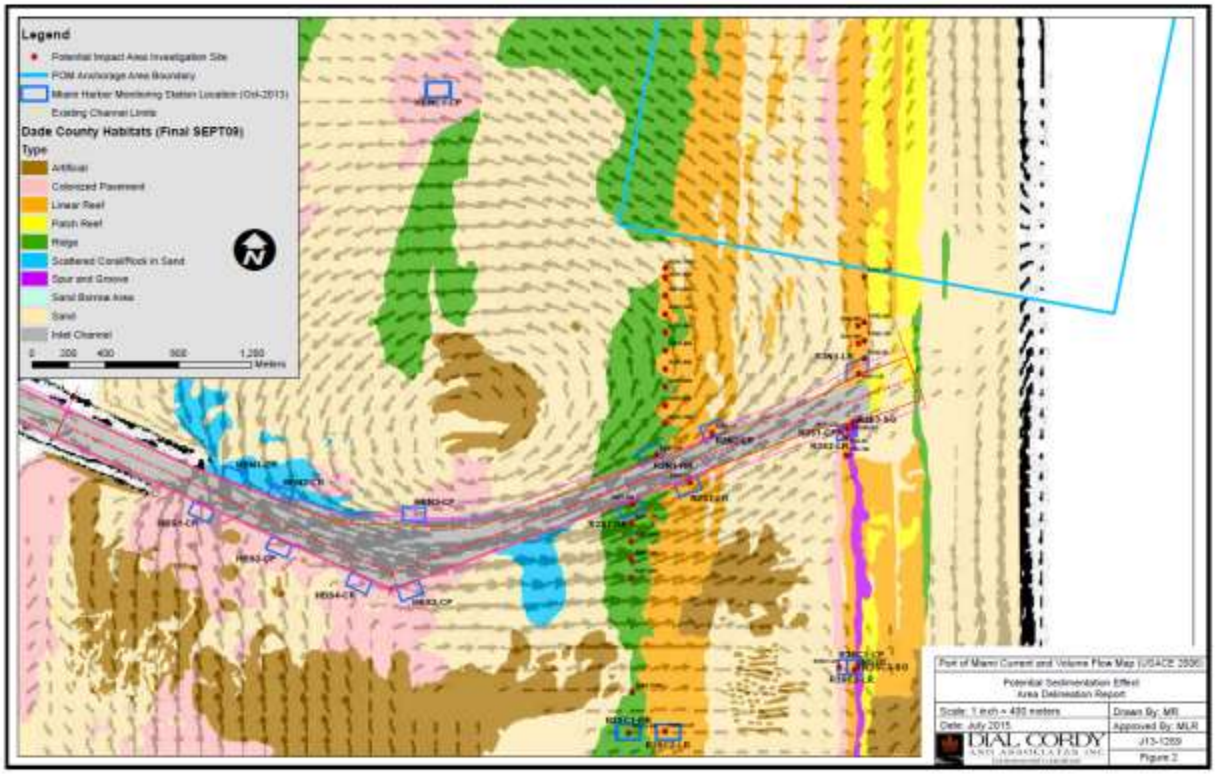


Figure 30. Hydrologic system in relation to monitoring sites within habitat types (Walker et al. 2008). Hydrologic flow modeling data provided by USACE (USACE 2006).

A second, documented limitation of the use of sediment depth as an indicator of dredge impact is the natural existence of migrating sands that have been encountered numerous times throughout the project corridor, between pre-project surveys in 2010 through collection of the one-year post-construction impact assessment data in 2016-2017. At times these sands were confined to depressions, grooves and gullies in the reef framework while at others, large areas of hardbottom were periodically covered by expansive, migrating sand waves. The first major encounter of a migrating sand wave by DCA divers was during the selection of compliance monitoring stations in 2013, when large areas mapped as scattered coral/rock in sand south of Government Cut by Walker (2009), an area proposed for permanent site HBS4-CR installation, were completely covered by acres of rippled sand (Figure 31 and 32). It was clear that these areas had once been hardbottoms as octocorals were found sticking out of the sand (Figure 32). The docmentation of these large expanses of natural reef sand habitat in areas delineated as scattered corals/rocks in sand, indicates that the available near-channel habitat maps did not reflect the state of the habitat in 2013. As a result sand coverage was underestimated prior to dredge-activities. This makes a control-impact design in which sites have not been previously verified as reef habitat unreliable.

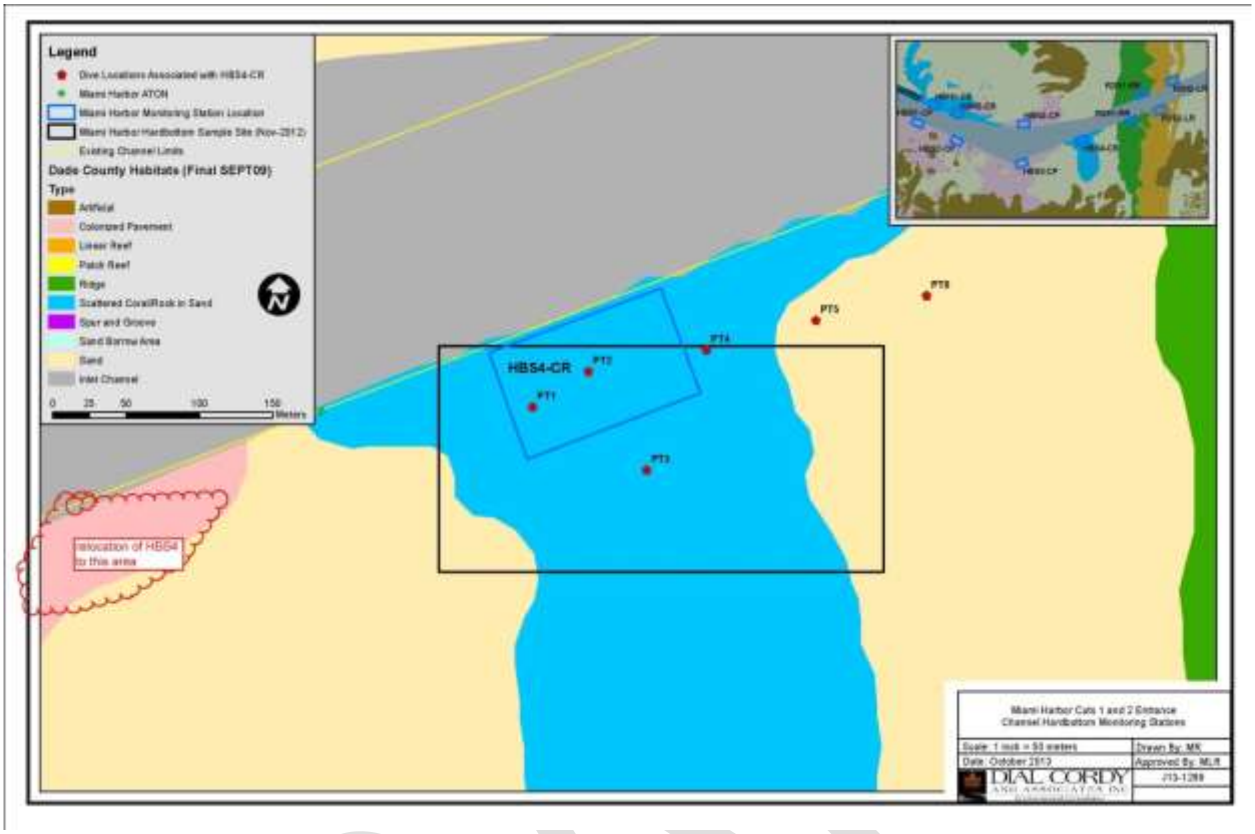


Figure 31. HBS4-CR point locations overlaid on the near-shore habitat map (Walker, 2009) where divers searched for hardbottom habitat. The proposed HBS4-CR relocation is also shown.

Figure 32. Images taken from the proposed HBS4-CR site locations prior to construction activities. Extensive sand habitat (left) dominated the proposed HBS4 site locations (left). Buried octocorals (right) indicate the dynamic nature of the area, which was hardbottom (scattered rock in sand) at one time in the not too distant past.

Migrating sand waves were also found to be highly dynamic, both temporally and spatially, as areas established as permanent monitoring sites in the summer of 2013 became buried by natural sand during the four week baseline survey period on the North side of the hardbottom habitat. All tagged corals at HBN1-CR that were surveyed and unburied in weeks 1 and 2 of baseline surveys were completely buried by the 4th week of baseline, prior to the start of construction activities (DCA 2015a) (Figure 33). In Figure 33 only the tops of the hardbottom habitat remain visible above the natural sand wave in week 4 of the baseline survey. Increased sediment was also noted at HBN2-CR and HBN3-CP as a result of the sand wave during the baseline period (DCA 2015a). The increased sand found in the northern hardbottom habitat is known to be ephemeral as tagged corals at HBN1-CR were unburied when surveyed on 9/5/2014 (DCA Compliance Report). Interestingly, despite months of sediment burial caused by the natural migrating sand, HBN1-CR had no total coral mortality between baseline and impact assessment surveys, making it the site with the lowest coral mortality of any permanent monitoring site (control or channel-side) (DCA 2017).

Hurricane Matthew passed through the project area on October 8, 2016. When the scientific divers returned to site R2N-75-RR on November 14, 2016, the bottom was covered in fine white fine sediment, and the previously abundant macroalgae was no longer present (Figure 33).

The documentation of significant influences of natural sand at all northern hardbottom sites, the influence of large storms on sediment distribution, and during the establishment of permanent site HBS4-CR (this accounts for 4 out of 15 permanent channel-side sites (26.7%)) suggests that natural sand and natural sand waves are a significant influence at near-channel sites.

The documentation of large (spanning several permanent monitoring sites), dynamic areas of natural sand at near-channel sites that were not documented at habitat controls prior to dredging suggests that a reliance on a control-impact design with regards to sediment depth information is in violation of the critical assumption that control and near-channel sediment environment are representative of one another in an un-impacted state. Analyses that fail to account for the increased influence of natural sediment at sites close to the PortMiami channel (NOAA-NMFS 2016a, 2016b; Karazsia 2016) are an over-estimation of potential impact of dredge-related sediment and are not consistent with the condition of the habitat prior to construction. In addition, migrating sand areas can bury benthic resources that would be described using the same sediment stress indicators of partial and total burial, and partial mortality of the base that would be used to describe sediment stress due to dredge activity (Figure 34 and 35).

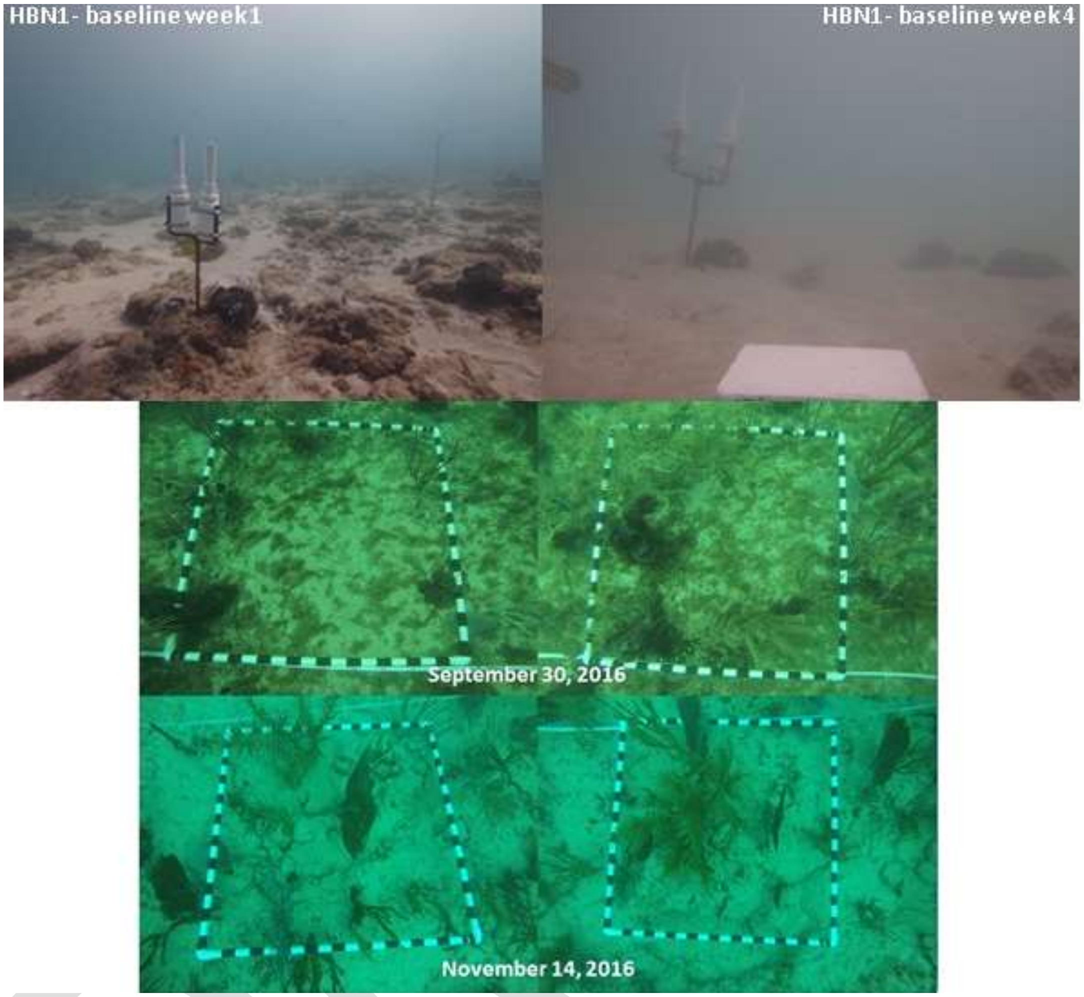


Figure 33. HBN1-CR in Week 1 of baseline and in Week 4 of baseline after burial event, documenting natural movement of sands in the hardbottom environment. Before and after Hurricane Matthew quadrat photos collected at R2N-75-RR on September 30, 2016 (before) and November 14, 2016 (after), notice macroalgae cover in before photo and lack of macroalgae in after photos as well as presence of fine white sediment over the bottom..

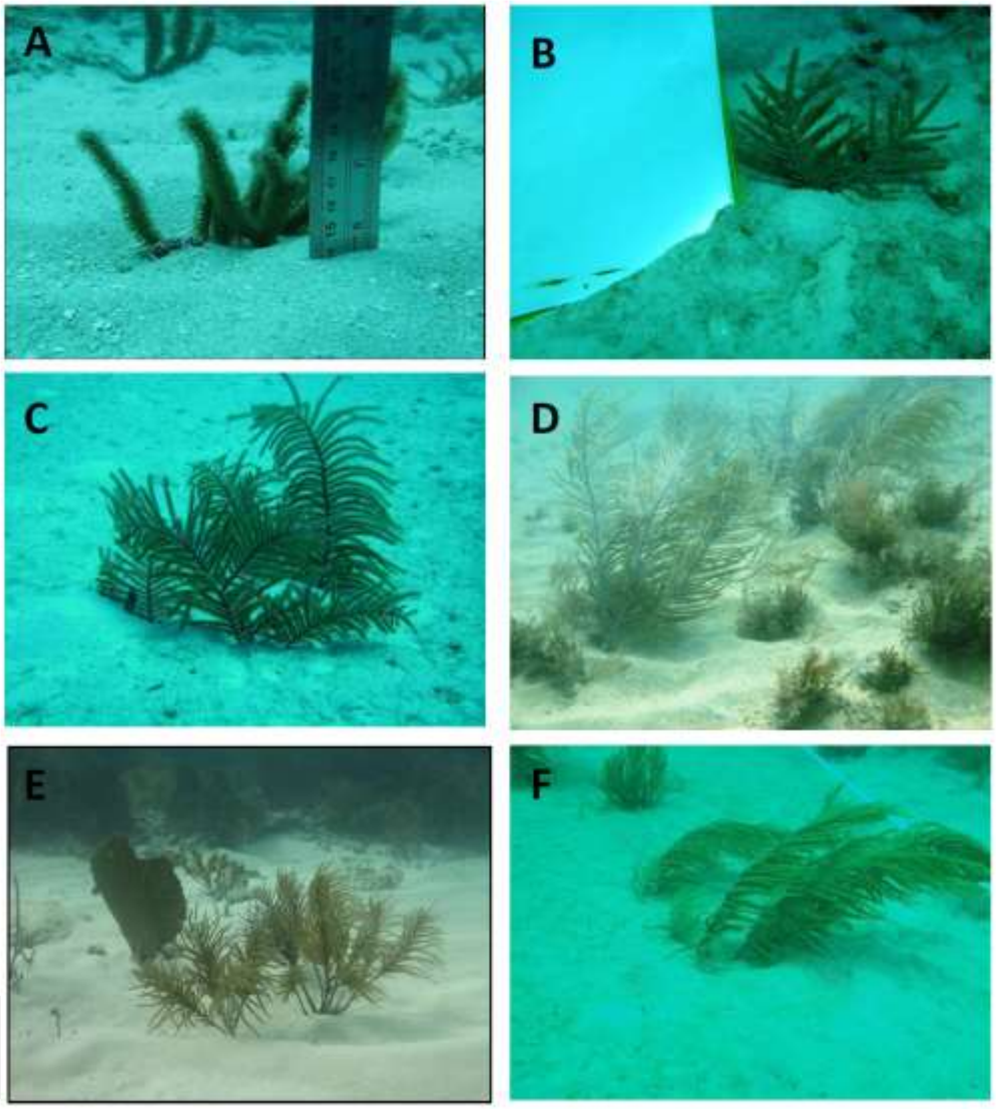


Figure 34. Underwater photographs of buried octocoral resources. (A) Photo of octocoral buried by migrating sand wave at R2-200m north. Depth of sediment is approximately 14 cm deep. Photo taken by NMFS in December 2015. Note poorly sorted carbonate sediments with abundant large, unbroken flakes of *Halimeda* typical of natural, moderate energy reef sedimentary deposits. (B) Partial burial of octocoral in low energy patch reef setting in Biscayne National Park. Photo taken in August 2014 by William Precht of DCA. (C) Partial burial of an octocoral by fine-grained sediments in groove between two reef-spurs. Photo taken in Grand Cayman, B.W.I. by William Precht in February 2016. (D) Hardbottom in the process of being engulfed by migrating sands. Note migrating sand waves burying both octocoral and algal resources. Photo taken on Second Reef adjacent to and just south of the active shipping channel at PortMiami in May 2011 by Dr. Phil Frank of Terramar Environmental Services, Inc. (E) Photo of migrating sands in the process of burying live octocorals at Crocker Reef in the Florida Keys National Marine Sanctuary. Photo taken by Dr. Ilsa Kuffner of the USGS in 2013. (F) Photo of octocoral buried by migrating sediment in an area on the Second Reef north of Port Everglades in Broward County, FL. Photo taken by William Precht in July 2017.

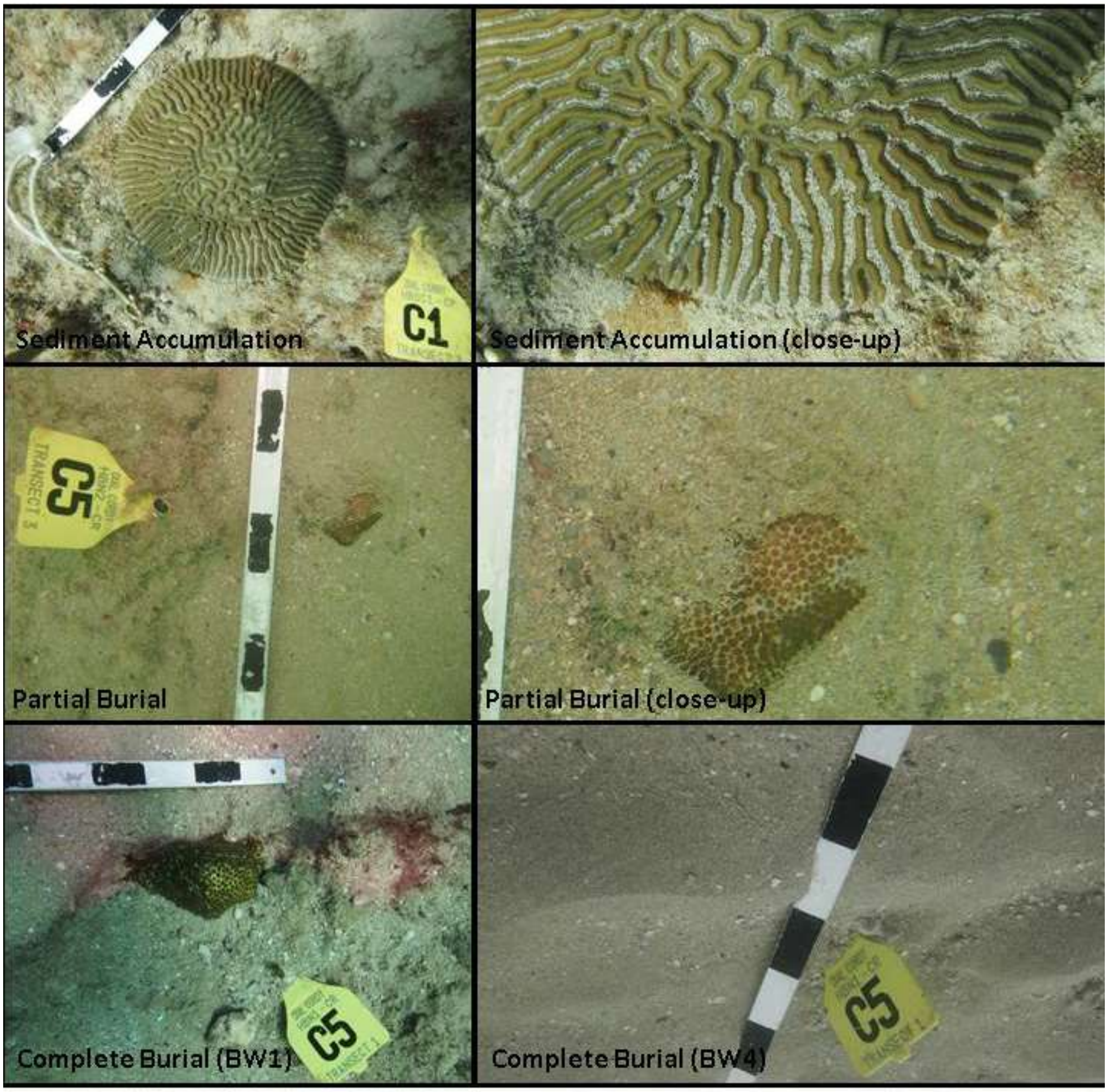


Figure 35. Photographs of coral conditions collected during baseline surveys. BW1 = baseline week 1; BW4 = baseline week 4. All examples of sediment conditions occurred prior to dredging in PortMiami near-channel sites.

Documentation of dynamic near-channel sedimentation environment that includes the burial of reef resources as part of the un-impacted state of the benthic habitat suggests that sediment depth-alone is an unreliable indicator of dredge-impact and should be considered along with sediment type to determine if the sand at a given location is typical of reef sediment or is more characteristic of the predominantly fine-grained dredge-related sediment. The fact that sediment indicators such as partial burial of the base, burial of the base, and burial as well as mortality indicators such as partial mortality and base and complete mortality do not distinguish between natural and dredge-related sediment is a limitation of these indicators.

For the purpose of this report we will report areas of fine sediment where the depth of sediment is >3 cm (a guideline established by NMFS for choosing *Acropora* restoration sites, T. Moore, personal communication, October 3, 2016), as likely areas of continued dredge impact. Areas of deep sediment that are characterized as "mixed" are assumed to be predominantly made of traditional reef sediment that may have been present prior to construction or are the result of dynamic reef sand movement and will not be considered areas of dredge-related impact.

2.2.2 Photo and Video

Scientific divers collected still photographs of corals, octocorals, and sponges from the best possible angle in order to capture the maximum size or diameter of each individual within a single photo frame along with a scale bar. Additional close-up oblique-angle photos were also collected to document stress conditions, when necessary. For review and QA/QC purposes, each diver took a photo of their datasheet once the relevant information for a given organism was filled out prior to photographing the organism. In some cases where octocorals and sponges were in close proximity to one another, a single photo would be taken with multiple individual organisms. When this occurred, the datasheet was marked in some form to convey which organisms were included in the photo. Additional photos were taken using a 1 m^2 quadrat which was placed at each individual meter along each transect. A downward-facing photo was taken from directly above each quadrat taking care to include the entire quadrat in the frame so that the entire surveyed area was photographed.

Quantitative digital video data were collected along each transect with the camera positioned approximately 40 cm above the substrate in a vertical orientation to produce birds-eye view digital video of each transect (50 m x 0.4 m). The video camera was equipped with a convergent laser guidance system to ensure that the camera remained at 40 cm above the bottom. At the beginning of each transect video, a dive slate was filled out with information regarding the site name, transect, date, and any relevant environmental conditions. The diver swam the camera along each transect at a speed of approximately 5 m per minute (approximately 10 minutes per transect) to ensure quality still images could be extracted for point count analysis using Coral Point Count with extensions (CPCe®) (Kohler and Gill 2006). However, quantitative analysis of digital video was not required for transect cross monitoring stations under this contract. In addition, 360^0 panoramic videos were collected at the start, middle, and end of each transect roughly 1 m above the seafloor and at an angle of roughly 30^0 to the horizon.

2.3 Data Analysis

2.3.1 In Situ Data

In the recommendations provided by DEP and NMFS for monitoring impacts of the Miami Harbor Phase III Federal Channel Expansion, using the described cross-site survey methods, near-channel data are to be compared to control sites to characterize the data by the degree to which the site characteristic differs from the control from each metric (FDEP 2016). The validity of this analysis depends on several assumptions inherent to the data. The various threats to the validity of using a control-impact analysis on the impact assessment data is found in Table 4.

Table 4. Threats to the validity of using a control-impact analysis of impact assessment metrics in this impact assessment.

Validity threat	Confounding influence in delineating impact of dredging?	Potential threat to validity	Specific threat to validity	Lessons learned
Channel-effect	YES	Documentation of a channel-effect prior to dredging suggests that a control-impact analysis is not suitable to delineate an impact since there are natural differences between near-channel and control resources that have not been taken into account.	In many cases benthic indicators such as organism density, partial mortality, and sediment abundance, have been documented as being different at near-channel locations than at controls prior to dredging. Since no baseline data has been collected at cross site locations natural differences between near-channel and control sites cannot be taken into account.	Repeated-measures or BACI design would allow for control of initial conditions at near-channel and control sites
Lack of baseline data	YES	Without baseline data the only way to evaluate impacts in the current survey is with a control-impact design. However, if information is present that indicates that there is a pre-existing channel effect with respect to resource availability, this design is invalid. If a control-impact design is used when there is a naturally occurring channel-effect, the impact of dredging on resources maybe overestimated.	Differences between near-channel and control sites were documented in hardbottom habitat prior to construction and several factors were found to have significant relationships with distance from the channel in the middle and outer reef.	Repeated-measures or BACI design would allow for control of initial conditions

Validity threat	Confounding influence in delineating impact of dredging?	Potential threat to validity	Specific threat to validity	Lessons learned
Pseudo-replication	YES	Data was collected in 10m sections of 50x50m cross design but no independent samples were collected. As a result, statistical analysis such as ANOVA are not possible using independent samples.	Data was collected along 10m sections of a 50x50m cross sampling design. None of the samples were independent within a survey site and therefore no statistical tests were performed.	Replicated transects of smaller length would allow for a mean and variance to be calculated which would provide more robust data for statistical comparisons.
Physical Disturbances	YES	1.5 years have passed since construction and in that time the resources have experienced 1.5 bleaching seasons and the passage of a hurricane (Matthew in 2016)	Benthic resources were naturally stressed due to temperature in the summers of 2014, 2015, and 2016. Hurricane Matthew passed over sampling area in October, 2016.	Repeated-measures with a smaller interval would help to partition sources of mortality outside of construction impacts.
Multiple disturbances	YES	Regional species-specific coral disease that devastated coral populations occurred at the same time as construction monitoring. It is impossible to partition disease mortality from construction influences when no baseline data are available and resources are not followed through time.	Regional species-specific disease was devastating to coral populations in South Florida since 2014. All resources were not affected equally. If a site contained highly susceptible species mortality was much higher than if the site was predominantly unaffected species.	Repeated-measures with a smaller interval would help to partition sources of mortality outside of construction impacts. Baseline data is essential.

Validity threat	Confounding influence in delineating impact of dredging?	Potential threat to validity	Specific threat to validity	Lessons learned
Environmental changes	YES	Natural changes in sediment have been documented that are capable of resource burial.	Large rippled sand waves have been found to influence near-channel sites in seasonal cycles. The inundation of large areas of natural sand produce similar conditions that were documented during construction. As a result, indicators such as partial mortality of the base, burial of the base, which are designed to elucidate project impacts can also have a natural cause that can vary seasonally.	Baseline data on sediment type and depth are important as well as documentation of seasonal patterns.

In particular, the fact that samples at cross sites are pseudo-replicates as opposed to independent samples, the presence of a channel-effect or naturally occurring differences in organismal distribution over space, and the presence of a regional species-specific coral disease were the largest threats to validity when analyzing 2016 impact assessment data.

The cross site impact assessment survey consisted of one sample of benthic count and condition data per cross site. Even though data were collected in 10 m increments, the samples were collected on the same transect line and lines crossed at the center of the site. As a result, the 10 m increments were not independent samples and therefore not consistent with the requirements for ANOVA significance testing. Even if these 50 m long transects are then subdivided into smaller blocks/samples these units must be treated as subsamples. Due to the lack of replication, the data from each site is a sample size of one (n=1) and no mean or variance may be calculated. Most models for statistical inference require true replication. True replication permits the estimation of variability within a treatment. Without estimating variability within treatments, it is impossible to do statistical inference.

Examples of pseudo-replication

- Many samples from a single site. These are actually subsamples.

- Only a single sample for each treatment condition. These are actually replicates, but cannot do statistics on a sample size of one.

The consequence of doing statistical inference using pseudo-replicates rather than true replicates is that the variability is non-existent or significantly underestimated. This will result in:

- Confidence intervals that are too small.
- An inflated probability of a Type I error (falsely rejecting a true null hypothesis).

Hurlbert (1984) recommend to avoid *pseudo-replication* at all costs and to carefully determine what the experimental/observational units are and to be sure each treatment is randomly applied to more than one experimental/observational unit. These authors also caution analyzing and reporting pseudo-replicated results as the danger of over-interpreting results or using invalid statistical tests is high.

In addition, to the small sample size of cross-site samples, documentation of a channel effect for most benthic health metrics and multiple mortality-inducing disturbances further threaten the validity of impact assessment results. 2010 ANOVA surveys of hardbottom data indicated that scleractinian and octocoral densities were significantly lower at the hardbottom channel-side locations when compared to hardbottom control sites (DCA 2012). Regression analyses of middle and outer reef habitat resources from 2010 indicate significant relationships with distance from the channel in coral, sponge, and octocoral densities (DCA 2012). The baseline analyses preformed in 2010 and 2013 indicates the presence of a channel-effect for most benthic categories. A channel-effect indicates that the presence of the high-traffic, high current channel may in and of itself create natural differences in organism density, size, or condition that are different than far-field control sites.

A summary of the various metrics acquired in the 2016 impact assessment survey and the confounding influences that affect each metric are provided in Table 5.

Table 5. Confounding factors influencing the ability to determine project-related infuences from other factors for various survey metrics.

Metric	Lack of Baseline Data	Natural Differences Between Habitat and Control	Channel-effect	Multiple Disturbances	Effects of Time	Ability to Differentiate Dredge-related Imapcts from Other Factors
Sediment Depth	**YES** No site-specific baseline data	**Unknown**	**YES** Sand wave activity only documented in near-channel habitat; Percent sand cover often higher than habitat controls.	**YES** Natural sand waves were documented in the near-channel habitat and occurred during and after construction monitoring.	**YES** Sand waves can be seasonal or influenced by major storms; Sand cover varied as much as 69% at control locations. Data collected over 9 months & passage of Hurricane Matthew	**LOW** Natural differences in sediment depth near the channel prevent control-impact analysis;
Sediment Type	**YES** No site-specific baseline data	**Unknown**	**Likely** Lirman et al. 2003 documented significantly higher sedimentation at channels. Near-channel sites are located near a source of significant water movement and runoff.	**Unknown**	**YES** Sand waves can be seasonal or influenced by major storms. Data collected over 9 months & passage of Hurricane Matthew	**Moderate** The natural distribution of fine and mixed sediments is unknown but likely different from controls due to high traffic channel. However, during construction very fine clay-like material was used an indicator of potential dredge impact.

Metric	Lack of Baseline Data	Natural Differences Between Habitat and Control	Channel-effect	Multiple Disturbances	Effects of Time	Ability to Differentiate Dredge-related Imapcts from Other Factors
Scleractinian Density	**YES** No site-specific baseline data	**YES** 2010 baseline survey	**YES** 2010 baseline showed significant difference b/ween channel-side and controls in HB. Significant relationships with distance to channel documented in Middle & Outer reef.	**YES** Species-specific disease occurred during monitoring	**YES** 2.5 bleaching seasons, Hurricane Matthew, Ongoing Disease	**NONE** Natural differences in density between near-channel sites and controls and species-specific disease mortality impede ability to delineate dredge-specific impacts.
Scleractinian Mortality Metrics (PM, PMB, Mean partial mortality, mean % mortality, DEAD corals)	**YES** No site-specific baseline data	**Unknown**	**Unknown**	**YES** Species-specific disease occurred during monitoring	**YES** 2.5 bleaching seasons, Hurricane Matthew, Ongoing Disease	**NONE** **S**pecies-specific disease mortality impede ability to delineate dredge-specific impacts. All mortality estimates contain old mortality, disease mortality, bleaching mortality and potential disease mortality.
Scleractinian Sediment Metrics (SED, SA, PBB, BBA, BUR)	**YES** No site-specific baseline data	**Unknown**	**Likely** Baseline data shows increased sediment at near-channel sites. Lirman et al. 2003 show significant increase in sedimentation near channels.	**YES** Natural sand waves were documented in near-channel habitat that caused similar increases in partial burial, partial mortality and base and burial to dredge impacts	**YES** Sediment metrics can vary significantly with weather. Data collection occurred over 9 months & Hurricane Matthew.	**NONE** Sediment indicators are not a measure of permanent impacts. Organisms must be followed through time to determine if sediment stress has led to mortality.

Metric	Lack of Baseline Data	Natural Differences Between Habitat and Control	Channel-effect	Multiple Disturbances	Effects of Time	Ability to Differentiate Dredge-related Imapcts from Other Factors
Octocoral Density	**YES** No site-specific baseline data	**YES** 2010 baseline survey	**YES** 2010 baseline showed significant relationships with distance from the channel.	**YES** Significant localized impacts from lobster traps were noted.	**YES** 2.5 bleaching seasons & Hurricane Matthew	**Moderate** Natural differences in octocoral density were established prior to dredging. As a result a control-impact analysis is not valid. Qualitative comparisons between 2016 impact assessment and 2010 baseline are possible.
Octocoral Mortality Metrics (PM, PMB, Mean partial mortality, mean % mortality, DEAD)	**YES** No site-specific baseline data	**Unknown**	**Unknown**	**YES** Significant localized impacts from lobster traps were noted.	**YES** 2.5 bleaching seasons & Hurricane Matthew	**LOW** Very little is known about these metrics as they have not been documented in any prior survey. It is unknown if Octocorals were affected by dredging and to what extent these metrics indicate dredge-related mortality or other mortality such as competition or disease;
Octocoral Sediment Metrics (SED, SA, PBB, BBA, BUR)	**YES** No site-specific baseline data	**Unknown**	**Likely** Baseline data shows increased sediment at near-channel sites. Lirman et al. 2003 show significant increase in sedimentation near channels.	**Unknown** No additional sources of mortality were documented during construction	**YES** 2.5 bleaching seasons & Hurricane Matthew	**NONE** Sediment indicators are not a measure of permanent impacts. Organisms must be followed through time to determine if sediment stress has led to mortality.

Metric	Lack of Baseline Data	Natural Differences Between Habitat and Control	Channel-effect	Multiple Disturbances	Effects of Time	Ability to Differentiate Dredge-related Imapcts from Other Factors
Sponge Density	**YES** No site-specific baseline data	**YES** 2010 baseline survey	**YES** 2010 baseline showed significant relationships with distance from the channel.	**Unknown** No additional sources of mortality were documented during construction	**YES** 2.5 bleaching seasons & Hurricane Matthew	**Moderate** Natural differences in sponge density were established prior to dredging. As a result a control-impact analysis is not valid. Qualitative comparisons between 2016 impact assessment and 2010 baseline are possible.
Sponge Mortality Metrics (PM, PMB, Mean partial mortality, mean % mortality, DEAD)	**YES** No site-specific baseline data	**Unknown**	**Unknown**	**Unknown** No additional sources of mortality were documented during construction	**YES** 2.5 bleaching seasons & Hurricane Matthew	**LOW** Very little is known about these metrics as they have not been documented in any prior survey. In addition, sponge tissue disintegrates rapidly following disturbance so evidence of mortality is likely recent. It is also unknown if sponges were affected by dredging and to what extent these metrics indicate dredge-related mortality or other mortality such as competition or disease;
Sponge Sediment Metrics (SED, SA, PBB, BBA, BUR)	**YES** No site-specific baseline data	**Unknown**	**Likely** Baseline data shows increased sediment at near-channel sites. Lirman et al. 2003 show significant increase in sedimentation near channels.	**Unknown** No additional sources of mortality were documented during construction	**YES** 2.5 bleaching seasons & Hurricane Matthew	**NONE** Sediment indicators are not a measure of permanent impacts. Organisms must be followed through time to determine if sediment stress has led to mortality.

The lack of replication and the presence of a channel-effect in the near-channel benthic resources in 2010 indicated that a traditional control-impact survey design would violate the assumption of no significant differences in study metrics between impact and control sites prior to dredging. In addition, since the data from 2010 was collected from different areas and using different methodologies than the 2016 impact assessment data, a Before-After-Control-Impact (BACI) design was not feasible for the near-channel PortMiami benthic resource data. As a result, the density and condition metrics collected in the 2016 impact assessment surveys are presented and discussed as qualitative information and no impact-control significance testing was performed. Condition values were calculated from raw data and are presented in the results section of this report as the percent of organisms with each condition. Density was calculated as follows:

$$\text{Density} = \frac{Total\ number\ of\ individuals\ for\ a\ group}{Total\ area\ of\ a\ transect}$$

2.3.2 Organism Condition Data

Coral condition data were collected and analyzed for all scleractinian corals, octocorals and sponges. Visual assessment of coral species identification and condition metrics was conducted on all scleractinian photos, in addition to the data collected in situ by a qualified observer to verify accuracy of field data collection. QA/QC was not conducted on octocoral or sponge condition data since photos were only available for a subset of individuals.

3.0 RESULTS

3.1 Determining Project-Related Impacts

As a result of confounding factors (discussed in Section 2.3.1), the 2016 impact assessment relied most heavily on sediment type, depth, as well as density of octocorals and sponges to make a determination of impact (Table 4). Scleractinian coral metrics were particularly poor indicators of impact using the impact assessment survey protocol as 1) their densities naturally vary with respect to distance from the channel, meaning that control sites were not representative of the near-channel habitat and 2) regional species-specific diseases have caused significant coral mortality that is visually indistinguishable from potential dredge impacts, without following individual corals through time. Additionally, since the disease was species-specific it causes high rates of mortality in areas that had higher density of susceptible species as opposed to communities made up of moderately susceptible or non-susceptible species. At permanently monitored sites this manifested in significantly higher rates of mortality at some channel-side sites that were dominated by susceptible species when compared to controls that were dominated by non-susceptible species. Therefore, no cause was attributed to the different types of coral mortality or to coral densities in the impact assessment data.

Although sponge and octocoral metrics were limited given natural differences with respect to density near the channel, there was no documentation of regional mortality that would weaken the validity of density trends.

At permanent monitoring stations where colonies were followed through time sediment burial was found to affect six out of 224 near-channel corals (2.7%) at impacted site locations compared to 72 out of 224 (32.1%~12x sediment burial mortality) that died as a result white-plague and concurrent diseases. In addition, there was no increase in disease-related mortality at any permanent monitoring location when species-specificity of the disease was accounted for (DCA 2017). Since dredging was not found to increase disease mortality at sites located within 10m of the channel edge there was no evidence of increased disease-related mortality due to dredging at distances further removed from construction operations.

3.2 Permanence, Extent and Functional Degradation or Loss

The FDEP permit requires that “Final monitoring results shall document permanent impacts, if any, to be used for estimates of additional mitigation using UMAM.”

In 2014-2015, impact assessment reports documented potential sediment effect areas within hardbottom, middle and outer reef habitats. Two qualitative indicators were used in these reports, the presence of “clay-like material” which was documented at channel-side sites (within 10 m of channel-edge) during construction and presence of partial mortality around the base of corals, also documented at channel-side sites during construction compliance surveys. The areas in which the clay-like material and partial mortality around the base of the coral were documented varied by habitat and location. Estimates of potential affected acreage at hardbottom, middle and outer reef habitats covered up to 213.7 acres (DCA 2015c, d, Table 6).

The distribution of sediments as recorded in the 2016-2017 impact assessment surveys suggest that the “clay-like” material that was used to delineate the potential sedimentation effects areas of 2014-2015 were a temporary impact of the project. During the 2016-2017 impact assessment surveys no “clay-like material” was recorded on data sheets. Given that over a year and a half has passed since construction activities it is likely these sediments have been incorporated into naturally occurring reef sediments, or otherwise dispersed (DCA 2015c, Griffin 1974, Blair et al. 1994).

Fine sediments were still present in the survey area but made up a relatively small proportion of the total area delineated in 2014-2015 as the area of potential sedimentation affects. Out of 1,200 sample points spanning the 2014-2015 potential sedimentation affects areas only 123 (10.25%) were characterized as fine, 1039 (86.5%) were characterized as mixed, 37 (3.1%) were characterized as coarse, and one point (0.08%) was characterized as rubble. Fine sediment was documented primarily in the northern middle and outer reef habitats, however fine sediment in and of itself is a natural part of the reef environment that is found at both control and near-channel locations. To represent a permanent impact to the site the fine sediment would have to prevent dense coral community establishment which has been linked to areas where mean sediment depth exceeds 5 cm in Florida Bay (Lirman et al. 2003) and to 3 cm for areas of *Acropora* restoration efforts. Only one point out of 1,006 near-channel sediment assessment locations (0.09%) was characterized as fine sediment and exceeded the 3 cm guideline for restoration efforts. The dramatic decline in clay-like material and general reduction of fine and deep sediment to a single sediment assessment location show that the potential dredge-related sediment delineated in 2014-2015 was a temporary effect of the project. The determination that dredge-related sediment was a temporary effect of the project are corroborated by percent cover analysis of sand at permanent sites related to the project. At most sites percent sand cover increased as a result of the project but had declined towards or returned to baseline values during the one-year post-construction impact assessment (DCA 2017).

The other key indicator used to delineate potential sedimentation effects areas in 2014-2015 was the presence of partial mortality around the base of the colony. In 2017, partial mortality at the base of the colony was found to be a poor indicator of dredge-related mortality. In the middle reef north ridge reef habitat where partial mortality of the base of the colony was highest for near-channel sites (97.1% of colonies at R2N1-RR had some level of partial mortality of the base), the corresponding habitat control had 81.6% of the corals with some level of partial mortality of the base. The fact that natural levels of coral mortality that included the base of the colony could exceed 81.6% suggest this is a poor indicator of dredge-related mortality since no dredge impact occurred at this control. Given the high levels of regional coral disease, bleaching, and other factors that can also cause mortality of the base of a coral we could not delineate to what extent mortality at the base of the corals was related to dredge-related influences from other factors.

Following the analysis of 2016-2017 impact assessment survey the extent of sediments used to delineate a potential sedimentation effect area have largely been incorporated into natural reef sediments and the significant reduction of fine sediments between 2014-2015 impact assessment surveys and 2016 impact assessment surveys is consistent with a temporary impact of the project. Other permanent impacts of the project such as the loss of six out of 224 (2.7%) of near-channel tagged corals may have affected areas that extend beyond the near-channel sites but due to the presence of a regional disease event that caused significantly greater mortality than sediment burial (an estimated 72 out of 224 (32.1%) tagged corals at near-channel sites died as a result of white-plague and concurrent diseases) we cannot partition the various causes of mortality using the cross-site impact assessment data; rates of sediment mortality are likely less than 2.7% as distance from the channel increases. In addition, the roughly 46% of corals that were found to have some partial mortality associated with sedimentation at permanent near-channel sites were determined to be indistinguishable to mortality found at habitat controls when planimetry measurements compared between permanent site channel-side and control sites (DCA 2017).

Despite the loss of six permanent tagged coral at near-channel sites there was no permanent loss of habitat function as a result of the project. Declines in coral density at most distances from the channel are what would be expected from a regional mortality event such as the white-plague disease event. This is corroborated by both the percent cover data at permanent monitoring sites which documented declines in coral cover occurred at both near-channel and control sites (if it were dredge-related the decline would have only been documented channel-side), as well as the species-susceptibility analysis performed on coral mortality data from permanent near-channel sites which showed no increase in disease-related mortality at sites located adjacent to the PortMiami channel (DCA 2017). No declines in octocoral or sponge density were documented at any distance from the channel when compared to 2010 baseline data. This is substantiated by the percent cover analysis of permanent monitoring sites in which near-channel sites saw declines in percent scleractinian coral cover but the remaining categories of benthic invertebrates remained virtually unchanged from baseline to impact assessment surveys (DCA 2017).

BEFORE THE PROJECT in 2013:
The mean percent cover of benthic invertebrates was approximately 15% of the bottom at the channel-side sites during baseline surveys: scleractinians (0.88%), octocorals (9.27%), sponges (4.48%) and zoanthids (0.54%), while CTB and sand comprised the remaining 84.1% of the benthic cover (DCA 2017).

AFTER THE PROJECT in 2016:
The mean percent cover of benthic invertebrates was approximately 16% of the bottom at channel-side sites: scleractinians (0.62%), octocorals (9.97%), sponges (4.7%) and zoanthids (0.46%), while CTB and sand comprised the remaining 84.09% of the bottom at channel-side sites (DCA 2017).

Table 6. Quantification of potentially impacted (2014-2015) and permanently impacted (2016-2017) by reef and side.

Site	Potential Impact Area (ac) 2014-2015	Permanent Impact Area 2016-2017
R3S	1.6	0
R3N	8.3	0
R3N FDEP	9.1	0
R2S	64.4	0
R2N	130.3	0
Total	213.7	0

3.3 Hardbottom Habitat

Hardbottom habitat results for sediment characterization, depth, corals, octocorals, and sponges are presented below for cross sites depicted in Figures 36 and 37.

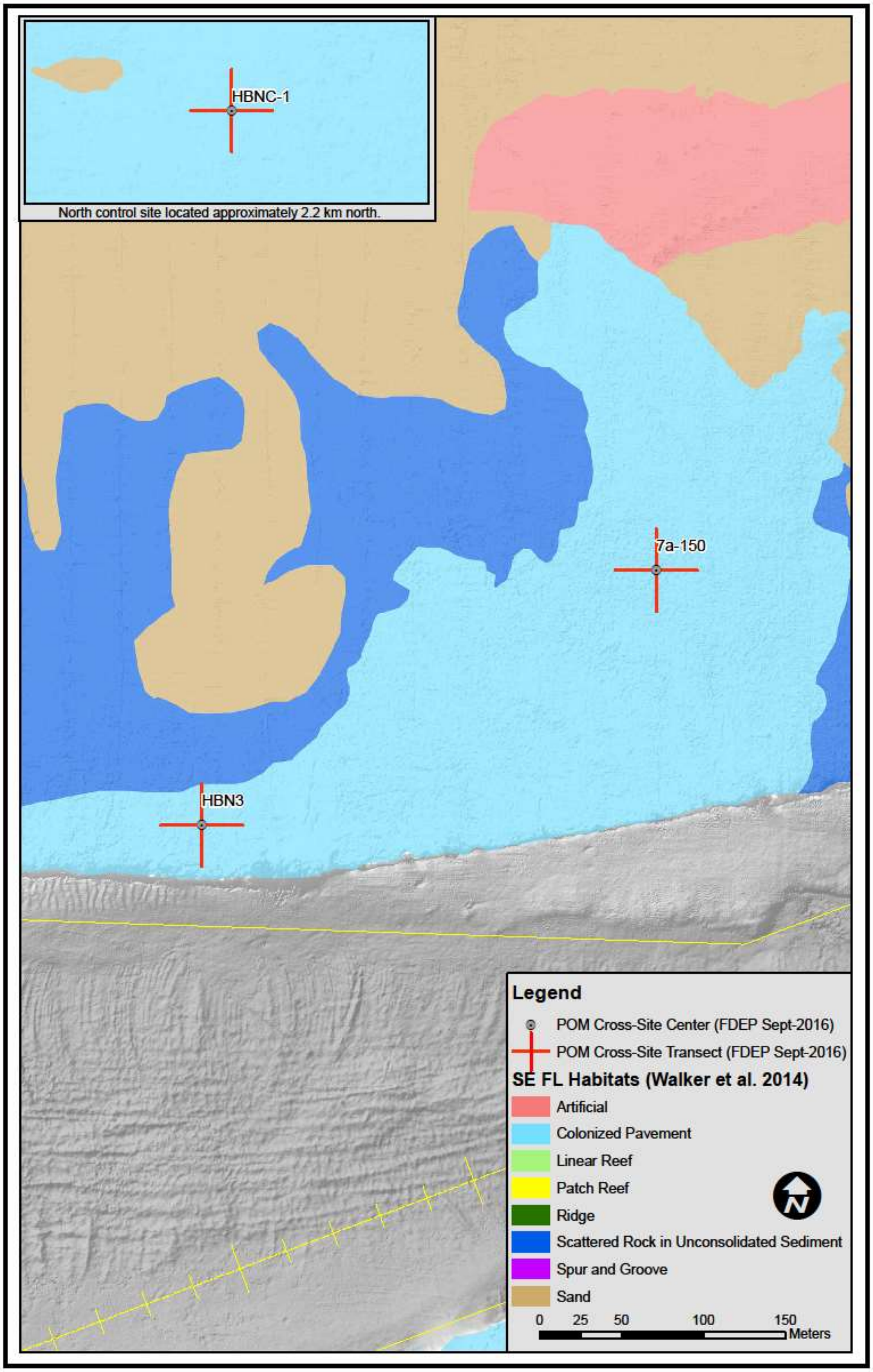


Figure 36. Northern hardbottom cross sites surveyed during the 2016-2017 impact assessment surveys.

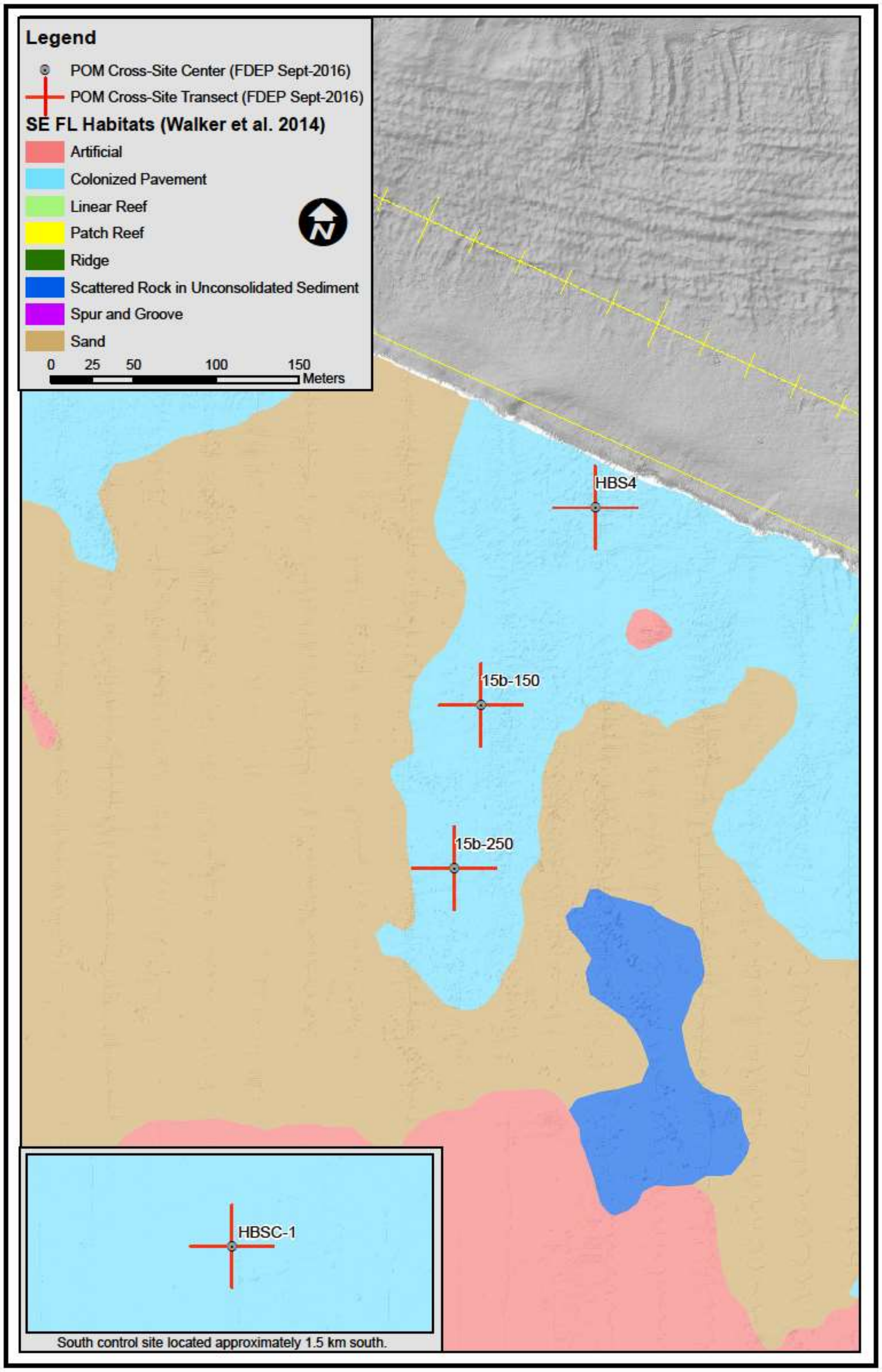


Figure 37. Southern hardbottom cross sites surveyed during the 2016-2017 impact assessment surveys

3.3.1 Qualitative Substrate Characterization and Sediment Depth

Qualitative substratum characterization was conducted for all transects, every 5 m along transects (Table 2, see Methods Section 2.2). All graphs of mean sediment depth are provided with the 5 cm and 3 cm depth benchmarks for visual comparison to PortMiami survey sites.

All points at hardbottom substratum characterization locations were characterized as sediment over hardbottom (Table 7). No substratum characterization locations were characterized as sediment only or exposed hardbottom at any hardbottom site.

The percentage of points characterized as deep sediment over hardbottom was variable in the hardbottom habitat. In the northern hardbottom habitat, the percentage of points characterized as deep sediment over hardbottom ranged from 5% at HBNC1-CP to 50% at site 7a-150 (Table 7). In the southern hardbottom habitat only two sites had points characterized as deep sediment over hardbottom, HBS4-CR (14%) and 15B-250 (9%) (Table 7).

Table 7. Sediment environment data for all hardbottom cross survey sites. Sites were characterized for the percentage of points assessed that were sediment over hardbottom (SOH), sediment only (SO), exposed hardbottom (EH), or deep sediment over hardbottom (Deep SOH). Deep SOH was calculated as a percentage of SOH which was only evaluated every 5m. Mean sediment depth, standard error of the mean, and the maximum sediment depth area also provided, but were calculated based on sediment depth measurements that were acquired every meter along the transect. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Channel (m)	SOH (%)	SO (%)	EH (%)	Deep SOH (%)	Mean Sed Depth (cm)	SE	Max Sed Depth (cm)
Hardbottom North	HBN3-CP	48	100	0	0	23	2.6	0.3	12.9
	7a-150	150	100	0	0	50	4.8	0.6	22.5
	HBNC1-CP	2350	100	0	0	5	0.7	0.1	6.5
Hardbottom South	HBS4-CR	32	100	0	0	14	1.7	0.2	8.9
	HBS-15b-150	150	100	0	0	0	1.6	0.2	7.5
	15B-250	250	100	0	0	9	1.6	0.2	10.0
	HBSC1-CP	1650	100	0	0	0	0.8	0.1	2.7

Mean sediment depth at near-channel sites in the northern hardbottom habitat ranged from 2.6 cm (HBN3-CP) to 4.8cm (7a-150). Site 7a-150 had the highest mean sediment depth of any impact assessment site (4.8cm) and exceeds the mean sediment threshold recommendation for an *Acropora* outplanting site (Figure 38). The maximum sediment depth (22.5 cm) was in a sediment patch. The mean level of sediment present at the northern hardbottom control site (HBNC1-CP) was 0.7cm.

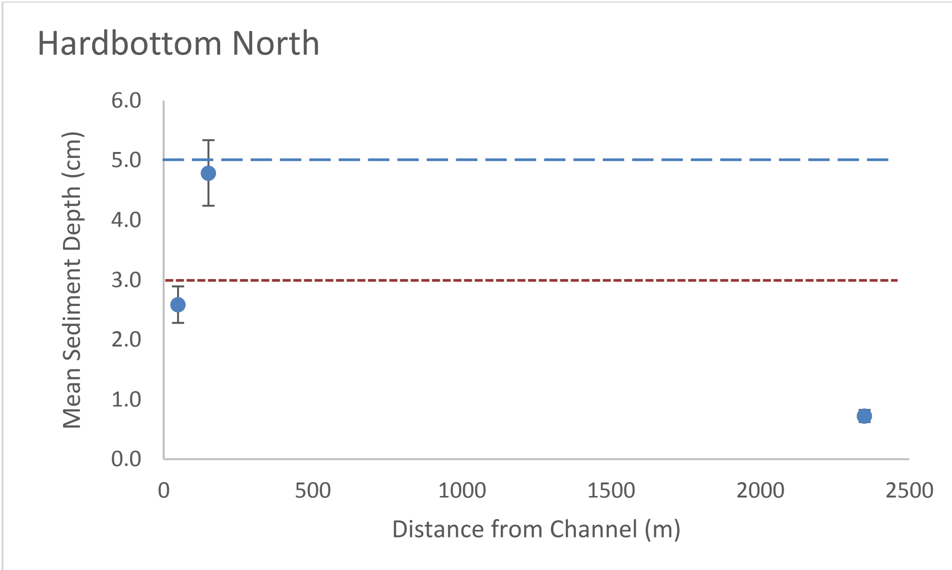


Figure 38. Mean sediment depth of northern hardbottom sites plotted against the distance of the site from the channel. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

Determining if the mean sediment depth and type found at sites HBN3-CP or site 7a-150 is characteristic of a dredge-related impact is imprecise without data concerning the sediment condition of the site prior to dredging. However, qualitative sediment indicators were collected. No material consistent with the clay-like material which was documented during dredging was present at northern hardbottom sites during the impact assessment in 2016-2017. The sediment type at both HBN3-CP and site 7a-150 is predominantly “mixed” (91% and 95% respectively, Table 8, Figure 39). No layers were found during excavations of deep sediment at either site. At HBN3-CP the two locations that were characterized by fine sediment had a maximum sediment depth of 0.6 cm and at site 7a-150, the one sediment assessment location characterized by fine sediment was 0.9 cm deep. In terms of sediment composition, the sediment present at both HBN3-CP and at 7a-150 are made of sediments that are characteristic of typical reef sediment found at the hardbottom controls The depths of the fine sediment encountered in the northern hardbottom habitat are well below the 3 cm *Acropora* restoration benchmark and are not determined to be impacted during the one-year post-construction impact assessment survey. It is important to note that while sediment depth of HBN3-CP is higher than the habitat control, repeat sampling (baseline through post-construction surveys) of the percent cover of sand at this site found that the percentage of sand cover had actually decreased from baseline surveys when it covered 51.2% of the substrate to 42.4% of the substrate during the one-year post construction impact assessment survey (DCA 2017). The baseline data also highlights the disparity in sand cover at near-channel and control sites where site HBN3-CP had 51.2% sand cover in baseline surveys whereas the habitat control only had 32.8% (DCA 2017). No percent cover information is available at site 7a-150 since this was a newly established site for the purpose of the cross impact assessment survey. These results highlight the importance of establishing baseline relationships of potential impact indicators as an increased level of sand at near-channel sites was found to pre-date construction activities. Repeated measures of sand cover also indicate that sand cover at HBN3-CP is below the cover documented in baseline surveys in 2013 (DCA 2017).The greater sediment depth noted at near-channel northern hardbottom sites is likely a reflection of the dynamic natural sand environment that was documented in baseline surveys and may also be due to increased traffic near the channel. The abundance of mixed sediment and data from permanent sites that show that greater levels of sand were present at near-channel hardbottom sites prior to construction and that cover during impact assessment surveys is below those from baseline suggest that there is no permanent impact of sediment at the northern hardbottom habitat.

Table 8. Percent sediment type at each hardbottom cross site location and the maximum depth of fine sediment. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Channel (m)	Fine	Mixed	Coarse	None	Rubble	Max Depth Fine Sediment (cm)
Hardbottom North	HBN3-CP	48	9%	91%	0%	0%	0%	0.6
	7a-150	150	5%	95%	0%	0%	0%	0.9
	HBNC1-CP	2350	0%	100%	0%	0%	0%	0.0
Hardbottom South	HBS4-CR	32	5%	86%	5%	0%	5%	0.7
	HBS-15b-150	150	0%	100%	0%	0%	0%	0.0
	15B-250	250	0%	100%	0%	0%	0%	0.0
	HBSC1-CP	1650	0%	82%	18%	0%	0%	0.0

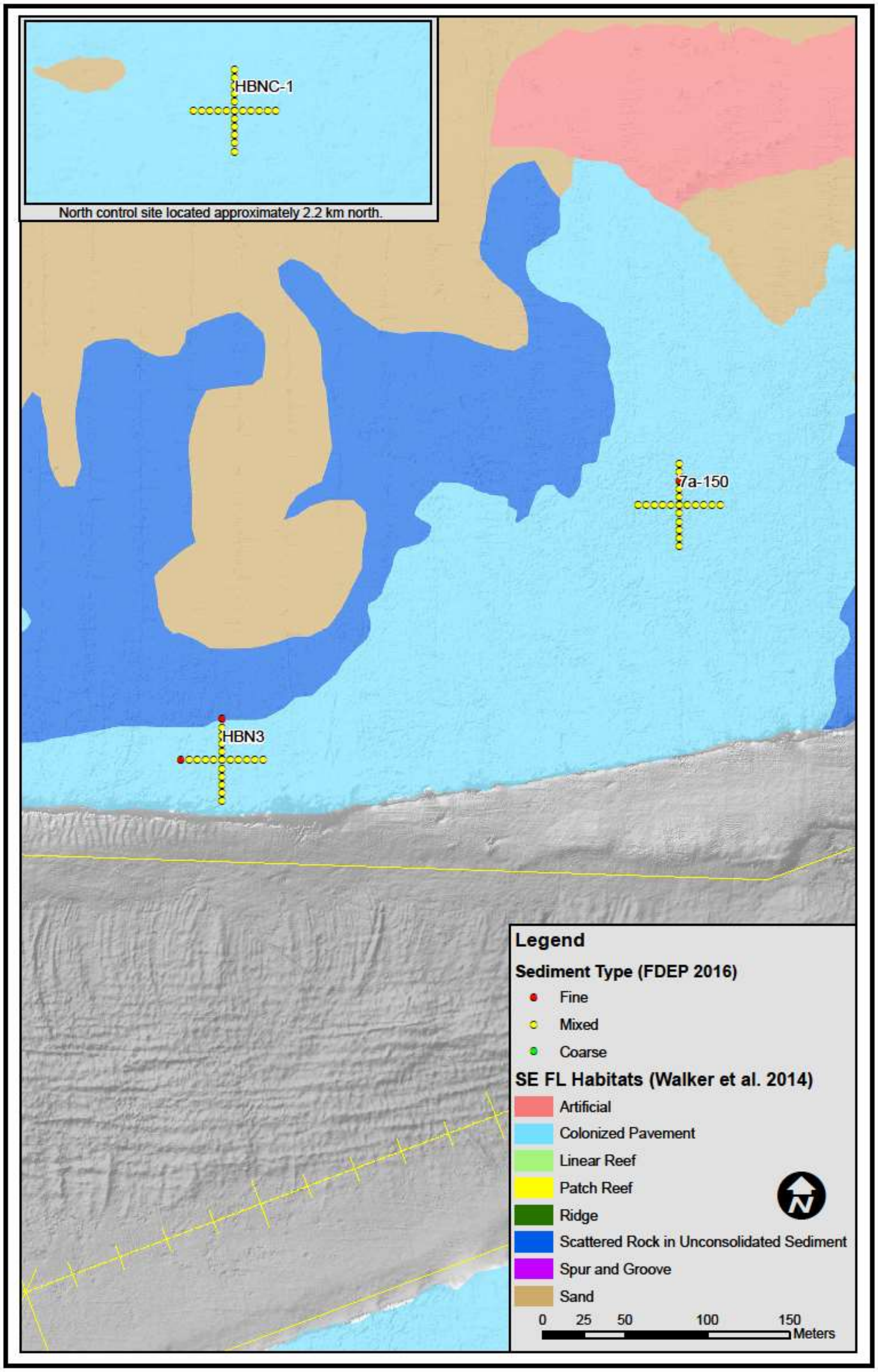


Figure 39 Sediment type assessed every 5m at northern hardbottom sites.

Mean sediment depth at near-channel sites in the southern hardbottom habitat did not vary much and ranged from 1.6 cm (HBS-15b-150 and 15B-250) to 1.7 cm (HBS4-CR) (Table 7). While the sediment depths measured at the near-channel sites were higher than the southern hardbottom control site (0.8 cm HBSC1-CP) they do not exceed the mean sediment threshold recommendation for an *Acropora* outplanting site or for dense coral community formation in Florida Bay (Lirman et al. 2003, Figure 40). In general sites surveyed closer to the channel had higher mean sediment depth. As previously discussed, higher sedimentation near an active channel is a characteristic of high traffic areas and is not a definitive indicator of construction impact.

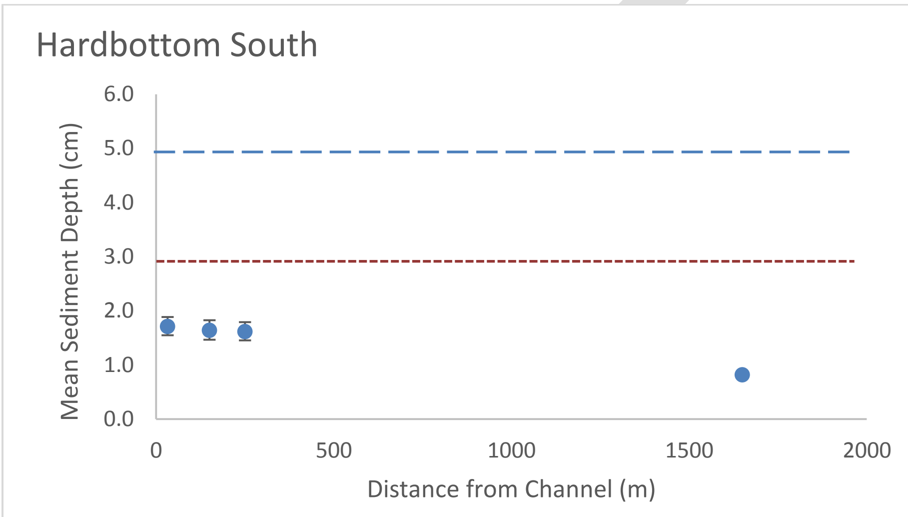


Figure 40. Mean sediment depth of southern hardbottom sites plotted against the distance of the site from the channel. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

Determining if the mean sediment depth of near-channel southern hardbottom sites has increased as a result of the PortMiami dredge project is imprecise without data concerning the sediment condition of the site prior to dredging. However, qualitative sediment indicators were collected during impact assessment cross site surveys. The sediment type of both HBS-15B-150 and 15B-250 was 100% mixed sediment (Figure 41). At HBS4-CR, one sediment assessment location was characterized by fine sediment (0.7 cm) and one location was characterized by coarse sand but the remaining locations were characterized as mixed sediment (Table 8). No layers were found during excavations of deep sediment at any site. In terms of sediment composition, the mixed sediment composition that are the predominant sediment type at all near-channel southern hardbottom monitoring locations are different than dredge sediment documented during previous impact assessment surveys when areas of fine “clay-like material, with sticky tactile properties and a white to grey color” (Figure 29) were found in the area (DCA 2014b). The lack of fine sediments, particularly any that exceed the 3 cm *Acropora* restoration threshold, suggest that previous dredge-sediment has been assimilated at each site. The increased sediment depth noted at near-channel southern hardbottom sites may be attributable to increased traffic near the channel, due to natural sand deposits that permeate the hardbottom habitat, or due to mixing of project related sediments with existing sand.

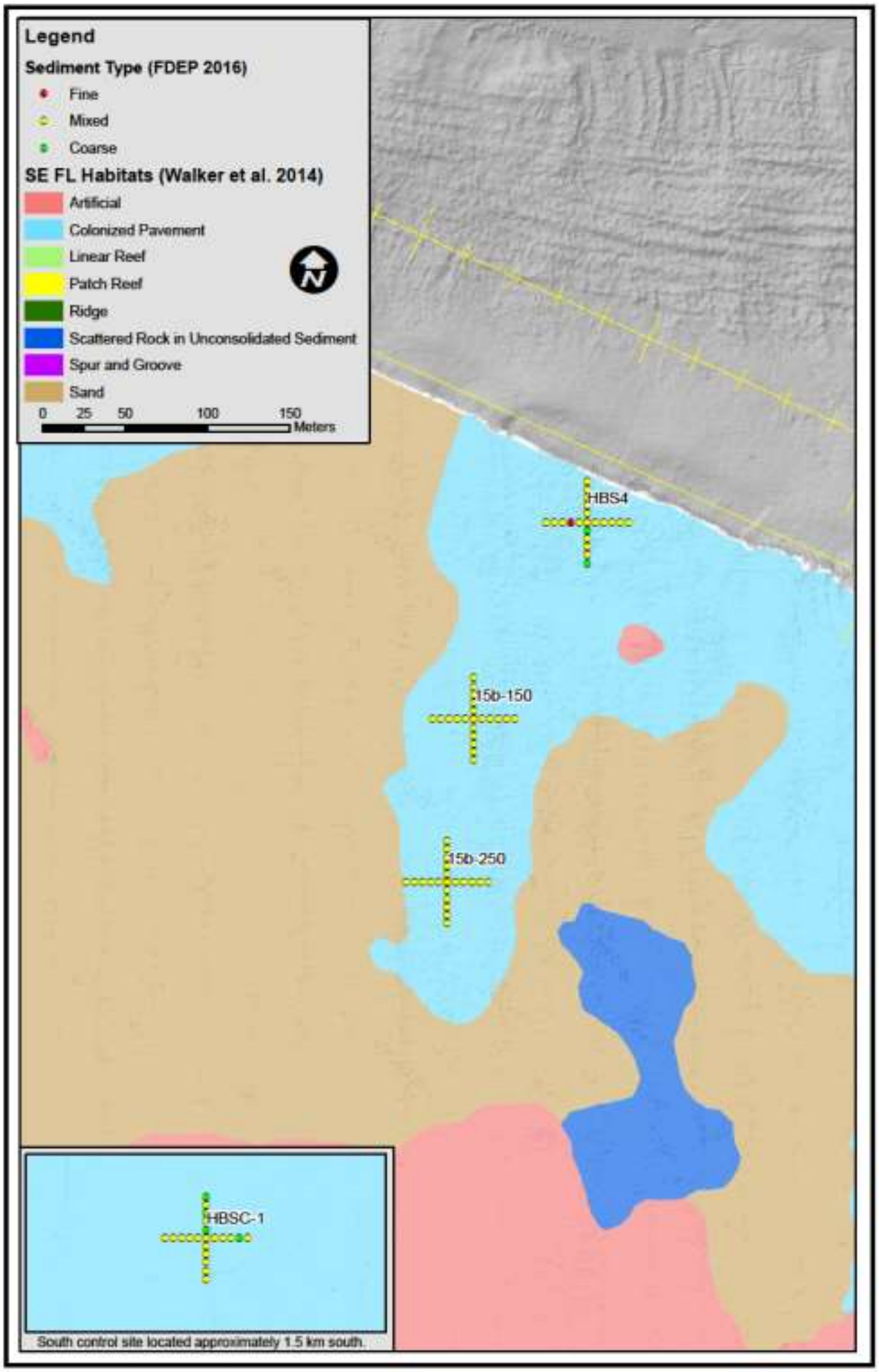


Figure 41. Sediment type as assessed every 5m at southern hardbottom sites.

3.3.2 Scleractinian Corals

The numbers of corals, coral density, coral recruit density (<3 cm), and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality (includes dead corals) are reported for each impact assessment. Sediment stress indicators including the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA), and complete burial (BUR) are presented. See Table 9 for scleractinian data.

Overall, scleractinian densities documented in 2016 were lower than densities measured in 2010 surveys at nearly all distances from the PortMiami channel. The change in coral density throughout the survey corridor is principally due to the impacts of white-plague disease (Precht et al. 2016)

3.3.2.1 Scleractinian Density

In 2010 areas of the hardbottom habitat were surveyed as part of a baseline survey during the PED phase of the project, and were used during permitting development. These areas do not directly correspond with 2016 impact assessment sites but provide a general guide to 2010 coral densities in the hardbottom habitat (Figure 2). In 2010 coral density ranged from 1.0 corals/m^2 at the hardbottom north channel-side location to 2.3 corals/m^2 at the hardbottom northern control. For the cross site impact assessment survey of 2016, coral density was lower at both near-channel northern hardbottom monitoring sites with coral density ranging from 0.43 to 0.50 corals/m^2 (Table 9). The hardbottom north control had coral density of 3.37corals/m^2. In the southern hardbottom habitat, near-channel coral density was 0.2 corals/m^2 in the 2010 baseline survey and 1.0 corals/m^2 at the southern hardbottom control (DCA 2012). In 2016 near-channel coral density ranged from 0.3-0.7 corals/m^2 and the southern hardbottom control had 1.4 corals/m^2 (Table 9).

Differences in coral density in the hardbottom habitat between 2010 and 2016 surveys are likely attributable to several factors, including differences in sampled areas (Figure 2), methods, as well as significant changes to coral community composition due to the species-specific white-plague event (Precht et al. 2016, Hayes et al. 2017, Aeby et al. 2017). The species-specific nature of the white-plague disease event creates a confounding mortality influence that makes control-impact site comparisons invalid unless species composition of the site is known prior to the disease event. Estimates of coral mortality as a result of the white-plague disease event ranged from 0% for abundant species *Porites astreoides* and *Siderastrea siderea* to greater than 97% mortality for species *Dichocoenia stokesi, Meandrina meandrites,* and *Eusmilia fastigata* (Precht et al. 2016). Comparison of coral density at hardbottom permanent monitoring sites between baseline surveys in 2013 and 2016 using the same methods and sample area showed declines in coral density at all surveyed sites (DCA 2017). No near-channel hardbottom monitoring site experienced mortality that exceeded the range predicted when species-susceptibility to white-plague disease was accounted for (DCA 2017, Figure 9).

At permanent monitoring sites where coral colonies were followed through time six corals out of 224 tagged corals died as a result of sediment burial representing 2.7% of all near-channel corals. The six colonies included one colony of *Dichocoenia stokes* at HBS4-CR, a *Siderastrea siderea* colony at HBN3-CP, two colonies of *S. siderea* at R2N2-LR, one *Porites porites* at R3N1-LR, and one *P. astreoides* at R3N1-LR. Over the same time period, seventy two corals died of white-plague and concurrent diseases accounting for the mortality of 32.1% of all near-channel corals. The repeated monitoring of tagged corals at permanent monitoring sites allowed quantification of various causes of mortality in a way that is not possible with the single-sample survey design of the cross impact assessment sites. As a result, the quantification of the various sources of coral mortality affecting project-related resources as presented in the permanent site impact assessment report (DCA 2017) is the most accurate estimate of sediment and disease-related mortality currently available. Other authors documented the same disease pattern of species specificity within a regional context (FRRP 2015, CSI 2016, DERM 2016, Hayes et al. 2017, Aeby et al. 2017). The single-sample cross-site survey design precludes specifying causes of coral mortality, or quantifying the species-susceptibility of individual assessment sites to white-plague disease as was performed in the permanent site impact assessment report. As a result, the cross impact assessment survey design is unsuitable for providing a post-hoc quantification of dredge-related mortality on coral density given the confounding effect of significant regional mortality.

3.3.2.2 Scleractinian Recruit Density

Coral recruit density, defined as corals 3 cm and less, was low across the hardbottom habitat. Recruit density was lower at near-channel sites (0.3-0.4 corals/m^2) when compared to the northern hardbottom control (3.0 corals/m^2) (Table 9). The same pattern was observed in the southern hardbottom habitat where near-channel recruit density ranged from 0.1-0.6 corals/m^2 compared to the southern hardbottom control that had 0.8 coral recruits/m^2.

Since no prior surveys of coral recruit densities have been performed at the cross impact assessment sites it is unknown if the pattern of lower recruit density near the channel is due to an effect of dredging or because total coral density is also lower near the channel, based on the previously documented channel effect. It is important to note, that the pattern of lower overall coral density near the channel in the hardbottom habitat pre-dates construction activities and was documented in the 2010 baseline survey (DCA 2012).

3.3.2.3 In-situ Scleractinian Mortality Assessments

Corals from the 2016 cross survey were not followed through time and thus no temporal assessment of partial or total mortality is available at any cross impact assessment site. Qualitative indicators of the relative health of corals were collected during the 2016 impact assessment and included: the percentage of corals showing signs of partial mortality (anywhere not including the base), partial mortality of the base (any partial mortality that included the base of the coral), percent partial mortality, and percent mean mortality (that includes standing dead corals) are provided in Table 9.

In the northern hardbottom habitat partial mortality ranged from 0.0% at HBN3-CP to 7.7% at site 7a-150 (Table 9). Partial mortality of the base was lowest at the hardbottom northern control (2.0%) and was highest at HBN3-CP where 20% of corals had some level of coral mortality that included the base of the colony. The mean percent partial mortality of corals at each hardbottom assessment site ranged from 0.6% at the northern hardbottom control site to a maximum level of 8.7% at HBN3-CP. Percent mean mortality, which included standing dead corals, ranged from 2.6% at HBNC1-CP to 18.3% at 7a-150.

In the southern hardbottom habitat partial mortality ranged from 0.0% at HBSC1-CP to 10.0% at site HBS4-CR (Table 9). Partial mortality of the base was lowest at impact assessment site 15B-250 (0.0%) and was highest at HBS4-CR where 30% of corals had some level of coral mortality that included the base of the colony. The mean percent partial mortality of corals at each southern hardbottom assessment site ranged from 0.3% at site 15B-250 to a maximum level of

9.5% at HBS-15B-150. Percent mean mortality, which included standing dead corals, ranged from 0.3% at site 15B-250 to 15.1% at HBS-15B-150.

Planimetry measurements of tagged colonies between baseline and impact assessment surveys, at R2N1-RR, the permanent site with the highest proportion of corals with sediment-related partial mortality, were not significantly different than the changes in coral area measured at the paired control R2NC2-RR. Although dredging affected channel-side corals as partial mortality, between baseline and impact assessment (-12.3%), there was no statistical difference in total tissue loss when compared to the paired control (-11.6%) (DCA 2017).

Since the species composition of each impact assessment site was not known prior to the 2016 survey, the level of coral mortality that is likely attributable to the region-wide white-plague disease event that has been ongoing since 2014, cannot be evaluated as provided in the permanent site impact assessment report (DCA 2017). As a result, the relative impact of the disease event vs. construction impacts for hard corals is unknown at cross site impact assessment locations. The coral mortality analysis provided in the permanent site report is a more robust analysis of potential construction impacts due to the fact that sources of coral mortality were quantified and the species-susceptibility to the ongoing disease event of individual sites was taken into account when analyzing coral mortality over the duration of the construction project (DCA 2017). It is important to note that since no previous data has been collected on the corals at the cross impact assessment sites, that the qualitative estimates of mortality provided above are inclusive of old mortality (that may pre-date construction activities), new mortality that occurred after the project ended but before this monitoring effort began, all disease-related mortality, and potential construction-related coral mortality and that these factors cannot be separated after-the-fact in a single-sample survey.

Table 9. Numbers of corals, coral density, coral recruit density (<3 cm) and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality (includes dead corals) are given for each hardbottom impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	N	Density/ m^2	Recruit density/ m^2	PM (%)	PMB (%)	% Mean Partial Mortality	% Mean Mortality
Hardbottom North	HBN3-CP	48	15	0.5	0.4	0.0	20.0	8.7	14.4
	7a-150	150	13	0.4	0.3	7.7	7.7	5.8	18.3
	HBNC1-CP	2350	101	3.4	3.0	2.0	2.0	0.6	2.6
Hardbottom South	HBS4-CR	32	10	0.3	0.1	10.0	30.0	4.0	12.7
	HBS-15b-150	150	15	0.5	0.3	6.7	20.0	9.5	15.1
	15B-250	250	20	0.7	0.6	5.0	0.0	0.3	0.3
	HBSC1-CP	1650	43	1.4	0.8	0.0	4.7	3.1	5.3

3.3.2.4 Scleractinian Coral Condition

Coral condition data in 2010 was collected using different methods and is not comparable to 2016 impact assessment condition indicators. As a result, no temporal conclusions can be drawn with respect to qualitative coral condition at the impact assessment sites.

Sediment was associated with many corals in the northern hardbottom habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was 0.0 at both HBN3-CP and site 7a-150 and highest at the hardbottom northern control (6.9%) (Table 10). Sediment accumulation (SA) ranged from 3.0% at HBNC1-CP to 15.4% at site 7a-150. Partial burial of the base (PBB) ranged from 13.3% at HBN3-CP to 16.8% at HBNC1-CP. Burial of the base (BBA) was high at all hardbottom monitoring sites and ranged from 30.8% at site 7a-150 to 46.7% at HBN3-CP. The percentage of corals with buried bases was 35.6% at the hardbottom north control site (HBNC1-CP), in between the two near-channel side sites. Burial (BUR) was only observed at the hardbottom north control and was rare at that site (1%). Sediment associated with corals in the hardbottom habitat was well documented in the baseline period, when northern hardbottom sites were buried, associated with naturally occurring seasonal sand movement.

Sediment was associated with many corals in the southern hardbottom habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was lowest at sites HBS4-CR and site 15B-250 where 0.0% of corals were documented with sediment dusting and highest at HBS-15B-150 where 13.3% of corals were noted with sediment dusting (Table 10). Sediment accumulation (SA) ranged from 0.0% at HBS4-CR and site 15B-250 to 40% at site HBS-15B-150. Partial burial of the base (PBB) ranged from 13.3% at HBS-15B-150 to 50.0% at HBS4-CR. Burial of the base (BBA) ranged from 0.0% at HBS4-CR to 33.3% at HBS-15B-150. Burial (BUR) was not documented in the southern hardbottom habitat.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data were available with respect to coral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts. In addition, sediment indicators can vary considerably with storm conditions and given that data were collected over a period of eight months will contain seasonal variability. At permanent sites where sediment indicators were taken with the same methods at baseline and during the post-construction impact assessment surveys, the mean proportion of corals exhibiting sediment stress was equivalent to or below baseline values for all near-channel hardbottom sites (DCA 2017).

Table 10. Distances of each hardbottom monitoring site from the PortMiami channel provided along with the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA), and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Hardbottom North	HBN3-CP	48	0.0	6.7	13.3	46.7	0.0
	7a-150	150	0.0	15.4	15.4	30.8	0.0
	HBNC1-CP	2350	6.9	3.0	16.8	35.6	1.0

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Hardbottom South	**HBS4-CR**	32	0.0	0.0	50.0	0.0	0.0
	HBS-15b-150	150	13.3	40.0	13.3	33.3	0.0
	15B-250	250	0.0	0.0	45.0	5.0	0.0
	HBSC1-CP	1650	9.3	9.3	27.9	25.6	0.0

3.3.3 Octocorals

The numbers of octocorals, octocoral density, the percentage of octocorals with partial mortality, partial mortality and base, and mean percent octocoral mortality within hardbottom habitat sites are presented below. Sediment-related indicators of octocoral condition for the hardbottom habitat are also reported.

3.3.3.1 Octocoral Density

2013 baseline octocoral density at channel-side sites in the northern hardbottom habitat ranged from 0.0 octocorals/m^2 at permanent monitoring site HBN1-CR to 2.2 octocorals/m^2 at HBN3-CP. Baseline octocoral density at the northern hardbottom control site was 22.5 octocorals/m^2 (DCA 2014a). For the cross site impact assessment survey, octocoral density was lowest at sites closest to the channel (HBN3-CP, 1.0 octocorals/m^2) and increased towards the hardbottom north control (HBNC1-CP, 33.5 octocorals/m^2) (Table 11). The trend of lower octocoral density near the channel pre-dates construction activities and was documented in the hardbottom baseline report (DCA 2014a). No direct comparisons between octocoral densities using the 50 x 50 m cross protocol are available at any northern hardbottom site. However, octocoral density as measured at cross site HBN3-CP (1.0 octocorals/m^2) was within the range documented at channel-side sites prior to construction activities and octocoral density at site 7a-150 (6.0 octocorals/m^2) and HBNC1-CP (33.5 octocorals/m^2) are higher than channel-side and control densities documented during baseline surveys in the northern hardbottom habitat (Table 11). In addition, two-way ANOVA's of octocoral densities at permanent site locations revealed no significant differences with respect to time or any interaction between site and time period between baseline and permanent site impact assessment surveys (DCA 2017). As a result, no significant differences in octocoral density have been identified at near-channel impact assessment locations in the northern hardbottom habitat.

2013 baseline octocoral density at channel-side sites in the southern hardbottom habitat ranged from 0.97 octocorals/m^2 at permanent monitoring site HBS2-CR to 9.9 octocorals/m^2 at HBS3-CP (DCA 2014a). Baseline octocoral density at the southern hardbottom control site was 7.23 octocorals/m^2 (DCA 2014a). In the southern hardbottom habitat octocoral densities were lowest between the channel and the control site at HBS-15b-150 (4.6 octocorals/m^2) and highest at the hardbottom control site HBSC1-CP (18.7 octocorals/m^2). No direct comparisons between octocoral densities using the 50x50m cross protocol are available at any southern hardbottom site. However, octocoral density as measured at cross sites HBS4-CR, HBS-15b-150, and 15b-250 are all within the range documented at channel-side sites prior to construction activities (Table 11). In addition, two-way ANOVA's of octocoral densities at permanent site locations revealed no significant differences with respect to time or any interaction between site and time period between baseline and permanent site impact assessment surveys (DCA 2017). As a result, no significant differences in octocoral density have been identified at near-channel impact assessment locations in the southern hardbottom habitat.

Table 11. Numbers of octocorals, octocoral density, and percent of octocorals with partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each hardbottom impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Hardbottom North	HBN3-CP	48	30	1.0	36.7	50.0	17.6
	7a-150	150	181	6.0	26.0	25.4	4.6
	HBNC1-CP	2350	1004	33.5	14.2	7.7	2.0
Hardbottom South	HBS4-CR	32	263	8.8	31.2	12.9	3.2
	HBS-15b-150	150	137	4.6	35.8	14.6	2.7
	15B-250	250	169	5.6	39.6	18.3	3.9
	HBSC1-CP	1650	561	18.7	25.0	6.1	2.4

3.3.3.2 In-situ Octocoral Mortality Assessments

Octocorals from the 2016 cross survey were not followed through time and thus no temporal assessment of partial or total mortality is available at any cross impact assessment site. Qualitative indicators of the relative health of octocorals were collected during the 2016 impact assessment and included: the percentage of octocorals showing signs of partial mortality (anywhere not including the base), partial mortality and base (any partial mortality that included the base of the octocoral), and percent mean mortality are provided in Table 11.

In-situ mortality indicators show the highest levels of partial mortality and partial mortality of the base at hardbottom sites near the channel (HBN3-CP and site 7a-150) than the hardbottom north control (HBNC1-CP). The numbers of corals with some partial mortality range from 14.2% at HBNC1-CP to 36.7% at HBN3-CP (Table 11). For partial mortality of the base the percentage of corals showing signs of this indicator ranged from 7.7% at HBNC1-CP to 50.0% at HBN3-CP. It is important to note that the sediment documented at HBN3-CP was predominantly characterized as mixed, which is the predominant sediment type of the hardbottom northern control. As a result, the partial mortality of the base documented at HBN3-CP is maybe due to naturally occurring sand waves that have been documented in the northern part of the hardbottom habitat. The average percent mortality of octocorals at northern impact assessment sites ranged from 2.0% (HBNC1-CP) to 17.6% at HBN3-CP. As previously determined for corals, the partial mortality and base indicator is not a direct reliable indicator of construction impacts since the sediment that was documented in the hardbottom habitat was of mixed grain size and cannot be differentiated from the sediment type at the hardbottom control locations. The percent mean mortality metric combines all sources of octocoral mortality.

In the southern hardbottom habitat near-channel locations had similar levels of partial mortality ranging from (31.2% at HBS4-CR to 39.6% at site 15B-250) when compared with the habitat control (25% partial mortality) (Table 11). A higher percentage of octocorals with partial mortality and base were found at the near-channel southern hardbottom sites (range 12.9% to 18.3%) compared to the southern hardbottom control that had 6.1% of octocorals with the partial mortality and base indicator. Regardless of the percentage of octocorals with a mortality indicator, mean levels of mortality were low at all sites ranging from 2.4% (HBSC1-CP) to 3.9% (15B-250).

It is important to note that no previous mortality data were collected for octocorals at the cross impact assessment sites, and that the estimates of mortality provided are inclusive of all types of octocoral mortality including disease, predation, competition, burial by naturally occurring sediment, and potential construction-related mortality.

3.3.3.3 Octocoral Condition

No octocoral condition data were collected in the 2010 baseline survey or during any construction monitoring assessment. As a result, no temporal conclusions can be drawn with respect to qualitative octocoral condition at the impact assessment sites. Sediment-related hardbottom octocoral condition data are presented in Table 12.

Sediment was not associated with many octocorals in the northern hardbottom habitat. Octocorals with the appearance of a sediment dusting (SED category) was lowest at HBN3-CP (3.3%) and highest at HBNC1-CP (11.2%) (Table 12). Sediment accumulation (SA) ranged from 3.3% at site 7a-150 to 11.7% at HBNC1-CP. Partial burial of the base (PBB) ranged from 0.0% at HBN3-CP to 2.2% at 7a-150. Burial of the base (BBA) ranged from 2.4% at HBNC1-CP to 10.0% at HBN3-CP. Burial (BUR) of octocorals was not observed at any northern hardbottom impact assessment site.

Sediment was not associated with many octocorals in the southern hardbottom habitat at both near-channel and control locations. Octocorals with the appearance of a sediment dusting (SED category) was lowest at the site HBS-15B-150 where 2.9% of octocorals were documented with sediment dusting and highest at the southern hardbottom control, HBSC1-CP where 4.3% of octocorals were noted with sediment dusting (Table 12). Sediment accumulation (SA) ranged from 0.0% at HBS-15B-150 and 15B-250 to 0.9% at HBSC1-CP. Partial burial of the base (PBB) ranged from 0.4% at HBSC1-CP to 2.3% at HBS4-CR. Burial of the base (BBA) ranged from 0.0% at HBSC1-CP to 4.4% at HBS-15B-150. Burial (BUR) was not documented in the southern hardbottom habitat.

Since sediment levels are known to be higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data were available with respect to octocoral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts. However, the fact that no site had greater than 11.7% of octocorals affected by any sediment indicators suggests that sediment is not currently impacting the octocoral communities at the impact assessment sites.

Table 12. Distances of each hardbottom monitoring site from the PortMiami channel provided along with the percentage of octocorals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Hardbottom North	**HBN3-CP**	48	3.3	10.0	0.0	10.0	0.0
	7a-150	150	6.6	3.3	2.2	8.8	0.0
	HBNC1-CP	2350	11.2	11.7	2.1	2.4	0.0
Hardbottom South	**HBS4-CR**	32	3.8	0.8	2.3	1.1	0.0
	HBS-15b-150	150	2.9	0.0	1.5	4.4	0.0
	15B-250	250	3.6	0.0	1.8	0.6	0.0
	HBSC1-CP	1650	4.3	0.9	0.4	0.0	0.0

3.3.4 Sponges

The numbers of sponges, sponge density, the percentage of sponges with partial mortality, partial mortality and base, and mean percent sponge mortality are presented for the hardbottom habitat. Sediment-related indicators of sponge condition in hardbottom habitat are reported below.

3.3.4.1 Sponge Density

No quantitative data on sponge density were required or collected in the hardbottom habitat in either the 2010 or 2013 PortMiami baseline assessments or the 2015 PortMiami post-construction surveys (DCA 2012; DCA 2014a). For the 2016 cross site impact assessment survey, sponge density was lowest at the site closest to the channel in the northern hardbottom habitat (HBN3-CP, 1.6 sponges/m^2) and highest at site 7a-150 (17.4 sponges/m^2) (Table 13). The hardbottom north control had sponge density of 6.5 sponges/m^2.

No direct comparisons between sponge densities using the 50x50m cross protocol are available at any northern hardbottom site. As a result, no temporal conclusions can be drawn with respect to sponge densities in the northern hardbottom habitat. Other qualitative indicators suggest little sponge mortality during the cross site impact assessment survey. No northern hardbottom site had a percent mean mortality of more than 0.9% (Table 13). Partial mortality near the base of sponge colonies was also less than 0.2% at all northern hardbottom sites. Mean partial mortality was less than 2.1% at all northern hardbottom monitoring sites.

For the cross site impact assessment survey, sponge density was lowest at the site 250m from the channel in the southern hardbottom habitat (15B-250, 9.2 sponges/m^2) and highest at site HBS-15B-150 (17.8 sponges/m^2) 150m from the channel (Table 13). The hardbottom southern control had sponge density of 16.1 sponges/m^2.

No direct comparisons between sponge densities using the 50x50m cross protocol are available at any southern hardbottom site. As a result, no temporal conclusions can be drawn with respect to sponge densities in the southern hardbottom habitat. Other qualitative indicators suggest little sponge mortality during the cross site impact assessment survey. No southern hardbottom site had a percent mean mortality of more than 0.8% (Table 13). Partial mortality near the base of sponge colonies was also less than 0.4% at all southern hardbottom sites. Percent partial mortality was less than 3.6% at all southern hardbottom monitoring sites.

Table 13. Numbers of sponges, sponge density, and percent of sponges with signs of partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each hardbottom impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Hardbottom North	HBN3-CP	48	47	1.6	2.1	0.0	0.9
	7a-150	150	521	17.4	0.6	0.2	0.3
	HBNC1-CP	2350	196	6.5	0.0	0.0	0.0
Hardbottom South	HBS4-CR	32	517	17.2	2.7	0.6	0.6
	HBS-15b-150	150	534	17.8	0.6	0.4	0.3
	15B-250	250	275	9.2	3.6	0.0	0.8
	HBSC1-CP	1650	484	16.1	0.8	0.4	0.1

3.3.4.2 Sponge Condition

No quantitative data on sponge sediment condition were collected in the hardbottom habitat in either the 2010 or 2013 PortMiami baseline assessments or in the 2015 post-construction PortMiami surveys (DCA 2012; DCA 2014a; DCA 2015b). As a result, no temporal conclusions can be drawn with respect to qualitative sponge condition in the hardbottom habitat. Sediment-related sponge condition data are presented for the hardbottom habitat in Table 14.

Sediment was associated with many sponges in the northern hardbottom habitat at both near-channel and control locations. Sponges with the appearance of a sediment dusting (SED category) was lowest at site 7a-150 (52.6%) and highest at the hardbottom northern control (75.5%) (Table 14). Sediment accumulation (SA) ranged from 24.5% at HBNC1-CP to 42.8% at site 7a-150. Partial burial of the base (PBB) ranged from 0.0% at HBNC1-CP to 15.2% at 7a-150. Burial of the base (BBA) ranged from 0.0% at HBNC1-CP to 38.3% at HBN3-CP. Burial (BUR) was not observed in the northern hardbottom habitat.

Sediment was associated with many sponges in the southern hardbottom habitat at both near-channel and control locations. Sponges with the appearance of a sediment dusting (SED category) was lowest at site 15B-250 (45.1%) and highest at the hardbottom southern control HBSC1-CP (60.5%) (Table 14). Sediment accumulation (SA) ranged from 30.4% at HBSC1-CP to 50.9% at site 15B-250. Partial burial of the base (PBB) ranged from 10.1% at HBSC1-CP to 24.8% at HBS4-CR. Burial of the base (BBA) ranged from 0.8% at HBSC1-CP to 9.1% at 15B-250. Burial (BUR) was rare in the southern hardbottom habitat ranging from 0.2% at HBS4-CR to 0.6% at HBS-15N-150.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data are available with respect to sponge sediment indicators, it is unknown how suspended or settled sediment may have impacted sponge populations near PortMiami either during or after construction activities. In addition, although sediment can be deleterious to sponge health, a recent review of sediment impacts on marine sponges concluded that most species can tolerate varying degrees of suspended and settled sediment and that many sponges have adaptations to not only persist but thrive in sedimented environments (Bell et al. 2015).

Table 14. Distances of each hardbottom monitoring site from the PortMiami channel provided along with the percentage of sponges with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Hardbottom North	**HBN3-CP**	48	66.0	31.9	6.4	38.3	0.0
	7a-150	150	52.6	42.8	15.2	6.9	0.0
	HBNC1-CP	2350	75.5	24.5	0.0	0.0	0.0
Hardbottom South	**HBS4-CR**	32	46.6	48.2	24.8	12.6	0.2
	HBS-15b-150	150	56.6	34.3	13.5	2.1	0.6
	15B-250	250	45.1	50.9	17.5	9.1	0.0
	HBSC1-CP	1650	60.5	30.4	10.1	0.8	0.0

3.3.5 Hardbottom Summary

In the hardbottom habitat, octocorals are the dominant benthic invertebrate (10.0 % of the bottom) followed by sponges (5.0%) and scleractinians (0.9%) (DCA 2017). To determine if there was a functional habitat loss due to the project, densities of dominant benthic invertebrates as measured in the impact assessment were compared to values documented prior to the project in 2010. Octocoral densities in 2016-2017 trend from low to high with distance from the channel and are consistent with 2010 values. No data is available for sponge densities in the hardbottom habitat prior to dredging so no temporal comparisons are made.

Scleractinian coral densities were lower than 2010 values at some locations and higher at others. Differences in coral densities are likely related to differences in methodologies and survey locations and were likely influenced by regional disease-related mortality not related to the project (DCA 2017). While scleractinian corals were impacted at near-channel sites during the project (2 out of 73 (2.7%) near-channel hardbottom corals died as a result of burial), this group represents less than 1% of cover according to pre-dredging data. When considering a 2.7% loss of less than 1% of the living benthic cover, this change should not be considered a functional loss of habitat. Furthermore partial mortality of corals documented during the project resulted in no net loss of function. This was determined based on planimetry analysis on post-project comparisons of photographs of tagged corals before, during and after the project. Looking at the hardbottom habitat function as the combined influence of the three major groups of benthic invertebrates; octocorals, sponges, and corals, no permanent effect of the project was detected in the 2016-2017 impact assessment. This is corroborated by percent cover analysis of near channel permanent monitoring sites in which the percent cover of dominant benthic invertebrates remained relatively unchanged between baseline and impact assessment surveys in the hardbottom habitat (octocorals 10.0%-9.2%; sponges 5.0%-5.8%; scleractinians 0.9%-0.5%; DCA 2017).

3.4 Middle Reef

Middle reef habitat results for sediment characterization, depth, corals, octocorals, and sponges are presented below for sites depicted in Figures 42 and 43.

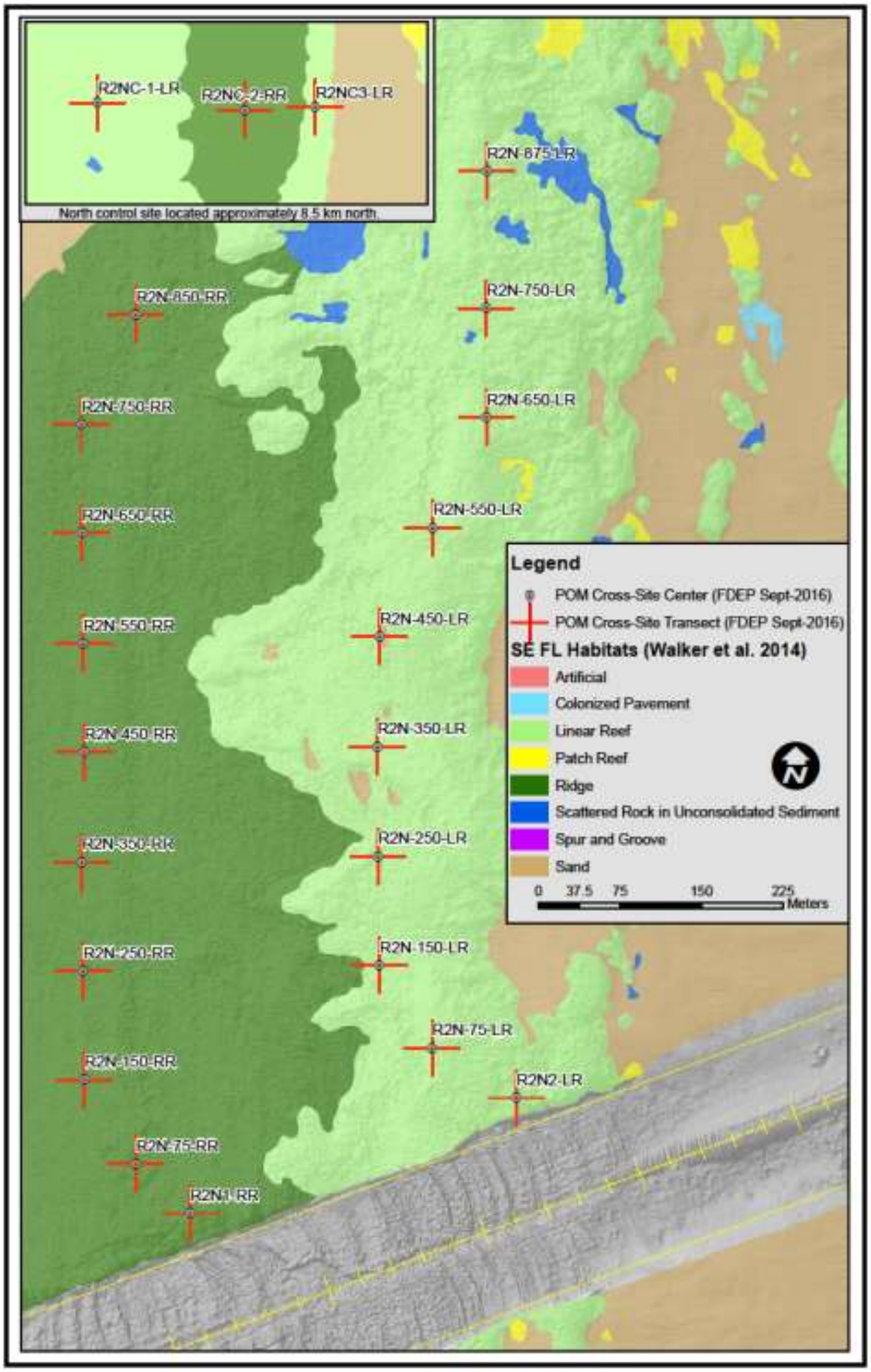


Figure 42. Northern middle reef cross sites surveyed during the 2016-2017 impact assessment surveys.

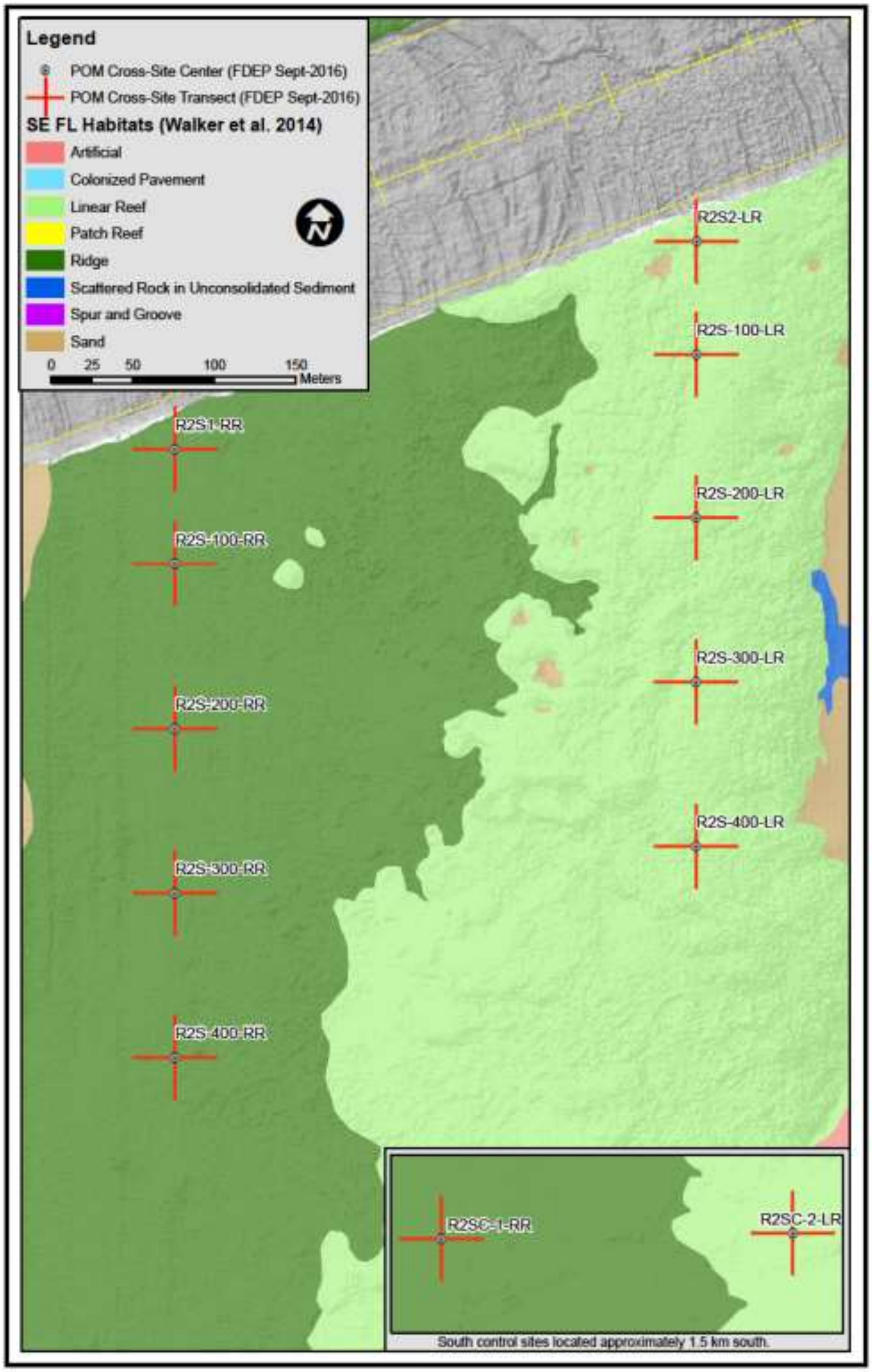


Figure 43. Southern middle reef cross sites surveyed during the 2016-2017 impact assessment surveys.

3.4.1 Qualitative Substrate Characterization and Sediment Depth

More than 95% of middle reef substratum characterization locations were characterized as sediment over hardbottom (Table 15). R2N-850-RR and R2N-250-LR had 5% of sediment assessment locations characterized as exposed hardbottom. No substratum characterization locations were characterized as sediment only at any middle reef site.

The percentage of points characterized as deep sediment over hardbottom was variable in the middle reef habitat. Of the twenty four sites surveyed in the northern middle reef habitat, four had points characterized as deep sediment over hardbottom. The percentage of points characterized as deep sediment over hardbottom ranged from 5% at R2N-250-RR to 27% at R2N1-LR. In the southern middle reef habitat, deep sediment over hardbottom was present at 5% of sediment assessment locations at R2S-100-LR and 13% at R2S-400-LR. All other sites in the southern middle reef habitat had no points characterized as deep sediment over hardbottom.

Table 15. Substratum characterization data for all middle reef cross survey sites. Sites were characterized for the % of points assessed that were sediment over hardbottom (SOH), sediment only (SO), exposed hardbottom (EH), or deep sediment over hardbottom (Deep SOH). Deep SOH was calculated as a percentage of SOH which was only evaluated every 5m. Mean sediment depth, standard error of the mean, and the max sediment depth area also provided but were calculated based on sediment depth measurements that were acquired every meter along the transect. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Channel (m)	SOH (%)	SO (%)	EH (%)	Deep SOH (%)	Mean Sed Depth (cm)	SE	Max Sed Depth (cm)
Middle Reef North (Ridge Reef)	**R2N1-RR**	28	100	0	0	0	0.6	0.0	2.5
	R2N-75-RR	75	100	0	0	0	0.4	0.0	3.0
	R2N-150-RR	150	100	0	0	0	0.6	0.0	2.0
	R2N-250-RR	250	100	0	0	5	0.7	0.1	4.0
	R2N-350-RR	350	100	0	0	0	0.5	0.0	1.5
	R2N-450-RR	450	100	0	0	0	0.4	0.0	2.5
	R2N-550-RR	550	100	0	0	0	0.5	0.0	2.0
	R2N-650-RR	650	100	0	0	0	0.6	0.0	2.1
	R2N-750-RR	750	100	0	0	0	0.5	0.0	1.7
	R2N-850-RR	850	95	0	5	0	0.6	0.0	1.7
	R2NC2-RR	9380	100	0	0	0	0.3	0.0	1.0

Site		Distance from Channel (m)	SOH (%)	SO (%)	EH (%)	Deep SOH (%)	Mean Sed Depth (cm)	SE	Max Sed Depth (cm)
Middle Reef North (Linear Reef)	R2N1-LR	18	100	0	0	27	2.2	0.3	15.0
	R2N-75-LR	75	100	0	0	0	0.6	0.1	8.5
	R2N-150-LR	150	100	0	0	0	1.0	0.2	13.6
	R2N-250-LR	250	95	0	5	0	0.6	0.1	3.9
	R2N-350-LR	350	100	0	0	0	0.4	0.0	2.3
	R2N-450-LR	450	100	0	0	9	1.0	0.2	7.5
	R2N-550-LR	550	100	0	0	0	0.5	0.0	2.7
	R2N-650-LR	650	100	0	0	0	0.5	0.0	2.5
	R2N-750-LR	750	100	0	0	0	0.6	0.0	2.4
	R2N-875-LR	875	100	0	0	0	0.5	0.0	2.4
	R2NC1-LR	9380	100	0	0	0	0.8	0.2	11.0
	R2NC3-LR	9380	100	0	0	0	0.4	0.0	2.5
Middle Reef South (Ridge Reef)	R2S1-RR	23	100	0	0	0	0.7	0.1	4.5
	R2S-100-RR	100	100	0	0	0	0.7	0.1	2.7
	R2S-200-RR	200	100	0	0	0	0.7	0.1	6.0
	R2S-300-RR	300	100	0	0	0	0.6	0.1	2.7
	R2S-400-RR	400	100	0	0	0	0.8	0.1	4.5
	R2SC1-RR	1270	100	0	0	0	0.5	0.1	2.7
Middle Reef South (Linear Reef)	R2S2-LR	21	95	0	5	0	0.5	0.0	2.4
	R2S-100-LR	100	100	0	0	5	0.6	0.1	12.5
	R2S-200-LR	200	100	0	0	0	0.5	0.0	1.5
	R2S-300-LR	300	100	0	0	0	0.5	0.0	2.5
	R2S-400-LR	400	100	0	0	13	0.7	0.1	8.0
	R2SC2-LR	1270	100	0	0	0	0.5	0.1	3.6

Mean sediment depth of near-channel sites in the northern middle reef ridge reef (RR) habitat did not vary considerably and ranged from 0.4 cm (R2N-75-RR, R2N-450-RR) to 0.7 cm at R2N-250-RR. The northern middle reef ridge reef control had a mean sediment depth of 0.3 cm. Maximum sediment depth was 4.0 cm or less at all northern ridge reef sites. Despite not having a comparison to pre-project conditions, these results do show that mean sediment levels were within 3 mm of the ridge reef control at all ridge reef sites and that the mean sediment depth never exceeded 0.7 cm on any site, a depth well below the *Acropora* restoration site benchmark, suggests these sites are no longer being impacted by significant dredge-related sedimentation (Figure 44). Fine sediment was still a substantial part of the sediment type at many northern ridge reef sites (Table 16, Figure 45) but maximum sediment depth of fine sediment was 1.7 cm or less throughout the entire northern ridge reef habitat. These maximum levels of fine sediment depth are well below the 3 cm *Acropora* restoration benchmark and thus, are not considered impacted.

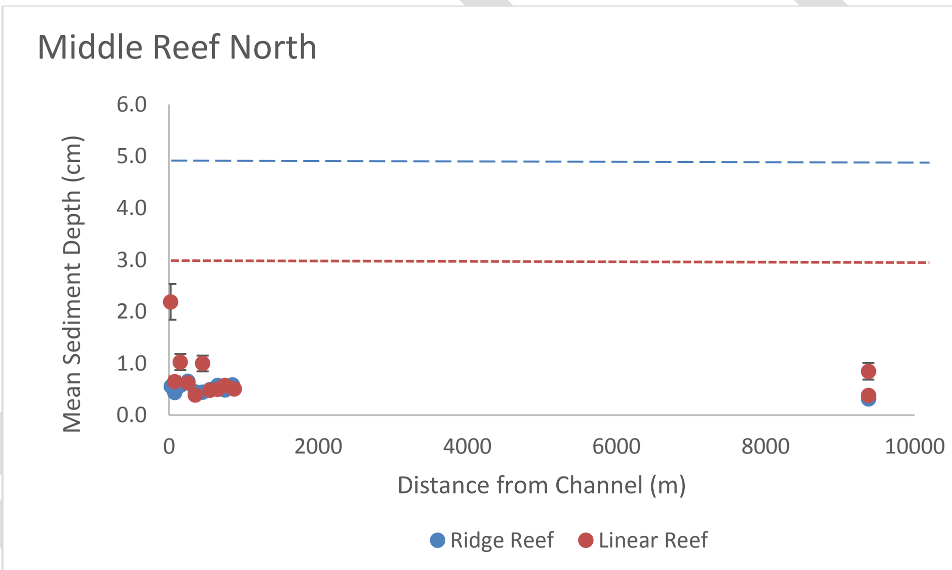


Figure 44. Mean sediment depth of middle reef sites plotted against the distance of the site from the channel. Blue points are middle reef ridge reef habitat and orange points are from linear reef habitat. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

Table 16. Percent sediment type at each middle reef cross site location and the maximum depth of fine sediment. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Channel (m)	Fine	Mixed	Coarse	None	Rubble	Max Depth Fine Sediment (cm)
Middle Reef North (Ridge Reef)	R2N1-RR	28	86%	14%	0%	0%	0%	1.5
	R2N-75-RR	75	13%	88%	0%	0%	0%	1.7
	R2N-150-RR	150	45%	55%	0%	0%	0%	1.0
	R2N-250-RR	250	32%	68%	0%	0%	0%	1.7
	R2N-350-RR	350	0%	100%	0%	0%	0%	0.0
	R2N-450-RR	450	0%	100%	0%	0%	0%	0.0
	R2N-550-RR	550	36%	64%	0%	0%	0%	0.5
	R2N-650-RR	650	32%	68%	0%	0%	0%	1.0
	R2N-750-RR	750	18%	82%	0%	0%	0%	1.0
	R2N-850-RR	850	0%	95%	0%	5%	0%	0.0
	R2NC2-RR	9380	9%	91%	0%	0%	0%	0.4
Middle Reef North (Linear Reef)	R2N2-LR	18	55%	45%	0%	0%	0%	0.5
	R2N-75-LR	75	0%	95%	5%	0%	0%	0.0
	R2N-150-LR	150	23%	77%	0%	0%	0%	0.8
	R2N-250-LR	250	0%	95%	0%	5%	0%	0.0
	R2N-350-LR	350	23%	77%	0%	0%	0%	0.8
	R2N-450-LR	450	14%	86%	0%	0%	0%	0.6
	R2N-550-LR	550	0%	100%	0%	0%	0%	0.0
	R2N-650-LR	650	27%	73%	0%	0%	0%	0.5
	R2N-750-LR	750	0%	100%	0%	0%	0%	0.0
	R2N-875-LR	875	23%	73%	5%	0%	0%	0.4
	R2NC1-LR	9380	0%	86%	14%	0%	0%	0.0
	R2NC3-LR	9380	0%	100%	0%	0%	0%	0.0

Site		Distance from Channel (m)	Fine	Mixed	Coarse	None	Rubble	Max Depth Fine Sediment (cm)
Middle Reef South (Ridge Reef)	**R2S1-RR**	23	0%	100%	0%	0%	0%	0.0
	R2S-100-RR	100	0%	95%	5%	0%	0%	0.0
	R2S-200-RR	200	0%	91%	9%	0%	0%	0.0
	R2S-300-RR	300	0%	86%	14%	0%	0%	0.0
	R2S-400-RR	400	0%	100%	0%	0%	0%	0.0
	R2SC1-RR	1270	0%	82%	18%	0%	0%	0.0
Middle Reef South (Linear Reef)	**R2S2-LR**	21	0%	95%	0%	5%	0%	0.0
	R2S-100-LR	100	0%	100%	0%	0%	0%	0.0
	R2S-200-LR	200	0%	100%	0%	0%	0%	0.0
	R2S-300-LR	300	0%	100%	0%	0%	0%	0.0
	R2S-400-LR	400	0%	96%	4%	0%	0%	0.0
	R2SC2-LR	1270	0%	100%	0%	0%	0%	0.0

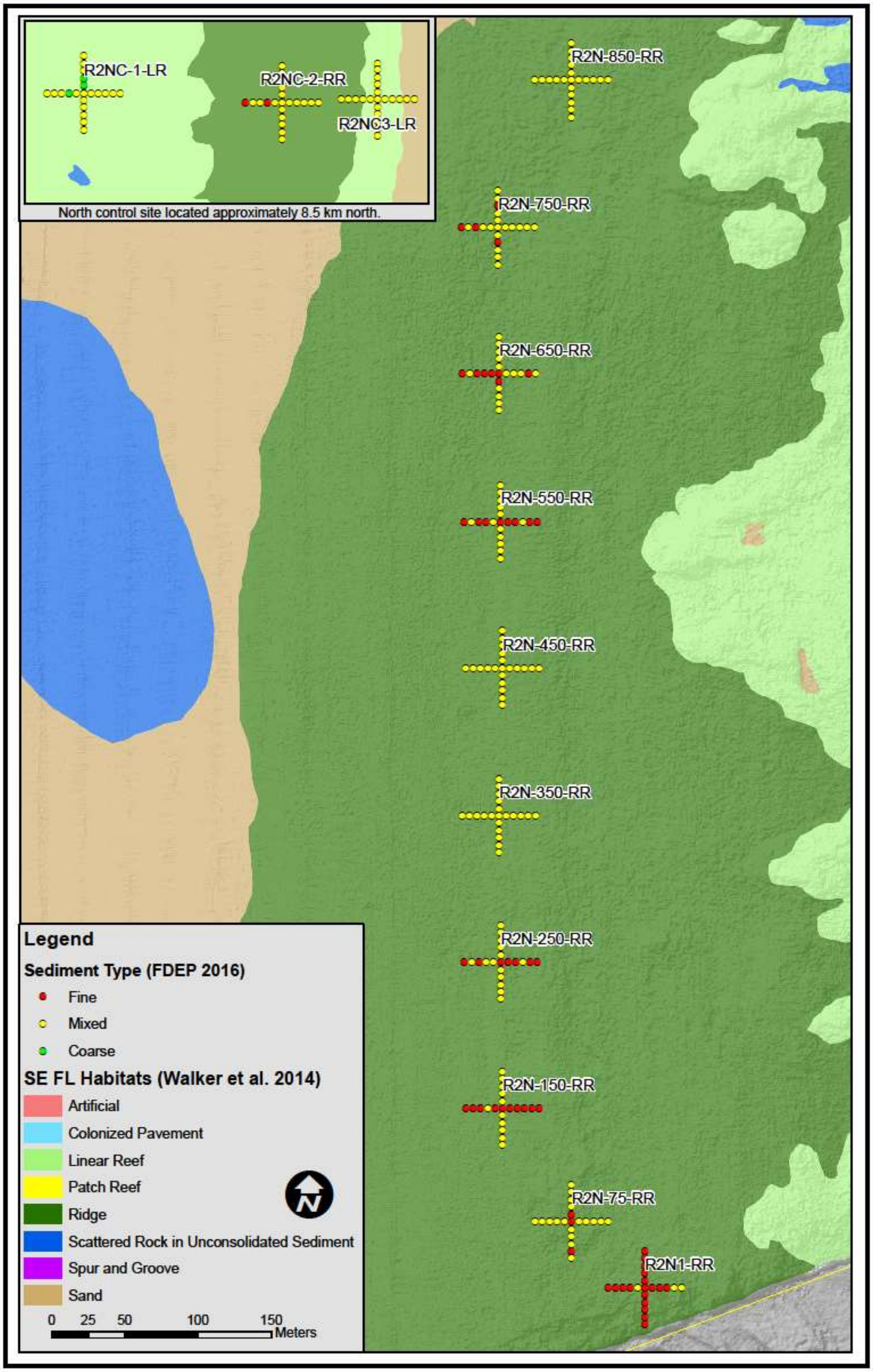


Figure 45. **Sediment type as assessed every 5m at northern middle reef ridge reef sites.**

Mean sediment depth of near-channel sites in the northern middle reef linear reef (LR) habitat ranged from 0.4 cm (R2N-350-LR) to 2.2 cm R2N1-LR. Mean sediment depth at northern middle reef linear reef control sites ranged from 0.4 to 0.8 cm. Only three linear reef sites had mean sediment depths higher than the range documented at linear reef controls, R2N1-LR (2.2 cm), which was more than a cm higher than habitat controls and R2N-150-LR (1.0 cm) and R2N-450-LR (1.0 cm) that were within 2 mm of habitat control sites. None of the northern middle reef linear reef sites had mean sediment depth levels above the 5 cm threshold for dense coral community establishment or 3 cm threshold recommended for *Acropora cervicornis* restoration guidelines.

Since sediment depth of R2N-150-LR and R2N-450-LR is within 2 mm of the mean sediment depth of one of the habitat control sites we do not consider these site of potential permanent impact. At R2N1-LR where mean sediment depth is more than a cm above habitat controls, determining the extent that sediment at site R2N1-LR is related to construction activity is in-exact without baseline sediment depth information, however, qualitative sediment data were collected. Twelve (12) out of 22 (55%) sediment assessment locations at R2N1-LR were characterized as "fine" sediment, but areas of fine sediment were shallow with a maximum fine sediment depth of 0.5 cm. All areas of deep sediment over hardbottom (>4 cm) at cross site R2N1-LR were characterized as "mixed" sediment with no layering. The deep pockets of sand are known to pervade the northern middle reef habitat and large pockets are defined in the Walker et al. (2014) habitat map (Figure 46). The deep pockets of sand that were encountered at cross site R2N1-LR are visible on the side-scan data of the northern middle reef habitat (Figure 46). The fact that the deep pockets of sediment documented during the impact assessment survey were "mixed" with no layering as opposed to the "fine" or "clay-like" texture that characterized previous surveys of dredge-sediment indicates that these deep pockets contain mostly typical reef sediment. The presence of natural sand pockets at R2N1-LR pre-dates PortMiami construction as evidenced in baseline photos (Figure 47). The shallow deposits of fine sediment observed at R2N1-LR may be a result of PortMiami construction, but given that the depth of any locations of fine sediment was within the levels measured at northern middle reef control sites (0.3-0.8 cm), and are well below the 3 cm *Acropora* restoration benchmark suggests that the depth of these sediments is consistent with those natural reef sedimentation and are not considered impacted. The lack of permanent impact at R2N1-LR is supported by percent cover analysis at R2N2-LR, which is in the same general area as R2N1-LR but was given a different name in the cross site impact assessment surveys, in which the percentage of sand cover has declined since post-construction to near-baseline levels (baseline sand cover was 20.5% and impact-assessment sand cover was 21.4%) (DCA 2017). These results highlight the value of repeated measures monitoring in assessing sediment impact since sediment depth at R2N1-LR is greater than that experienced at the habitat control, but repeated sampling indicated that the overall cover was consistent with pre-dredging values. This information combined with the lack of deep, fine sediment indicate no permanent impact of dredge sediment at this site.

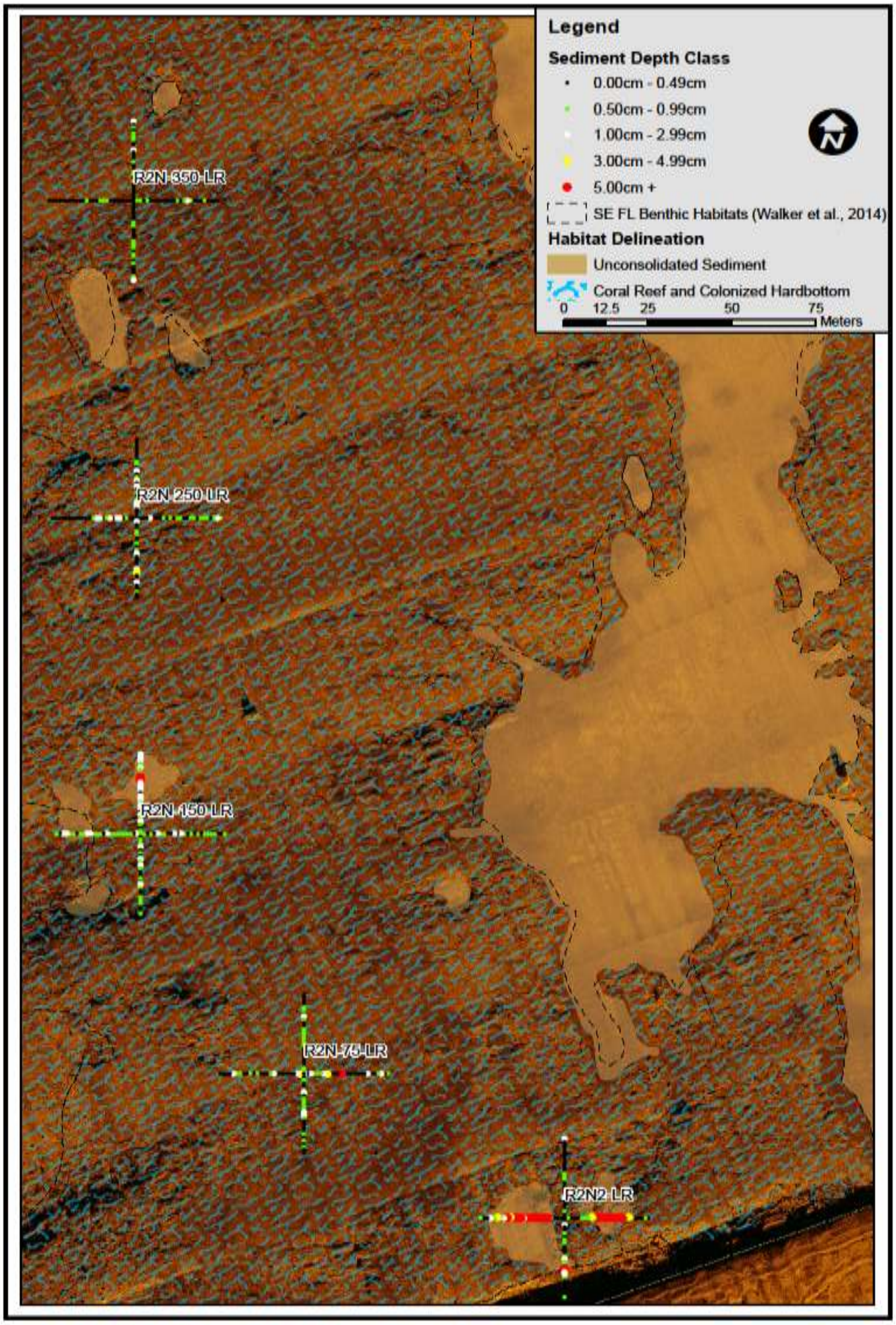


Figure 46. Middle linear reef north cross site locations overlaid on side-scan data of the northern middle reef linear reef habitat. Horizontal lines are artifacts of side scan data collection as adjacent sonar transects interface. Slight offsets in sediment depth and side scan mapped sand pockets may occur due to inherent rugosity differences between linear measurements, actual geometric surface area, and sonar image mosaics.

Figure 47. Photograph of permanent site R2N2-LR taken during the first week of middle reef baseline surveys (11/20/2013). Maintenance dredging began in the hardbottom habitat on 11/20/2013, more than 750 m away, as allowed by permit. The sediment pictured accumulated prior to dredge operations.

Mean sediment depth of near-channel sites in the southern middle reef ridge reef (RR) habitat did not vary considerably and ranged from 0.6 cm (R2S-300-RR) to 0.8 cm at R2S-400-RR. The southern middle reef ridge reef control had a mean sediment depth of 0.5 cm (Figure 48). Fine sediment was not encountered at any sediment assessment location in the southern ridge reef habitat. The lack of fine sediments in the southern ridge reef habitat coupled with the fact that mean sediment levels of all near-channel sites were within 3 mm of the ridge reef control suggests these sites were not permanently impacted by dredge-related sedimentation.

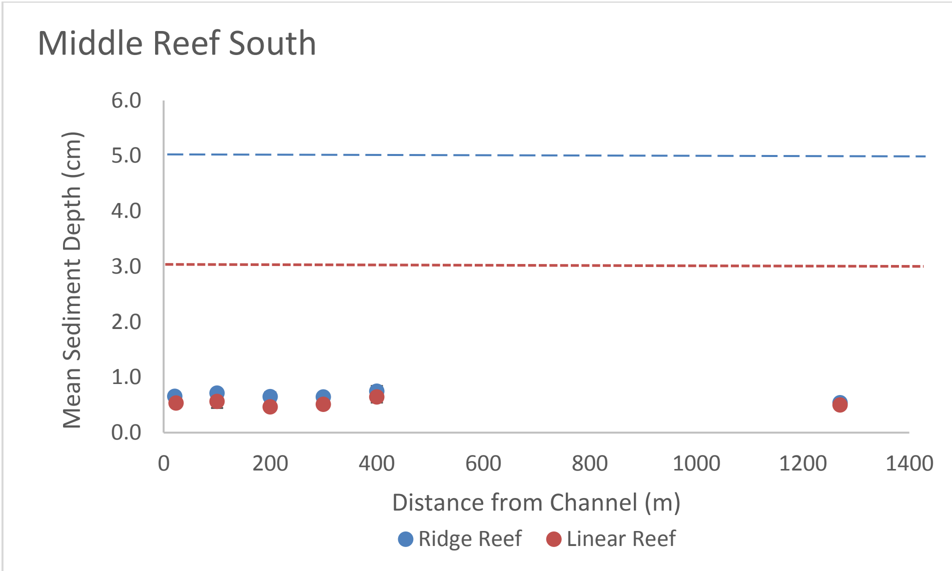


Figure 48. Mean sediment depth of southern middle reef sites plotted against the distance of the site from the channel. Blue points are middle reef ridge reef habitat and orange points are from linear reef habitat. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

Mean sediment depth of near-channel sites in the southern middle reef linear reef (LR) habitat did not vary considerably and ranged from 0.5 cm (R2S2-LR, and R2S-300-LR) to 0.7 cm at R2S-400-LR. The southern middle reef linear reef control had a mean sediment depth of 0.5 cm (Figure 48). Fine sediment was not encountered at any sediment assessment location in the southern linear reef habitat, where all sediment was characterized as mixed (Figure 49). The lack of fine sediments in the southern linear reef habitat coupled with the fact that mean sediment levels of all near-channel sites were within 2 mm of the ridge reef control site suggests the near-channel areas are no longer being impacted by significant dredge-related sedimentation.

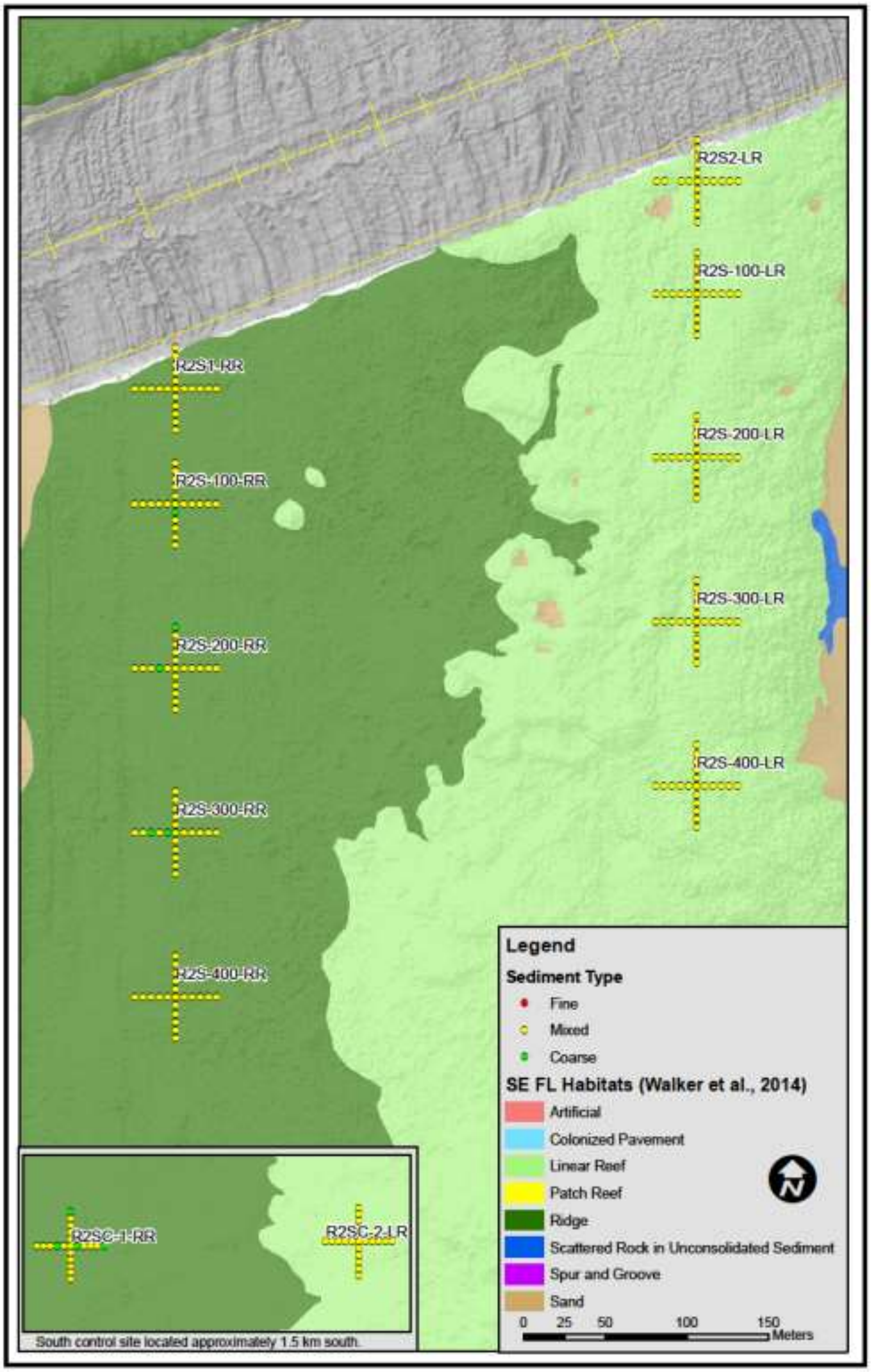


Figure 49. Sediment type as assessed every 5m at southern middle reef sites.

3.4.2 Scleractinian Corals

In the following sections the numbers of corals, coral density, coral recruit density (<3 cm), and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality are presented for the middle reef habitat. In addition, indicators of sediment stress including the percentage of corals with the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA), and complete burial (BUR) are reported for the middle reef habitat.

Overall, scleractinian densities documented in 2016 were lower than densities measured in 2010 surveys at nearly all distances from the PortMiami channel. The change in coral density throughout the survey corridor is principally due to the impacts of white-plague disease.

3.4.2.1 Scleractinian Density

In 2010 surveys of the middle reef ridge reef habitat were assessed as part of a preliminary baseline survey of reef habitat near the PortMiami entrance channel. Although the sites surveyed in 2010 were different survey sites and used different methodology, these results provide a general guide to 2010 coral densities in the middle reef ridge reef habitat. In 2010 near-channel coral density of the northern middle reef ridge reef habitat ranged from 0.7 corals/m^2 at R2N020 to 4.7 corals/m^2 at site R2N100 (Figure 50). In 2016 coral density at near-channel sites from the EW sample line ranged from 0.6 to 1.4 corals/m^2 and from 0.4 to 0.95 corals/m^2 on the NS sample line in the northern middle reef ridge reef habitat (Figure 50, Table 17, 18). The middle reef ridge reef north control site (R2NC2-RR) had coral density of 1.6 corals/m^2 on the EW sample line and 1.4 corals/m^2 on the NS sample line.

No baseline data were collected in the northern linear reef habitat in 2010 (Figure 1). In 2016 coral density in the northern middle reef linear reef habitat ranged from ranged from 0.3 to 2.2 corals/m^2 on the EW sample line and from 0.6 to 2.2 corals/m^2 on the NS sample line (Figure 50, Table 17, 18). The middle linear reef north control sites (R2NC1-LR and R2NC3-LR) had coral densities of 2.6 and 1.4 corals/m^2 respectively on the EW sample line, and 2.4 and 1.4 corals/m^2 respectively on the NS sample line (Table 17, 18).

In 2010 near-channel coral density of the southern middle reef ridge reef habitat ranged from 0.3 corals/m^2 at R2S500 to 4.2 corals/m^2 at site R2S040 (Figure 51). In 2016, coral density at near-channel sites ranged from 0.8 to 1.2 corals/m^2 in the southern middle reef ridge reef habitat (Figure 51, Table 17). The middle reef ridge reef southern control site (R2SC1-RR) had coral density of 3.5 corals/m^2 (Table 17).

No baseline data were collected in the southern linear reef habitat in 2010. In 2016 coral density in the southern middle reef linear reef habitat ranged from ranged from 0.3 to 1.7 corals/m^2 (Table 17). The middle linear reef southern control site (R2SC2-LR) had 1.6 corals/m^2 during the 2016 impact assessment survey (Table 17).

Differences in coral density in the middle reef habitat between 2010 and 2016 surveys are likely attributable to several factors, including differences in sampled areas (Figure 2), methods, as well as significant changes to coral community composition due to the species-specific white-plague event that affected Southeast Florida beginning in the fall of 2014 (Precht et al. 2016). The species-specific nature of the white-plague disease event creates a confounding mortality influence that makes control-impact site comparisons invalid unless species composition of the site is known prior to the disease event. Estimates of coral mortality as a result of the white-plague disease event ranged from 0% for abundant species *Porites astreoides* and *Siderastrea siderea* to greater than 97% mortality for species *Dichocoenia stokesi, Meandrina meandrites,* and *Eusmilia fastigata* (Precht et al. 2016). Comparison of coral density at middle reef permanent monitoring sites between baseline surveys in 2013 and 2016 using the same methods and sample area showed declines in coral density at eight of the nine middle reef sites (DCA 2017). Importantly, even when coral colonies were followed over time, no near-channel middle reef permanent monitoring site experienced greater mortality than the range predicted when species-susceptibility to white-plague disease was accounted for (DCA 2017).

At permanent monitoring sites where coral colonies were followed through time six corals out of 224 tagged corals died as a result of sediment burial representing 2.7% of all near-channel corals. The six colonies included one colony of *Dichocoenia stokes* at HBS4-CR, a *Siderastrea siderea* colony at HBN3-CP, two colonies of *S. siderea* at R2N2-LR, one *Porites porites* at R3N1-LR, and one *P. astreoides* at R3N1-LR. Over the same time period, 72 corals died of white-plague and concurrent diseases accounting for the mortality of 32.1% of all near-channel corals. The repeated monitoring of tagged corals at permanent monitoring sites allowed quantification of various causes of mortality in a way that is not possible with the single-sample survey design of the cross impact assessment sites. As a result, the quantification of the various sources of coral mortality affecting project-related resources as presented in the permanent site impact assessment report (DCA 2017) is the most accurate estimate of sediment and disease-related mortality currently available. The single-sample cross-site survey design precludes specifying causes of coral mortality, or quantifying the species-susceptibility of individual assessment sites to white-plague disease as was performed in the permanent site impact assessment report. As a result, the cross impact assessment survey design is unsuitable for providing a post-hoc quantification of dredge-related mortality on coral density given the confounding effect of significant regional mortality.

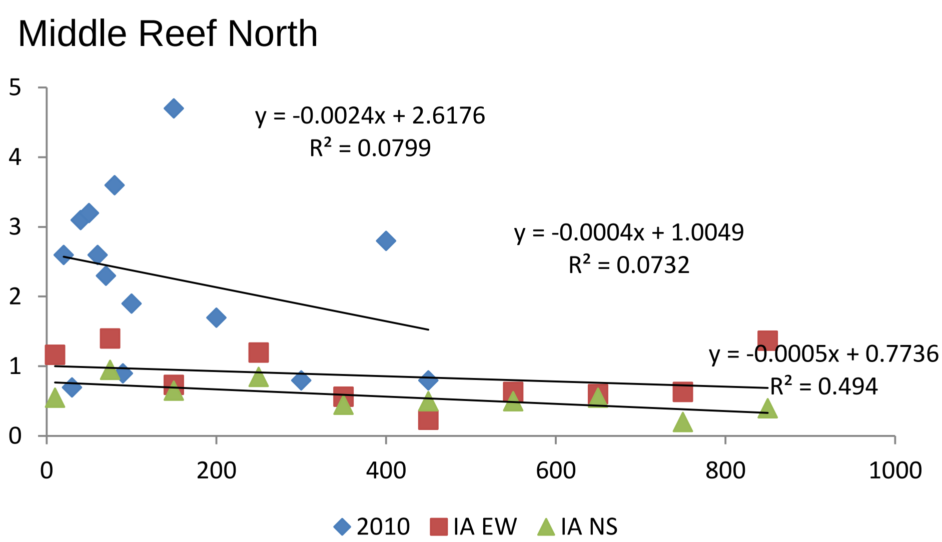


Figure 50. Coral densities of near channel survey sites with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey east-west transects (red) and north-south transects (green).

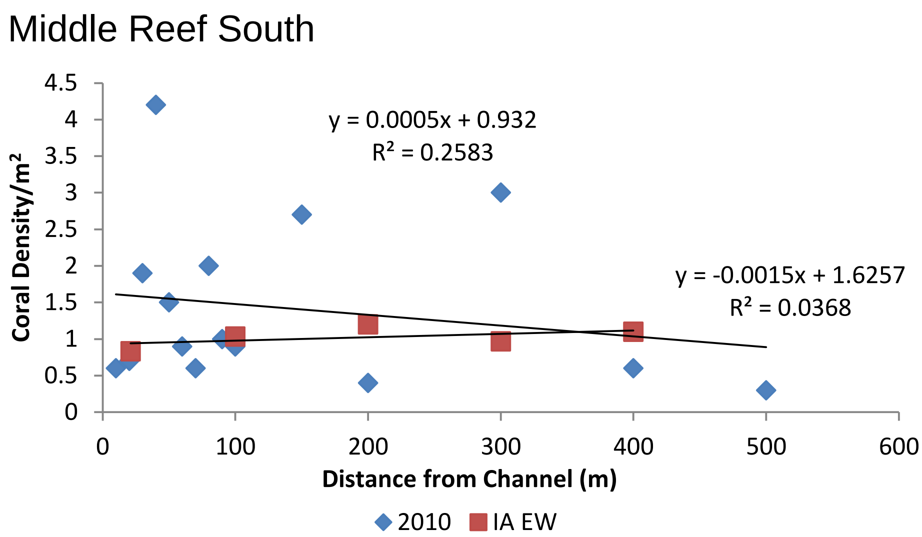


Figure 51. Coral densities of near channel survey sites with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey east-west transects (red).

Table 17. Numbers of corals, coral density, coral recruit density (≤3 cm) and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality (includes dead corals) are given for each EW survey line of each middle reef impact assessment site. Data were collected over 30 m² on the EW survey lines.

Site		Distance from Channel (m)	N	Density/ m²	Recruit density / m²	PM (%)	PMB (%)	Mean % Partial Mortality	Mean % Mortality
Middle Reef North (Ridge Reef)	R2N1-RR	28	35	1.2	0.6	2.9	97.1	13.7	37.1
	R2N-75-RR	75	41	1.4	0.3	9.8	14.6	5.5	7.7
	R2N-150-RR	150	22	0.7	0.3	36.4	50.0	15.5	45.3
	R2N-250-RR	250	35	1.2	0.6	2.9	65.7	14.1	18.8
	R2N-350-RR	350	17	0.6	0.1	11.8	70.6	23.2	45.6
	R2N-450-RR	450	7	0.2	0.0	0.0	28.6	2.1	14.4
	R2N-550-RR	550	19	0.6	0.3	26.3	10.5	5.0	18.0
	R2N-650-RR	650	18	0.6	0.3	38.9	33.3	9.7	9.7
	R2N-750-RR	750	19	0.6	0.1	42.1	47.4	27.6	54.2
	R2N-850-RR	850	41	1.4	0.9	9.8	9.8	2.5	16.7
	R2NC2-RR	9380	49	1.6	0.8	4.1	81.6	20.0	36.7
Middle Reef North (Linear Reef)	R2N1-LR	18	35	1.2	0.3	5.7	17.1	8.4	10.9
	R2N-75-LR	75	37	1.2	0.6	16.2	10.8	11.2	25.3
	R2N-150-LR	150	17	0.6	0.1	11.8	29.4	18.2	22.8
	R2N-250-LR	250	66	2.2	1.1	15.2	9.1	8.2	10.9
	R2N-350-LR	350	25	0.8	0.2	36.0	28.0	14.2	36.9
	R2N-450-LR	450	27	0.9	0.3	44.4	33.3	16.5	22.2
	R2N-550-LR	550	27	0.9	0.1	63.0	14.8	19.8	32.3
	R2N-650-LR	650	28	0.9	0.0	53.6	21.4	19.1	38.8
	R2N-750-LR	750	10	0.3	0.1	0.0	30.0	11.0	44.4
	R2N-875-LR	875	25	0.8	0.1	0.0	28.0	6.6	31.3
	R2NC1-LR	9380	79	2.6	0.5	12.7	8.9	4.4	7.9
	R2NC3-LR	9380	41	1.4	0.2	14.6	4.9	2.8	11.4

Site		Distance from Channel (m)	N	Density/ m^2	Recruit density / m^2	PM (%)	PMB (%)	Mean % Partial Mortality	Mean % Mortality
Middle Reef South (Ridge Reef)	**R2S1-RR**	23	25	0.8	0.4	16.0	20.0	9.6	13.1
	R2S-100-RR	100	31	1.0	0.5	12.9	12.9	5.7	14.0
	R2S-200-RR	200	36	1.2	0.7	11.1	5.6	4.6	14.2
	R2S-300-RR	300	29	1.0	0.8	13.8	10.3	2.7	14.5
	R2S-400-RR	400	33	1.1	0.6	9.1	18.2	6.1	8.8
	R2SC1-RR	1270	105	3.5	0.6	13.3	17.1	4.0	9.2
Middle Reef South (Linear Reef)	**R2S2-LR**	21	29	1.0	0.2	31.0	13.8	5.7	26.1
	R2S-100-LR	100	12	0.4	0.0	0.0	75.0	23.2	45.8
	R2S-200-LR	200	9	0.3	0.0	44.4	44.4	20.4	62.3
	R2S-300-LR	300	25	0.8	0.4	20.0	8.0	7.4	22.8
	R2S-400-LR	400	51	1.7	0.5	9.8	31.4	8.0	20.4
	R2SC2-LR	1270	47	1.6	0.4	23.4	14.9	9.8	18.4

Table 18. Numbers of corals, coral density, coral recruit density (≤3 cm) and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality (includes dead corals) are given for each NS survey line of each middle reef impact assessment site. Data were collected over 20 m² on the NS survey line.

Site		Distance from Channel (m)	N	Density/ m²	Recruit density/ m²	PM (%)	PMB (%)	% Mean Partial Mortality	% Mean Mortality
Middle Reef North (Ridge Reef)	R2N1-RR	28	9	0.5	0.1	55.6	22.2	14.1	40.5
	R2N-75-RR	75	19	1.0	0.4	47.4	10.5	9.7	36.5
	R2N-150-RR	150	13	0.7	0.3	15.4	69.2	11.5	23.3
	R2N-250-RR	250	17	0.9	0.2	11.8	64.7	12.6	29.3
	R2N-350-RR	350	9	0.5	0.1	11.1	55.6	10.8	19.7
	R2N-450-RR	450	9	0.5	0.1	0.0	44.4	22.2	36.4
	R2N-550-RR	550	10	0.5	0.2	20.0	60.0	18.0	41.4
	R2N-650-RR	650	11	0.6	0.0	45.5	27.3	14.7	27.8
	R2N-750-RR	750	3	0.2	0.1	66.7	0.0	8.3	69.4
	R2N-850-RR	850	8	0.4	0.2	25.0	0.0	1.5	28.4
	R2NC2-RR	9380	28	1.4	0.6	0.0	82.1	15.0	25.6
Middle Reef North (Linear Reef)	R2N1-LR	18	27	1.4	0.4	0.0	11.1	1.9	11.7
	R2N-75-LR	75	16	0.8	0.4	0.0	6.3	1.9	21.5
	R2N-150-LR	150	23	1.2	0.5	13.0	8.7	4.8	18.9
	R2N-250-LR	250	44	2.2	0.6	34.1	6.8	11.3	15.2
	R2N-350-LR	350	19	1.0	0.4	36.8	0.0	9.5	21.8
	R2N-450-LR	450	17	0.9	0.3	5.9	23.5	17.1	21.7
	R2N-550-LR	550	11	0.6	0.2	54.5	18.2	20.5	66.3
	R2N-650-LR	650	18	0.9	0.4	44.4	5.6	13.6	32.4
	R2N-750-LR	750	25	1.3	0.7	0.0	4.0	4.8	8.5
	R2N-875-LR	875	18	0.9	0.4	16.7	27.8	14.7	36.0
	R2NC1-LR	9380	47	2.4	0.1	6.4	4.3	3.7	7.6
	R2NC3-LR	9380	28	1.4	0.0	32.1	10.7	10.9	22.0

3.4.2.2 Scleractinian Recruit Density

Coral recruit density, defined as corals 3 cm and less, was low across the middle reef ridge reef habitat. Near-channel recruit density ranged from 0.0 (R2N-450-RR) to 0.9 corals/m^2 (R2N-850-RR) on the EW survey line and from 0.0 (R2N-650-RR) to 0.4 corals/m^2 (R2N-75-RR) on the NS survey line in the northern middle reef ridge reef habitat (Table 17, 18). Coral recruit density at the middle reef northern control was 0.8 corals/m^2 on the EW survey line and was 0.6 corals/m^2 on the NS survey line (Table 17, 18). On the EW survey line coral recruit density was higher at sites closest to the channel and declined between 450 and 750 m from the channel. The coral recruit pattern mirrors that of total coral density on the EW survey line and that established in 2010 baseline surveys in which a negative relationship between coral density and distance from the channel was documented (DCA 2012). The NS survey line followed a similar pattern with recruit density being highest between 75 and 150m from the channel with lower densities documented with distances from the channel.

In the northern middle reef linear reef habitat near-channel recruit density ranged from 0.0 (R2N-650-LR) to 1.1 corals/m^2 (R2N-250-LR) on the EW survey line and from 0.2 (R2N-550-RR) to 0.7 corals/m^2 (R2N-750-LR) on the NS survey line in the northern middle reef ridge reef habitat (Table 17, 18). Coral recruit density at the middle reef linear reef northern control sites was 0.5 corals/m^2 at R2NC1-LR and 0.2 corals/m^2 at R2NC3-LR on the EW survey line and 0.1 corals/m^2 at R2NC1-LR and 0.0 corals/m^2 at R2NC3-LR on the NS survey line. In the ridge reef habitat recruit densities on the EW line were lowest between 550 and 875 m from the channel but no directional pattern was evident on the NS line where recruit density was lowest at the habitat control (R2NC3-LR, 0.0 corals/m^2). As a result, coral densities were higher at near-channel sites when compared to habitat controls on the NS survey line.

At southern middle reef impact assessment sites coral data were only surveyed on the EW line. In the southern middle reef ridge reef habitat coral recruit densities ranged from 0.4 to 0.8 corals/m^2 at near-channel sites and 0.6 corals/m^2 at the middle reef ridge reef southern control (R2SC1-RR) (Table 17). Only R2S1-RR and R2S-100-RR had lower coral recruit densities than the habitat control. It is unclear if the pattern of lower recruit density at near-channel sites is a result of construction activities or is a factor of the lower overall coral density found at the near-channel sites when compared with the habitat control.

In the southern middle reef linear reef habitat coral recruit densities ranged from 0.0 to 1.7 corals/m^2 at near-channel sites and 0.4 corals/m^2 at the middle reef linear reef southern control (R2SC2-LR) (Table 17). With the exception of R2S-400-LR (coral density 1.7 corals/m^2), the near-channel sites of the linear reef habitat had the same or lower coral recruit densities than the habitat control. It is unclear if the pattern of lower recruit density at near-channel sites is a result of construction activities or is a factor of the lower overall coral density found at the near-channel sites when compared with the habitat control.

3.4.2.3 In-situ Scleractinian Mortality Assessments

Corals from the 2016 cross survey were not followed through time and thus no temporal assessment of partial or total mortality is available at any cross impact assessment site. Qualitative indicators of the relative health of corals were collected during the 2016 impact assessment and included: the percentage of corals showing signs of partial mortality (anywhere not including the base), partial mortality and base (any partial mortality that included the base of the coral), percent partial mortality, and percent mean mortality (that includes standing dead corals) are provided in Table 17 and 18.

In the northern middle reef ridge reef habitat, the percentage of corals with some level of partial mortality ranged from 0.0% at R2N-450-RR to 42.1% at site R2N-750-RR on the EW survey line (Table 17) and 0.0% at R2N-450-RR to 66.7% at site R2N-750-RR on the NS survey line (Table 18). The number of corals with partial mortality of the base on the EW line was lowest at site R2N-850-RR (9.8%) and was highest at R2N1-RR where 97.1% of corals had some level of coral mortality that included the base of the colony. On the NS line partial mortality of the base ranged from 0.0% (R2N1-750-RR and R2N1-850-RR) to 82.1% at the middle reef ridge reef control (R2NC2-RR). While partial mortality of the base was less than the habitat control at all sites on the NS line, R2N1-RR had higher partial mortality of the base than the habitat control on the EW line (97.1% at R2N1-RR EW compared to 81.6% at R2NC2-RR). The high estimate of the number of corals with partial mortality at the base at the cross site location R2N1-RR is consistent with the estimated number of corals that were affected by sediment during construction at permanent site location R2N1-RR where 94% of corals were observed by divers to have some level of sediment related partial mortality (DCA 2017). However, the corresponding high level of partial mortality of the base at R2NC2-RR (82.1%) suggests that this metric is not a reliable indicator of construction impacts as the majority of corals at R2NC2-RR (82.1%) were found with partial mortality near the base of the coral, but no construction influences were observed at this habitat control site.

Partial Mortality of the Base
R2N1-RR is the near-channel site with the highest rate of partial mortality of the base, where 97.1% of corals had some level of coral mortality that included the base of the colony. However, the second highest level of partial mortality of the base occurred at the habitat control R2NC2-RR where 82.1% of colonies had some level of coral mortality that included the base of the coral. The high natural rate of partial mortality of the base documented at habitat control sites suggests that the metric of partial mortality of the base is not a reliable indicator of construction impacts as the majority of corals at R2NC2-RR (82.1%) were found with partial mortality near the base of the coral, but no construction influences were observed at this site.

The mean % partial mortality of corals ranged from 2.1% at R2N-450-RR to 27.6% at site R2N-750-RR on the EW survey line (Table 17) and 8.3% at R2N-750-RR to 22.2% at site R2N-450-RR on the NS survey line (Table 18). Percent mean mortality that included standing dead corals, ranged from 9.7% at R2N-650-RR to 54.2% at site R2N-750-RR on the EW survey line and 19.7% at R2N-350-RR to 69.4% at site R2N-750-RR on the NS survey line. Percent mean mortality at the middle reef ridge reef control (R2NC2-RR) was 36.7% on the EW survey line (Table 17) and 25.6% on the NS survey line.

In the northern middle reef linear reef habitat partial mortality ranged from 0.0% at R2N-750-LR and R2N-875-LR to 63.1% at site R2N-550-RR on the EW survey line (Table 12) and 0.0% at R2N1-LR, R2N-75-LR, and R2N-750-LR to 54.5% at site R2N-550-LR on the NS survey line (Table 18). Partial mortality of the base on the EW line was lowest at R2NC3-LR (4.9%) and was highest at R2N-450-LR where 33.3% of corals had some level of coral mortality that included the base of the colony. On the NS line partial mortality of the base ranged from 0.0%

(R2N-350-RR) to 27.8% at the middle reef ridge reef control (R2N-875-LR). The mean percent partial mortality of corals in the northern linear reef habitat ranged from 2.8% at R2NC3-LR to 19.8% at site R2N-550-LR on the EW survey line and 1.9% at R2N1-LR and R2N-75-LR to 20.5% at site R2N-550-LR on the NS survey line. Percent mean mortality that includes standing dead corals, ranged from 7.9% at R2NC1-LR to 44.4% at site R2N-750-LR on the EW survey line and 7.6% at R2NC1-LR to 66.3% at site R2N-550-LR on the NS survey line. Percent mean mortality at the middle reef linear reef control sites was 7.9% at R2NC1-LR and 11.4% at R2NC3-LR on the EW survey lines and 7.6% at R2NC1-LR and 22.0% at R2NC3-LR on the NW survey lines.

In the southern middle reef ridge reef habitat the number of corals with some partial coral mortality (that did not include the base) ranged from 9.1% at R2S-400-RR to 16.0% at site R2S1-RR (Table 17). Partial mortality of the base was lowest at impact assessment site R2S-200-RR (5.6%) and was highest at R2S1-RR where 20% of corals had some level of coral mortality that included the base of the colony. The southern middle reef ridge reef control had 17.1% of corals with some level of partial morality of the base of the colony. The mean percent partial mortality of corals at each southern middle reef ridge reef assessment site ranged from 2.7% at site R2S-300-RR to a maximum level of 9.6% at R2S1-RR. Percent mean mortality that includes standing dead corals, ranged from 8.8% at site R2S-400-RR to 14.5% at R2S-300-RR.

In the southern middle reef linear reef habitat the number of corals with some partial coral mortality (that did not include the base) ranged from 0.0% at R2S-100-LR to 44.4% at site R2S-200-LR (Table 17). Partial mortality of the base was lowest at impact assessment site R2S-300-LR (8.0%) and was highest at R2S-100-LR where 75.0% of corals had some level of coral mortality that included the base of the colony. The southern middle reef linear reef control had 14.9% of corals with some level of partial morality of the base of the colony. The mean percent partial mortality of corals at each southern middle reef linear reef assessment site ranged from 5.7% at site R2S2-LR to a maximum level of 23.2% at R2S-100-LR. Percent mean mortality, which includes standing dead corals, ranged from 18.4% at site R2S-400-LR to 62.3% at R2S-200-RR.

Planimetry measurements of tagged colonies between baseline and impact assessment surveys, at R2N1-RR, the permanent site with the highest proportion of corals with sediment-related partial mortality (which is the same general location as the middle reef impact assessment site with the highest level of partial mortality of the base 97.1%), were not significantly different than the changes in coral area measured at the paired control R2NC2-RR. Although dredging affected channel-side corals as partial mortality, between baseline and impact assessment (-12.3%), there was no statistical difference in total tissue loss when compared to the paired control (-11.6%) (DCA 2017).

Since the species composition of each impact assessment site was not known prior to the 2016 survey, the level of coral mortality that is likely attributable to the region-wide white-plague disease event that started in 2014, cannot be evaluated as provided in the permanent site impact assessment report (DCA 2017). As a result, the relative impact of the disease event vs. construction impacts is unknown at cross site impact assessment locations. The coral mortality analysis provided in the permanent site report is a more robust analysis of potential construction impacts due to the fact that sources of coral mortality were quantified and the species-susceptibility to the ongoing disease event of individual sites was taken into account when analyzing coral mortality over the duration of the construction project (DCA 2017). It is important to note that since no previous data has been collected on the corals at the cross impact assessment sites, that the qualitative estimates of mortality provided above are inclusive of old mortality (that may pre-date construction activities), new mortality, all disease-related mortality, and potential construction-related coral mortality and that these factors cannot be separated in this post-hoc analysis.

3.4.2.4 Scleractinian Condition

Coral condition data in 2010 were collected using different methods and is not comparable to 2016 impact assessment condition indicators. In particular, no sediment related condition codes were collected in 2010 and as a result, no temporal conclusions can be drawn with respect to qualitative coral condition at the cross impact assessment sites. Sediment coral condition are presented for data collected on EW transect lines in the middle reef habitat in Table 19 and for data collected on the NS transect lines in Table 20.

Sediment was associated with many corals in the northern middle ridge reef habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) ranged from 0.0% at both R2N1-RR and R2NC2-RR to 25.7% at R2N-250-RR on the EW survey line (Table 19) and from 0.0% (R2N-75-RR, R2N-550-RR, R2N-650-RR, R2N-750-RR) to 22.2% at sites R2N1-RR and R2N-450-RR on the NS survey line (Table 20). Sediment accumulation (SA) ranged from 0.0% at sites R2N-750-RR and R2N-450-RR to 20.0% at site R2N1-RR on the EW survey line and from 0.0% (at sites 150, 250, 450, 550, 650, and 750m from the channel) to 22.2% at R2N1-RR on the NS survey line. Partial burial of the base (PBB) ranged from 4.9% at R2N-75-RR to 82.9% at R2N1-RR on the EW survey line and from 11.1% at site R2N-450-RR to 78.9% at site R2N-75-RR on the NS survey line. Partial burial of the base was also high at the middle reef ridge reef control (R2NC2-RR) with 71.4% of corals on both the EW and NS survey lines having their base partially buried by sediment. Burial of the base (BBA) ranged from 0.0% (R2N1-RR, R2N-150-RR, R2N-750-RR, and R2NC2-RR) to 42.9% of corals with their bases buried at site R2N-450-RR on the EW survey line and from 0.0% (R2N1-RR, R2N-75-RR, R2N-150-RR, R2N-350-RR, R2N-650-RR, R2N-750-RR and R2NC2-RR) to 41.2% at R2N-250-RR on the NS survey line. Burial (BUR) was only observed at sites R2N-250-RR and R2N-550-RR on the EW survey lines and affected less than 10.5% of corals at these two sites. On the NS survey line, burial was only noted at R2N-350-RR and only affected 11.1% corals at that site.

In the northern middle reef linear reef habitat corals with the appearance of a sediment dusting (SED category) ranged from 0.0% at both R2N-450-LR and R2N-650-LR to 29.4% at R2N-150-LR on the EW survey line (Table 19) and from 0.0% (R2NC3-LR) to 31.3% at site R2N-75-LR on the NS survey line (Table 20). Sediment accumulation (SA) ranged from 0.0% at site R2NC1-LR to 50.0% at site R2N-750-LR on the EW survey line and from 0.0% (at sites R2N-75-LR, R2N-875-LR, and R2NC3-LR) to 27.3% at R2N1-550-LR on the NS survey line. Partial burial of the base (PBB) ranged from 2.7% at R2N-75-LR to 44.4% at R2N-450-LR on the EW survey line and from 0.0% at site R2N-350-RR to 64.0% at site R2N-750-LR on the NS survey line. Burial of the base (BBA) ranged from 0.0% at most northern middle reef linear reef sites to 16.2% of corals with their bases buried at site R2N-75-LR on the EW survey line. No corals were noted with their bases buried at any northern middle reef linear reef impact assessment site on the NS survey line. Burial (BUR) was not observed on the ES or NS survey lines at any northern middle reef linear reef site.

Sediment was associated with many corals in the southern middle reef ridge reef habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was lowest at site R2S-300-RR where 0.0% of corals were documented with sediment dusting and highest at R2S1-RR where 16.7% of corals were noted with sediment dusting (Table 19). Sediment accumulation (SA) ranged from 0.0% at R2S-300-RR to 9.7% at site R2S-100-RR. Partial burial of the base (PBB) ranged from 0.0% at sites R2S-300-RR and R2S-400-RR to 30.6% at R2S-200-LR. Burial of the base (BBA) ranged from 2.9% at R2SC1-RR to 41.4% at R2S-300-LR. Burial (BUR) was not documented in the southern middle reef ridge reef habitat.

Sediment was associated with many corals in the southern middle reef linear reef habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was lowest at site R2S2-LR where 0.0% of corals were documented with sediment dusting and highest at R2S-200-LR where 44.4% of corals were noted with sediment dusting (Table 19). Sediment accumulation (SA) ranged from 2.1% at R2SC2-LR to 28.0% at site R2S-300-LR (Table 19). Partial burial of the base (PBB) ranged from 0.0% at sites R2S-200-LR and R2S-300-LR to 17.0% at R2SC2-LR. Burial of the base (BBA) ranged from 0.0% at R2S-100-LR to 40.0% at R2S-300-LR. Burial (BUR) was not documented in the southern middle reef linear reef habitat.

Since sedimentation is known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data were available with respect to coral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts compared with natural fluctuations of sediment indicators. In addition, sediment indicators vary considerably under normal conditions due to the passage of storm events (DCA 2014a). Since the 2016 cross impact assessment data were collected between September 12th, 2016 and May 30th, 2017, during which a hurricane (Hurricane Matthew, October 8th, 2016) and several winter storms affected the survey area, it is likely that many of the sediment related indicators are reflective of these storm events. At permanent sites where sediment indicators were taken with the same methods, on the same corals at baseline and during the post-construction impact assessment surveys, the mean proportion of corals exhibiting sediment stress was equivalent to or below baseline values for all near-channel middle reef sites (DCA 2017).

Table 19. Distances of each middle reef monitoring site from the PortMiami channel provided along with the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR) from the EW survey lines at the 2016 middle reef impact assessment monitoring sites. Data were collected over 30 m² on the EW survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef North (Ridge Reef)	R2N1-RR	28	0.0	20.0	82.9	0.0	0.0
	R2N-75-RR	75	19.5	7.3	4.9	9.8	0.0
	R2N-150-RR	150	4.5	0.0	68.2	0.0	0.0
	R2N-250-RR	250	25.7	17.1	42.9	40.0	2.9
	R2N-350-RR	350	0.0	11.8	41.2	5.9	0.0
	R2N-450-RR	450	0.0	0.0	28.6	42.9	0.0
	R2N-550-RR	550	21.1	5.3	31.6	42.1	10.5
	R2N-650-RR	650	11.1	11.1	27.8	33.3	0.0
	R2N-750-RR	750	0.0	0.0	63.2	0.0	0.0
	R2N-850-RR	850	12.2	17.1	14.6	19.5	0.0
	R2NC2-RR	9380	0.0	6.1	71.4	0.0	0.0
Middle Reef North (Linear Reef)	R2N1-LR	18	22.9	8.6	8.6	0.0	0.0
	R2N-75-LR	75	13.5	5.4	2.7	16.2	0.0
	R2N-150-LR	150	29.4	41.2	47.1	5.9	0.0
	R2N-250-LR	250	24.2	16.7	24.2	0.0	0.0
	R2N-350-LR	350	8.0	28.0	24.0	0.0	0.0
	R2N-450-LR	450	0.0	18.5	44.4	0.0	0.0
	R2N-550-LR	550	3.7	18.5	14.8	0.0	0.0
	R2N-650-LR	650	0.0	10.7	7.1	0.0	0.0
	R2N-750-LR	750	10.0	50.0	10.0	0.0	0.0
	R2N-875-LR	875	24.0	20.0	12.0	12.0	0.0
	R2NC1-LR	9380	10.1	0.0	8.9	2.5	0.0
	R2NC3-LR	9380	2.4	2.4	24.4	0.0	0.0
Middle Reef South (Ridge Reef)	R2S1-RR	23	16.0	4.0	12.0	8.0	0.0
	R2S-100-RR	100	9.7	9.7	25.8	29.0	0.0
	R2S-200-RR	200	13.9	5.6	30.6	11.1	0.0
	R2S-300-RR	300	0.0	0.0	0.0	41.4	0.0
	R2S-400-RR	400	9.1	6.1	0.0	15.2	0.0
	R2SC1-RR	1270	10.5	5.7	4.8	2.9	0.0

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef South (Linear Reef)	R2S2-LR	21	0.0	3.4	10.3	24.1	0.0
	R2S-100-LR	100	25.0	16.7	8.3	0.0	0.0
	R2S-200-LR	200	44.4	11.1	0.0	22.2	0.0
	R2S-300-LR	300	16.0	28.0	0.0	40.0	0.0
	R2S-400-LR	400	2.0	21.6	11.8	9.8	0.0
	R2SC2-LR	1270	17.0	2.1	17.0	4.3	0.0

Table 20. Distances of each middle reef monitoring site from the PortMiami channel provided along with the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR) from the NS survey lines at the 2016 middle reef impact assessment monitoring sites. Data were collected over 20 m^2 on the NS survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef North (Ridge Reef)	R2N1-RR	28	22.2	22.2	44.4	0.0	0.0
	R2N-75-RR	75	0.0	5.3	78.9	0.0	0.0
	R2N-150-RR	150	15.4	0.0	69.2	0.0	0.0
	R2N-250-RR	250	11.8	0.0	11.8	41.2	0.0
	R2N-350-RR	350	0.0	22.2	33.3	0.0	11.1
	R2N-450-RR	450	22.2	0.0	11.1	11.1	0.0
	R2N-550-RR	550	0.0	0.0	10.0	30.0	0.0
	R2N-650-RR	650	0.0	0.0	27.3	0.0	0.0
	R2N-750-RR	750	0.0	0.0	33.3	0.0	0.0
	R2N-850-RR	850	12.5	12.5	25.0	12.5	0.0
	R2NC2-RR	9380	3.6	14.3	71.4	0.0	0.0
Middle Reef North (Linear Reef)	R2N1-LR	18	25.9	14.8	11.1	0.0	0.0
	R2N-75-LR	75	31.3	0.0	18.8	0.0	0.0
	R2N-150-LR	150	13.0	8.7	30.4	0.0	0.0
	R2N-250-LR	250	22.7	2.3	4.5	0.0	0.0
	R2N-350-LR	350	26.3	5.3	0.0	0.0	0.0

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
	R2N-450-LR	450	17.6	11.8	29.4	0.0	0.0
	R2N-550-LR	550	9.1	27.3	27.3	0.0	0.0
	R2N-650-LR	650	22.2	5.6	33.3	0.0	0.0
	R2N-750-LR	750	24.0	16.0	64.0	0.0	0.0
	R2N-875-LR	875	16.7	0.0	50.0	0.0	0.0
	R2NC1-LR	9380	12.8	6.4	6.4	0.0	0.0
	R2NC3-LR	9380	0.0	0.0	7.1	0.0	0.0

Relationships between fine sediment and other coral health indicators

Only two sites had >50% of sediment assessment locations characterized as fine sediment; R2N1-RR (86% fine sediment) and R2N1-LR (55% fine sediment). The relationship between the presence of fine sediment and other coral health indicators of the same reef type was not clear. The high percentage of fine sediments at R2N1-RR did not correlate with lowest coral density, lowest recruit density, highest partial mortality, and highest mean mortality. Coral density and recruit density was lowest at R2N-450-RR (0.2 and 0.0 corals/m^2 respectively). The percent of corals with partial mortality was highest at R2N-650-RR and mean percent partial mortality and mean percent mortality were highest at R2N-750-RR (27.6% and 54.2% respectively). R2N1-RR was the site in the northern ridge reef habitat with the highest level of partial mortality of the base (97.1%). However, the second highest level of partial mortality and base (81.6%) was found at R2NC2-RR where one of the lowest percentages of fine sediment in the northern ridge reef habitat (9%) was documented.

A lack of correlation between fine sediment and coral health indicators was also noted in the northern middle reef linear reef habitat. The high percentage of fine sediments at R2N1-LR did not correlate with lowest coral density, lowest recruit density, highest partial mortality, highest partial mortality and base, or highest mean mortality. Coral density was lowest at R2N-750-LR (0.3 corals/m^2) and recruit density was lowest at R2N-600-LR (0.0 corals/m^2). The percent of corals with partial mortality was highest at R2N-550-LR (63.0%) and mean percent partial mortality was highest at R2N-550-LR (19.8%). Mean percent mortality was highest at R2N-750-LR (44.4%). R2N-450-LR was the site in the northern linear reef habitat with the highest level of partial mortality of the base (33.3%).

Relationship between fine sediment and coral health metrics
Areas where the highest percentage of fine sediment were noted were not predictive of lowest coral density, lowest recruit density, highest partial mortality, or highest mean mortality in the middle reef. The lack of correlation between fine sediment and coral health indicators is likely due to several factors including, the time passed since dredge activity, the historical health of corals at each site, the number of corals found in low relief areas or depressions within a site, the variability of white-plague disease on surveyed communities, and the natural variability inherent within the various surveyed habitats. As a result no strong relationships were found between the presence of fine sediment and coral health indicators.

The presence of a large percentage of fine sediment was not predictive of other coral health metrics in the middle reef habitat. The lack of correlation between fine sediment and coral health indicators is likely due to several factors including, the time passed since dredge activity, the historical health of corals at each site, the number of corals found in low relief areas or depressions within a site, the variability of white-plague disease on surveyed communities, and the natural variability inherent within the various surveyed habitats. As a result no strong relationships were found between the presence of fine sediment and coral health indicators.

3.4.2.5 ESA listed species

Of the seven coral species currently listed as "threatened" under the Endangered Species Act only three, *Acropora cervicornis, Orbicella annularis,* and *Orbicella faveolata* were found at the cross impact assessment sites. Twenty-two colonies of *Acropora cervicornis* were documented along transects (Figure 52). No *Acropora* was documented within hardbottom or outer reef habitats, this is consistent with previous documented occurrences. These on-transect colonies were present at nine sites: seven sites on Reef 2 North (R2N1-RR, R2N-150-RR, R2N-350-RR, R2N-450-RR, R2N-550-RR, R2N-650-RR, and R2N-750-RR) and two sites on Reef 2 South (R2SC1-RR, R2S-300-LR). In addition to the twenty-two colonies documented on transects, several colonies of *A. cervicornis* were observed off-transect. Off-transect colonies were located at sites R2N1-RR, R2N-75-RR, R2N-150-RR, and R2N-450-RR. Three of these cross sites had on-transect colonies present at the time of survey; while R2N-75-RR did not have on-transect colonies. The *A. cervicornis* colonies observed at R2N-75-RR were located off the NS transect (Figure 53). In the 2010 baseline surveys, only 3 colonies of *A. cervicornis* were noted on survey transects and all three were located at R2N450, 450 m from the channel. The *A. cervicornis* colonies noted in the 2016 impact assessment survey were located at several distances from the channel including R2N1-RR, the impact assessment site located closest to the PortMiami channel. Many of the *A. cervicornis* colonies found within 450 m of the channel maybe new recruits to the habitat since all colonies within 150 m were re-located in 2013-2014 (CSA 2014a, NOAA-NMFS 2015).

Three colonies of *O. annularis* were located on impact assessment transects. All three colonies were found in the middle reef north habitats. Two colonies were located at R2N-150-LR and one colony was found at R2N-650-RR. Three colonies of *O. faveolata* were also located on impact assessment transects. Two *O. faveolata* corals were found in the middle reef north habitat (one each at site R2N1-RR and R2N-450-LR) and one colony was located at a middle reef south control (R2SC2-LR). In 2010 two colonies of *O. faveolata* were documented in survey transects near the PortMiami channel. One *O. faveolata* was found in the outer reef south direct-effect area and the other was located at R3S2150 (Site 71) (DCA 2012). One colony of *O. annularis* was documented in the 2010 baseline surveys and was located at R3N040 (Site 19) (DCA 2012).

Figure 52. *Acropora cervicornis* on NS transect at R2N-650-RR on September 28, 2016.

Figure 53. Off-transect *Acropora cervicornis* found at R2N-75-RR on September 30, 2016.

3.4.3 Octocorals

The numbers of octocorals, octocoral density, the percentage of octocorals with partial mortality, partial mortality and base, and mean percent octocoral mortality are presented for middle reef sites. Sediment-related indicators of octocoral condition are also reported.

3.4.3.1 Octocoral Density

Octocoral density data were collected in 2010 using 10 m transects spaced at regular intervals from the channel out to 450 m (DCA 2012). These data were only taken in the middle reef ridge reef habitat but they represent an independent baseline dataset that can be used for qualitative comparison of octocoral densities near the PortMiami channel. The near-channel northern middle reef ridge reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 54. In 2010 octocoral densities ranged from 6.0 octocorals/m^2 at 150 m from the channel, to 18.9 octocorals/m^2 at 450m from the channel-edge. During the 2016 impact assessment surveys near-channel octocoral densities ranged from 11.1 octocorals/m^2 at R2N1-RR (28 m from the channel) to 24.9 octocorals/m^2 at R2N-750-RR (Table 20). No control data were acquired in 2010 but in 2016 the ridge-reef control site (R2NC2-RR) had an octocoral density of 45.3 octocorals/m^2. Although the methods and site locations are not the same, the density of octocorals measured in the northern middle reef ridge reef habitat during the 2016 impact assessment are equal to or higher than values established prior to dredging in 2010 (Figure 54).

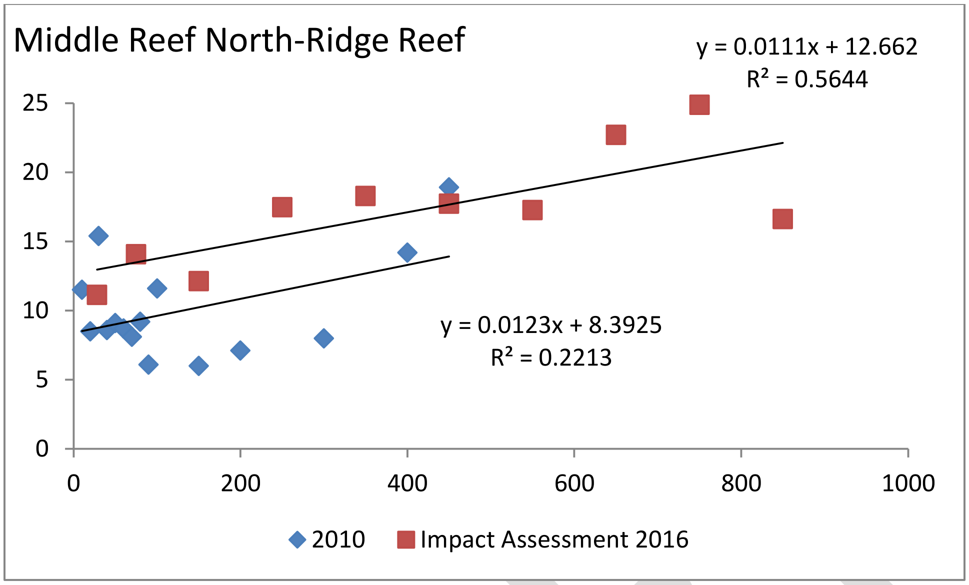


Figure 54. Octocoral densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

2010 data were not taken in the northern middle reef linear reef habitat but 2016 density data from this habitat were similar to the ridge reef habitat during the 2016 impact assessment surveys. Octocoral density at the near-channel northern middle reef linear reef sites ranged from 2.8 octocorals/m^2 at R2N1-LR to 20.8 octocorals/m^2 at R2N-550-LR (Table 21). The density of octocorals at R2N1-LR (2.8 octocorals/m^2) is the only site with octocoral density below the range from 2010. However, it is likely that the lower octocoral density at this site is due to site variability since baseline densities of octocorals at the permanent site R2N1-LR measured 1.83 octocorals/m^2 at the three 20m transects located in a similar location to the 2016 50 m x 50 m cross site location.

The fact that octocoral densities from the north linear reef were consistent with both 2010 and 2016 north ridge reef data and the fact that analysis of permanent site octocoral densities found no significant interaction between site and time period with respect to octocoral densities (DCA 2017) this suggests that there was no significant impact to octocoral densities located along the northern linear middle reef due to construction activities.

The near-channel southern middle reef ridge reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 55. In 2010 octocoral densities ranged from 0.1 octocorals/m^2 at R2S100, to 7.9 octocorals/m^2 at R2S500. During the 2016 impact assessment surveys near-channel octocoral densities ranged from 4.6 octocorals/m^2 at R2S-400-RR to 9.8 octocorals/m^2 at R2S-100-RR. No control data were acquired in 2010 but in 2016 the ridge-reef control site (R2SC1-RR) had an octocoral density of 12.5 octocorals/m^2. Although the methods and site locations are not the same, the density of octocorals measured in the southern middle reef ridge reef habitat during the 2016 impact assessment are equal to or higher than density values established prior to dredging in 2010 (Figure 55).

2010 data were not taken in the southern middle reef linear reef habitat but 2016 density data from the linear reef were slightly higher than the ridge reef habitat during the 2016 impact assessment surveys. Octocoral density at the near-channel northern middle reef linear reef sites ranged from 10.4 octocorals/m^2 at R2S2-LR and to 15.0 octocorals/m^2 at R2S-100-LR (Table 21). The southern middle reef linear reef control site (R2SC2-LR) had 10.9 octocorals/m^2. The pattern of higher density of octocorals at southern linear reef sites in comparison to ridge-reef sites was consistent in both the 2013 baseline data and permanent site impact assessment report (DCA 2014a; DCA 2017).

The fact that octocoral densities from the linear reef were higher than 2016 ridge reef values, which is consistent with the 2013 baseline data, and the fact that analysis of permanent site octocoral densities found no significant interaction between site and time period with respect to octocoral densities (DCA 2017), suggests that there is no evidence of a significant impact to octocoral densities due to construction activities at the southern middle reef.

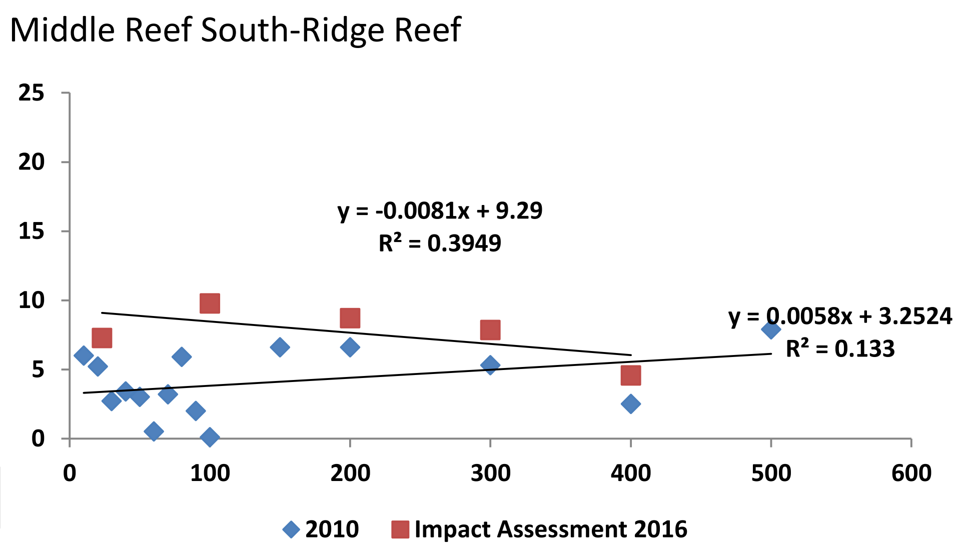


Figure 55. Octocoral densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

3.4.3.2 In-situ octocoral mortality assessments

No baseline data on octocoral condition were collected prior to impact assessment surveys and thus no temporal conclusions are available.

In-situ octocoral mortality assessments show that partial mortality was variable in the northern middle reef ridge reef habitat with levels ranging from 6.8% at R2NC2-RR to 36.5% at R2N-75-RR (Table 21). Partial mortality including the base (PMB) was variable in the northern middle reef ridge reef habitat with the highest level (12.0%) found at R2N-850-RR and the lowest value 0.0% being found near the channel at R2N-75-RR. Mean % mortality was highest at R2N1-RR (6.1%) and was lowest at R2NC2-RR (1.7%). The difference in partial mortality at all near-channel sites was 3.1% ranging from 3.0 % mean mortality at R2N-850-RR to 6.1% at R2N1-RR.

No spatial pattern of percent mortality data were evident at the northern middle reef linear reef. Partial mortality was low at the two habitat controls (8.4 and 4.6% respectively) but ranged from 23.1% to 33.9% at all near-channel sites (Table 21). Mean percent mortality ranged from 4.0% at R2N-875-LR to 5.6% at R2N-650-LR. Partial mortality of the base (PMB) was also variable with levels ranging from 0.0% at R2N1-LR to 13.9% at R2N-650-LR.

In the southern middle reef ridge reef habitat near-channel locations had lower levels of mean percent mortality than ridge reef controls. R2SC1-RR had mean percent mortality of 3.9% whereas the highest level at any near-channel ridge reef location was 3.6%. Levels of partial mortality did not vary considerably among southern ridge reef sites ranging from 19.7% at R2S-400-RR to 26.3% at R2S-100-RR (Table 21). Similarly, partial mortality of the base had low variability with levels ranging from 4.5% at R2S-300-RR to 13.9% at R2S-400-RR.

In the southern middle reef linear reef habitat, near-channel locations had low percent mean mortality ranging from 3.3% (R2S2-LR) to 4.3% (R2S-300-LR) with the exception of R2S-400-LR which had 10.1% mean mortality (Table 21). The level of mortality at this site seems to be site-specific as adjacent sites have lower mortality values. Sediment depths at this site were not notably elevated and do not explain the higher than average mortality. Partial mortality ranged from 10.4% at R2S2-LR to 19.0% at R2S-300-LR. Partial mortality of the base (PMB) was similar across all southern linear reef sites with near-channel locations ranging from 8.0% (R2S2-LR) to 18.0% R2S-400-LR compared to the southern linear reef control (R2SC2-LR) that had 10.4% PMB.

Overall, mortality indicators were variable across middle reef impact assessment sites, but no site had greater than 10.1% average octocoral mortality at any survey site (Table 21). Since no baseline partial mortality data were available, no temporal comparison is possible for this metric.

Table 21. Numbers of octocorals, octocoral density, and percent of octocorals with partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each middle reef impact assessment site. Octocoral metrics were based on 50m of surveyed area, 30m on the EW survey line and 20m of the NS survey lines.

Site		Distance from Channel (m)	N	Density/m²	PM (%)	PMB (%)	% Mean Mortality
Middle Reef North (Ridge Reef)	R2N1-RR	28	557	11.1	30.5	4.8	6.1
	R2N-75-RR	75	704	14.1	36.5	0.0	4.7
	R2N-150-RR	150	607	12.1	16.5	8.2	4.3
	R2N-250-RR	250	874	17.5	17.6	7.8	5.0
	R2N-350-RR	350	914	18.3	15.3	3.3	3.7
	R2N-450-RR	450	886	17.7	10.7	6.7	3.6
	R2N-550-RR	550	863	17.3	26.4	2.2	3.9
	R2N-650-RR	650	1135	22.7	30.3	0.8	4.3
	R2N-750-RR	750	1244	24.9	23.5	0.9	3.7
	R2N-850-RR	850	831	16.6	26.1	12.0	3.0
	R2NC2-RR	9380	2263	45.3	6.8	1.1	1.7

Site		Distance from Channel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Middle Reef North (Linear Reef)	R2N2-LR	18	142	2.8	28.9	0.0	4.4
	R2N-75-LR	75	661	13.2	34.6	2.3	4.8
	R2N-150-LR	150	670	13.4	34.0	1.9	4.5
	R2N-250-LR	250	944	18.9	32.4	7.9	4.5
	R2N-350-LR	350	1072	21.4	27.1	6.9	4.2
	R2N-450-LR	450	974	19.5	23.1	8.2	4.1
	R2N-550-LR	550	1039	20.8	33.9	8.3	5.3
	R2N-650-LR	650	808	16.2	31.8	13.9	5.6
	R2N-750-LR	750	625	12.5	32.6	5.9	4.7
	R2N-875-LR	875	548	11.0	33.2	11.1	4.0
	R2NC1-LR	9380	986	19.7	8.4	0.0	0.9
	R2NC3-LR	9380	1467	29.3	4.6	0.3	0.9
Middle Reef South (Ridge Reef)	R2S1-RR	23	218	7.3	20.2	11.9	3.6
	R2S-100-RR	100	293	9.8	26.3	6.8	2.9
	R2S-200-RR	200	261	8.7	24.9	7.3	3.4
	R2S-300-RR	300	235	7.8	25.1	4.3	2.1
	R2S-400-RR	400	137	4.6	19.7	13.9	2.6
	R2SC1-RR	1270	376	12.5	21.5	8.0	3.9
Middle Reef South (Linear Reef)	R2S2-LR	21	311	10.4	22.2	8.4	3.3
	R2S-100-LR	100	449	15.0	20.3	8.0	3.3
	R2S-200-LR	200	427	14.2	17.3	9.6	3.2
	R2S-300-LR	300	571	19.0	21.2	11.2	4.3
	R2S-400-LR	400	367	12.2	34.6	18.0	10.1
	R2SC2-LR	1270	326	10.9	13.2	10.4	2.4

3.4.3.3 Octocoral Condition

No octocoral condition data were collected in the 2010 baseline survey or during any construction monitoring assessment. As a result, no temporal conclusions can be drawn with respect to qualitative octocoral condition at the impact assessment sites. Sediment-related indicators of octocoral condition are presented for the middle reef in Table 22.

Sediment was not associated with many octocorals in the northern middle reef ridge reef habitat. Octocorals with the appearance of a sediment dusting (SED category) was lowest at R2N-450-RR (0.9%) and highest at R2NC2-RR (38.6%) (Table 22). Sediment accumulation (SA) ranged from 0.2% at site R2N-450-RR to 14.7% at R2NC2-RR. Partial burial of the base (PBB) ranged from 0.2% at R2N-450-RR to 10.8% at R2N1-RR. Burial of the base (BBA) ranged from 0.7% at R2N-75-RR and R2N-450-RR to 8.6% at R2N1-RR. Burial (BUR) of octocorals was not observed at any northern middle reef ridge reef impact assessment site.

With the exception of sediment dusting indicators, sediment was not associated with many octocorals in the northern middle reef linear reef habitat. Octocorals with the appearance of a sediment dusting (SED category) was lowest at R2N-650-LR (2.6%) and highest at R2NC3-LR (59.1%). Sediment accumulation (SA) ranged from 0.1% at site R2NC1-LR to 11.8% at R2N-450-LR. Partial burial of the base (PBB) ranged from 0.2% at R2NC1-LR to 2.6% at R2N-650-LR. Burial of the base (BBA) ranged from 0.0% at R2N1-LR to 4.6% at R2N-875-LR. Burial (BUR) of octocorals was not observed at any northern middle reef linear reef impact assessment site.

Sediment indicators were low across the southern middle reef ridge reef habitat at both near-channel and control locations. Octocorals with the appearance of a sediment dusting (SED category) was lowest at the site R2S-300-RR where 0.9% of octocorals were documented with sediment dusting and highest R2S-100-RR where 6.8% of octocorals were noted with sediment dusting (Table 22). Sediment accumulation (SA) ranged from 0.0% at R2S1-RR to 4.2% at R2S200-RR. Partial burial of the base (PBB) ranged from 0.0% at R2S-100-RR to 2.8% at R2S3-LR. Burial of the base (BBA) ranged from 0.0% at R2S-100-RR to 3.7% at R2S1-RR. Burial (BUR) of octocorals was not documented in the southern middle reef ridge reef habitat.

With the exception of sediment dusting, no sediment indicator was greater than 8.0% across the southern linear reef impact assessment sites. Octocorals with the appearance of a sediment dusting (SED category) was lowest at site R2S-300-LR where 3.9% of octocorals were documented with sediment dusting and highest at site R2S2-LR where 19.9% of octocorals were noted with sediment dusting (Table 22). Sediment accumulation (SA) ranged from 3.2% at R2S-300-LR to 7.9% at R2S-400-LR. Partial burial of the base (PBB) ranged from 0.0% at R2S-400-LR to 8.0% at R2S2-LR. Burial of the base (BBA) ranged from 0.8% at R2S-400-LR to 5.7% at R2S-200-LR. Burial (BUR) of octocorals was not documented in the southern middle reef linear reef habitat.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data were available with respect to octocoral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts. However, with the exception of sediment dusting, the majority of sediment indicators were below 10% at middle reef impact assessment sites (Table 22).

Table 22. Distances of each middle reef monitoring site from the PortMiami channel provided along with the percentage of octocorals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 50 m^2, 30m^2 on the EW survey line and 20 m^2 on the NS survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef North (Ridge Reef)	R2N1-RR	28	1.8	3.4	10.8	8.6	0.0
	R2N-75-RR	75	7.4	4.7	1.7	0.7	0.0
	R2N-150-RR	150	1.8	1.0	2.8	1.3	0.0
	R2N-250-RR	250	5.6	3.8	4.7	2.6	0.0
	R2N-350-RR	350	3.6	1.3	2.3	3.5	0.0
	R2N-450-RR	450	0.9	0.2	0.2	0.7	0.0
	R2N-550-RR	550	5.7	2.7	1.4	2.3	0.0
	R2N-650-RR	650	12.8	6.0	3.2	4.1	0.0
	R2N-750-RR	750	12.2	2.7	1.8	2.3	0.0
	R2N-850-RR	850	5.1	3.0	2.3	2.2	0.0
	R2NC2-RR	9380	38.6	14.9	1.8	1.3	0.0
Middle Reef North (Linear Reef)	R2N1-LR	18	55.6	4.2	0.7	0.0	0.0
	R2N-75-LR	75	16.8	5.1	1.2	1.1	0.0
	R2N-150-LR	150	5.4	1.9	0.3	0.6	0.0
	R2N-250-LR	250	11.1	9.9	0.3	0.2	0.0
	R2N-350-LR	350	4.5	6.1	1.5	0.5	0.0
	R2N-450-LR	450	5.3	11.8	0.5	2.3	0.0
	R2N-550-LR	550	4.6	5.1	0.7	0.5	0.0
	R2N-650-LR	650	2.6	3.1	2.6	0.7	0.0
	R2N-750-LR	750	5.9	6.4	0.8	1.0	0.0
	R2N-875-LR	875	4.2	1.8	2.0	4.6	0.0
	R2NC1-LR	9380	56.4	0.1	0.2	0.1	0.0
	R2NC3-LR	9380	59.1	2.1	0.3	0.3	0.0

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef South (Ridge Reef)	**R2S1-RR**	23	3.2	0.0	2.8	3.7	0.0
	R2S-100-RR	100	6.8	2.7	0.0	0.0	0.0
	R2S-200-RR	200	4.2	4.2	0.4	1.9	0.0
	R2S-300-RR	300	0.9	2.6	0.4	1.3	0.0
	R2S-400-RR	400	2.2	0.7	1.5	1.5	0.0
	R2SC1-RR	1270	3.2	0.8	1.6	1.1	0.0
Middle Reef South (Linear Reef)	**R2S2-LR**	21	19.9	5.1	8.0	2.3	0.0
	R2S-100-LR	100	5.6	6.0	4.7	4.5	0.0
	R2S-200-LR	200	5.4	2.6	2.8	5.2	0.0
	R2S-300-LR	300	3.9	3.2	0.7	3.0	0.0
	R2S-400-LR	400	7.9	7.9	0.0	0.8	0.0
	R2SC2-LR	1270	16.0	5.8	1.5	3.4	0.0

3.4.4 Sponges

The numbers of sponges, sponge density, the percentage of sponges with partial mortality, partial mortality and base, and mean percent sponge mortality are presented for the middle reef habitat. Sediment-related indicators of sponge condition are also presented for middle reef sites.

3.4.4.1 Sponge Density

Sponge density data were collected in 2010 using 10m transects spaced at regular intervals from the channel out to 450m (DCA 2012). These data were only taken in the middle reef ridge reef habitat but they represent an independent baseline dataset that can be used for qualitative comparison of sponge densities near the PortMiami channel. The near-channel northern middle reef ridge reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 56. In 2010 sponge densities ranged from 6.0 sponges/m^2 at 200m from the channel, to 16.1 sponges/m^2 at 100m from the channel-edge (Figure 56). During the 2016 impact assessment surveys near-channel sponge densities ranged from 8.4 sponges/m^2 at R2NC2-RR to 22.2 sponges/m^2 at R2N-350-RR (Table 23). No control data were acquired in 2010. Although the methods and site locations are not the same, the density of sponges measured in the northern middle reef ridge reef habitat during the 2016 impact assessment are equal to or higher than values established prior to dredging in 2010 (Figure 56).

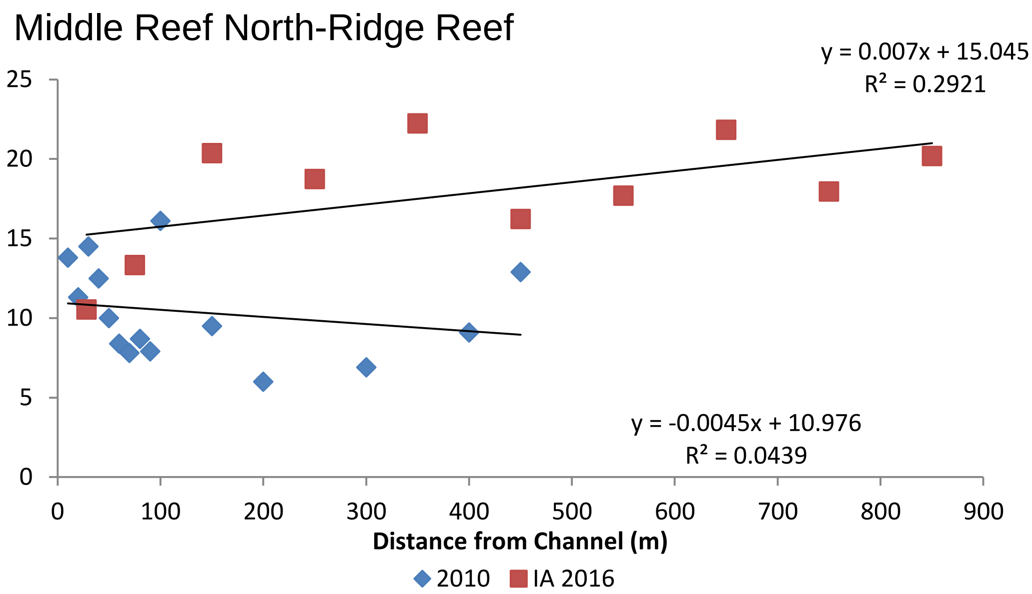


Figure 56. Sponge densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

2010 data were not collected in the northern middle reef linear reef habitat but 2016 density data from this habitat are similar to the ridge reef habitat during the 2016 impact assessment surveys. Sponge density at the near-channel northern middle reef linear reef sites ranged from 10.2 sponges/m^2 at R2NC1-LR to 25.0 sponges/m^2 (Table 23). No linear reef sites had sponge densities below the range established in the ridge reef habitat in the 2010 baseline.

The near-channel southern middle reef ridge reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 57. In 2010 sponge densities ranged from 2.0 sponges/m^2 at 90 m from the channel, to 8.8 sponges/m^2 at 200 m from the channel-edge (Figure 57). During the 2016 impact assessment surveys near-channel sponge densities ranged from 24.9 sponges/m^2 at R2S1-RR to 14.3 sponges/m^2 at R2SC1-RR (Table 23). No control data were acquired in 2010. Although the methods and site locations are not the same, the density of sponges measured in the southern middle reef ridge reef habitat during the 2016 impact assessment are equal to or higher than values established prior to dredging in 2010 (Figure 57).

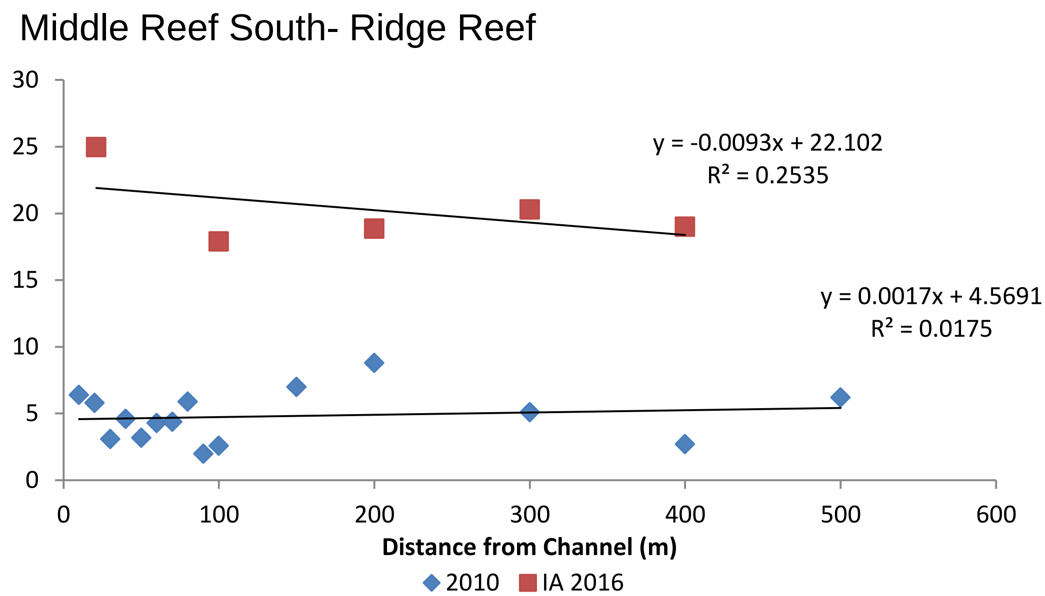


Figure 57. Sponge densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

2010 data were not taken in the southern middle reef linear reef habitat but 2016 density data from the linear reef are equal to or greater than the range established in the ridge reef habitat. Sponge density at the near-channel southern middle reef linear reef sites ranged from 15.8 sponges/m^2 at R2S2-LR to 36.6 sponges/m^2 at R2S-400-LR (Table 23). The southern middle reef linear reef control site (R2SC2-LR) had 22.6 sponges/m^2.

From the permanent site impact assessment surveys the only channel-side location that was found to have significantly different density of sponges was R2N1-LR in which sponge density had declined from 21.75 sponges/m^2 to 4.98 sponges/m^2 (DCA 2017) (Table 23). The lowest density of sponges measured at a near-channel middle reef cross sites was 10.5 sponges/m^2 measured at R2N1-RR, which was similar to the control value of 8.4 sponges/m^2.

Table 23. The distance of each middle reef monitoring site from the PortMiami channel along with the numbers of sponges, sponge density, and percent of sponges with signs of partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each middle reef impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Middle Reef North (Ridge Reef)	R2N1-RR	28	316	10.5	9.2	0.3	0.8
	R2N-75-RR	75	400	13.3	5.8	0	1
	R2N-150-RR	150	611	20.4	4.9	6.5	1
	R2N-250-RR	250	562	18.7	8.4	0	0.7
	R2N-350-RR	350	667	22.2	3.1	0	0.3
	R2N-450-RR	450	487	16.2	9.4	0	1.1
	R2N-550-RR	550	531	17.7	7.9	0.2	1
	R2N-650-RR	650	655	21.8	4.6	0	0.4
	R2N-750-RR	750	539	18	9.5	0.2	0.9
	R2N-850-RR	850	606	20.2	1	0.5	0.2
	R2NC2-RR	9380	252	8.4	2.8	0	0.8
Middle Reef North (Linear Reef)	R2N1-LR	18	724	24.1	2.2	0.3	0.2
	R2N-75-LR	75	682	22.7	1.5	0	0.1
	R2N-150-LR	150	744	24.8	0.8	0	0.1
	R2N-250-LR	250	772	25.7	1	0	0.1
	R2N-350-LR	350	327	10.9	2.4	0	0.4
	R2N-450-LR	450	435	14.5	1.4	0.2	0.1
	R2N-550-LR	550	750	25	2	0.1	0.3
	R2N-650-LR	650	695	23.2	1.9	0.3	0.3
	R2N-750-LR	750	481	16	1.7	0	0.4
	R2N-875-LR	875	577	19.2	1.9	0.2	0.2
	R2NC1-LR	9380	307	10.2	2	0	0.1
	R2NC3-LR	9380	320	10.7	1.9	0	0.3

Site		Distance from Channel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Middle Reef South (Ridge Reef)	**R2S1-RR**	23	747	24.9	0.9	0.1	0.2
	R2S-100-RR	100	537	17.9	0.9	0	0.1
	R2S-200-RR	200	566	18.9	1.6	0.5	0.3
	R2S-300-RR	300	612	20.4	0.7	0.2	0.6
	R2S-400-RR	400	570	19	2.5	0.7	0.2
	R2SC1-RR	1270	430	14.3	0.9	0	0.1
Middle Reef South (Linear Reef)	**R2S2-LR**	21	474	15.8	1.9	0.8	0.5
	R2S-100-LR	100	568	18.9	1.8	0	0.1
	R2S-200-LR	200	562	18.7	1.4	0	0.2
	R2S-300-LR	300	526	17.5	5.1	0	1.2
	R2S-400-LR	400	1098	36.6	1.9	0.1	0.3
	R2SC2-LR	1270	679	22.6	4	0.6	0.5

3.4.4.2 Sponge Condition

No quantitative data on sponge sediment condition were collected in the middle reef habitat in either the 2010 or 2013 PortMiami baseline assessments or in the 2015 PortMiami post-construction surveys (DCA 2012; DCA 2014c; DCA 2015b). As a result, no temporal conclusions can be drawn with respect to qualitative sponge condition in the middle reef habitat. Sediment-related sponge condition data are presented for the middle reef habitat in Table 24.

Sediment was associated with many sponges in the northern middle reef ridge reef habitat at both near-channel and control locations. Sponges with the appearance of a sediment dusting (SED category) was lowest at site R2N-450-RR (37.8%) and highest at R2N-150-RR (71.2%) (Table 24). Sediment accumulation (SA) was lowest at R2N1-RR (15.2%) and was highest at the nearby site R2N-75-RR where 46.5% of sponges were noted with sediment accumulation. Partial burial of the base (PBB) ranged from 1.2% at R2NC2-RR to 16.3% at R2N-850-RR. Burial of the base (BBA) ranged from 0.0% at R2NC2-RR, R2N1-RR, and R2N-75-RR to 4.5% at R2N-550-RR. Burial (BUR) was only noted at R2N-750-RR and was rare at this assessment location (0.2%).

In the linear reef habitat of the middle reef sponges with the appearance of a sediment dusting (SED category) was lowest at site R2N-450-LR (25.4%) and highest at the linear reef northern control R2NC3-LR (61.6%) (Table 24). Sediment accumulation (SA) was lowest at R2NC1-RR (11.1%) and was highest at site R2N1-LR where 58.1% of sponges were noted with sediment accumulation. Partial burial of the base (PBB) ranged from 0.2% at R2N-450-LR to 14.8% at R2N-750-LR. Burial of the base (BBA) ranged from 0.0% at R2NC3-LR, and R2N-450-LR to

5.4% at R2N-750-LR. Burial (BUR) was only noted at R2N-750-LR and was rare at this assessment location (0.2%).

In the southern middle reef ridge reef habitat, the percentage of sponges with the appearance of a sediment dusting (SED category) was lowest at site R2S-200-RR (43.4%) and highest at the ridge reef southern control R2SC1-RR (59.1%) (Table 24). Sediment accumulation (SA) ranged from 34.7% at R2SC1-RR to 50.9% at site R2S-400-RR. Partial burial of the base (PBB) ranged from 9.8% at R2S-400-RR to 15.0% at R2S-300-RR. Burial of the base (BBA) ranged from 1.6% at R2SC1-RR to 7.4% at R2S-400-RR. Burial (BUR) was rare in the southern ridge reef habitat ranging from 0.0% to 0.6% (R2S-100-RR).

In the southern middle reef linear reef habitat, the percentage of sponges with the appearance of a sediment dusting (SED category) was lowest at site R2S-300-LR (37.6%) and highest at the linear reef southern control R2SC2-LR (67.6%) (Table 24). Sediment accumulation (SA) ranged from 20.0% at R2SC2-LR to 56.5% at site R2S-300-LR. Partial burial of the base (PBB) ranged from 4.4% at R2S2-LR to 16.7% at R2S-300-LR. Burial of the base (BBA) ranged from 0.6% at R2S2-LR to 7.4% at R2S-300-LR. Burial (BUR) was rare in the southern ridge reef habitat ranging from 0.0% to 0.4%.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data are available with respect to sponge sediment indicators, it is unknown how suspended or settled sediment may have impacted sponge populations near PortMiami either during or after construction activities. In addition, although sediment can be deleterious to sponge health, a recent review of sediment impacts on marine sponges concluded that most species can tolerate varying degrees of suspended and settled sediment and that many sponges have adaptations to not only persist but thrive in sedimented environments (Bell et al. 2015).

Table 24. Distances of each middle reef monitoring site from the PortMiami channel provided along with the percentage of sponges with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Middle Reef North (Ridge Reef)	R2N1-RR	28	58.2	15.2	1.6	0.0	0.0
	R2N-75-RR	75	38.0	46.5	2.3	0.0	0.0
	R2N-150-RR	150	71.2	21.8	11.9	3.4	0.0
	R2N-250-RR	250	40.0	48.0	6.9	2.1	0.0
	R2N-350-RR	350	60.6	34.6	6.7	1.3	0.0
	R2N-450-RR	450	37.8	46.4	6.4	2.9	0.0
	R2N-550-RR	550	40.5	36.3	12.6	4.5	0.0
	R2N-650-RR	650	57.1	33.9	7.5	3.4	0.0
	R2N-750-RR	750	49.5	40.6	15.6	1.7	0.2
	R2N-850-RR	850	51.2	43.1	16.3	1.3	0.0

Site		Distance from Channel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
	R2NC2-RR	9380	46.4	28.6	1.2	0.0	0.0
Middle Reef North (Linear Reef)	R2N1-LR	18	34.5	58.1	1.9	0.4	0.0
	R2N-75-LR	75	45.9	44.9	2.6	1.6	0.0
	R2N-150-LR	150	49.6	41.7	2.2	1.2	0.0
	R2N-250-LR	250	51.9	32.9	4.8	0.3	0.0
	R2N-350-LR	350	25.4	52.9	5.8	0.6	0.0
	R2N-450-LR	450	26.0	40.0	0.2	0.0	0.0
	R2N-550-LR	550	55.1	35.3	2.9	0.7	0.0
	R2N-650-LR	650	39.7	56.7	11.1	1.0	0.0
	R2N-750-LR	750	41.8	52.0	14.8	5.4	0.2
	R2N-875-LR	875	45.6	45.8	12.7	3.6	0.0
	R2NC1-LR	9380	59.6	11.1	2.3	0.3	0.0
	R2NC3-LR	9380	61.6	15.6	2.5	0.0	0.0
Middle Reef South (Ridge Reef)	R2S1-RR	23	56.6	41.4	10.0	2.1	0.0
	R2S-100-RR	100	43.4	50.7	11.9	4.8	0.6
	R2S-200-RR	200	52.1	43.1	14.3	4.8	0.0
	R2S-300-RR	300	48.0	47.4	15.0	6.9	0.0
	R2S-400-RR	400	43.5	50.9	9.8	7.4	0.4
	R2SC1-RR	1270	59.1	34.7	10.0	1.6	0.2
Middle Reef South (Linear Reef)	R2S2-LR	21	53.4	33.5	4.4	0.6	0.0
	R2S-100-LR	100	57.4	39.3	7.7	0.7	0.2
	R2S-200-LR	200	57.1	39.9	5.5	1.1	0.0
	R2S-300-LR	300	37.6	56.5	16.7	4.8	0.4
	R2S-400-LR	400	56.6	34.0	5.7	1.0	0.0
	R2SC2-LR	1270	67.6	20.0	7.8	1.5	0.4

3.4.5 Middle Reef Summary

In the middle reef habitat, octocorals are the dominant benthic invertebrate (8.6% of the bottom) followed by sponges (3.7%) and scleractinians (1.0%) (DCA 2017). Densities of dominant benthic invertebrates as measured in the impact assessment were compared to values documented prior to the project in 2010 to determine if there was functional habitat loss due to the project. Octocoral densities in 2016-2017 were equal to or higher than values documented in 2010 at all distances from the channel, in both the northern and southern middle reef habitat. Sponge densities followed the same pattern as octocorals in which densities at near-channel sites in 2016-2017 were equal to or higher than values documented in 2010 at all distances from the channel, in both the northern and southern middle reef habitat. Scleractinian coral densities were lower in 2016 than densities measured in 2010 at nearly all distances from the

PortMiami channel. The change in coral density throughout the survey corridor is principally due to the impacts of a regional white-plague disease event as documented in the permanent site report (DCA 2017). Importantly, there was no increased white-plague disease-related coral mortality at any near-channel site as a result of the project (DCA 2017). While scleractinian corals were impacted at near-channel sites during the project (2 out of 105 (1.9%) near-channel middle reef corals died as a result of burial), this group represents less than 1% of cover according to pre-dredging data. When considering a 1.9% loss of less than 1% of the living benthic cover, this change should not be considered a functional loss of habitat. Furthermore partial mortality of corals documented during the project resulted in no net loss of function. This was determined based on planimetry analysis on post-project comparisons of photographs of tagged corals before, during and after the project. Looking at the middle reef habitat function as the combined influence of the three major groups of benthic invertebrates; octocorals, sponges, and corals, no permanent effect of the project was detected in the 2016-2017 impact assessment. This is corroborated by percent cover analysis of near channel permanent monitoring sites in which the percent cover of dominant benthic invertebrates remained relatively unchanged between baseline and impact assessment surveys in the middle reef habitat (octocorals 8.6%-8.6%; sponges 3.7%-4.5%; scleractinians 1.0%-0.9%; DCA 2017).

3.5 Outer Reef

Outer reef habitat results for sediment characterization, depth, corals, octocorals, and sponges are presented below for sites depicted in Figures 58 and 59.

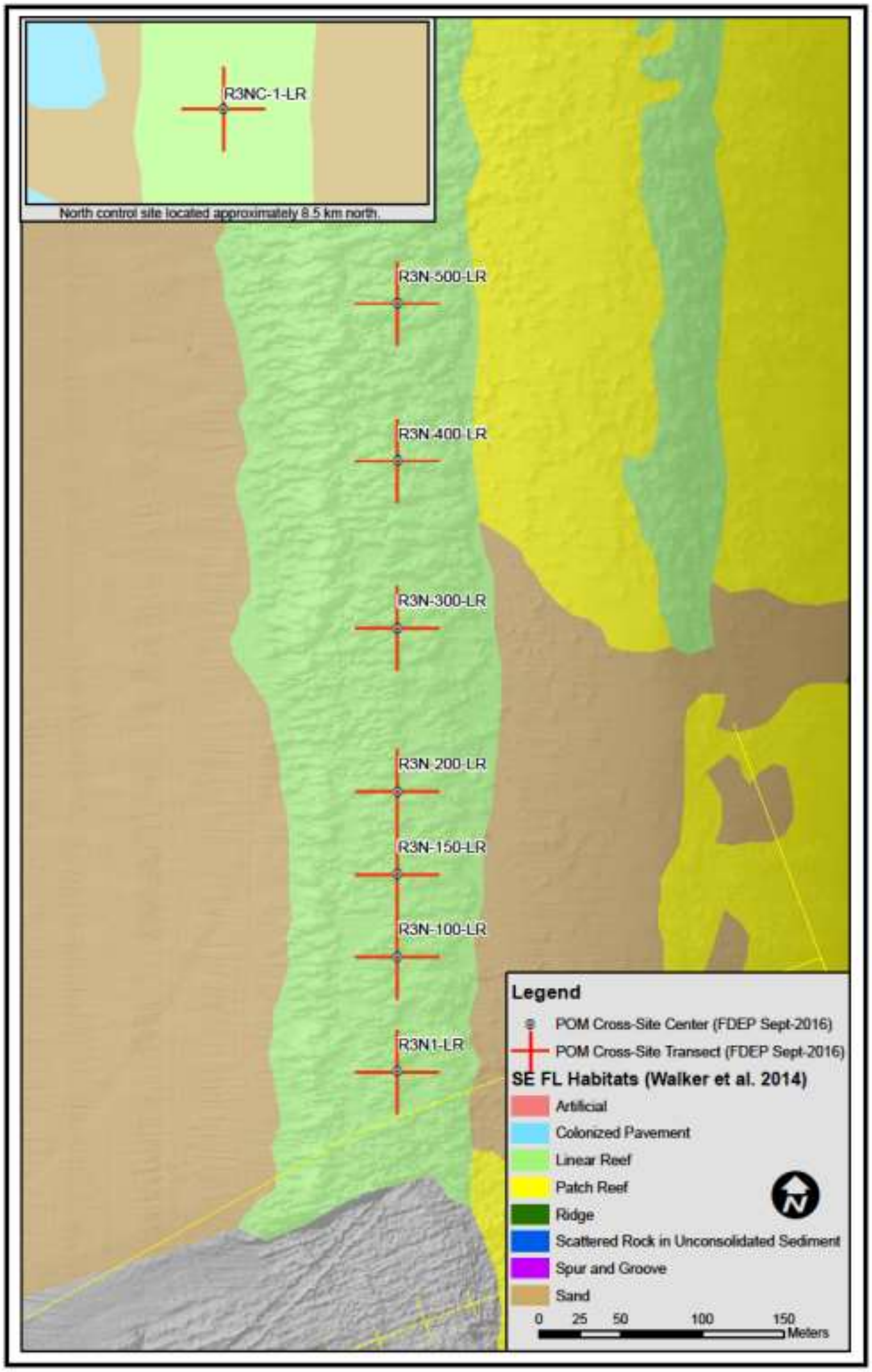


Figure 58. Northern outer reef cross sites surveyed during the 2016-2017 impact assessment surveys

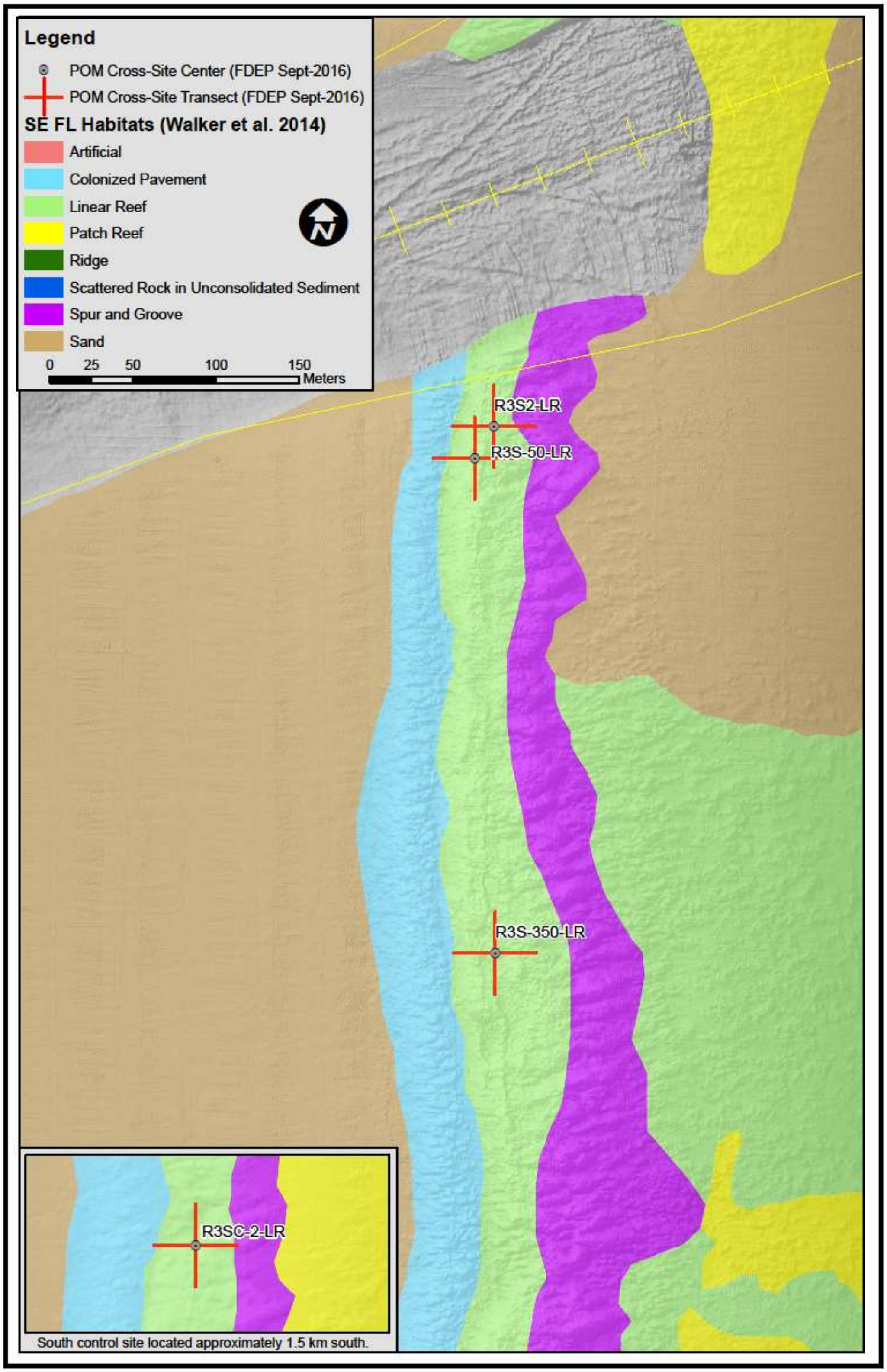


Figure 59. Southern outer reef cross sites surveyed during the 2016-2017 impact assessment surveys

3.5.1 Qualitative Substrate Characterization and Sediment Depth

At least 95% of outer reef substratum characterization locations were characterized as sediment over hardbottom. R3S-350-LR had 5% of substratum characterization locations characterized as exposed hardbottom. No substratum characterization locations were characterized as sediment only at any outer reef site.

The percentage of points characterized as deep sediment over hardbottom was variable in the outer reef habitat. All eight sites surveyed in the northern outer reef habitat had points characterized as deep sediment over hardbottom. Northern outer reef habitat is characterized by spur and groove features, with high relief spurs and sand channels, these features explain the high occurrence of deep sediment over hardbottom measurements (Figure 60). The percentage of points characterized as deep sediment over hardbottom in the northern outer reef habitat ranged from 4% at R3N-400-LR to 38% at R3N-100-LR. In the southern outer reef habitat, deep sediment over hardbottom was present at 5% of sediment assessment locations at both R3S2-LR and R3S-50-LR, and 0% at all other southern outer reef sites. The southern portion of the outer reef is lower relief spur and groove when compared to the north side, which may explain the lower prevalence of deep sediment over hardbottom.

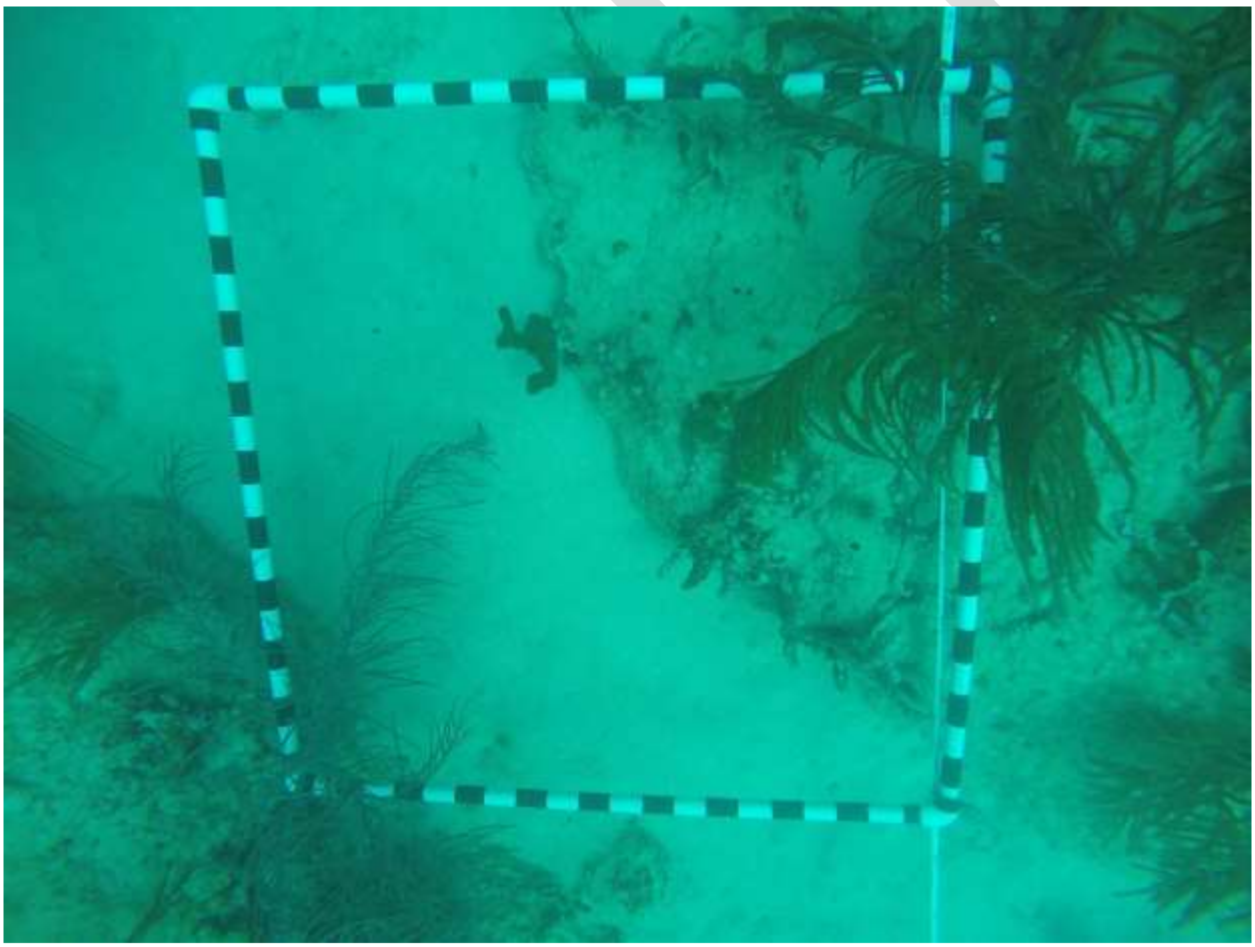


Figure 60. Birds eye view of sand channel between spurs at northern outer reef site R3N1-LR. Deep sediment over hardbottom is a natural feature of these sand channels and accounted for DSOH measurements on the outer reef.

Mean sediment depth in the near-channel northern outer reef habitat ranged from 0.8 cm (R3N-400-LR) to 4.0 cm (R3N1-LR) (Table 25). The northern outer reef control site had mean sediment depth of 1.7 cm. The first three sites closest to the channel (R3N1-LR, R3N-100-LR, and R3N-150-LR) had sediment measurements that were above the outer reef northern control site and were above the 3 cm threshold for optimal *Acropora* restoration site selection (Figure 61). No *Acropora* colonies have been documented at outer reef sites as part of this study, or any other in this portion of the Southeast Florida reef tract. Determining the extent that sediment at the near-channel sites in the northern outer reef is related to PortMiami construction activity is in-exact without baseline sediment depth information, however, qualitative sediment data were collected. Divers characterized the sediment at all sediment assessment locations at R3N1-LR as being “mixed” or “coarse”. At R3N-100-LR five out of 22 sediment assessment locations (23%) had fine sediment and one location had a fine sediment depth that was >3 cm (4.8 cm). All other fine sediment assessment locations that were encountered had sediment depths of 1 cm or less. At R3N-150-LR all sediment assessment locations were characterized as “mixed” or “coarse” and no layers were found during sediment excavations of deep sediment (Figure 62).

Table 25. Sediment environment data for all outer reef cross survey sites. Sites were characterized for the % of points assessed that were sediment over hardbottom (SOH), sediment only (SO), exposed hardbottom (EH), or deep sediment over hardbottom (Deep SOH). Deep SOH was calculated as a percentage of SOH which was only evaluated every 5m. Mean sediment depth, standard error of the mean, and the max sediment depth area also provided but were calculated based on sediment depth measurements that were acquired every meter along the transect. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Chanel (m)	SOH (%)	SO (%)	EH (%)	Deep SOH (%)	Mean Sed Depth (cm)	SE	Max Sed Depth (cm)
Outer Reef North	R3N1-LR	23	100	0	0	32	4.0	0.6	28.0
	R3N-100-LR	100	100	0	0	38	3.6	0.5	24.0
	R3N-150-LR	150	100	0	0	32	3.4	0.5	16.2
	R3N-200-LR	200	100	0	0	16	1.6	0.3	14.0
	R3N-300-LR	300	100	0	0	19	1.3	0.2	19.5
	R3N-400-LR	400	100	0	0	4	0.8	0.1	4.1
	R3N-500-LR	500	100	0	0	9	1.2	0.2	7.5
	R3NC1-LR	9380	100	0	0	28	1.7	0.3	10.3
Outer Reef South	R3S2-LR	21	100	0	0	5	0.6	0.1	5.0
	R3S-50-LR	50	100	0	0	5	0.9	0.1	6.0
	R3S-350-LR	350	95	0	5	0	0.6	0.1	6.1
	R3SC2-LR	1300	100	0	0	0	0.7	0.1	4.1

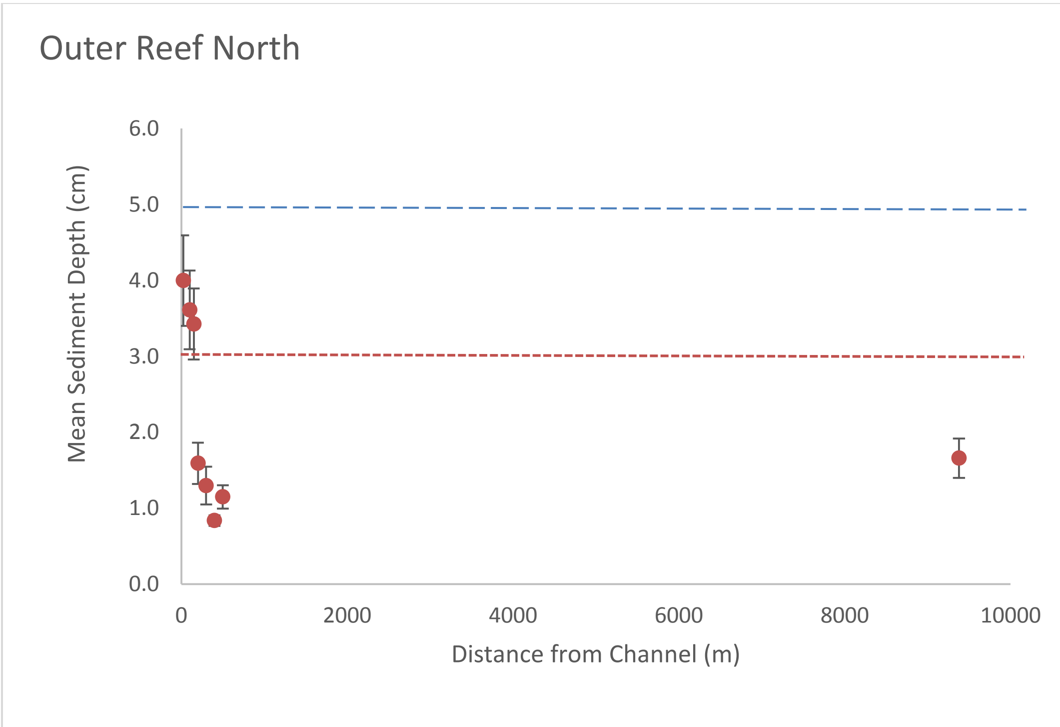


Figure 61. Mean sediment depth of northern outer reef sites plotted against the distance of the site from the channel. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

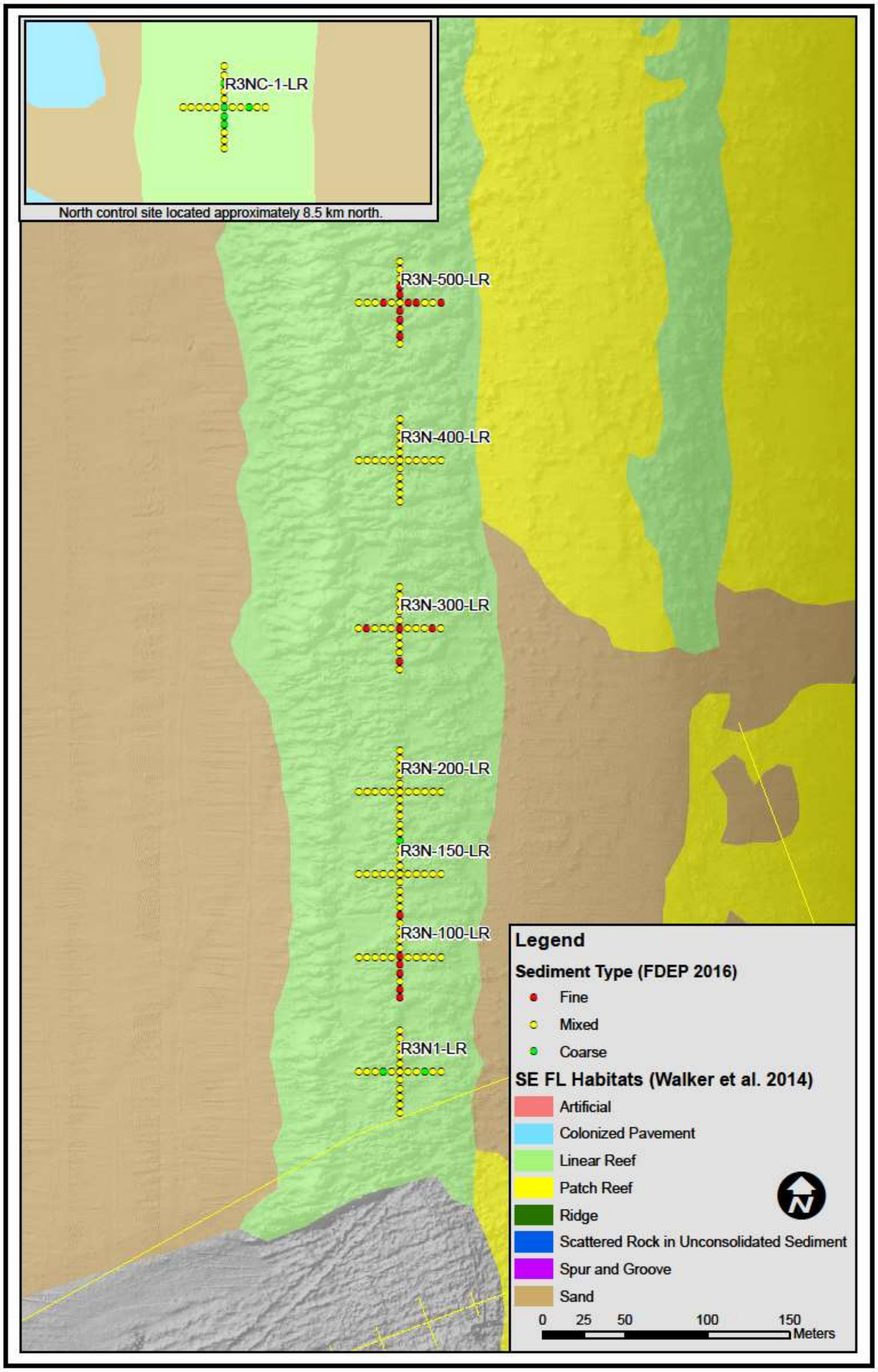


Figure 62. Sediment type as assessed every 5m at northern outer reef sites.

As a result, only one sediment assessment location at R3N-100-LR had fine sediment depth that exceeded the 3 cm *Acrpopora* restoration site guidelines and may therefore be considered impacted. The fact that the sediment composition of the three sites closest to the channel at the northern outer reef are predominantly different than dredge sediment indicates that the fine dredge sediment previously documented in this habitat has been incorporated into existing reef sediment or has otherwise dissipated. It is important to note that higher levels of sand at near-channel northern outer reef sites is likely a reflection of the natural state of the sediment environment at these sites due to the natural presence of sand between the spurs of the spur-and-groove habitat. Repeat monitoring of percent cover of sand at R3N1-LR found that levels of sand cover during the one-year post-construction impact assessment report had declined since post construction and were consistent with levels documented in the 2013 baseline period (baseline sand cover at R3N1-LR was 12.6% compared with 14.4% during the one-year post-construction impact assessment survey). The extent of sand cover of the near-channel site during both baseline and impact assessment surveys (12.6-14.4%) is also greater than the percent cover documented at the habitat control over the same time period (7.7-7.6%) (DCA 2017). These data highlight the necessity of repeated measures monitoring in assessing impact at survey locations rather than relying on a control-impact design in which the control and impact sites are often not representative of one another in their natural state (i.e. the near-channel site had higher sand cover than the control during baseline surveys). The combined lack of fine pockets of deep sediment and near baseline cover of sand at permanent site locations are not indicative of a permanent sediment impact in the northern outer reef.

On the southern side of the outer reef, mean sediment depths at near-channel sites ranged from 0.6 cm (R3S2-LR and R3S-350-LR) to 0.9 cm (R3S-50-LR) (Table 25, Figure 63). Mean sediment depth of the outer reef southern control was 0.7 cm. Fine sediment was only noted at R3S-50-LR and maximum depth of fine sediment was 0.7 cm (Table 25, Figure 64). None of the southern outer reef sites had fine sediment levels above the thresholds recommended for *Acropora* restoration sites and were well below the threshold of dense coral community development. Mean sediment depths were within 2 mm of the southern outer reef control site and these sites were not considered permanently impacted (Figure 63).

Table 26. Percent sediment type at each outer reef cross site location and the maximum depth of fine sediment. Data were collected over 50 m^2 on the NS and EW survey lines.

Site		Distance from Chanel (m)	Fine	Mixed	Coarse	None	Rubble	Max Depth Fine Sediment (cm)
Outer Reef North	R3N1-LR	23	0%	91%	9%	0%	0%	0.0
	R3N-100-LR	100	23%	73%	0%	0%	4%	4.8
	R3N-150-LR	150	0%	95%	5%	0%	0%	0.0
	R3N-200-LR	200	0%	100%	0%	0%	0%	0.0
	R3N-300-LR	300	18%	82%	0%	0%	0%	2.3
	R3N-400-LR	400	0%	96%	4%	0%	0%	0.0
	R3N-500-LR	500	39%	57%	4%	0%	0%	0.9
	R3NC1-LR	9380	0%	68%	32%	0%	0%	0.0

Site		Distance from Chanel (m)	Fine	Mixed	Coarse	None	Rubble	Max Depth Fine Sediment (cm)
Outer Reef South	**R3S2-LR**	21	0%	100%	0%	0%	0%	0.0
	R3S-50-LR	50	18%	82%	0%	0%	0%	0.7
	R3S-350-LR	350	0%	86%	9%	5%	0%	0.0
	R3SC2-LR	1300	0%	95%	5%	0%	0%	0.0

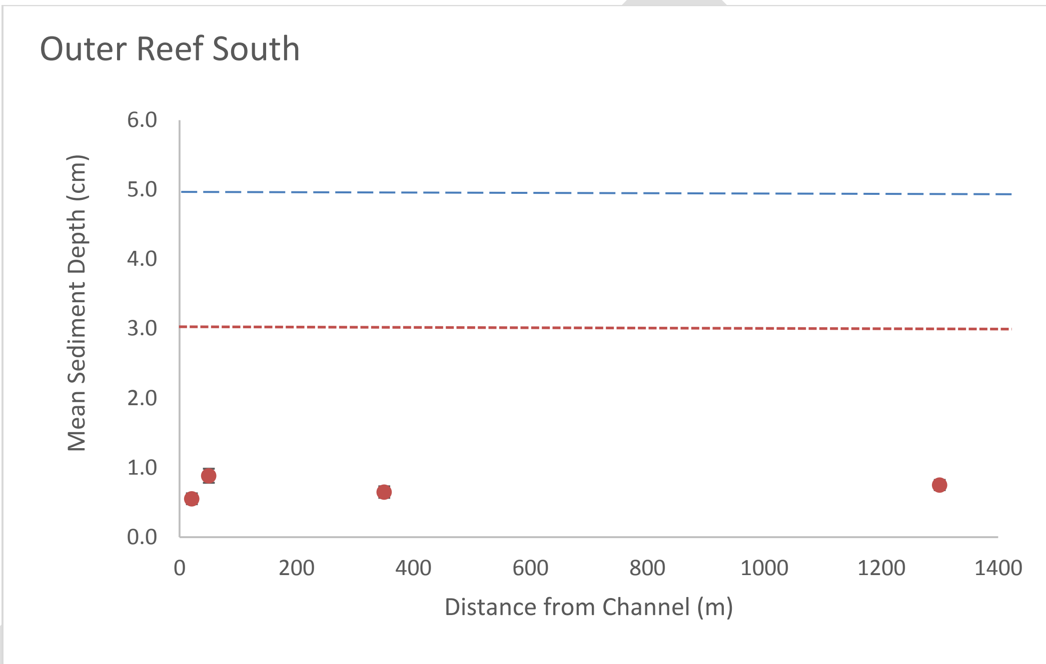


Figure 63. Mean sediment depth of southern outer reef sites plotted against the distance of the site from the channel. Error bars represent the standard error of the mean. The blue dashed line represents the 5 cm threshold of dense coral communities found in Florida Bay, and the orange dotted line is the 3 cm threshold for *Acropora* restoration site selection.

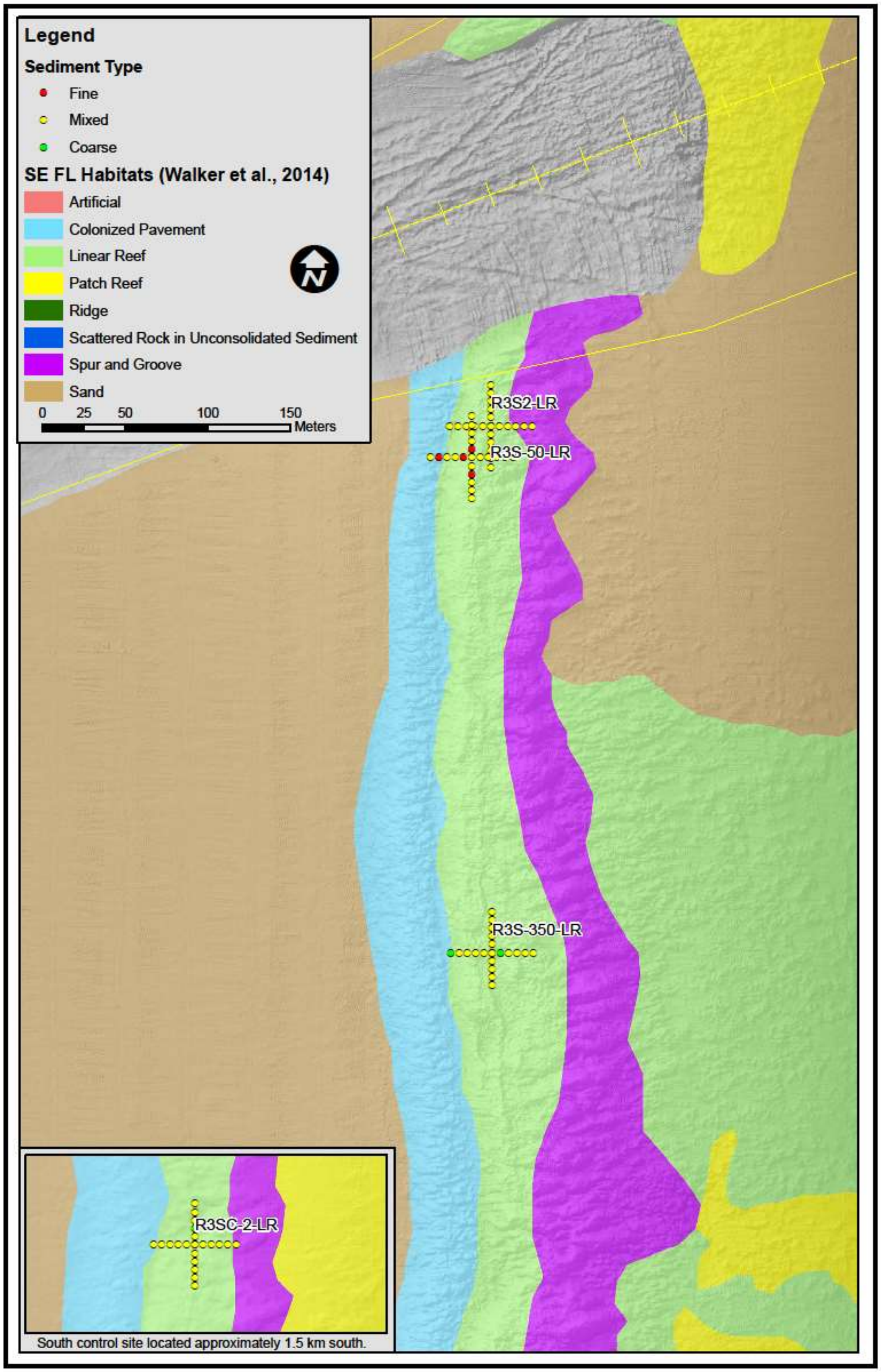


Figure 64. Sediment type as assessed every 5m at southern outer reef sites.

3.5.2 Scleractinian Corals

In the following sections the numbers of corals, coral density, coral recruit density (<3 cm), and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB),average percent partial mortality, and percent mean mortality (includes dead corals) are reported for each outer reef impact assessment site. In addition, indicators of sediment stress including the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA), and complete burial (BUR) are presented for outer reef habitat sites.

Overall, scleractinian densities documented in 2016 were generally lower than densities measured in 2010 surveys at nearly all distances from the PortMiami channel. The change in coral density throughout the survey corridor is principally due to the impacts of white-plague disease.

3.5.2.1 Scleractinian Density

In 2010 areas of the outer reef habitat were surveyed as part of a baseline survey (DCA 2012). These areas do not directly correspond with 2016 impact assessment sites but provide a general guide to 2010 coral densities in the outer reef habitat (Figure 2). In 2010 near-channel coral density ranged from 0.2 corals/m^2 at site R3N020 to 1.3 corals/m^2 at the outer reef site R2N300. For the cross site impact assessment survey of 2016 coral density was very similar. Coral density of near-channel sites ranged from 0.3 corals/m^2 at R3N1-LR to 1.0 corals/m^2 at R3N-400-LR (Figure 65, Table 27). The outer reef north control had coral density of 1.2 corals/m^2 (Figure 65).

In the southern outer reef habitat, near-channel coral density ranged from 0.8 corals/m^2 at R3S2500 to 3.1 corals/m^2 at site R3S2040 in the 2010 baseline survey (DCA 2012, Figure 46). In 2016 near-channel outer reef coral density ranged from 1.6 corals/m^2 at R3S-350-LR corals/m^2 to 2.3 corals/m^2 at R3S2-LR (Figure 66, Table 27). The southern outer reef control had 2.5 corals/m^2 during the 2016 impact assessment surveys.

Differences in coral density in the outer reef habitat between 2010 and 2016 surveys are likely attributable to several factors, including differences in sampled areas (Figure 2), methods, as well as significant changes to coral community composition due to the species-specific white-plague event that affected Southeast Florida beginning in the fall of 2014 (Precht et al. 2016). The species-specific nature of the white-plague disease event creates a confounding mortality influence that makes control-impact site comparisons invalid unless species composition of the site is known prior to the disease event. Estimates of coral mortality as a result of the white-plague disease event ranged from 0% for abundant species *Porites astreoides* and *Siderastrea siderea* to greater than 97% mortality for species *Dichocoenia stokesi, Meandrina meandrites,* and *Eusmilia fastigata* (Precht et al. 2016). Comparison of coral density at outer reef permanent monitoring sites between baseline surveys in 2013 and 2016 using the same methods and sample area showed declines in coral density at all surveyed sites. No outer reef monitoring site experienced higher levels of mortality than the range predicted when species-susceptibility to white-plague disease was accounted for (DCA 2017).

At permanent monitoring sites where coral colonies were followed through time six corals out of 224 tagged corals died as a result of sediment burial representing 2.7% of all near-channel corals. The six colonies included one colony of *Dichocoenia stokes* at HBS4-CR, a *Siderastrea* *siderea* colony at HBN3-CP, two colonies of *S. siderea* at R2N2-LR, one *Porites porites* at R3N1-LR, and one *P. astreoides* at R3N1-LR. Over the same time period, 72 corals died of white-plague and concurrent diseases accounting for the mortality of 32.1% of all near-channel corals. The repeated monitoring of tagged corals at permanent monitoring sites allowed quantification of various causes of mortality in a way that is not possible with the single-sample survey design of the cross impact assessment sites. As a result, the quantification of the various sources of coral mortality affecting project-related resources as presented in the permanent site impact assessment report (DCA 2017) is the most accurate estimate of sediment and disease-related mortality currently available. The single-sample cross-site survey design precludes specifying causes of coral mortality, or quantifying the species-susceptibility of individual assessment sites to white-plague disease as was performed in the permanent site impact assessment report. As a result, the cross impact assessment survey design is unsuitable for providing a post-hoc quantification of dredge-related mortality on coral density given the confounding effect of significant regional mortality.

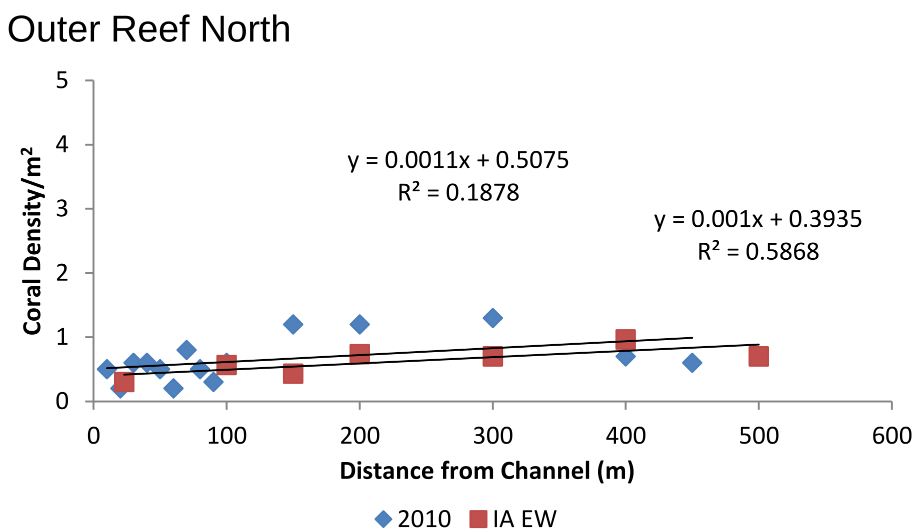


Figure 65. Coral densities of near channel survey sites with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey east-west transects (red).

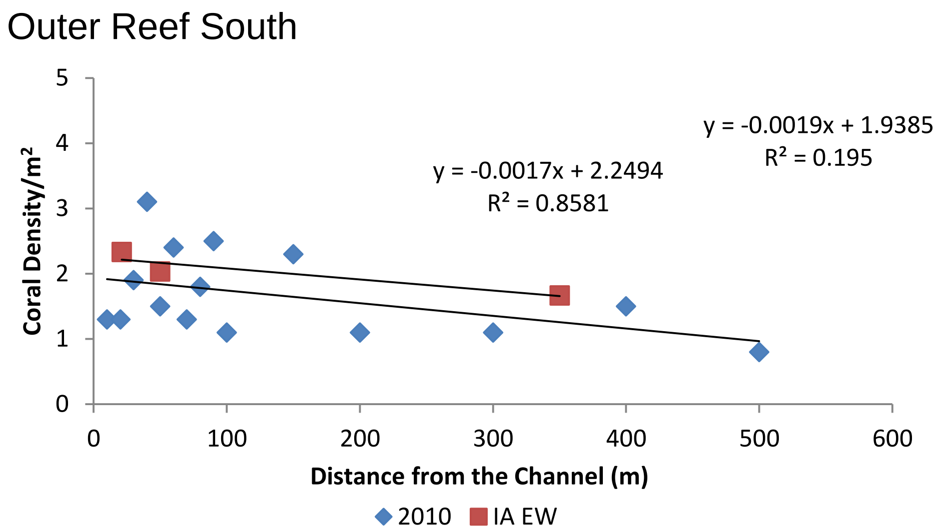


Figure 66. Coral densities of near channel survey sites with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey east-west transects (red).

Table 27. Numbers of corals, coral density, coral recruit density (<3 cm), and the percent of corals with signs of partial mortality (PM), partial mortality of the base (PMB), average percent partial mortality, and percent mean mortality (includes dead corals) are given for each outer reef impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Chanel (m)	N	Density/ m^2	Recruit density/ m^2	PM (%)	PMB (%)	% Mean Partial Mortality	% Mean Mortality
Outer Reef North	R3N1-LR	23	9	0.3	0.0	33.3	11.1	7.7	30.8
	R3N-100-LR	100	17	0.6	0.1	0.0	17.6	4.4	9.7
	R3N-150-LR	150	13	0.4	0.0	0.0	38.5	8.1	14.6
	R3N-200-LR	200	22	0.7	0.0	22.7	22.7	4.7	12.7
	R3N-300-LR	300	21	0.7	0.0	4.8	28.6	8.7	20.1
	R3N-400-LR	400	29	1.0	0.1	13.8	17.2	3.7	3.7
	R3N-500-LR	500	21	0.7	0.1	4.8	9.5	3.3	11.7
	R3NC1-LR	9380	35	1.2	0.4	5.7	14.3	3.6	11.2
Outer Reef South	R3S2-LR	21	70	2.3	0.7	12.9	2.9	4.2	10.6
	R3S-50-LR	50	61	2.0	0.9	11.5	21.3	6.0	14.4
	R3S-350-LR	350	50	1.7	0.3	4.0	24.0	5.6	7.4
	R3SC2-LR	1300	75	2.5	0.4	13.3	16.0	5.2	12.2

3.4.2.2 Scleractinian Recruit Density

Coral recruit density, defined as corals 3 cm and less, was low across the northern outer reef habitat. Recruit density was lower at near-channel sites (0.0-0.1 corals/m^2) when compared to the northern outer reef control (0.4 corals/m^2) (Table 27). Recruit density was greater in the southern hardbottom habitat where near-channel recruit density ranged from 0.3-0.7 recruit corals/m^2 compared to the southern outer reef control that had 0.4 coral recruits/m^2.

Since no prior surveys of coral recruit densities have been performed at the cross impact assessment sites it is unknown if the pattern of lower recruit density near the channel in the northern outer reef habitat is due to an effect of dredging or because total coral density is also lower near the channel. The pattern of lower overall coral density near the channel in the outer reef habitat pre-dates construction activities and was documented in the 2010 baseline survey (DCA 2012). It is likely that the higher overall recruit density found on the southern outer reef is linked to the higher total coral density of this habitat. The pattern of higher overall recruit densities of near-channel southern outer reef sites was observed in both 2016 and 2010.

3.4.2.3 In-situ Scleractinian Mortality Assessments

Corals from the 2016 cross survey were not followed through time and thus no temporal assessment of partial or total mortality is available at any cross impact assessment site. Qualitative indicators of the relative health of corals were collected during the 2016 impact assessment and included: the percentage of corals showing signs of partial mortality (anywhere not including the base), partial mortality of the base (any partial mortality that included the base of the coral), percent partial mortality, and percent mean mortality (that includes standing dead corals) are provided in Table 27.

In the northern outer reef habitat partial mortality ranged from 0.0% at R3N-100-LR and R3N-200-LR to 33.3% at R3N1-LR (Table 27). Partial mortality of the base was lowest at site R3N-500-LR (9.5%) and was highest at R3N-150-LR where 38.5% of corals had some level of coral mortality that included the base of the colony. The mean percent partial mortality of corals at each outer reef assessment site ranged from 3.3% at R3N-500-LR to 8.7% at R3N-300-LR. Percent mean mortality that included standing dead corals, ranged from 3.7% at R3N-400-LR to 30.8% at R3N1-LR.

In the southern outer reef habitat partial mortality ranged from 4.0% at R3S-350-LR to 13.3% at the southern outer reef control R3SC2-LR (Table 27). Partial mortality of the base was lowest at impact assessment site R3S2-LR (2.9%) and was highest at R3S-350-LR where 24.0% of corals had some level of coral mortality that included the base of the colony. The mean percent partial mortality of corals at each southern hardbottom assessment site ranged from 4.2% at site R3S2-LR to a maximum level of 6.0% at R3S-50-LR. Percent mean mortality that included standing dead corals, ranged from 7.4% at site R3S-50-LR to 14.4% at R3S-50-LR.

Planimetry measurements of tagged colonies between baseline and impact assessment surveys, at R2N1-RR, the permanent site with the highest proportion of corals with sediment-related partial mortality, were not significantly different than the changes in coral area measured at the paired control R2NC2-RR. Although dredging affected channel-side corals as partial mortality, between baseline and impact assessment (-12.3%), there was no statistical difference in total tissue loss when compared to the paired control (-11.6%) (DCA 2017).

Since the species composition of each impact assessment site was not known prior to the 2016 survey, the level of coral mortality that is likely attributable to the region-wide white-plague disease event that started in 2014, cannot be evaluated as provided in the permanent site impact assessment report (DCA 2017). As a result, the relative impact of the disease event vs. construction impacts is unknown at cross site impact assessment locations. The coral mortality analysis provided in the permanent site report is a more robust analysis of potential construction impacts due to the fact that sources of coral mortality were quantified and the species-susceptibility to the ongoing disease event of individual sites was taken into account when analyzing coral mortality over the duration of the construction project (DCA 2017). It is important to note that since no previous data has been collected on the corals at the cross impact assessment sites, that the qualitative estimates of mortality provided above are inclusive of old mortality (that may pre-date construction activities), new mortality, all disease-related mortality, and potential construction-related coral mortality and that these factors cannot be separated after-the-fact.

3.5.2.4 Scleractinian Condition

Coral condition data in 2010 were collected using different methods and is not comparable to 2016 impact assessment condition indicators. As a result, no temporal conclusions can be drawn with respect to qualitative coral condition at the impact assessment sites.

Sediment was associated with many corals in the northern outer reef habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was lowest at R3N-150-LR (0.0%) and highest at R3N-200-LR (18.9%) (Table 28). Sediment accumulation (SA) ranged from 14.3% at R3N-500-LR to 33.3% at R3N1-LR. Partial burial of the base (PBB) ranged from 0.0% at R3N-150-LR to 38.1% at R3N-300-LR. Burial of the base (BBA) ranged from 0.0% at sites R3N-200-LR and R3N-300-LR to 23.8% at R3N-500-LR. The percentage of corals with buried bases was 5.7% at the outer reef north control site (R3NC1-LR). Burial (BUR) was not observed at any northern outer reef impact assessment site.

Sediment was associated with many corals in the southern outer reef habitat at both near-channel and control locations. Corals with the appearance of a sediment dusting (SED category) was lowest at the southern outer reef control R3SC2-LR where 6.7% of corals were documented with sediment dusting and highest at R3S-350-LR where 24.0% of corals were noted with sediment dusting (Table 28). Sediment accumulation (SA) ranged from 4.0% at R3SC1-LR to 20.0% at site R3S2-LR. Partial burial of the base (PBB) ranged from 14.7% at R3SC2-LR to 49.2% at R3S-50-LR. Burial of the base (BBA) ranged from 0.0% at R3S-50-LR to 10.7% at R3SC2-LR. Burial (BUR) was not documented in the southern outer reef habitat.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data are available with respect to coral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts.

Table 28. Distances of each outer reef monitoring site from the PortMiami channel provided along with the percentage of corals with the appearance of sediment dusting (SED), sediment accumulation (SA), and partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Chanel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Outer Reef North	R3N1-LR	23	11.1	33.3	11.1	11.1	0.0
	R3N-100-LR	100	11.8	17.6	23.5	11.8	0.0
	R3N-150-LR	150	0.0	23.1	0.0	7.7	0.0
	R3N-200-LR	200	18.2	22.7	9.1	0.0	0.0
	R3N-300-LR	300	9.5	23.8	38.1	0.0	0.0
	R3N-400-LR	400	17.2	17.2	24.1	10.3	0.0
	R3N-500-LR	500	4.8	14.3	28.6	23.8	0.0
	R3NC1-LR	9380	2.9	20.0	17.1	5.7	0.0
Outer Reef South	R3S2-LR	21	12.9	20.0	41.4	8.6	0.0
	R3S-50-LR	50	14.8	8.2	49.2	0.0	0.0
	R3S-350-LR	350	24.0	8.0	26.0	2.0	0.0
	R3SC2-LR	1300	6.7	4.0	14.7	10.7	0.0

3.5.3 Octocorals

The numbers of octocorals, octocoral density, the percentage of octocorals with partial mortality, partial mortality and base, and mean percent octocoral mortality are presented for the outer reef habitat. Sediment-related indicators of octocoral condition are also presented for outer reef habitat sites.

3.5.3.1 Octocoral Density

Outer reef octocoral density data were collected in 2010 using 10 m transects spaced at regular intervals from the channel out to 450 m. These data represent an independent baseline dataset that can be used for qualitative comparison of octocoral densities near the PortMiami channel. The near-channel northern outer reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 67. In 2010 octocoral densities ranged from 0.4 octocorals/m^2 at R3N030, to 2.1 octocorals/m^2 at R3N200 (Figure 67). During the 2016 impact assessment surveys the near-channel octocoral densities ranged from 1.7 octocorals/m^2 at R3N1-LR (23m from the channel) to 6.5 octocorals/m^2 at R3N-300-RR (Table 29). No control data were acquired in 2010 but in 2016 the northern outer reef control site (R3NC1-LR) had an octocoral density of 10.6 octocorals/m^2. Although the methods and site locations are different, the density of octocorals measured in the northern outer reef habitat during the 2016 impact assessment are higher than values established prior to dredging in 2010 at all distances from the channel (Figure 67). This data indicates no significant decline in octocoral densities in the northern outer reef habitat as a result of construction activities.

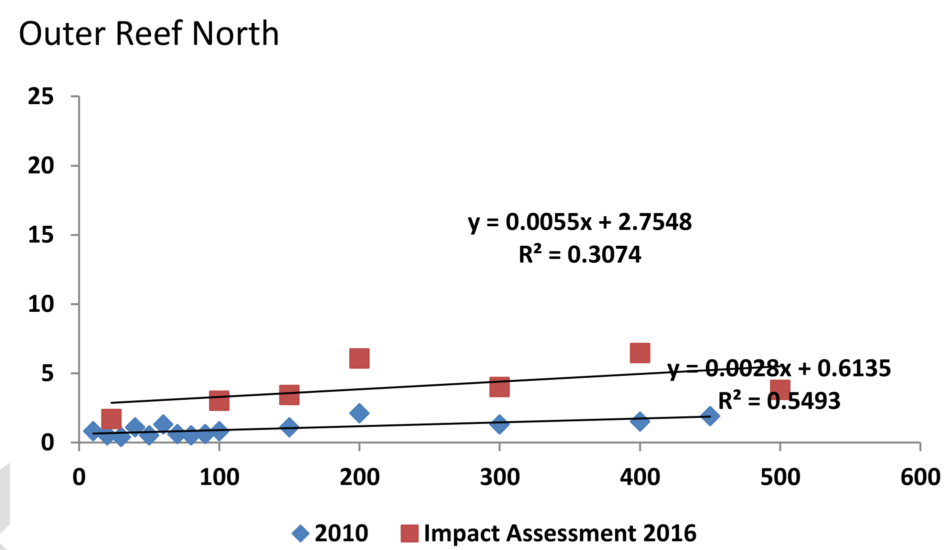


Figure 67. Octocoral densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

The near-channel southern outer reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 68. In 2010 octocoral densities ranged from 0.3 octocorals/m^2 at R3S2010, to 5.8 octocorals/m^2 at R3S2070 (Figure 68). During the 2016 impact assessment surveys the near-channel octocoral densities ranged from 2.5 octocorals/m^2 at R3S2-LR (21m from the channel) to 5.7 octocorals/m^2 at R3N-350-LR (Table 29). No control data were acquired in 2010 but in 2016 the southern outer reef control site (R3SC2-LR) had an octocoral density of 6.8 octocorals/m^2. Although the methods and site locations are not the same, the density of octocorals measured in the northern outer reef habitat during the 2016 impact assessment are equal to or higher than values established prior to dredging in 2010 (Figure 68). These data indicates no significant decline in octocoral densities in the southern outer reef habitat as a result of construction activities.

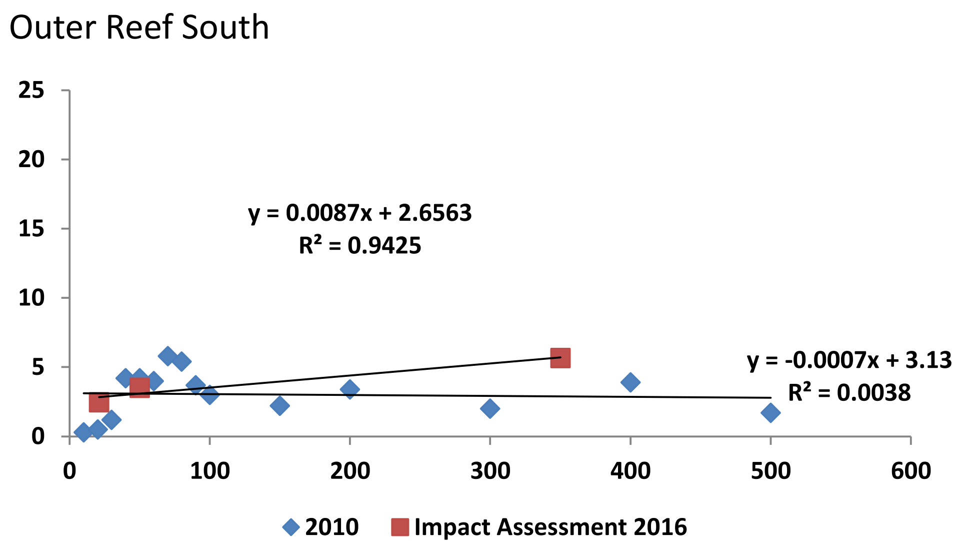


Figure 68. Octocoral densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

Table 29. Numbers of octocorals, octocoral density, and percent of octocorals with partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each outer reef impact assessment site. Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Chanel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Outer Reef North	R3N1-LR	23	51	1.7	52.9	15.7	7.2
	R3N-100-LR	100	90	3.0	48.9	10.0	5.4
	R3N-150-LR	150	103	3.4	38.8	14.6	3.7
	R3N-200-LR	200	182	6.1	33.0	6.0	2.9
	R3N-300-LR	300	120	4.0	17.5	6.7	1.8
	R3N-400-LR	400	194	6.5	14.9	4.6	2.7
	R3N-500-LR	500	114	3.8	29.8	15.8	6.3
	R3NC1-LR	9380	319	10.6	16.6	6.3	1.9
Outer Reef South	R3S2-LR	21	74	2.5	47.3	6.8	3.6
	R3S-50-LR	50	105	3.5	15.2	19.0	5.0
	R3S-350-LR	350	170	5.7	28.2	10.0	1.4
	R3SC2-LR	1300	204	6.8	30.9	7.8	3.9

3.5.3.2 In-situ Octocoral Mortality Assessments

No octocoral condition data were collected in the 2010 baseline survey or during any construction monitoring assessment. As a result, no temporal conclusions can be drawn with respect to qualitative octocoral condition at the impact assessment sites.

In-situ octocoral mortality assessments showed moderate levels of partial mortality (not including the base) of octocorals at sites closer to the channel in the northern outer reef habitat. The number of corals with signs of partial mortality were lowest at R3N-400-LR (14.9%) and were highest at R3N1-LR (52.9%) (Table 29). Partial mortality including the base (PMB) ranged from 6.0% at R3N-200-LR to 15.8% at R3N-500-LR. Mean percent mortality ranged from 1.8% at R3N-300-LR to 7.2% at R3N1-LR.

In the southern outer reef habitat near-channel locations had similar levels of mean percent mortality as outer reef controls. Near-channel southern outer reef percent mean mortality ranged from 1.4% to 5.0%, compared with the outer reef control R3SC2-LR that had 3.9% mean mortality (Table 29). Partial mortality ranged from 28.2% at R3S-350-LR to 47.3% at R3S2-LR. Partial mortality including the base ranged from 6.8% at R3S2-LR to 19.0% at R3S50-LR.

Overall, *in-situ* octocoral mortality indicators varied across impact assessment sites but no site had more than 7.2% average mean octocoral mortality at any outer reef impact assessment site (Table 29).

3.5.3.3 Octocoral Condition

No octocoral condition data were collected in the 2010 baseline survey or during any construction monitoring assessment. As a result, no temporal conclusions can be drawn with respect to qualitative octocoral condition at the impact assessment sites. Sediment-related octocoral condition data are presented for the outer reef habitat in Table 30.

Sediment indicators were variable in the northern outer reef habitat. Octocorals with the appearance of a sediment dusting (SED category) was lowest at R3N-200-LR (2.2%) and highest at R3NC1-LR (37.0%) (Table 30). Sediment accumulation (SA) ranged from 3.9% at site R3N1-LR and R3N-150-LR to 52.5% at R3N-300-LR. Partial burial of the base (PBB) ranged from 0.0% at R3N1-LR and R3N-300-LR to 6.7% at R3N-100-LR. Burial of the base (BBA) ranged from 0.0% at R3N1-LR and R3N-200-LR to 6.8% at R3N-150-LR. Burial (BUR) of octocorals was not observed at any northern outer reef impact assessment site.

With the exception of sediment dusting indicators, sediment was not associated with many octocorals in the southern outer reef habitat. Octocorals with the appearance of a sediment dusting (SED category) was lowest at R3S-50-LR (10.5%) and highest at R3SC2-LR (29.4%) (Table 30). Sediment accumulation (SA) ranged from 4.1% at R3S2-LR to 20.6% at R3S-350-LR. Partial burial of the base (PBB) ranged from 0.0% at R3S-350-LR to 4.1% at R3S2-LR. Burial of the base (BBA) ranged from 1.0% at R3SC2-LR to 15.2% at R3S-50-LR. Burial (BUR) of octocorals was not observed at any southern outer reef impact assessment site.

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data are available with respect to octocoral sediment indicators at cross site locations, it is unknown how these indicators reflect potential dredging impacts. However, potential dredging indicators such as partial burial of the base, burial of the base, and burial were generally low across all southern outer reef impact assessment sites.

Table 30. Distances of each outer reef monitoring site from the PortMiami channel provided along with the percentage of octocorals with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m² on the EW survey line.

Site		Distance from Chanel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Outer Reef North	R3N1-LR	23	9.8	3.9	0.0	0.0	0.0
	R3N-100-LR	100	1.1	14.4	6.7	3.3	0.0
	R3N-150-LR	150	7.8	3.9	1.9	6.8	0.0
	R3N-200-LR	200	2.2	8.8	3.8	0.0	0.0
	R3N-300-LR	300	3.3	52.5	0.0	1.7	0.0
	R3N-400-LR	400	28.4	20.1	1.5	0.5	0.0
	R3N-500-LR	500	18.4	11.4	2.6	0.9	0.0
	R3NC1-LR	9380	37.0	4.4	2.2	3.4	0.0
Outer Reef South	R3S2-LR	21	10.8	4.1	4.1	1.4	0.0
	R3S-50-LR	50	10.5	7.6	1.9	15.2	0.0
	R3S-350-LR	350	27.6	20.6	0.0	1.8	0.0
	R3SC2-LR	1300	29.4	4.4	2.5	1.0	0.0

3.5.4 Sponges

The numbers of sponges, sponge density, the percentage of sponges with partial mortality, partial mortality and base, and mean percent sponge mortality are presented for the outer reef habitat. Sediment-related indicators of octocoral condition are reported for the outer reef habitat cross sites.

3.5.4.1 Sponge Density

Sponge density data from the outer reef was collected in 2010 using 10m transects spaced at regular intervals from the channel out to 450m to the north and 500 m to the south (cite Miami baseline report, dated March 2012). These data represent an independent baseline dataset that can be used for qualitative comparison of sponge densities near the PortMiami channel. The near-channel northern outer reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 69. In 2010 sponge densities ranged from 2.3 sponges/m² at R2N030 to 16.5 sponges/m² at R3N400 (Figure 69). During the 2016 impact assessment surveys, near-channel sponge densities ranged from 11.9 sponges/m² at R3N-150-LR to 23.9 sponges/m² at R3N-300-LR (Figure 69, Table 31). No control data were acquired in 2010. Although the methods and site locations are not the same, the density of sponges measured in the northern outer reef habitat during the 2016 impact assessment are equal to or higher than values established prior to dredging in 2010 at all distances from the channel (Figure 69).

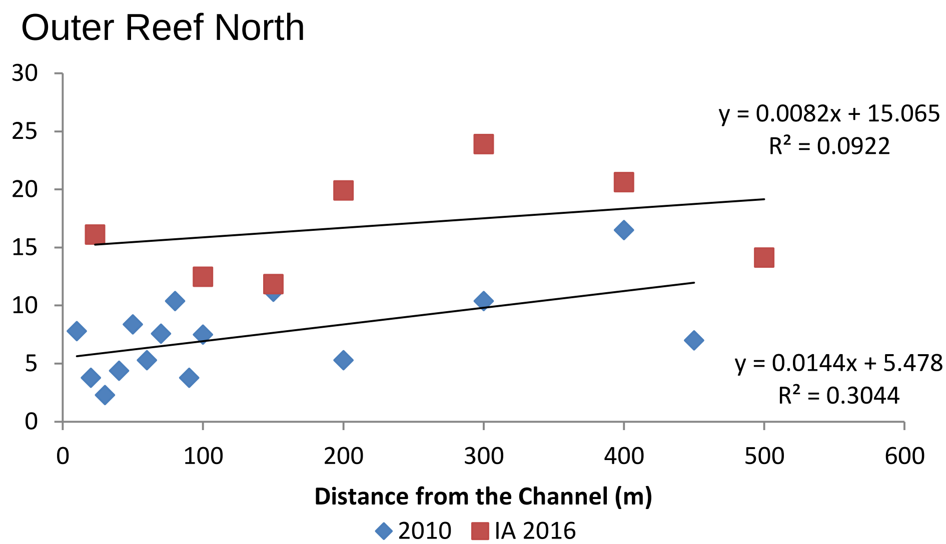


Figure 69. Sponge densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

The near-channel southern outer reef data from both 2010 and 2016 have been plotted against distance from the channel in Figure 56. In 2010 sponge densities ranged from 3.9 sponges/m^2 at R3S2010 to 13.2 sponges/m^2 at R2S2090 (Figure 70). During the 2016 impact assessment surveys, near-channel sponge densities ranged from 8.2 sponges/m^2 at R3S2-LR to 17.6 sponges/m^2 at R3S-350-LR (Table 31, Figure 70). No control data were acquired in 2010 but in 2016 the southern outer reef control site (R3SC2-LR) had a sponge density of 14.9 sponges/m^2. Although the methods and site locations are not the same, the density of sponges measured in the southern outer reef habitat during the 2016 impact assessment are higher than values established prior to dredging in 2010 (Figure 70). From the permanent site impact assessment surveys no channel-side location that was found to have a significant interaction between site and period between 2013 and 2016 (DCA 2017).

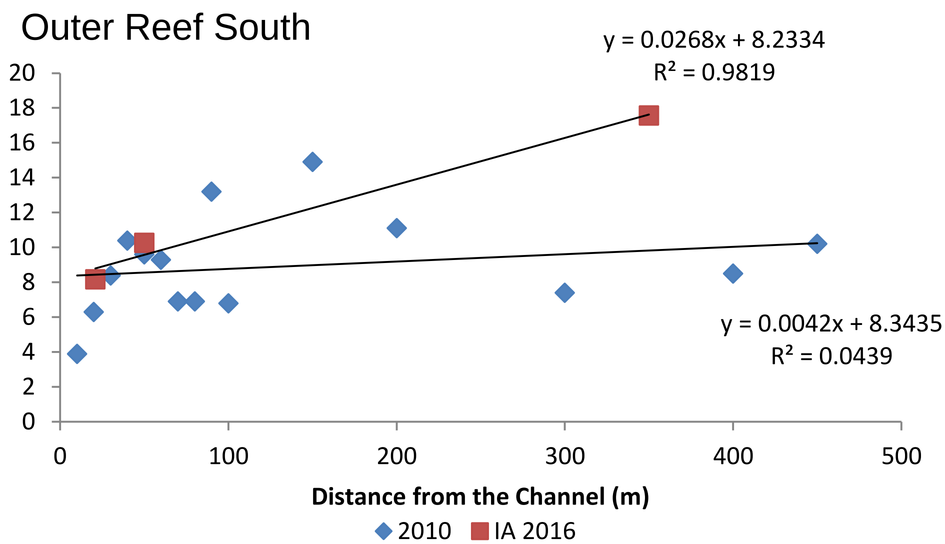


Figure 70. Sponge densities with respect to site distance from the channel as measured during 2010 baseline survey (blue) and 2016 impact assessment survey (red).

Table 31. The distance of each outer reef monitoring site from the PortMiami channel along with the numbers of sponges, sponge density, and percent of sponges with signs of partial mortality (PM), partial mortality of the base (PMB), and average percent mortality are given for each middle reef impact assessment site. Data were collected over 30 m² on the EW survey line.

Site		Distance from Chanel (m)	N	Density/ m^2	PM (%)	PMB (%)	% Mean Mortality
Outer Reef North	R3N1-LR	23	484	16.1	3.5	1.0	0.4
	R3N-100-LR	100	375	12.5	1.9	0.0	0.2
	R3N-150-LR	150	355	11.8	3.4	1.1	0.6
	R3N-200-LR	200	598	19.9	2.2	0.3	0.4
	R3N-300-LR	300	717	23.9	1.8	0.0	0.3
	R3N-400-LR	400	619	20.6	0.8	0.2	0.1
	R3N-500-LR	500	425	14.2	4.2	0.9	1.3
	R3NC1-LR	9380	643	21.4	4.5	0.3	0.5
Outer Reef South	R3S2-LR	21	244	8.1	0.0	0.0	0.0
	R3S-50-LR	50	309	10.3	1.0	0.0	0.5
	R3S-350-LR	350	527	17.6	3.6	0.9	0.5
	R3SC2-LR	1300	448	14.9	2.9	0.0	0.6

3.5.4.2 Outer Reef Sponge Condition

No quantitative data on sponge sediment condition were collected in the outer reef habitat in either the 2010 or 2013 PortMiami baseline assessments or in the 2015 PortMiami post-construction surveys (DCA 2012; DCA 2014c; DCA 2015b). As a result, no temporal conclusions can be drawn with respect to qualitative sponge condition in the outer reef habitat. Sediment-related sponge condition for the outer reef habitat is presented in Table 32.

Sediment was associated with many sponges in the northern outer reef habitat at both near-channel and control locations. Sponges with the appearance of a sediment dusting (SED category) was lowest at site R3N-100-LR (33.1%) and highest at R3NC1-LR (59.6%) (Table 32). Sediment accumulation (SA) was lowest at R3NC1-LR (26.4%) and was highest at the nearby site R3N-100-LR where 62.7% of sponges were noted with sediment accumulation. Partial burial of the base (PBB) ranged from 3.9% at R3NC1-LR to 15.2% at R3N-100-LR. Burial of the base (BBA) ranged from 1.9% at R3NC1-LR to 5.0% at R3N1-LR. Burial (BUR) was rare and ranged from 0.0 to 0.3% at the northern outer reef habitat.

In the southern outer reef habitat, the percentage of sponges with the appearance of a sediment dusting (SED category) was lowest at site R3S-50-LR (31.7%) and highest at R2S-350-LR (67.0%) (Table 32). Sediment accumulation (SA) ranged from 23.1% at R3S-350-LR to 51.5% at site R3S-50-LR. Partial burial of the base (PBB) ranged from 2.9% at R3S-50-LR to 8.5% at R3SC2-LR. Burial of the base (BBA) was not noted at any southern outer reef impact assessment site (R2S-100-RR).

Since sediment impacts are known to be significantly higher near high-traffic harbor entrance locations (Lirman et al. 2003), and no temporal data are available with respect to sponge sediment indicators, it is unknown how suspended or settled sediment may have impacted sponge populations near PortMiami either during or after construction activities. In addition, although sediment can be deleterious to sponge health, a recent review of sediment impacts on marine sponges concluded that most species can tolerate varying degrees of suspended and settled sediment and that many sponges have adaptations to not only persist but thrive in sedimented environments (Bell et al. 2015).

Table 32. Distances of each outer reef monitoring site from the PortMiami channel provided along with the percentage of sponges with the appearance of sediment dusting (SED), sediment accumulation (SA), partial burial of the base (PBB), burial of the base (BBA) and complete burial (BUR). Data were collected over 30 m^2 on the EW survey line.

Site		Distance from Chanel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Outer Reef North	R3N1-LR	23	41.9	50.6	8.1	5.0	0.0
	R3N-100-LR	100	33.1	62.7	15.2	4.3	0.3
	R3N-150-LR	150	45.4	48.5	12.1	3.1	0.0
	R3N-200-LR	200	44.8	47.2	8.4	2.8	0.2
	R3N-300-LR	300	51.5	38.4	9.5	3.3	0.0
	R3N-400-LR	400	56.9	35.2	6.9	4.2	0.0
	R3N-500-LR	500	43.5	47.8	13.9	2.4	0.0
	R3NC1-LR	9380	59.6	26.4	3.9	1.9	0.0

Site		Distance from Chanel (m)	SED (%)	SA (%)	PBB (%)	BBA (%)	BUR (%)
Outer Reef South	R3S2-LR	21	39.3	46.7	4.9	1.2	0.0
	R3S-50-LR	50	31.7	51.5	2.9	1.0	0.0
	R3S-350-LR	350	67.0	23.1	8.2	1.7	0.0
	R3SC2-LR	1300	53.8	41.5	8.5	1.1	0.0

3.5.5 Outer Reef Summary

In the outer reef habitat, octocorals are the dominant benthic invertebrate (9.5% of the bottom) followed by sponges (5.3%) and scleractinians (0.6%) (DCA 2017). Densities of dominant benthic invertebrates as measured in the impact assessment were compared to values documented prior to the project in 2010 to determine if there was functional habitat loss due to the project. Octocoral densities in 2016-2017 were equal to or higher than values documented in 2010 at all distances from the channel and in both the northern and southern outer reef habitat. Sponge densities followed the same pattern as octocorals in that densities at near-channel sites in 2016-2017 were equal to or higher than values documented in 2010 at all distances from the channel and in both the northern and southern outer reef habitat. Scleractinian coral densities were lower in 2016 than densities measured in 2010 at most distances from the PortMiami channel. As in the middle reef habitat, the change in coral density throughout the survey corridor is principally due to the impacts of a regional white-plague disease event as documented in the permanent site report (DCA 2017). No increased white-plague disease-related coral mortality was documented at any outer reef near-channel site as a result of the project (DCA 2017). While scleractinian corals were impacted at near-channel sites during the project (2 out of 46 (4.3%) near-channel outer reef corals died as a result of burial), this group represents less than 1% of cover according to pre-dredging data. When considering a 4.3% loss of less than 1% of the living benthic cover, this change should not be considered a functional loss of habitat. Furthermore partial mortality of corals documented during the project resulted in no net loss of function. This was determined based on planimetry analysis on post-project comparisons of photographs of tagged corals before, during and after the project. Looking at the outer reef habitat function as the combined influence of the three major groups of benthic invertebrates; octocorals, sponges, and corals, no permanent effect of the project was detected in the 2016-2017 impact assessment. This is corroborated by percent cover analysis of near channel permanent monitoring sites in which the percent cover of dominant benthic invertebrates remained relatively unchanged between baseline and impact assessment surveys in the outer reef habitat (octocorals 9.5%-13.8%; sponges 5.3%-3.5%; scleractinians 0.6%-0.3%; DCA 2017).

CONCLUSION

The benthic community of the hardbottom, middle and outer reef adjacent to the PortMiami entrance channel has the important ecological function of providing habitat for corals, octocorals, algae, fish, sponges, crustaceans, echinoderms, and other hardbottom and reef dwelling flora and fauna. Hardbottom and reef habitat across the study area were dominated by sand, crustose turf and bare space, macroalgae, octocorals, sponges and hard corals. To determine the degree to which a permanent loss of ecological value had occurred in potentially impacted areas as a result of the project, numerous monitoring results were considered.

Organism density from the impact assessment was compared to densities prior to the project to identify areas in which project-related declines may have occurred. According to these results, the density of sponges and octocorals was equal to or greater than densities measured prior to dredging in 2010 baseline surveys, at all distances from the channel. These data indicate that no permanent negative impact to sponge and octocoral resources occurred as a result of the project. Also, permanent site functional cover data were compared between 2013 (pre-dredging) and 2016 (impact assessment) to document project-related declines in functional group cover. Although not available for areas away from the channel, these sites were adjacent to the channel and would have been the most affected communities based on proximity to the Project; these results support the 2010/2016 comparison from an independent data set for permanent sites. Functional group data from the permanent sites, which compared 2013 (pre-dredging) and 2016 (impact assessment) data, showed almost no change between pre- and post-dredging surveys for all major living groups: octocoral (9.27% to 9.97%), sponge (4.48% to 4.70%), zoanthids (0.54% to 0.46%) and sceractinians (0.88% to 0.62%). Scleractinians in the area suffered substantial mortality associated with a region-wide coral disease but this mortality was not associated with the project. While scleractinian corals were impacted at near-channel sites during the project (2.7% of channel-side corals died as a result of burial), this group represents less than 1% of living cover according to pre-dredging data. When considering a 2.7% loss of the hard coral functional group, which represents less than 1% of the living benthic cover, no permanent loss of ecological functions occurred as a result of this loss. Furthermore, partial mortality of corals documented during the project resulted in no net loss of tissue over the time period sampled. This was determined based on planimetry analysis of post-project comparisons of photographs of tagged corals before, during and after the project. When 2016/17 sediment data were considered, only one point out of 1,006 near-channel sediment assessment locations (0.09%) was characterized as fine sediment and exceeded the 3 cm guideline for restoration efforts. To represent a permanent impact to the site the fine sediment would have to prevent dense coral community establishment which has been linked to areas where mean sediment depth exceeds 5 cm in Florida Bay (Lirman et al. 2003) and 3 cm for areas of *Acropora* restoration efforts. Therefore, no permanent functional loss of habitat was documented in the 2016/17 cross site survey.

BEFORE THE PROJECT in 2013:
The mean percent cover of benthic invertebrates was approximately 15% of the bottom at the channel-side sites during baseline surveys: scleractinians (0.88%), octocorals (9.27%), sponges (4.48%) and zoanthids (0.54%), while CTB and sand comprised the remaining 84.1% of the benthic cover (DCA 2017).

AFTER THE PROJECT in 2016:
The mean percent cover of benthic invertebrates was approximately 16% of the bottom at channel-side sites: scleractinians (0.62%), octocorals (9.97%), sponges (4.7%) and zoanthids (0.46%), while CTB and sand comprised the remaining 84.09% of the bottom at channel-side sites (DCA 2017).

EPILOGUE

Figure 71. Satellite image of Hurricane Irma on September 9th making its second Florida landfall off the southwest coast.

From September 8-10, 2017 Hurricane Irma a strong Category 3 storm crossed over the south Florida peninsula bringing strong onshore winds and waves to the southeast Florida coast. Preliminary observations of reef habitats from the Florida Keys north to Broward County show damage to reef flora and fauna. Conspicuous injuries to octocorals and sponges have been noted and are being documented at this writing. In addition, large volumes of reef sediments were displaced. The “white” optical properties of the fine-grained carbonate sediments that were placed in suspension by the passage of the storm are clearly visible in the pre- and post-storm images below (see Figure 2). The reef landscape was altered by the passage of this storm, which redistributed sediments and affected the benthic communities. The quantitative effects of this storm on these benthic resources, adjacent to PortMiami, have not been quantified, but likely differ substantially from those collected in 2016/2017.

Figure 72. Satellite image of the south Florida peninsula pre-Hurricane Irma on September 8th (left panel) and post-Hurricane Irma on September 11 (right panel). Note shelf-wide increases in turbidity.

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