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

One-Year Post-Construction Impact Assessment for Hardbottom Middle and Outer Reef Benthic Communities at Permanent Sites

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EXECUTIVE SUMMARY

The one-year post-construction impact assessment report for permanent sites documents the permanent and temporary impacts of the Miami Harbor Phase III Project. The project was permitted through the Florida Department of Protection (FDEP), under Permit No. 0305721-001-BI. This report is responsive to Specific Condition 32 a ii. d of the permit. In order to characterize impacts of the dredging project at channel-side sites, 19 of the originally established 26 permanent monitoring sites were selected by FDEP for follow-up monitoring. These sites included nine (9) impacted channel-side sites and their respective controls. Five (5) channel-side sites and two control sites were eliminated from this impact assessment as these sites were located outside of the areas delineated as potentially affected by sedimentation, during impact assessment surveys performed in 2015.

The overall goal of the FDEP mandated monitoring program was to "detect natural variation in the resources and to assist in determining the effects of the actual dredge operations on the resources surrounding the project area." Site selection was predetermined by FDEP using published regional benthic habitat maps. Baseline surveys documented differences between benthic communities at channel-side and control sites. Reasons for differences include water clarity, sedimentation, current regimes, habitat complexity, and benthic community composition due to both local and intra-regional variability. Baseline surveys conducted prior to dredging established information on the sedimentation environment, percent cover of benthic resources, and population dynamics of corals, octocorals, and sponges that dominate the benthic communities adjacent to the Federal Navigation Channel. These baseline results were used as a point of comparison for the impact assessment survey to document changes attributable to dredging one-year after the completion of construction activities while considering other environmental and/or anthropogenic factors that influence benthic resources in the area. Changes in the benthic habitats between baseline and impact assessment surveys were attributable to a number of factors, including regional stress events, natural environmental conditions, and project related activities.

<u>Sediment Monitoring Results</u>

Throughout the monitoring of the project, there were seasonal differences in sea-state resulting in high sedimentation variability. Sedimentation rate data collected at project controls revealed monthly differences in both the size and amount of natural reef sediments accumulating on the reef surface. The sedimentation environment varied substantially at both channel-side and control locations over the course of project monitoring. During the one-year post-construction impact assessment surveys, channel-side sediment accumulation rates were found to be equal to or below baseline values, except during a rare weather event - Hurricane Matthew, October 9, 2016. Mean sediment accumulation rates measured over all channel-side locations were below baseline values during the one-year post-construction impact assessment survey. The sedimentation accumulation results indicate that the channel-side sedimentation environment has returned to levels observed prior to commencement of dredging activities.

<u>Biological Monitoring Results</u>

Functional group percent cover data describe the overall composition of benthic organisms and abiotic cover at a site. Project-related sites were assessed in terms of the percent cover of corals, octocorals, sponges, zoanthids, macroalgae, CTB (crustose coralline algae, turf and bare), sand, and other during baseline and impact assessment periods. The mean percent cover of benthic invertebrates was approximately 17% of the bottom at the channel-side sites during baseline surveys: scleractinians (0.88%), octocorals (10.01%), sponges (5.01%) and zoanthids (1.13%), while CTB and sand comprised the remaining 83% of the benthic cover. During impact assessment surveys the mean percent cover of benthic invertebrates was again 17% of the bottom at channel-side sites: scleractinians (0.51%), octocorals (9.18%), sponges (5.78%) and zoanthids (1.13%), while CTB and sand comprised the remaining 83% of the bottom at channel-side sites. The functional group percent cover analysis documented that mean cover of corals, octocorals, sponges and zoanthids was within a standard error of baseline values at channel-side and control locations in each of the sampled habitats.

Temporary impacts due to the project were documented as increased levels of sand cover and nearly reciprocal declines in CTB cover at channel-side locations. These differences were greater than changes documented at the control sites over the same time period. Overall, mean sand cover increased at channel-side sites from 13.6% to 29.3% (15.7% increase) from baseline to impact assessment surveys in comparison to a 0.6% increase in mean sand cover at control sites. A corresponding decline in the mean cover of CTB was also measured between baseline and impact assessment periods with a decline in mean CTB cover declining from 70.5% to 54.8% (-15.7%) at channel-side locations compared to a 3.7% increase in mean CTB cover at control sites. Increased sand cover was spatially restricted to middle reef and southern hardbottom channel-side sites during the impact assessment survey. These increases in sand cover documented at channel-side sites were within the variability of sand cover documented over time at the control sites. At control locations, sand cover varied as much as 68.3% over the course of project monitoring due to seasonal variability. The range mean sand cover at control site locations was 40.0% over the course of the project. The increased sand cover documented at channel-side sites during the impact assessment survey is within the range of control site variability. The increase in sand cover channel-side is expected to be temporary, as sand cover at channel-side sites has declined since construction completion and continues to trend downward toward baseline values.

Repeated Measures Coral Monitoring Results

A total of 476 scleractinian corals were tagged at the 19 selected control and channel-side sites. These sites were monitored as often as twice per week during construction activities. Over the course of the project each tagged coral, at each site, was monitored and photographed at least 40 times. In the laboratory, some 20,000 individual observations of *in situ* coral condition were compared to paired photographs allowing the analysis of coral health/stress through time. In cases where corals died, the cause of mortality was discerned by carefully evaluating the sequence of events recorded (and photographed), prior to death.

Significant coral mortality associated with a regional white-plague coral disease was observed at channel-side and control locations over the course of project monitoring, starting in 2014. Following a regional, thermally induced, coral bleaching event in the summer of 2014, white-plague disease was first documented at the middle reef south control sites and then at channel-side locations during project monitoring. In the summer of 2015, the Florida Reef Resilience Program (FRRP) documented high levels (>10%) of coral disease in Broward-Miami, Biscayne, Upper and Lower Keys sub-regions. In the summer of 2016 FRRP documented high levels of coral disease in Martin, Broward-Miami, Upper, Lower, and Dry Tortugas sub regions. The location of the project in the Broward-Miami sub region was within the affected disease areas in both 2015 and 2016.

In total, eighty-five (85) out of 252 tagged coral colonies at control sites (33.7%) died during project monitoring. The overwhelming majority of identifiable mortality (81%, 69 out of 85) died from white-plague and other concurrent diseases, followed by unidentified mortality (14% 12 out of 85) white-band disease (4%, 3 out of 85), and competition (1%, 1 out of 85).

Ninety-eight out of 224 (43.7%) of tagged coral colonies at channel-side sites died during project monitoring. The overwhelming majority of identifiable mortality (74%, 72 out of 98) died from white-plague and other concurrent diseases followed by unidentified mortality (18%, 18 out of 98), sediment burial (6%, 6 out of 98), competition (1%, 1 out of 98), and bleaching (1%, 1 out of 98) explained the remaining coral mortality throughout the project area.

Six (6) tagged channel-side scleractinian corals were buried and died as a direct result of sediment accumulation during dredging. The loss of these six (6) corals is considered a permanent impact of the project. These six (6) corals represent 2.7% (6 out of 224 channel-side corals) of all tagged corals at the channel-side site locations.

Implication of Regional Coral Disease Outbreak

The FDEP permit authorized a BACI (before, after control, impact) study design, which compared channel-side sites with far-field controls. However, Precht et al. (2016) documented species-specific rates of white-plague disease infection and estimates of species mortality throughout Miami-Dade County starting in fall 2014 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.* The species specificity of the white-plague disease resulted in a disparity in channel-side and control site coral mortality. This difference was found to be related to differences in susceptibility of coral species to white-plague disease without reference to location, either close to, or far away from dredge activity. Taking disease-susceptibility into account, no channel-side sites had higher levels of coral mortality than would be predicted from regional white-plague disease prevalence. Declines in scleractinian density between baseline and impact assessment surveys at channel-side and control locations were directly linked to the white-plague disease event.

Partial Coral Mortality

In cases where divers noted partial coral mortality due to sediment, the coral was noted with a condition code “PM”. The PM condition code is a qualitative indication that sediment has caused some level of partial mortality to a surveyed coral but no quantitiative assessment of tissue loss was made *in situ*. Partial mortality associated with sediment affected up to 64.8% of corals across the nine (9) channel-side sites and 19.4% of corals at the ten (10) control sites at post-construction. The difference of ~46% in sediment related partial mortality at the channel-side sites may be attributed to the dredging project. To measure the amount of tissue lost from sediment-related partial mortality, planimetry measurements were performed on non-diseased corals at the most affected site (R2N1-RR) and changes from baseline surveys were compared to live tissue measurements of non-diseased corals at the paired control site (R2NC2-RR) over the time period. There was no significant difference in percent change in live coral tissue at R2N1-RR (-12.28%) when compared with its paired-control R2NC2-RR (-11.6%) between baseline and impact assessment surveys.

Coral Recruit Monitoring Results

Coral recruit (3cm and smaller) densities were found to be less than paired controls at four channel-side sites, higher than paired control sites at four channel-side sites and have equivalent recruit densities at one paired channel-side and control site. Since data on recruit density was not collected prior to the impact assessment survey there is no way to determine if these densities have changed due to project-related effects.

Octocoral and Sponge Monitoring Results

No significant changes in octocoral density were documented at channel-side sites when compared to paired-controls. In addition, no significant changes in sponge density were documented between baseline and impact assessment, except at R2N2-LR. The sponges lost at R2N2-LR were primarily encrusting and finger sponges and are also a potential impact of dredge activities.

Project Mitigation

The FDEP permit authorized direct impact of 7.07 acres of reef to achieve the navigational goals of the project. The FDEP permit required 9.28 acres of artificial reef mitigation to offset these permitted impacts. Of the permitted direct impacts (7.07 acres), the post-construction survey documented direct impact of 6.88 acres. A total of 11.6 acres of artificial reef were constructed and accepted as complete by the Corps on April 22, 2015. The addition of 2.32 acres of artificial reef habitat above the required 9.28 acres required, represents a functional gain to the system and may be considered advanced mitigation for other project related impacts. In addition, 157 *Acropora cervicornis* colonies from within 450 m of the channel were relocated to the RSMAS coral nursery by NOAA (October, 2014) as a part of the NEPA minimization process. From these colonies 1,059 fragments were created, grown, outplanted and monitored. In 2017, an additional 2,040 colonies were outplanted to the RSMAS coral nursery (personal communication to USACE; Tom Moore, NOAA). The addition of 3,099 outplanted *A. cervicornis* colonies may also be considered mitigation for additional project-related impacts.

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 PortMiami 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 NEPA process and a Record of Decision was signed on May 22, 2006. The offshore portion of the project was deemed complete on April 8, 2015. The entire project was completed on September 17, 2015.

The one-year post-construction impact assessment report for permanent sites (referred to as impact assessment throughout this report) documents the permanent and temporary impacts of the Project. The project was permitted through the Florida Department of Protection (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 first of two monitoring efforts in the one-year post-construction period. Specifically, this report documents the effects of the project on benthic resources within permanent monitoring sites on hardbottom, middle and outer reefs adjacent to the outer entrance channel.

In order to characterize impacts at channel-side sites, 19 of the 26 permanent sites were selected by FDEP for follow-up monitoring during the FDEP recommended impact assessment protocol (FDEP June 2016). These sites included 9 impacted channel-side sites and their respective controls (one site R2N1-RR, had two control sites). In the area of the norther middle reef control sites, three habitats were present (ridge reef (RR), linear reef (LR), and ridge reef (RR), see Figure 1), while channel-side only a single representative of each habitat type was present (RR and LR). A control site was set up at each of the northern control habitat types and monitored in baseline and post-construction surveys. Site selection by FDEP were sites with the greatest sedimentation related effects according to construction and post-construction period impact assessment surveys (DCA 2014b, DCA 2015a, Miller et al 2016). A second impact assessment survey is required by the FDEP permit and as of March 2017, field work for that effort is still ongoing. A number of parameters including benthic organism density, cover, and condition, as well as quantitative sedimentation rates were measured to test the null hypothesis:

Ho: Benthic community structure and function in the indirect effect (channel-side) sites will remain unchanged between the baseline and one-year post-construction impact assessment surveys.

During the project, the deposition of clay-like material at channel-side sites was documented during required compliance monitoring. At channel-side monitoring sites, this material resulted in the complete mortality of 6 scleractinian corals and the partial mortality of approximately 64.8% of the nine surveyed channel-side sites during the impact assessment survey.

According to cover estimates an increase in sand was also documented between baseline and impact assessment surveys, with all sites trending towards baseline, in the one-year post-construction survey period. While sand increased at channel-side sites, living constituent cover of sponges, octocorals, and zoanthids did not change significantly between baseline and impact assessment surveys. The only living and non-living cover that declined substantially between baseline and impact assessment surveys was the other major space occupier besides sand, CTB (crustose coralline algae, turf algae and bare) cover, which declined by 15% across all surveyed channel-side sites.

1.2 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 (Figure 1).

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 Corps showed predominantly south to north flow with eddies over the middle reef and hardbottom north of the channel (Figure 1). Tidal forces move water east or west along the channel at greater than 1 knot, twice per day. These tides caused 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.

1.3 FDEP Permitted Impacts and 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. Mitigation was completed during the project and a portion of the mitigation was completed before the direct impact occurred on the outer reef, representing a benefit to the overall ecosystem before any impacts occurred. No up-front mitigation was built for sediment accumulation associated impacts, as these effects were expected to be temporary.

1.3.1 Mitigation

In order to mitigate for the direct impact of the permitted loss of 6.88 acres of reef habitat, 9.28 acres of artificial reef habitat was accepted as advanced mitigation for this direct impact of the PortMiami dredge project. A total of 11.6 acres of artificial reef were constructed and accepted as complete by the Corps on April 22, 2015. The construction of the artificial reef resulted in the construction of 2.32 acres of additional mitigationand may be considered advanced mitigation for other project related permanent impacts. The addition of 2.32 acres of artificial reef habitat above the required 9.28 acres required, represents a functional gain to the system.

1.3.1.1. Non-Acroporid Corals

The FDEP permit required all corals greater than 25 cm be relocated from within the direct impact area and up to 1300 colonies between 10 cm and 25 cm be relocated to natural reefs (50%) and artificial reef (50%). As a result, 827 colonies greater than 10 cm 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 CSi (CSi 2016).

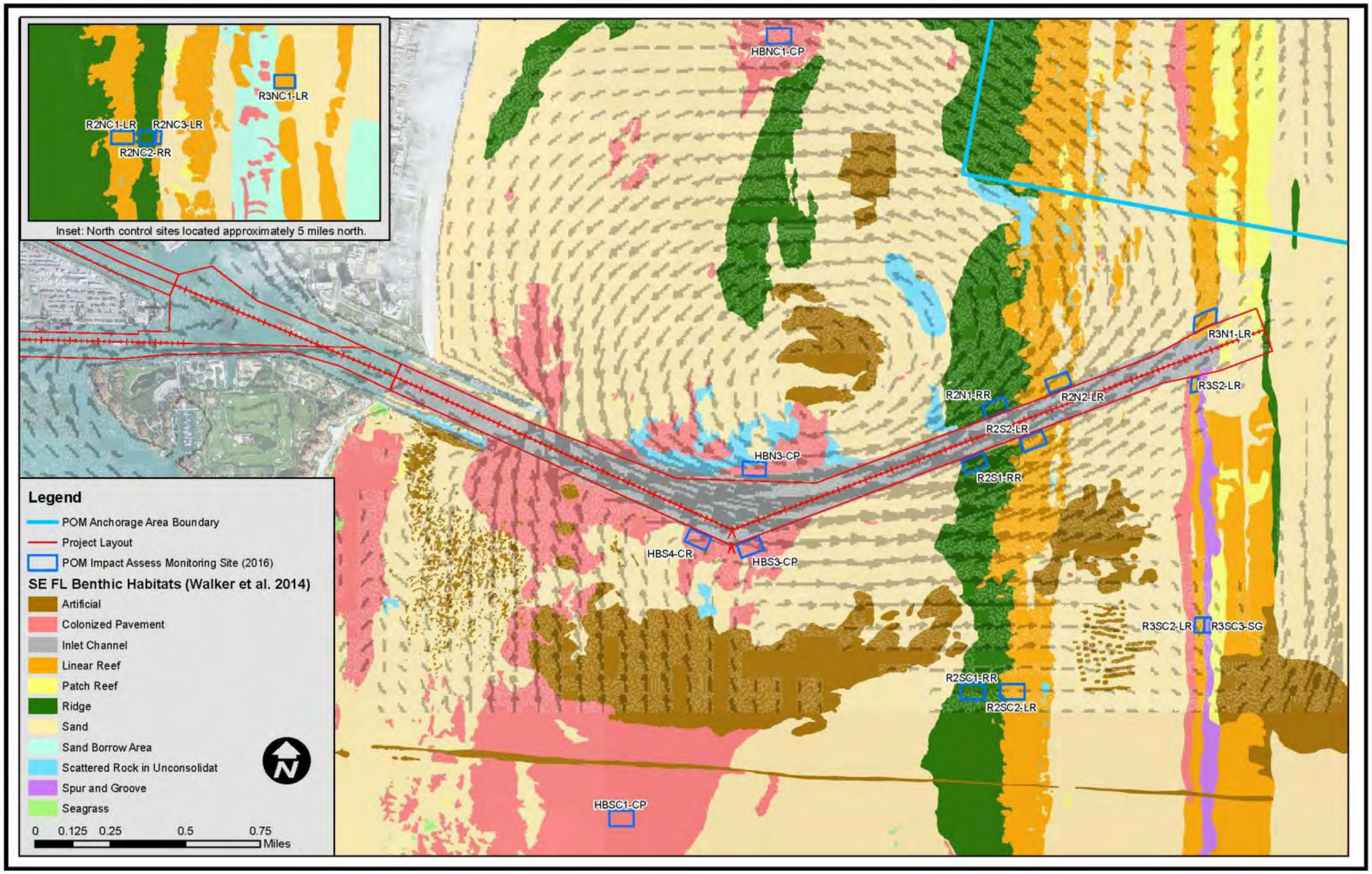


Figure 1. Miami Harbor Cuts 1 and 2 Entrance Channel hardbottom, middle, and outer reef FDEP required monitoring stations surveyed during one-year post-construction impact assessment survey. Grey arrows show water flow based on USACE 2006. Habitat maps used were developed by Walker et al. 2014.

1.4 Avoidance and Minimization

Through the NEPA process a number of avoidance and minimization measures were conducted before and during the project to protect resources.

1.4.1 Avoidance

Through the contracting process, the Corps chose a Contractor to perform the work based on a number of reasons, including surpassing environmental goals presented in the RFP. The contractor was chosen in part because of the ability to anchor only within the existing channel, thereby avoiding direct impacts from anchoring adjacent to the channel. Although these impacts were permitted, they were completely avoided as a result of the selection process.

1.4.2 Minimization

1.4.2.1 Acropora cervicornis

The threatened species *Acropora cervicornis* colonies within 33 m (100 feet) of the channel were moved prior to construction (CSA 2014a). Thirty-eight (38) colonies were relocated, tagged and monitored during and after construction (CSi 2016). From these colonies, a number of fragments were collected and provided to the RSMAS coral nursery for propagation and outplanting. During the project (October 2014), an additional 157 *A. cervicornis* colonies from within 450 m of the channel were relocated to the RSMAS coral nursery by NOAA. From these colonies 1,059 fragments were created, grown, outplanted and monitored (NMFS 2015). In 2017, an additional 2,040 colonies were outplanted offshore in Southeast Florida (personal communication to USACE; Tom Moore, NOAA). Although initially considered minimization, these outplants represent new colonies created from the minimization effort and may be considered mitigation.

1.4.2.2 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 as well as relocated 50 large *Xestospongia muta* colonies from within the direct impact area (CSA 2014b). ACM was not required by permit.

1.4.2.3 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 coordinated with NMFS as required under the 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.

1.5 Baseline Quantitative Study 2013, Compliance and Post-Construction Surveys 2015

The Project monitoring study design, required in the FDEP permit, was developed using a repeated measures design, with three permanent transects established at each of 26 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 within the hardbottom, middle, and outer reefs. For more information on post-construction survey results see DCA 2015a for hardbottom and DCA 2015b for middle and outer reef results.

1.6 Impact Assessment Surveys 2014-Present

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 up to 38.7 acres of nearshore hardbottom habitat, covered with project related clay-like material (Figure 2). 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 Nearshore hardbottom March 2015).

Impact assessment surveys were conducted on the middle and outer reefs in April and May 2015 and identified 213.7 acres of habitat potentially effected by sedimentation (Figure 3, DCA 2015d).

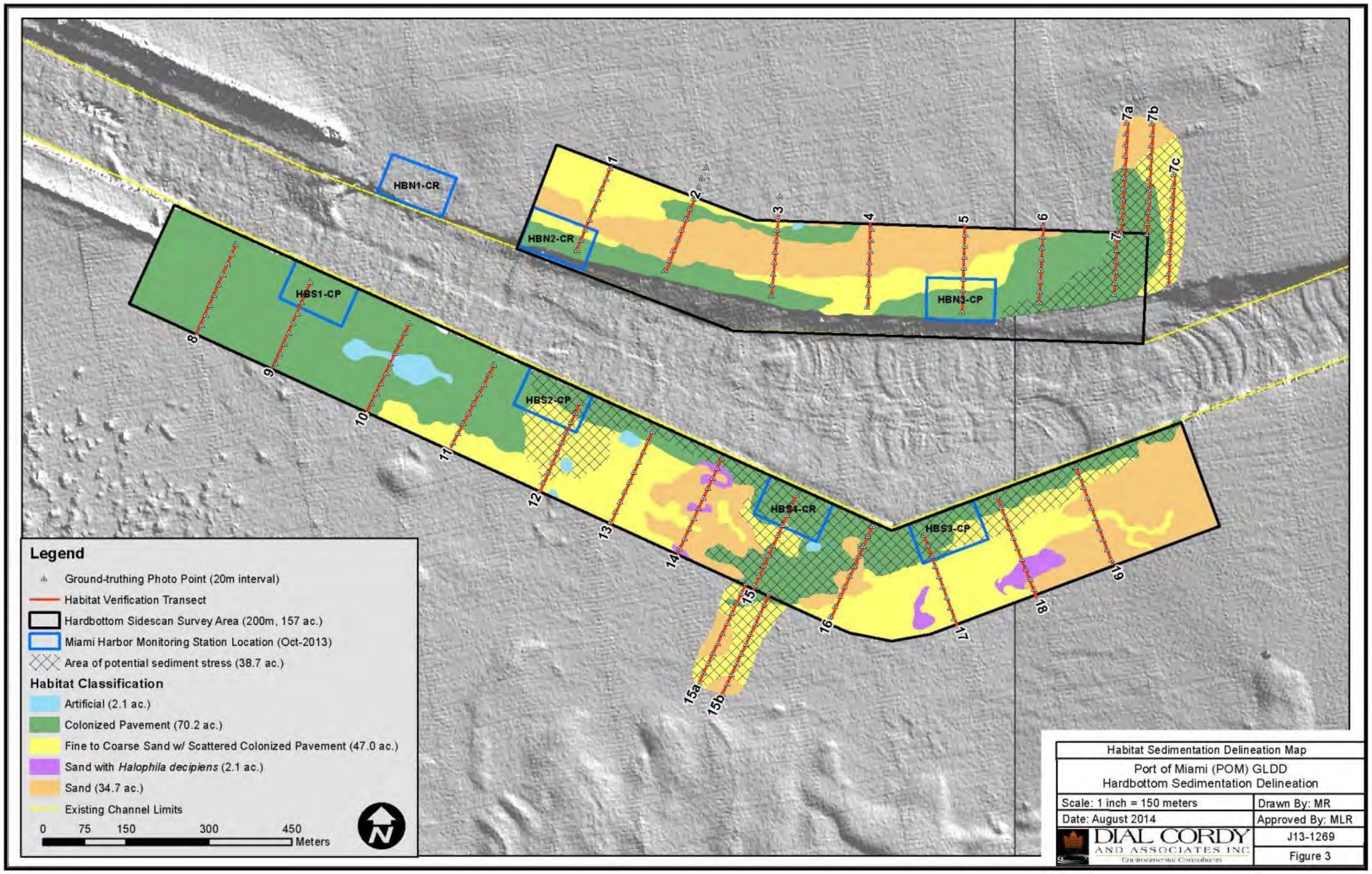


Figure 2. **Hardbottom habitat sedimentation delineation map (DC&A 2014a).**

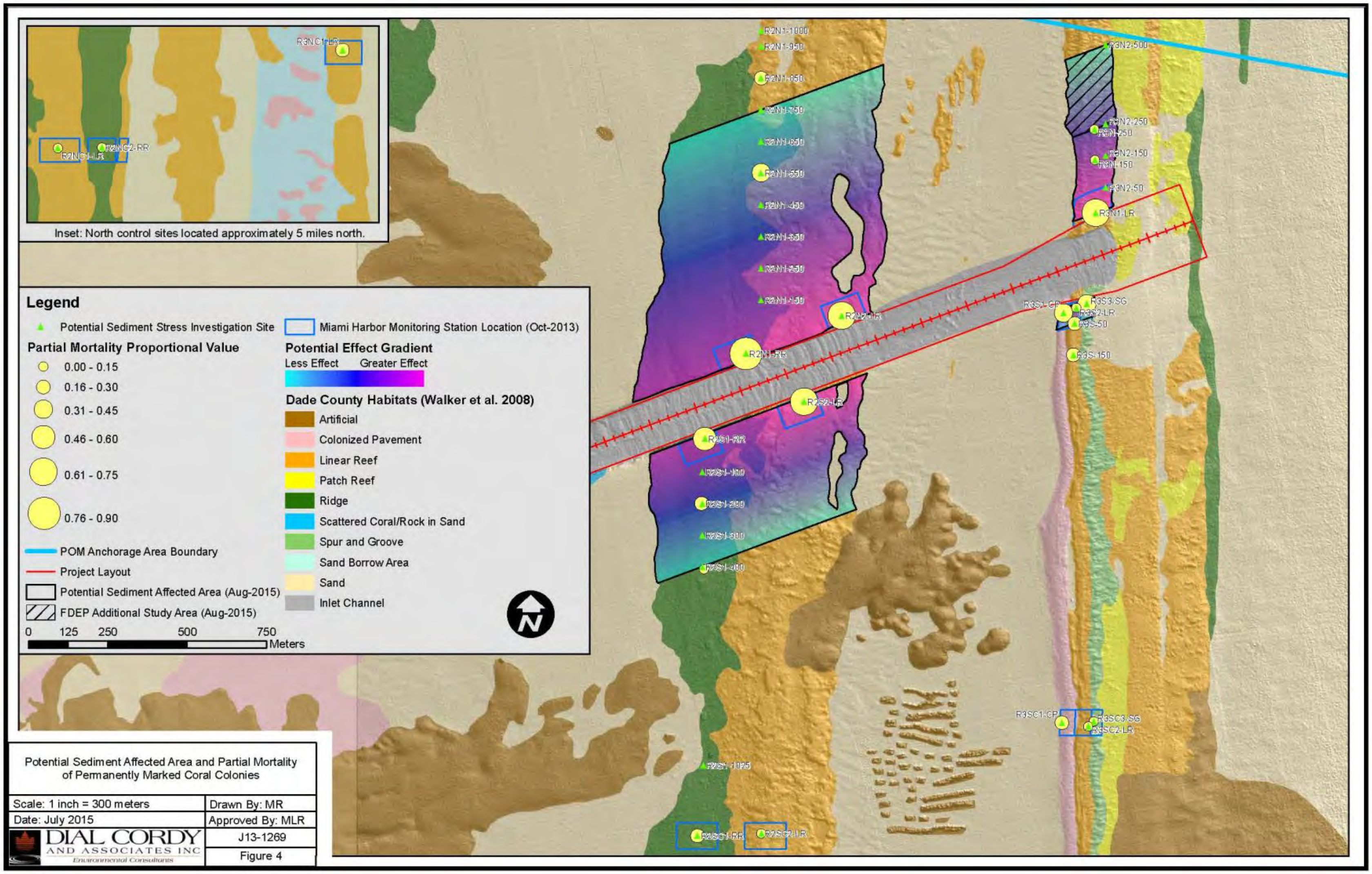


Figure 3. Middle and outer reef impact assessment map (DCA 2015a).

No sediment project related sediment impacts were documented at control sites. Due to the lack of knowledge on the state-of-the-benthic resources between the FDEP defined channel-side and control sites, a tiered survey approach was developed to: 1) identify potentially impacted and un-impacted areas to the north and south of channel-side sites at middle and outer reef habitats and 2) for middle and outer reef areas to quantitatively describe coral condition using methods consistent with construction monitoring techniques both within and outside potentially impacted areas.

A sedimentation impact study was conducted in December 2015 on the north middle reef only, and results were published in Miller et al. (2016). In that study, authors wrote that sedimentation impacts were documented up to 700 m away from the channel on the northern middle reef (Miller et al. 2016).

2.0 METHODS

2.1 Study Site Description

The study site includes the hardbottom, 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. Landscape photographs from baseline through impact assessment surveys are provided in Appendix A.

One-year post-construction impact assessment results are compared to baseline results to document changes attributable to dredging while considering other environmental or anthropogenic factors that influenced hardbottom, middle, and outer reefs resources in the area. The impact assessment survey evaluated the most affected sites and their controls, which was a subset of the total number of sites surveyed and evaluated through post-construction surveys.

2.1.1 Study Site Selection

In 2013, site selection was conducted using ArcView™ software. The ArcView™ random point generator was used to establish a center point for the monitoring site within the FDEP permit site establishment polygons. Site selection was conducted per FDEP Permit # 0305721-001-BI and based on habitat descriptions by Walker et al. 2008.

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 north or south – N or 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”.

2.1.2 Control Sites

A total of ten control sites were selected and surveyed during impact assessment surveys: two sites at hardbottom, five sites at the middle reef, and three sites at the outer reef (Figure 1). Control sites consisted of four habitat types: colonized pavement (CP), linear reef (LR), ridge reef (RR), and spur and groove (SG). Both hardbottom control sites consisted of colonized pavement habitat while middle and outer reef control sites were either linear reef, ridge reef, or spur and groove habitats. 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. Distances and directions of all control sites with respect to the channel can be found in Table 1. 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.

Table 1. Distances and directions from the channel of all control sites monitored during impact assessment surveys.

Area	Site	Direction and Distance from Channel (km)
Hardbottom	HBNC1-CP	2.35 (N)
	HBSC1-CP	1.65 (S)
Middle Reef	R2NC1-LR	9.38 (N)
	R2NC2-RR	9.38 (N)
	R2NC3-LR	9.38 (N)
	R2SC1-RR	1.27 (S)
	R2SC2-LR	1.27 (S)
Outer Reef	R3NC1-LR	9.38 (N)
	R3SC2-LR	1.30 (S)
	R3SC3-SG	1.30 (S)

2.1.3 Channel-Side Sites

A total of nine channel-side sites were selected by FDEP and surveyed during impact assessment surveys: three sites at hardbottom, four sites at the middle reef, and two sites at the outer reef (Figure 1). Channel-side sites consisted of four habitat types: colonized pavement (CP), coral rock/rubble (CR), linear reef (LR), and ridge reef (RR). Both hardbottom control sites consisted of colonized pavement habitat while middle and outer reef control sites were either linear or ridge reef habitats. All channel-side sites were located approximately 10 m from the edge of the existing channel edge. It should be noted that no *Acropora cervicornis* colonies were included at channel-side monitoring sites because they were previously relocated as part of the avoidance and minimization measures.

2.1.4 Site Layout

At each monitoring site, three permanent 20 m transects were established during baseline, parallel to each other in a north (0 m) to south (20 m) direction. Transect number increases from east to west (1-3) at each site. Stainless steel eyebolts (3/8-in. by 8-in.) were drilled into the bottom at 0, 10, and 20 m locations along each transect. Small closed-cell foam floats coated with anti-fouling paint were attached to each eyebolt with a short length of nylon braided line to aid in transect relocation. Two floats marked the beginning of each transect, while mid and end points are marked with a single float (Figure 4). This provided the diver with an orientation while laying out transect tapes during each monitoring dive. Sediment blocks were positioned at the center of the site, between Transect 1 and 2. Sediment blocks were removed following the completion of post-construction surveys as required by permit. Although sediment blocks did not work during construction as expected (to accumulate and measure sediment), the lack of sediment accumulation was in itself an important result. This result illustrated the high current condition at channel-side and control sites that swept all sediment off of blocks from baseline through post-construction survey periods (2013-2015). Adjustments to exact transect placement in the field were conducted based on avoiding sand areas, maximizing coral reef and/or hardbottom, and maximizing the number of hard corals on a single transect. HYPACK Navigational™ software was used to record the geographic location of the site center point, and start and end points of all transects at all sites.

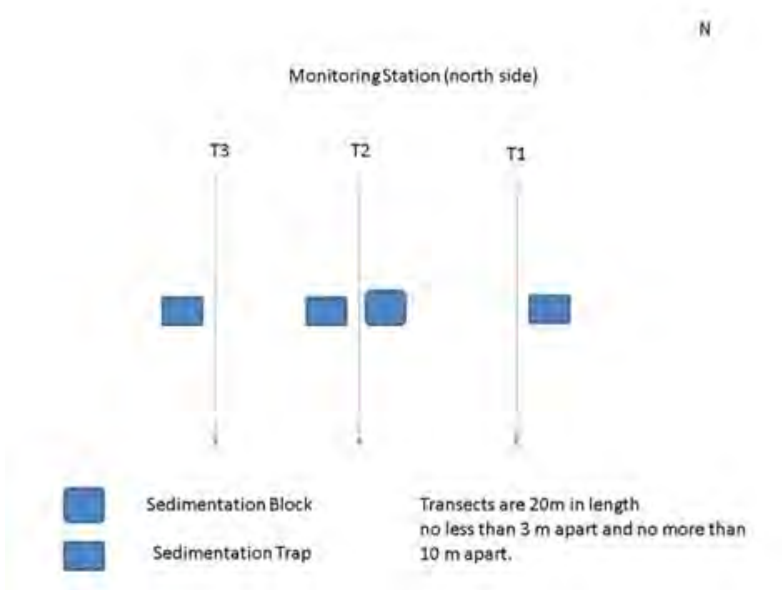


Figure 4. Hardbottom, middle and outer reef monitoring site layout. Sedimentation blocks and traps were removed following the completion of post-construction monitoring. Sediment traps were reinstalled for one-year post-construction impact assessment surveys. Sediment blocks were removed and not replaced because they did not accumulate sediment as predicted, indicating a sufficiently strong current to remove sediment from sediment blocks and other high surfaces exposed to current.

2.1.5 Sedimentation Traps

Quantitative sediment samples were collected during baseline, construction, post-construction, and impact assessment periods to allow the comparison of net sediment trap accumulation at all sites and between channel-side and control sites. Three sediment traps (Figure 5) at each site (one per transect) held three replicate 500 mL Nalgene bottles. The sediment traps were constructed of 1 in. interior diameter x 8 in. interior length polyvinyl chloride (PVC) pipe and a 500 ml Nalgene collection jar, or similar, making modifications to best sample sedimentation within the environment, based on hydrodynamics, currents and particle size (Storlazzi et al. 2011). Both trap necks and jars were coated with anti-fouling paint to minimize epibiotic growth. The PVC traps with the attached jar lids were fastened to the steel sediment trap frame with hose clamps. The frames were drilled and cemented into the substrate at all hardbottom sites, and were installed to collect sediment from the water column approximately 18 inches off the bottom. Sediment traps were removed at 28-day intervals by unscrewing the Nalgene trap jars from the PVC collars and capping the jars *in situ*. New jars were installed when collections were made and a new 28 day sediment monitoring period began. Replicates were combined for analysis so a single estimate per transect was calculated. Sediment samples were collected to determine daily sedimentation rates, and to evaluate the fraction of sediment withheld by a #230 sieve (coarse grain) and the fraction of sediment that passed through the #230 sieve (fine grain).

Sedimentation data were collected to understand the sediment dynamics at the monitoring sites following the completion of dredging. Infrequently during the study period, one or more bottles were lost or the stand was tipped over due to weather, waves, or human interaction. When the sediment traps were disturbed, the sample was discarded and a note made in the sample record to alert the sediment sample analysis team. Following completion of the post-construction monitoring program, all sediment traps and frames were removed.

Prior to the start of impact assessment surveys, new sediment traps were constructed and deployed at 17 of the 19 selected sites. Sediment trees were not deployed at HBS4-CR or R2NC3-LR during the impact assessment survey period. For this impact assessment, the sediment bottle mounts were cemented in concrete blocks that were distributed across the site in similar locations as they were previously. As was stipulated by the permit, sediment traps were scheduled to be collected at 28-day intervals, weather permitting, and replaced with new traps. For impact assessment, sediment traps were deployed and collected twice. The first deployment of sediment traps across all sites ranged from 26 to 29 days. The second deployment ranged from 66 to 68 days due to sustained periods of inclement weather that prevented the dive team from retrieving these samples on schedule. A complete list of deployment and retrieval days can be found in Table 2.

Figure 5. Sediment traps installed at all offshore sites for environmental monitoring of hardbottom and reef resources in Cuts 1 and 2.

Table 2. Sediment trap deployment and retrieval dates for hardbottom, middle, and outer reef sites during impact assessment.

Area	Site	Sediment Trap Deployment					
		Deployment	Retrieval	Days Deployed	Deployment	Retrieval	Days Deployed
Hardbottom	HBN3-CP	8/9/2016	9/6/2016	28	9/6/2016	11/13/2016	68
	HBNC1-CP	8/9/2016	9/6/2016	28	9/6/2016	11/12/2016	67
	HBS3-CP	8/8/2016	9/6/2016	29	9/6/2016	11/13/2016	68
	HBS4-CR	N/A	N/A	N/A	N/A	N/A	N/A
	HBSC1-CP	8/8/2016	9/6/2016	29	9/6/2016	11/13/2016	68
Middle Reef	R2N1-RR	8/10/2016	9/7/2016	28	9/7/2016	11/12/2016	66
	R2N2-LR	8/11/2016	9/7/2016	27	9/7/2016	11/12/2016	66
	R2NC1-LR	8/10/2016	9/7/2016	28	9/7/2016	11/12/2016	66
	R2NC2-RR	8/10/2016	9/7/2016	28	9/7/2016	11/12/2016	66
	R2NC3-LR	N/A	N/A	N/A	N/A	N/A	N/A
	R2S1-RR	8/11/2016	9/7/2016	27	9/7/2016	11/13/2016	67
	R2S2-LR	8/11/2016	9/7/2016	27	9/7/2016	11/13/2016	67
	R2SC1-RR	8/9/2016	9/6/2016	28	9/6/2016	11/13/2016	68
	R2SC2-LR	8/9/2016	9/6/2016	28	9/6/2016	11/13/2016	68
Outer Reef	R3N1-LR	8/12/2016	9/7/2016	26	9/7/2016	11/12/2016	67
	R3NC1-LR	8/10/2016	9/7/2016	28	9/7/2016	11/12/2016	67
	R3S2-LR	8/12/2016	9/7/2016	26	9/7/2016	11/13/2016	68
	R3SC2-LR	8/11/2016	9/7/2016	27	9/7/2016	11/12/2016	67
	R3SC3-SG	8/11/2016	9/7/2016	27	9/7/2016	11/12/2016	67

2.2 Data Collection

All scientific divers were trained and qualified to conduct benthic surveys in hardbottom, middle and outer reef environments, as required by the FDEP permit and USACE specifications for the project. Project specific training materials were developed and included coral species identification and coral 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 AGGRA coral identification keys (Atlantic Gulf Reef Rapid Assessment 2013). A trained scientific diver from Coastal Systems International (CSI) provided QA/QC oversight during 10% of diving operations.

Impact assessment surveys of the hardbottom, middle and outer reef sites were conducted between August 8, 2016 and August 20, 2016 with the exception of HBS4-CR, which was surveyed on December 1, 2016 (Table 3). In the month of October 2016, no scientific diving operations were conducted due to inclement weather. 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.

Table 3. Impact Assessment surveys were conducted at hardbottom, middle, and outer reef sites between August 8, 2016 and December 1, 2016.

Area	Site	Date Surveyed
Hardbottom	HBN3-CP	8/10/2016
	HBNC1-CP	8/9/2016
	HBS3-CP	8/9/2016
	HBS4-CR	12/1/2016
	HBSC1-CP	8/8/2016
Middle Reef	R2N1-RR	8/12/2016
	R2N2-LR	8/12/2016
	R2NC1-LR	8/11/2016
	R2NC2-RR	8/11/2016
	R2NC3-LR	8/19/2016
	R2S1-RR	8/17/2016
	R2S2-LR	8/17/2016
	R2SC1-RR	8/10/2016
	R2SC2-LR	8/10/2016
Outer Reef	R3N1-LR	8/20/2016
	R3NC1-LR	8/19/2016
	R3S2-LR	8/20/2016
	R3SC2-LR	8/18/2016
	R3SC3-SG	8/18/2016

2.2.1 Abiotic Characteristics

Abiotic data were collected to describe the general conditions of each monitoring site. The presence of hardbottom, rock, rubble, sand, sedimentation, bare substrate, maximum water depth and rugosity were documented at hardbottom sites. Contrary to previous surveys, rugosity data were not collected along each transect for the impact assessment survey.

2.2.2 In Situ Data

In situ data were collected along three 20 m x 1 m belt transects at each hardbottom, middle and outer reef monitoring site for impact assessment surveys. Scientific divers placed transect tapes, marked in metric and standard increments along the pre-established transects, securing the tape at the beginning, middle, and end points. *In situ* post-construction data were collected using underwater data sheets and clipboards.

2.2.2.1 Quality Assurance and Control

After *in situ* data collection, 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, after which impact assessment data were entered into an Excel based spreadsheet program. 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). Raw data, photos and video were provided to the FDEP in December 2016 for all permanent sites.

2.2.2.2 Scleractinians

Data were collected for all scleractinian species (tagged and untagged) occurring within the three, 20-m x 1-m belt transects at all hardbottom, middle and outer reef sites. Each transect contained up to 10 permanently marked scleractinian corals, at each site. During the baseline period, nearshore hardbottom sites had to upto 11 coral colonies at each site, with the predominant species being *Siderastrea siderea, Stephanocoenia intersepta,* and *Solenastrea bournoni* During the baseline period, the middle reef sites included 11-17 coral species and outer reef sites had 10-15 coral species. For each coral, divers recorded the species, size (max diameter), estimated percent mortality, and stress condition (if present). All size of scleractinian corals were recorded in impact assessment surveys, which is different than the methods for baseline and post-construction surveys when only corals above 3 cm were recorded. Stress conditions due to sediment were recorded separately from other stress conditions. A guide for estimating percent mortality can be found in Figure 6. 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 each colony with a ruler provided for scale. Photographs of all tagged colonies during baseline, construction, post-construction, and impact assessment surveys are provided in Appendix A.

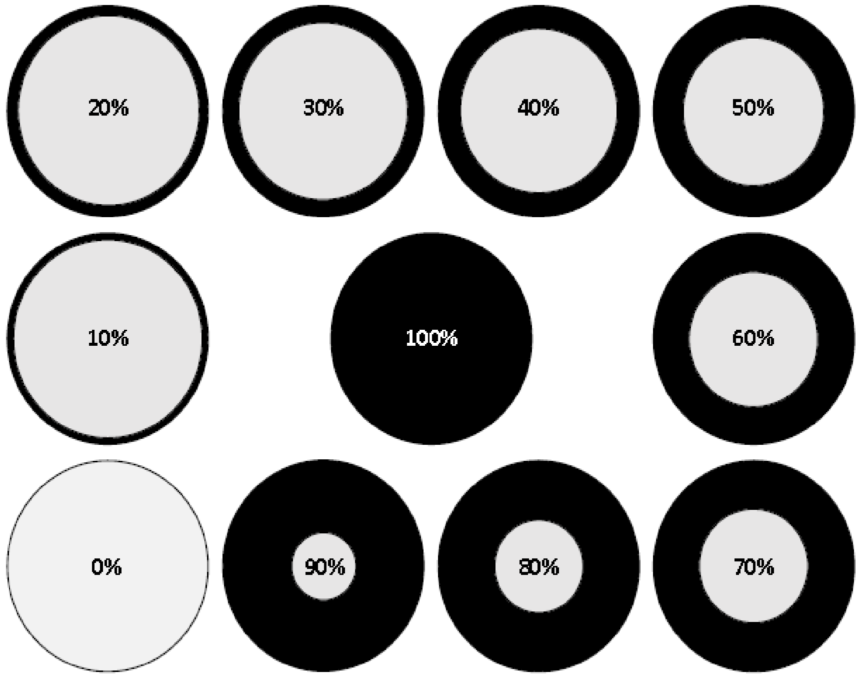


Figure 6. Guide for estimating percent mortality for scleractinians during impact assessment.

2.2.2.3 Scleractinian Condition Surveys

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 included bleaching, mucus production, polyp extension disease, and sediment accumulation in addition to other codes (Table 4) (Bruckner 2001, Dial Cordy Training PPT 2013). Examples of corals with conditions captured during compliance monitoring, post-construction, and impact assessment surveys are provided in Figures 7-11. Each coral colony was assessed for each of the health parameters and assigned a condition of either "0" or "1" for each parameter. A score of "0" indicated no observed bleaching, mucus production, polyps extended, disease, or other adverse condition, while a "1" would be assigned if one or more conditions was present. Conditions were not additive, if a coral exhibited more than one condition, for example, mucus and polyps extended, the coral still received a score of "1".

Table 4. Coral stress indicator categories for *in situ* data collection, which were observed during baseline, construction, post-construction, and impact assessment surveys at hardbottom, middle, and outer reef sites (adapted from FRRP (Florida Reef Resilience Program) and DCA 2012). * designates condition categories that were not present during baseline, but were added during compliance monitoring as needed

. Condition	Cause	Appearance	Field Code
Sedimentation Indicators			

. Condition	Cause	Appearance	Field Code
Sediment	Sedimentation	Low amount, a “dusting” of sediment on top of the coral.	SED
Sediment Accumulation	Sedimentation	Moderate sediment accumulation on top of colony (more than dusting). Accumulation in grooves and/or between polyps.	SA
Partial Burial	Sedimentation	Portion(s) of the colony buried by sediment.	PBUR
Burial	Sedimentation	Entire colony buried by sediment.	BUR
Partial Mortality*	Sedimentation	Partial mortality of coral colony appears white with no live polyps visible. Generally, occurs around the margin of the colony. Visible when sediment recedes.	PM
Bleaching Indicators			
Paling	Stressed/Elevated Irradiance/Temperature	Live tissue with some loss of color.	P
Partial Bleaching	Stressed/Elevated Irradiance/Temperature	Patches of fully bleached or white tissue.	PB
Bleaching	Stressed/Elevated Irradiance/Temperature	Live tissue with complete loss of color across the entire colony.	BL
Disease Indicators			
Black Band	Stress	Black band surrounds dead patch.	BB
Yellow Band	Stress	Yellow band surrounds dead patch.	YB
White-Band (*Acropora* only)	Stress	White lines or bands of recently dead coral tissue found in species of the genus *Acropora.*	WB
White-Plague	Stress	White lines or bands of recently dead coral tissue affecting non-acroporid corals.	WP

. Condition	Cause	Appearance	Field Code
Unknown Band	Stress	Unknown band-like mortality around the base of the colony, later presumed to be white-plague on *Dichocoenia stokesi*	UB
Unknown *Solenastrea* Disease	Stress	Patchy discoloration of living tissue resulting in a mottled bleached appearance. Only noted for *Solenastrea* spp.	UD
Stress Indicators			
Polyp Extension	Stress and feeding	Tentacles are extended on 100% of polyps on the colony.	PE
Fish Bite(s)	Grazing	Bites of live tissue removed.	FB
Mucus Production	Sediment stress/Lunar cycle	Excessive mucus production results in a mucus film and/or sediment balled up in mucus.	M
Cliona spp.	Competition	Red boring sponge present on colony. Typically accompanied by tissue mortality radiating outward from the point of sponge emergence.	CD
Unknown Partial Mortality	Stress	Tissue mortality from an unknown cause.	UPM
Physical Disturbance	Abrasion	Abrasion or physical disturbance such as a gouge or a nick, not in a discernable pattern like fish bites.	PD
Competitive Mortality *	Competition	Recent partial mortality from a competition event. Typically the result of sponge or zoanthid overgrowth.	CM
Dark Spot *	Stress	Dark spots on otherwise normal *Siderastrea* spp.	DS

. Condition	Cause	Appearance	Field Code
Unknown Condition *	Stress	Discoloration of living tissue from an unknown cause. Not related to known bleaching or disease indicators.	UC
Complete Mortality Indicator			
Complete Mortality*	Any	Death of the entire colony; no live tissue remaining on the skeleton.	DEAD

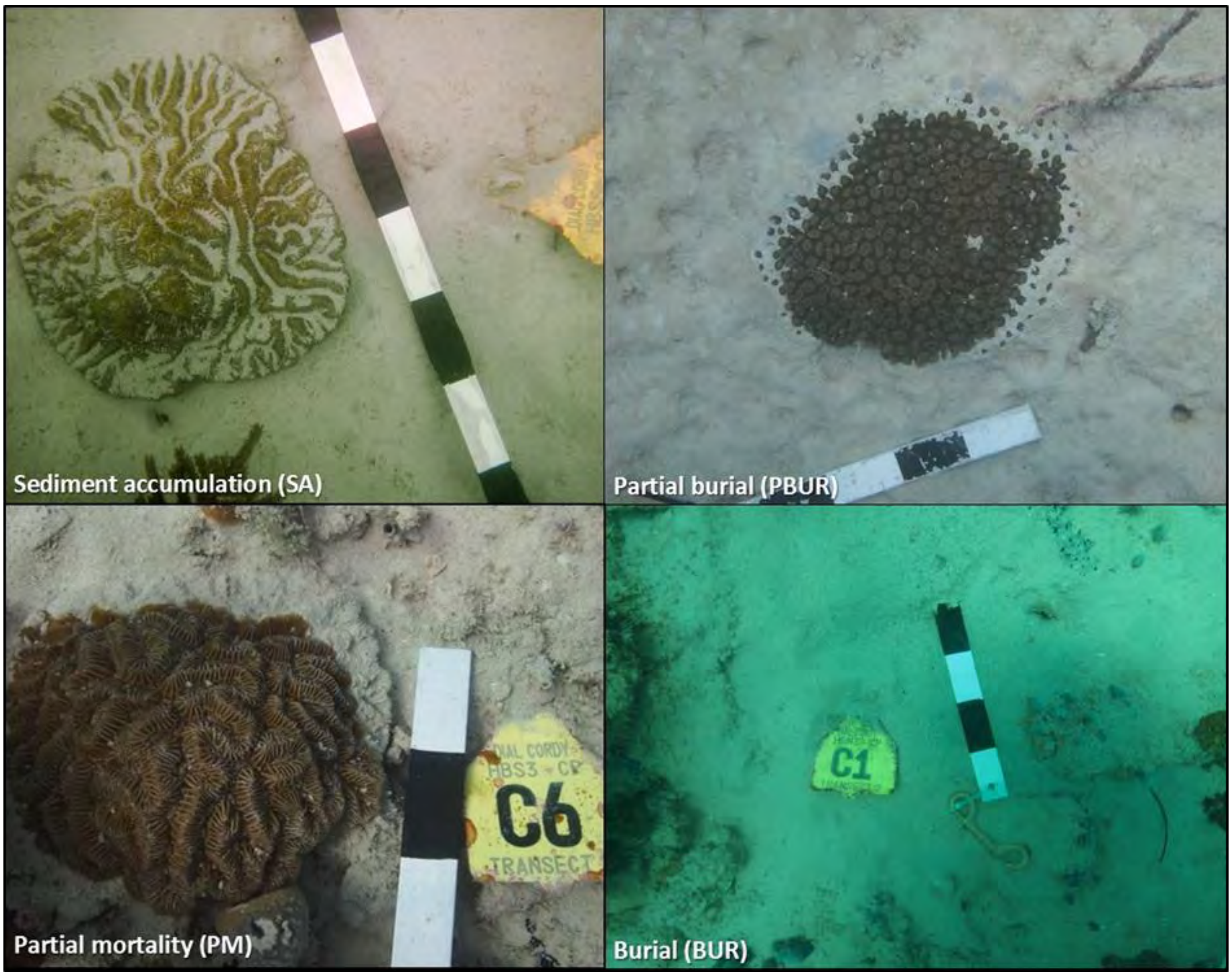


Figure 7. Photographs of sedimentation indicators documented during compliance and post-construction surveys.

Figure 8. Photographs of bleaching conditions documented during compliance and post-construction surveys.

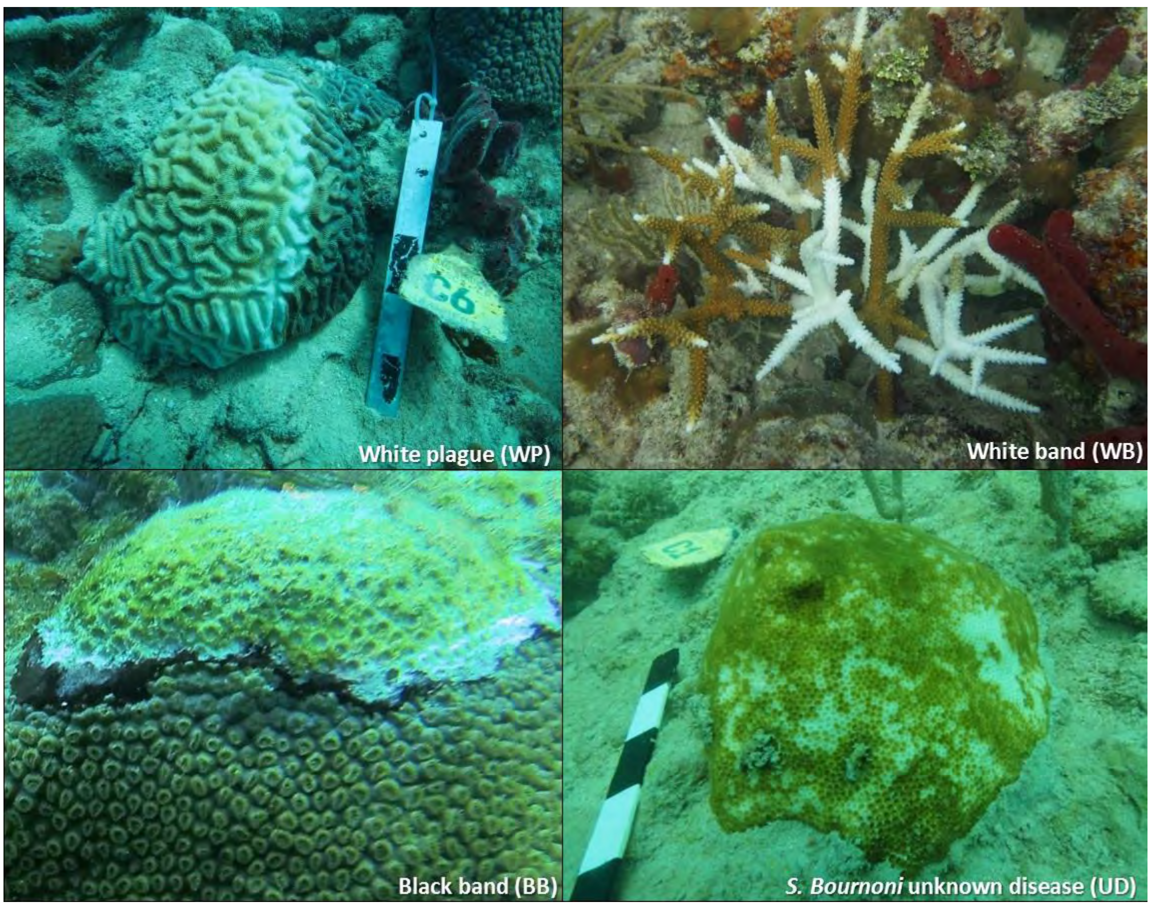


Figure 9. Photographs of disease conditions documented during baseline through post-construction surveys.

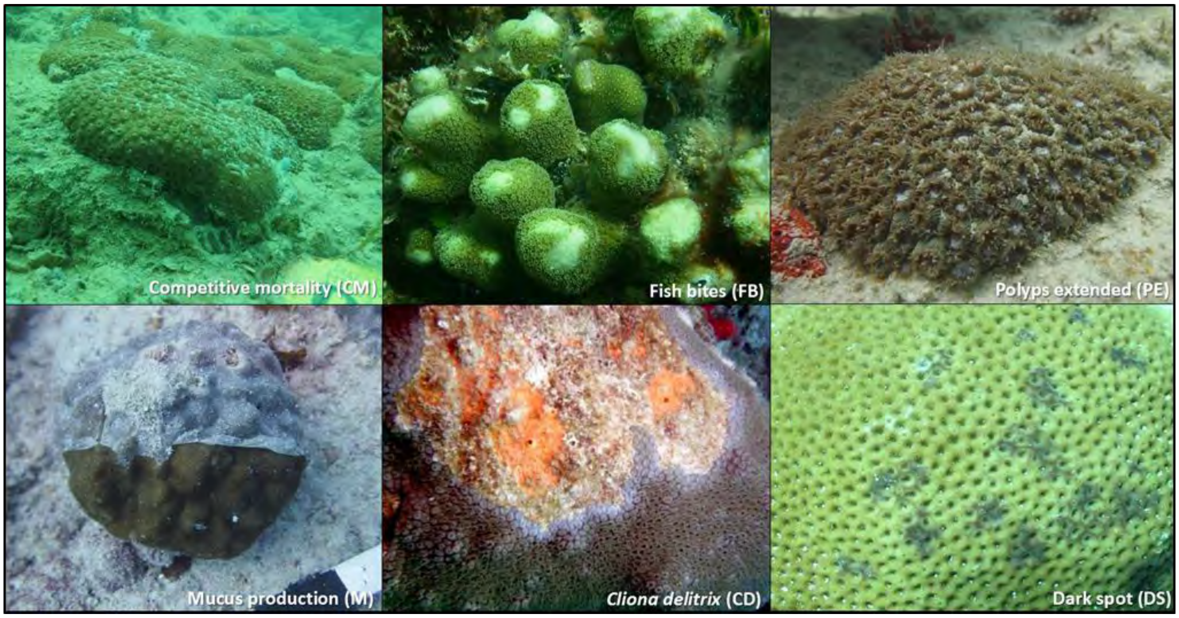


Figure 10. Photographs of stress indicators documented during compliance and post-construction surveys.

Figure 11. Photographs of stress indicators collected during compliance and post-construction surveys.

2.2.2.4 Ocotocorals and Sponges

In situ data were also collected on the abundance, condition, and maximum size (height or diameter) for all octocorals, sponges, and zoanthids within each 20-m x 1-m belt transect. Octocorals and zoanthids were recorded to the genus-level while sponges were recorded by morphotype. All sizes were recorded during impact assessment survey, which is different than baseline and post-construction survey methods, when only counts of octocorals and sponges were required for hardbottom sites and sizes above 3 cm were collected for middle and outer reef sites. Conditions for octocorals and sponges consisted of similar indicators used for scleractinian corals relating to sedimentation, mortality, stress, and disease. Representative photos of sponges and octocorals were collected during surveys.

2.2.3 Photo and Video

Scientific divers collected still photographs of permanently marked corals from a vertical perspective, so that the maximum diameter of the colony was present within a single photo frame along with the permanent marker and scale bar. Additional close-up oblique-angle photos were also collected to document stress conditions. Photos of all tagged corals during baseline, construction, post-construction, and impact assessment monitoring periods are provided in Appendix B. Additional photographs were collected at the center of the site, facing four directions at approximately 1.5 m above the bottom from an oblique angle so that the water column and general site characteristics were captured in the photographs.

Quantitative digital video data were collected along each transect with the camera positioned 40 cm above the substrate in a vertical orientation to produce birds-eye view digital video of each transect (20 m x 0.4 m), during each compliance monitoring, post-construction, and impact assessment surveys (Aronson et al. 1994). The video camera was equipped with a measuring bar to ensure the camera remains at 40 cm above the bottom and a scale bar was visible at the bottom of the video record at all times (Figure 12). The diver swam the camera along each transect at a speed of approximately 5-m per minute to ensure quality still images could be extracted for point count analysis using Coral Point Count with extensions (CPCe®) (Kohler and Gill 2006). This method was used to evaluate functional group cover at both the channel-side sites and the control sites during impact assessment surveys.

Figure 12. Scientific diver collecting video data of transects during baseline surveys. Photo taken October 24, 2013.

2.3 Data Analysis

2.3.1 *In Situ* Data

Parametric and non-parametric statistical methods were used to describe the scleractinian and octocoral abundance, density, diversity (H'), and evenness (J'). All statistical analysis results are provided in Appendix C. Condition values were calculated from raw data and are presented in the results section of this report. Abundance, density, diversity (H'), and evenness (J') were calculated as follows (p_i represents the proportion of individuals, and S represents species richness):

$$\text{Relative Species Abundance} = \frac{Total\ number\ of\ individuals\ for\ a\ species}{Total\ number\ of\ individuals\ at\ a\ given\ site}$$

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

$$\text{Diversity (H}') = \sum_{j=1}^{\%} p_i\ ln\ p_i$$

$$\text{Evenness (J}') = \frac{H'}{\ln S}$$

2.3.2 Coral Condition Data

Coral condition data were collected and analyzed for all scleractinian corals surveyed during impact assessment surveys. Although all scleractinian corals were photographed during surveys, only permanently marked scleractinian corals were allowed for visual record and comparison between baseline and impact assessment datasets. QA/QC was conducted on permanently marked scleractinian photos for all coral conditions in the office.

Coral condition data were only analyzed for tagged corals during baseline surveys, since these corals were photographed and could be verified and QA/QC performed in the laboratory, therefore the same was done with impact assessment data.

2.3.3 Baseline Data Revisions

Transcription and calculation errors were identified in baseline graphs and tables during the post-construction data analysis time period. These errors or miscalculations are identified in the figure or table caption in this impact assessment report. If an error was not noted, then no changes have been made to the baseline figure or table. All comparisons within this impact assessment report were made with the updated and corrected baseline data. No error or miscalculation changed any of the trends for baseline data.

2.3.4 Functional Group Percent Cover Analysis and QA/QC

Video analysts conducted quality control exercises prior to evaluating transect still images. A training dataset of 30 hardbottom images, with 10 random points/image was compiled by two expert analysts. All video analysts independently performed a functional group analysis of the training dataset. Image-scoring from each analyst was compared on a per-image basis to the expert results. If an analyst diverged from the expert assessment by more than one point per benthic category, the images were reviewed with the analyst; the difference was discussed and corrected.

Video transect footage was analyzed for all impact assessment hardbottom, middle and outer reef sites. Video transect footage was segmented (frame grab) into non-overlapping still images using GOM Player™ software. For each 20 m transect, 40 individual still images were generated. Each image was analyzed by using Coral Point Count with extensions™ (CPCe), and overlaying 10 randomly generated points (Somerfield et al. 2008). The organism or feature underneath each random point on the image was characterized by functional group. Functional groups were as follows: macroalgae (rhodophyta, phaeophyta, chlorophyta, and cyanobacteria) (MACA); crustose coralline algae, turf algae, and bare substrate (CTB); sediment/sand (S); zoanthids (Z); hard coral (CORAL); octocoral/gorgonian (GORG); sponge (SPO); and tape, wand, shadow (TWS).

Crustose coralline algae, turf algae, and bare substrate (CTB) are difficult to differentiate using video techniques and therefore were grouped together for analysis (Aronson and Precht 2000). CTB and sand were the largest cover components for most sites, from baseline through impact assessment periods. In order to most accurately and precisely classify these categories over the entire duration of the project, project specific definitions were developed to insure continuity of results. For visual analysis purposes, CTB was defined as rough substrate, or bottom with a textural component. In contrast, sand was visually defined for analysis as textureless and appeared as though it would obscure the tip of a pencil. Figure 13 is an image from baseline at R3NC1-LR, and shows the difference between CTB and sand functional groups. Cyanobacteria periodically covered substrate and complicated analysis as cyanobacterial mats on-top of sand appeared to have texture, similar to CTB. Periodically, during the course of compliance monitoring, cyanobacteria would colonize sediment and was visually indistinguishable from CTB. In these cases, the estimation of CTB was higher than actual CTB because of limitations of this method. TWS designates points that cannot be identified from photographs because the benthos is obscured by survey tape, camera measuring pole, or because image quality was too poor. These points are automatically excluded from the total sum of the means of each category.

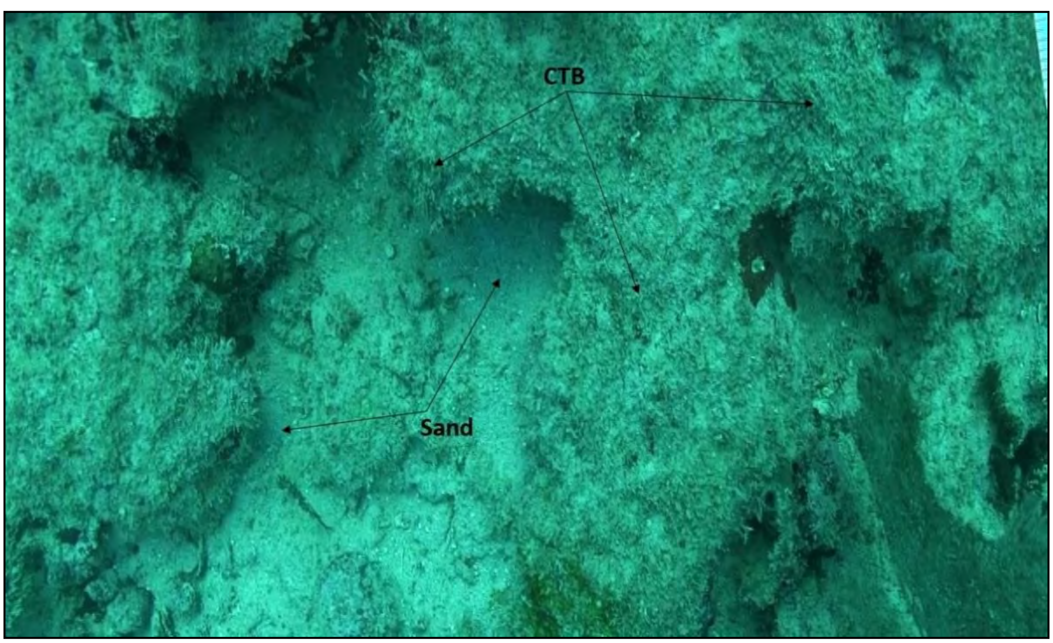


Figure 13. Still image from R3NC1-LR during baseline surveys showing the distinction between coarse-grain sand, fine-grain sand, and the CTB category.

In addition to the training of the analysts, all evaluated transects underwent QA/QC screening. For each transect that was analyzed for relative abundance of functional groups by a trained analyst, a second analyst reviewed 10% (4 frames, 40 points) of the resulting frames. If disagreement of more than 20% (8 or more points) existed between analysts, the site was re-analyzed and subjected to a second round of QA/QC evaluation. Significant disagreement between analysts was discussed until a consensus was reached. Following the completion of this QA/QC screening, a second independent QA/QC evaluation was also conducted by personnel from CSI.

2.3.5 Sediment Accumulation Assessment

As described above, all three transects within a monitoring site had an associated sediment trap installation that contained three collection bottles, with the exception of R2NC3-LR and HBS4-CR. A total of nine bottles collected sediment accumulation data at each monitoring site. For analysis, three replicates (bottles) from the sediment traps were combined to produce an aggregate sample per transect. These three samples were then averaged to create a site mean sedimentation rate.

The mass of the specimen in each bottle was measured. The sediment samples were washed from the collection bottles through a U.S. Standard #230 sieve until water flowed freely through the fraction retained on the sieve. All wash water and sediment passing the #230 sieve was collected. Organisms that may have grown or crawled (i.e., fish, crabs, worms, algae) into the sediment collection bottle, if visibly retained on the sieve, were removed during the wash process and noted. None was observed for the post-construction samples. Sand retained on the #230 sieve was washed into a labeled tare. Some of the water was aspirated off the sand fraction and the tare was placed in a forced-draft oven at 66°C (150°F) until dry and for a minimum of 24 hours.

Containers with the fraction passing the #230 sieve were allowed to settle for a minimum of 48 hours. After settling, the water was aspirated off the settled sample and the fine fraction was consolidated using additional wash water into the appropriate size labeled and weighed container and allowed to settle another 48 hours. The conductivity of the water was measured after the second settling phase. The water was aspirated off and the fraction of sample finer than the #230 sieve was placed in the oven until dry and for at least 24 hours. The samples were removed from the oven and placed in the desiccator until cooled. The masses of the fractions retained and passing the #230 sieve were measured and recorded to the nearest 0.01 gram. All the data was entered into an Excel spreadsheet.

Sedimentation rates were calculated by dividing the sample dry weight value by the number of days the sediment collection bottles were in the water, with the first day being the day after the bottles were installed. Transect values were averaged to calculate a site mean.

3.0 RESULTS AND DISCUSSION

Impact assessment biological monitoring results are compared with baseline and post-construction monitoring results when applicable and provided below. 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 in the Southeast Florida region (Figure 14 and 15, also see, Hayes et al 2017, CSi 2016, DERM 2016, Precht et al. 2016). The Florida Reef

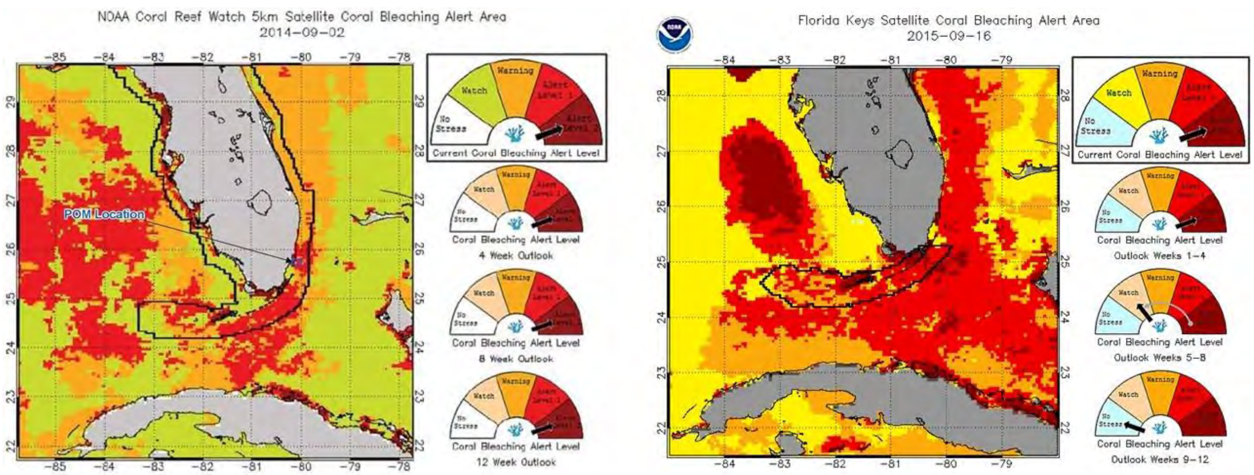


Figure 14. NOAA Coral Reef Watch 5 km Satellite Coral Bleaching Alert Area in 2014 (left) and 2015 (right) showing regional bleaching in South Florida and location of project area (NOAA 2014a). POM in the figure refers to the PortMiami. Bleaching alert levels are based on sea surface temperature data.

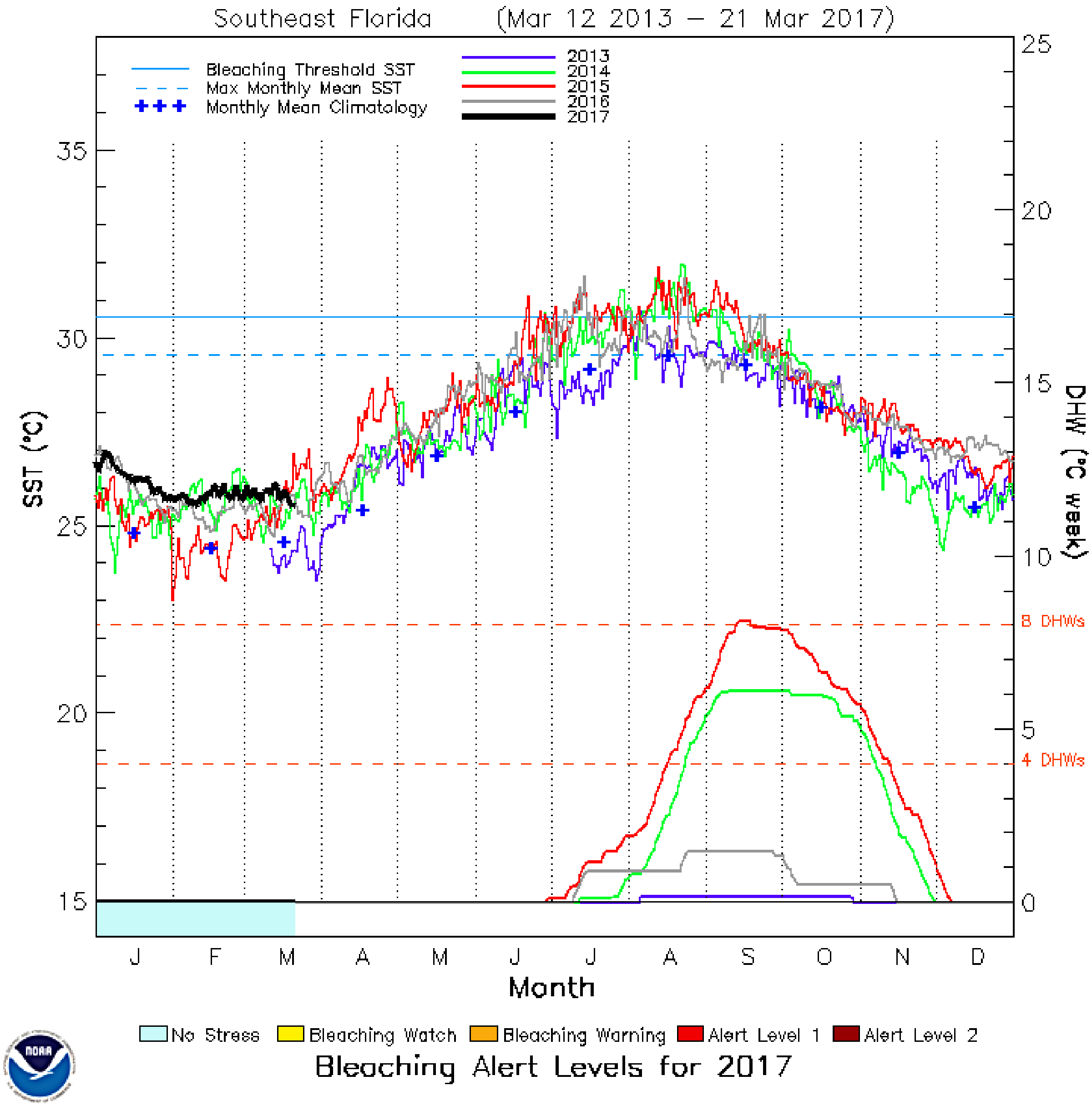


Figure 15. Annual Southeast Florida temperature data and degree heating weeks (DHW). Data from NOAA Coral Reef Watch Program (NOAA 2016).

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 14), 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). 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 16, Hayes et al 2017, CSi 2016, DERM 2016, Precht et al. 2016). The effect of this disease event has affected susceptible coral species at both channel-side and control sites, resulting in the complete mortality of many of the tagged corals associated with the project (Table 5; Precht et al. 2016). The loss of these colonies had a direct bearing on the post-construction and impact assessment data sets as presented below.

The purpose of this report is to document any permanent changes in benthic resources as a function of project-activities one year following the completion of dredging. To best report those results, sedimentation accumulation information will be presented first, followed by an analysis of the functional group cover from baseline to impact assessment surveys, followed by detailed analysis of various benthic constituents including: corals, octocoral and sponges.

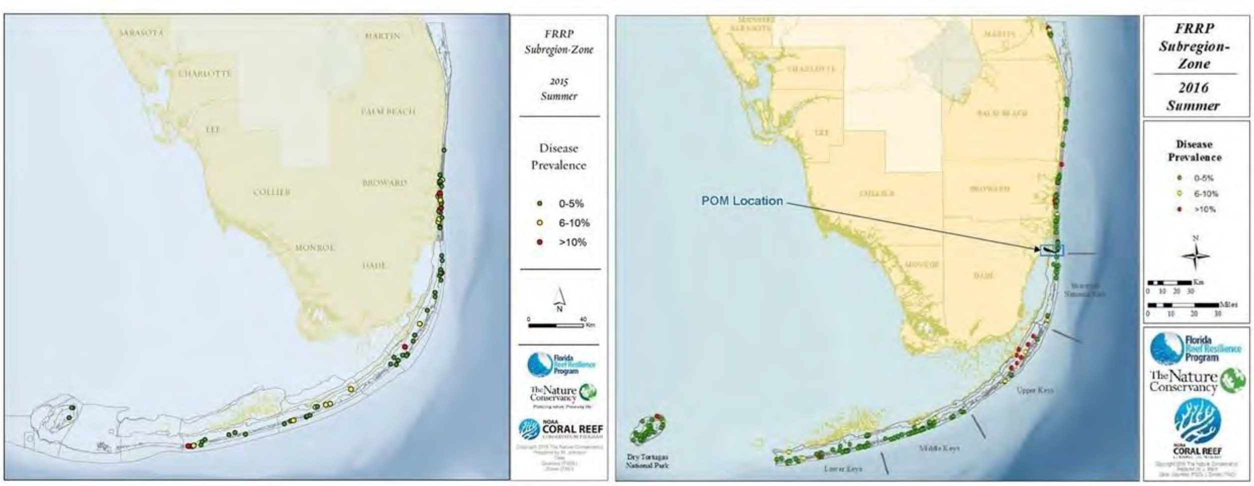


Figure 16. Disease presence as documented by the Florida Reef Resilience Program (FRRP) in 2016. The project area is shown as POM Location.

Table 5. List of tagged corals species monitored in association with the Project. White plague disease susceptible species are marked with an *. Susceptible species data from Precht et al. 2016, CSi 2016, DERM 2016, Hayes et al. 2017.

Coral Species	Coral Species
Acropora cervicornis	*Orbicella faveolata**
Agaricia agaricites	*Porites astreoides*
Agaricia lamarcki	*Porites porites*
*Colpophyllia natans**	*Pseudodiploria clivosa**
*Dichocoenia stokesi**	*Pseudodiploria strigosa**
*Diploria labyrinthiformis**	*Scolymia cubensis*
*Eusmilia fastigiata**	*Siderastrea radians*
Madracis decactis	*Siderastrea siderea*
*Meandrina meandrites**	*Siderastrea sp.*
*Montastrea cavernosa**	*Solenastrea bournoni**
Mycetophyllia aliciae	*Stephanocoenia intersepta*
*Oculina diffusa**	

3.1 Seasonal Differences on Southeast Florida Reefs

In addition to the thermal anomaly and white plague disease that affected the region, seasonal changes attributed to wind and waves were visible within the reef system. In spring and summer warm water temperatures and higher light levels produce turf and macroalgae in abundance. In winter, when wind and waves move sediment around the system and colder waters inhibit turf and macroalgae growth, the system was covered in a fine layer of sediment. The transition between warm weather and cold weather conditions was captured during the baseline period, before dredging began, both at control and channel-side sites (Figure 17 and 18).

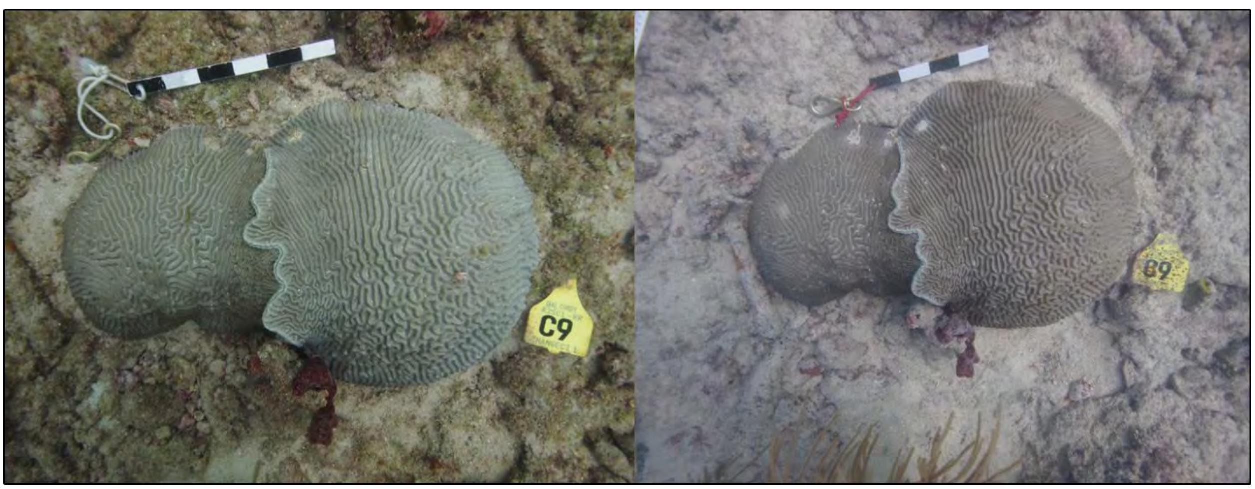


Figure 17. The same location before and after the passage of a cold front during baseline surveys (R2SC1-RR). Photo on the left was collected on October 19, 2013 in baseline week 1 and the photo on the right was collected in baseline week 4 on November 18, 2013. Both photos were recorded before maintenance dredging began on November 20, 2013.

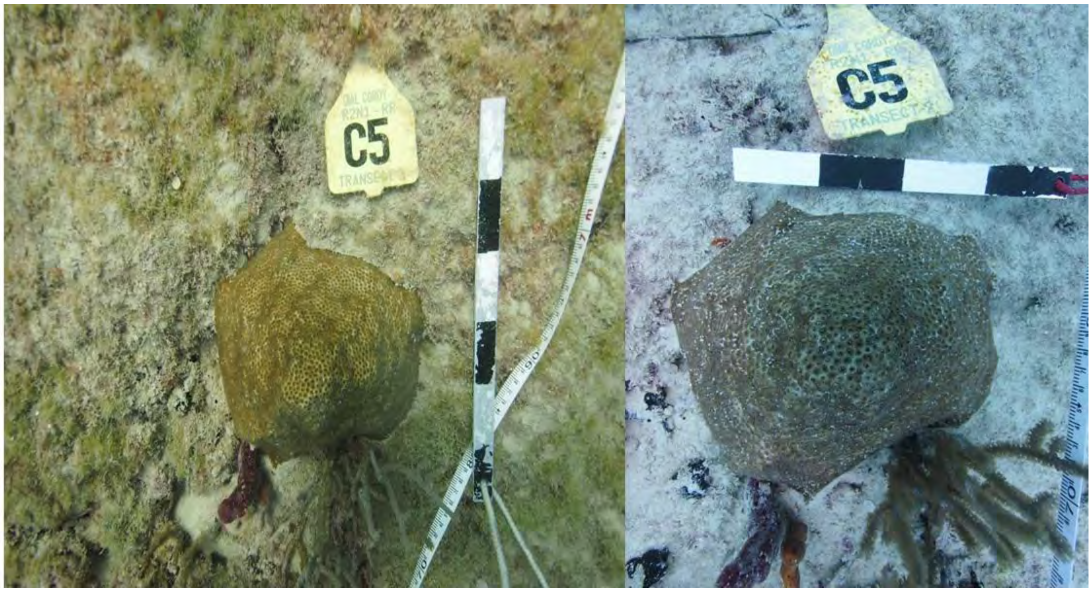


Figure 18. The same location before and after the passage of a cold front during baseline surveys (R2N1-RR). Photo on the left was collected on October 21, 2013 in baseline week 1 and the photo on the right was collected in baseline week 4 on November 18, 2013. Both photos were recorded before maintenance dredging began on November 20, 2013.

3.2 Sedimentation Accumulation Rates

Increased sedimentation associated with dredge activities were noted at all nine of the channel-side locations during previous impact-assessment surveys that were completed immediately-following dredge activities (DCA 2014b and 2015). These sites were selected by FDEP for the one-year post-construction impact assessment surveys. During the one-year post-construction impact assessment surveys, sediment accumulation rates were found to be equal to or below baseline values at all channel-side sites, except during rare weather events such as the passage of a hurricane near project sites (Hurricane Matthew, October 9, 2016). Mean sediment accumulation as measured at channel-side sites was below baseline values during the one-year post-construction impact assessment survey.

Sedimentation accumulation rates were assessed twice during the one-year post-construction impact assessment surveys. During the first impact assessment period sediment accumulation rates were equal to or below baseline values at all channel-side and control sites (Table 6). However, increased daily sediment accumulation rates during the second impact assessment sampling was noted at all sites. The increased sedimentation rates of the second impact assessment sampling were the result of 28 days of strong winds and winter storms, including the passage of Hurricane Matthew off the coast of Florida on October 9, 2016.

Table 6. Mean daily sediment accumulation rates for baseline, and both impact assessment samples for each permanent monitoring station. No sediment traps were deployed at HBS4-CR during the impact assessment survey. Sediment accumulation is recorded separately for ≥230mm and <230mm fractions.

Location	Site	Sediment Sample	Baseline 2013	Impact Assessment September 2016	Impact Assessment November 2016 (after Hurricane Matthew)
Hardbottom	HBN3-CP	>230 Sieve	4.13	0.16	0.48
		<230 Sieve	0.81	0.18	0.05
	HBNC1-CP	>230 Sieve	0.37	0.03	0.31
		<230 Sieve	0.76	0.20	0.30
	HBS3-CP	>230 Sieve	0.40	0.07	0.22
		<230 Sieve	0.72	0.16	0.22
	HBSC1-CP	>230 Sieve	0.30	0.04	0.29
		<230 Sieve	0.49	0.20	0.26
Middle Reef	R2N1-RR	>230 Sieve	1.81	0.08	1.73
		<230 Sieve	0.58	0.11	0.21
	R2N2-LR*	>230 Sieve	1.77	0.06	4.63
		<230 Sieve	0.71	0.09	0.40
	R2NC1-LR	>230 Sieve	2.74	0.05	1.01
		<230 Sieve	0.59	0.09	0.35
	R2NC2-RR*	>230 Sieve	0.07	0.01	0.80
		<230 Sieve	0.22	0.07	0.20
	R2S1-RR	>230 Sieve	0.51	0.08	0.40
		<230 Sieve	0.52	0.10	0.23
	R2S2-LR*	>230 Sieve	0.49	0.03	0.39
		<230 Sieve	0.49	0.05	0.24
	R2SC1-RR	>230 Sieve	0.62	0.01	0.57
		<230 Sieve	0.42	0.06	0.25
	R2SC2-LR*	>230 Sieve	0.80	0.02	0.50
		<230 Sieve	0.61	0.05	0.17
Outer Reef	R3N1-LR*	>230 Sieve	0.09	0.09	0.50
		<230 Sieve	0.08	0.03	0.16
	R3NC1-LR*	>230 Sieve	0.05	0.02	0.28
		<230 Sieve	0.07	0.03	0.16
	R3S2-LR*	>230 Sieve	0.04	0.02	0.22
		<230 Sieve	0.09	0.03	0.15
	R3SC2-LR*	>230 Sieve	0.05	0.01	0.23
		<230 Sieve	0.07	0.02	0.14
	R3SC3-SG*	>230 Sieve	0.08	0.02	0.16
		<230 Sieve	0.11	0.04	0.15

*baseline sediment samples collected after the commencement of maintenance dredging.

The temporal changes in sedimentation rates for channel-side and control sites are presented in Figures 19 and 20. Fine fraction material (<230 sieve) included the clay-like material that was documented as impacting channel-side sites and beyond during the impact assessment surveys in 2014 and 2015 (DCA 2014b and 2015). Sediment accumulation rates were calculated from sediment trap data collected approximately every 30 days between baseline and post-construction surveys. Mean daily sedimentation rate for coarse grained sediments (≥230 sieve fraction) only exceeded baseline values at channel-side locations at 3 sampling points over the course of the project, compared to control site locations that have remained below baseline values over the entire survey period (Figure 19). Daily sedimentation rates of the ≥230 sieve fraction have remained below baseline values since the dredge Texas finished offshore work in December, 2014. For fine-grained (<230 sieve fraction) sediments there were six time periods out of 28 sampling events where mean daily sedimentation rates at channel-side sites exceeded baseline values (Figure 20). Daily sedimentation rates of fine grained sediments have been equivalent to or below baseline values since the Dredge Texas finished offshore work in December, 2014 and have remained below baseline values since all offshore dredging was finished in March, 2015. Daily sedimentation rates for fine-grained sediments have been below baseline values for the entire survey period (Figure 20). All quantitative sedimentation data from baseline through impact assessment surveys is provided in Appendix D.

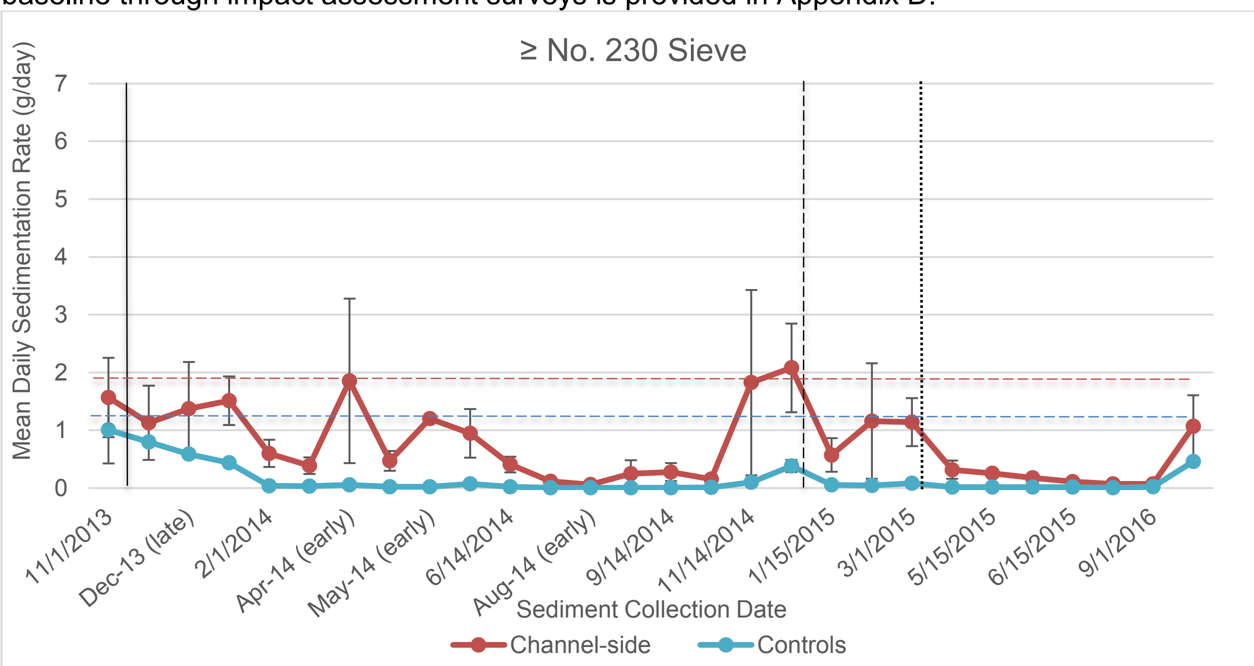


Figure 19. Mean daily sedimentation rates at channel-side and control locations for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. Error bars are standard errors. The solid black line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The black dash line represents the last day offshore of Dredge Texas (12/23/2014) and the dotted black line is the last day of offshore dredging by the clamshell dredge (3/16/2015). The horizontal orange line is the mean daily sedimentation rate of channel-side sites during baseline and the horizontal blue line is the mean daily sedimentation rate of control site locations during baseline surveys.

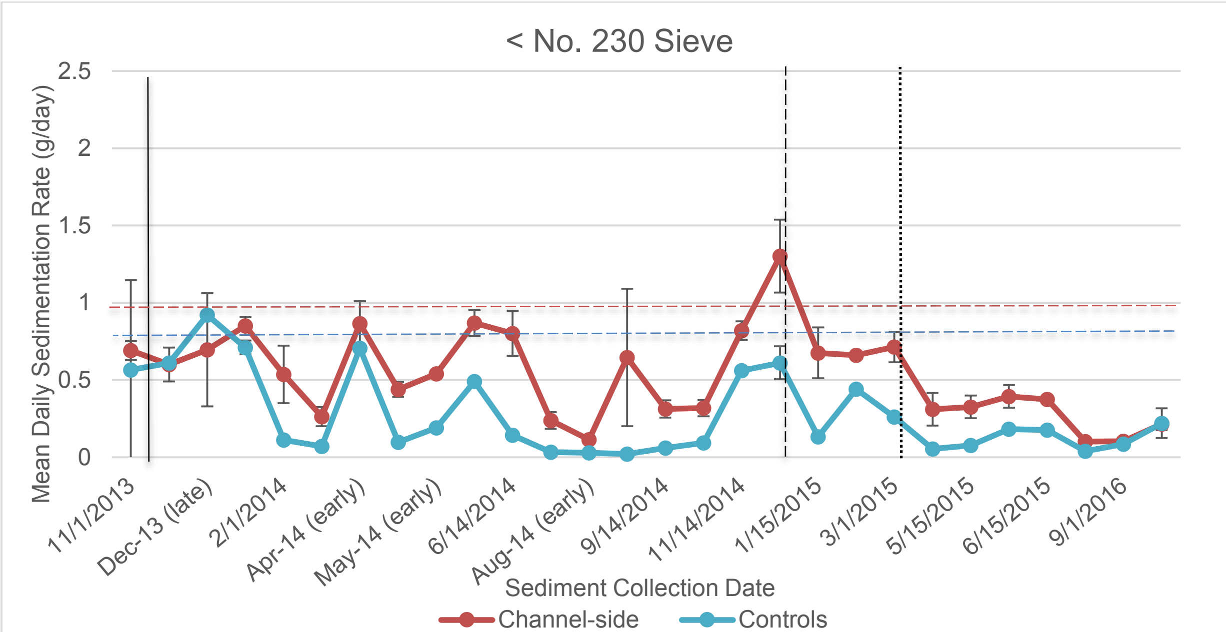


Figure 20. Mean daily sedimentation rates at channel-side and control locations for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. Error bars are standard errors. The solid black line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The black dash line represents the last day offshore of Dredge Texas (12/23/2014) and the dotted black line is the last day of offshore dredging by the clamshell dredge (3/16/2015). The horizontal orange line is the mean daily sedimentation rate of channel-side sites during baseline and the horizontal blue line is the mean daily sedimentation rate of control site locations during baseline surveys.

Sedimentation data for individual sites varied across hardbottom, middle reef, and outer reef sites as a function of location, season, and weather conditions. Although seasonal weather conditions play a major role in movement of sediment, site proximity to the dredge was also a factor on sedimentation rates during construction (Table 7). Data from baseline through impact assessment are presented by site in the succeeding sections in order to demonstrate the variability in sedimentation rates over time.

Table 7. Dredge commencement and completion dates are presented for each dredge offshore. Periods where dredges may not have been working, including maintenance are not represented, but were generally two weeks or less in duration.

Dredge	Type	Start Date	End Date
Texas	Cutterhead	12/17/2013	12/23/2014
Terrapin Island	Hopper (maintenance dredging)	11/20/2013	12/27/2013
Liberty Island	Hopper (maintenance dredging)	5/14/2014	7/3/2014
55	Clamshell	4/5/2014	3/16/2015

3.2.1 Hardbottom

During the baseline survey period in 2013 a natural sand wave event buried and partially buried all northern channel-side hardbottom sites (HBN1, HBN2, and HBN3-CP) (DCA 2014). Permanently marked corals were buried, and later exposed (documented September 2014), with no apparent mortality. The sediment characteristics were consistent with beach sand and represented a seasonal affect at these sites, as it was reburied in the fall of 2014. During baseline, sedimentation rates were greatest for the northern channel-side sites, with a maximum of 6.98 g/day. Fine-grain sedimentation remained low across all hardbottom sites and ranged from 0.49 to 0.96 g/day (Figures 21-24). Daily sedimentation of both coarse and fine grained sediment was significantly higher at sites located to the north of the channel (Kruskal-Wallis test, P=0.016 and P=0.005 respectively), which was part of a natural sand transport event (see DCA 2014a DCA 2014b. This natural sand transport event buried HBN1-CR during the baseline period and partially buried HBN2-CP and HBN3-CP (DCA 2014a). Winter-weather conditions during baseline, including high winds and significant sea states, caused re-suspension of sand material and contributed to the elevated mean daily sedimentation rates for fine-grain sediments at all hardbottom sites during that time. Dredging operations, including maintenance, had not commenced when hardbottom baseline sediment samples were collected, so these results reflect a non-dredging condition of seasonal winter conditions.

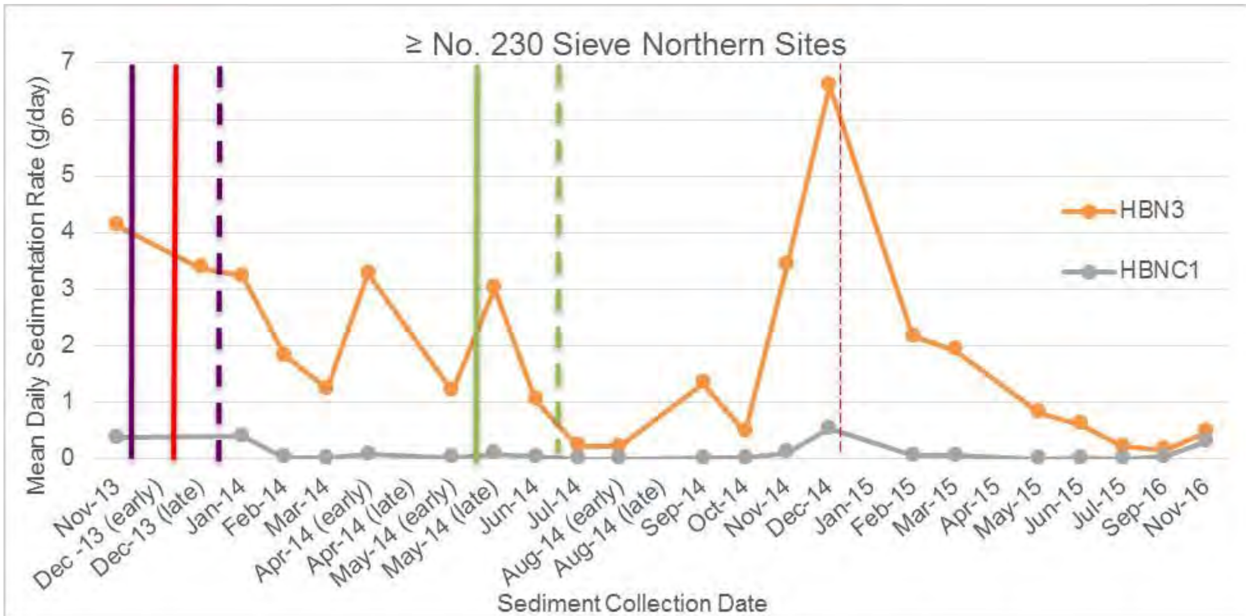


Figure 21. **Daily sedimentation rates at northern hardbottom sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of maintenance dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore of Dredge Texas (12/23/2014).**

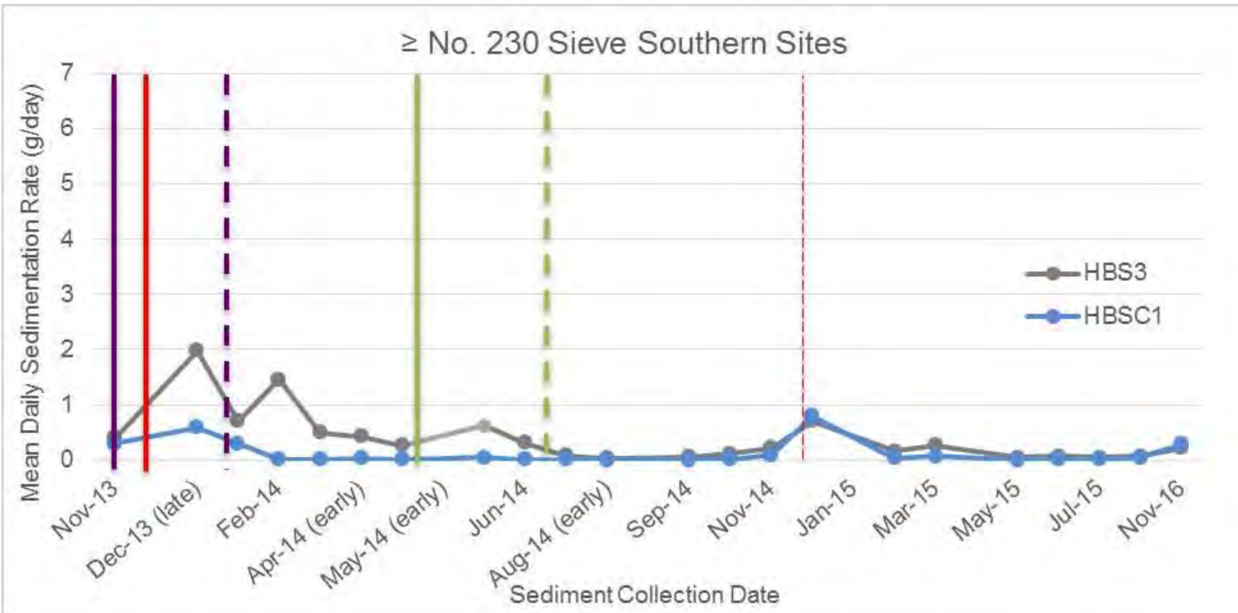


Figure 22. Daily sedimentation rates at southern hardbottom sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of maintenance dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore of Dredge Texas (12/23/2014).

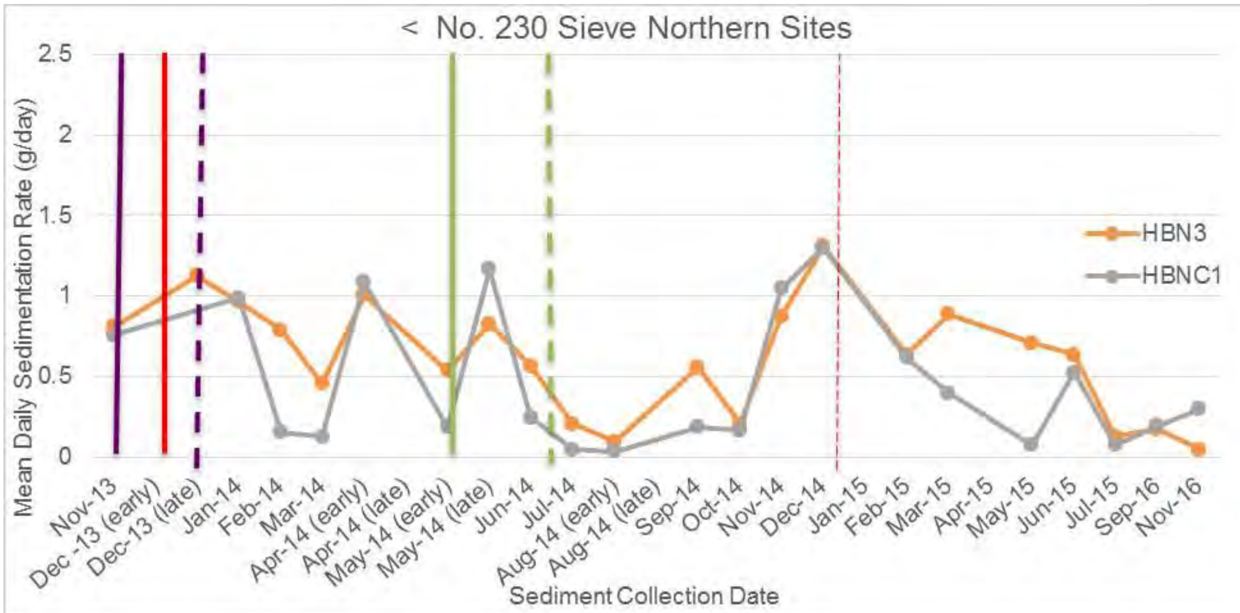


Figure 23. Daily sedimentation rates at northern hardbottom sites for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore of Dredge Texas (12/23/2014).

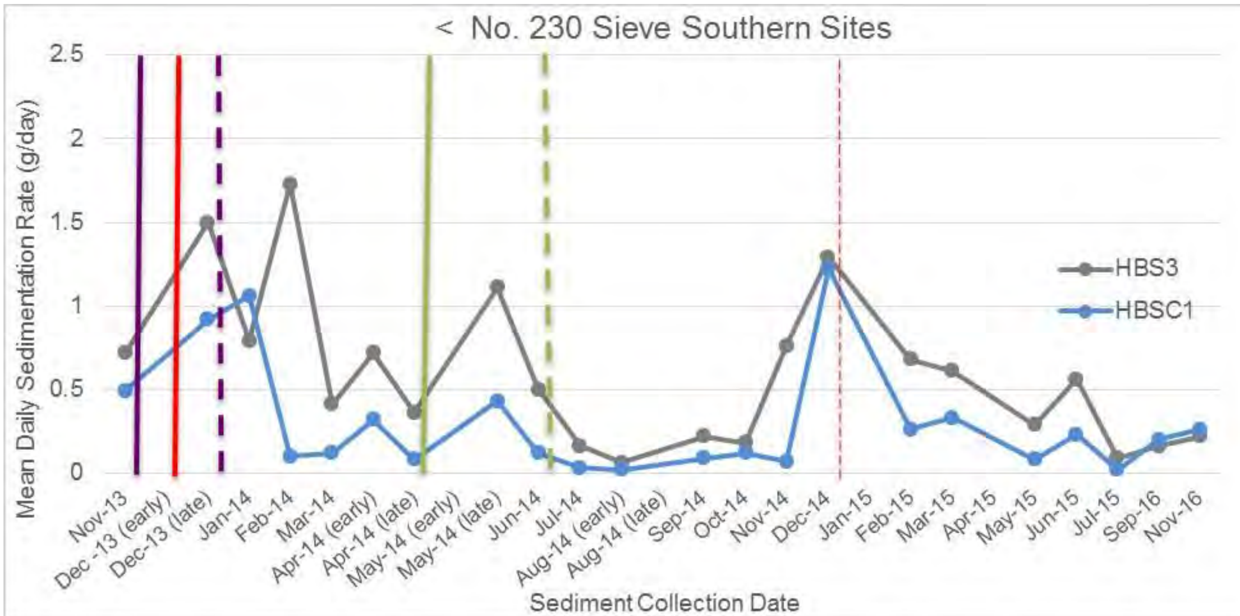


Figure 24. Daily sedimentation rates at southern hardbottom sites for fine-grain sediment (< #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of maintenance dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore of Dredge Texas (12/23/2014).

During impact assessment, sedimentation rates were lower for both coarse and fine grained sediments at all hardbottom sites when compared to baseline surveys (Figure 21-24). Lower rates of sedimentation in post-construction and impact assessment is likely a seasonal effect, baseline surveys were conducted in the fall/winter, whereas impact assessment surveys were conducted during the summer and fall. During impact assessment, sedimentation rates for coarse-grain sediments were greatest at HBN3-CP for both the first round (0.16g/day) and second round of samples (0.48 g/day), while the rates for fine-grain sediments were highest at HBCN1-CP for both the first round (0.20 g/day) and second round of samples (0.30 g/day). An increase in coarse and fine grain sediments was observed across all hardbottom sites during the second sampling of impact assessment (November 2016). This observed increase was likely due to the re-suspension of sediment caused by high winds and wave action experienced for 28 out of 65 days, including the passage of Hurricane Matthew, during the second impact assessment sampling.

Between baseline and impact assessment, sedimentation rates differed depending on their relation to the channel (north or south) and depending on grain size (coarse or fine). In general, the northern side of the channel experienced greater sedimentation rates for coarse and fine grain sediment.

3.2.2 Middle Reef

During baseline surveys sediment traps were installed and collected at R2N1-RR, R2S1-RR, R2NC1-LR, and R2SC1-RR before dredging began, whereas sediment bottles at the remaining middle reef sites, R2N2-LR, R2NC2-RR, R2S2-LR, and R2SC2-LR were collected after maintenance construction activities began near the hardbottom sites. As a result, there is a possibility that the R2S2-LR and R2N2-LR may have increased sedimentation during baseline sampling due to dredging in nearby habitats. Despite this possibility, sedimentation rates for R2S2-LR (sampled after the start of maintenance dredging) was less than R2S1-RR (sampled prior to dredging) for both fine and coarse grained sediments (Table 6) and only fine grained sediment accumulation rates at R2N2-LR (sampled after the start of dredging in hardbottom locations) were higher than R2N1-RR (sampled prior to dredging) during baseline samples. In the case of the northern reference sites which were five miles away, baseline samples were not collected until 38 (R2NC1-LR), 88 (R2NC3-LR) and 89 (R2NC2-LR) days after installation due to weather-driven limitations on safe boating and diving conditions.

Between the baseline and impact assessment survey periods, sedimentation rates differed depending on their relation to the channel (north or south) and depending on grain size (coarse or fine). In general, the northern side of the channel experienced greater sedimentation rates for coarse and fine grain sediment.

Average sedimentation daily rates for the project were tabulated and presented here for each site, from baseline through impact assessment (Figure 25-28).

Sedimentation rates of both coarse-grain and fine-grain sediments were lower across all middle reef sites during the impact assessment period compared to baseline values, with the exception of coarse-grained sediment at R2N2-LR, during the second sampling period of impact assessment. Although coarse sediment values were documented to be below 0.1 g/day during the initial sampling period of impact assessment surveys in September 2016, this value increased to the highest documented sediment values across all middle reef sites for all survey periods (4.63 g/day) only two months later, after exposure to high wave action caused by severe weather associated with Hurricane Matthew. High winds and rough seas persisted for the 28 out of 65 day sampling period.

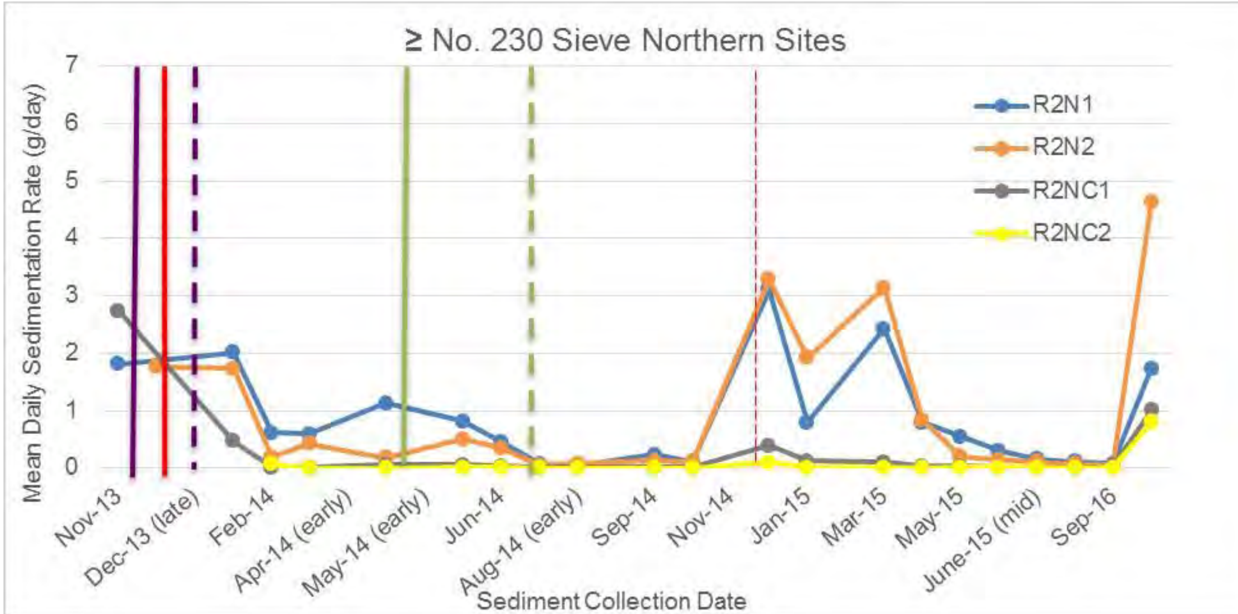


Figure 25. **Daily sedimentation rates at northern middle reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for Dredge Texas (12/23/2014).**

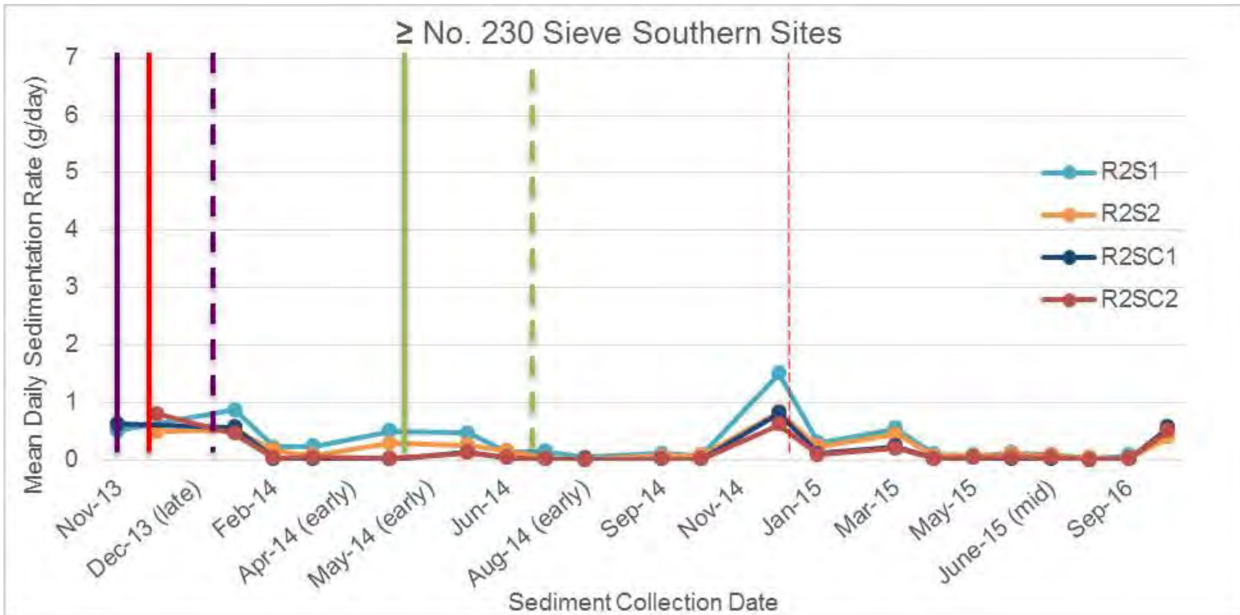


Figure 26. Daily sedimentation rates at southern middle reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for Dredge Texas (12/23/2014).

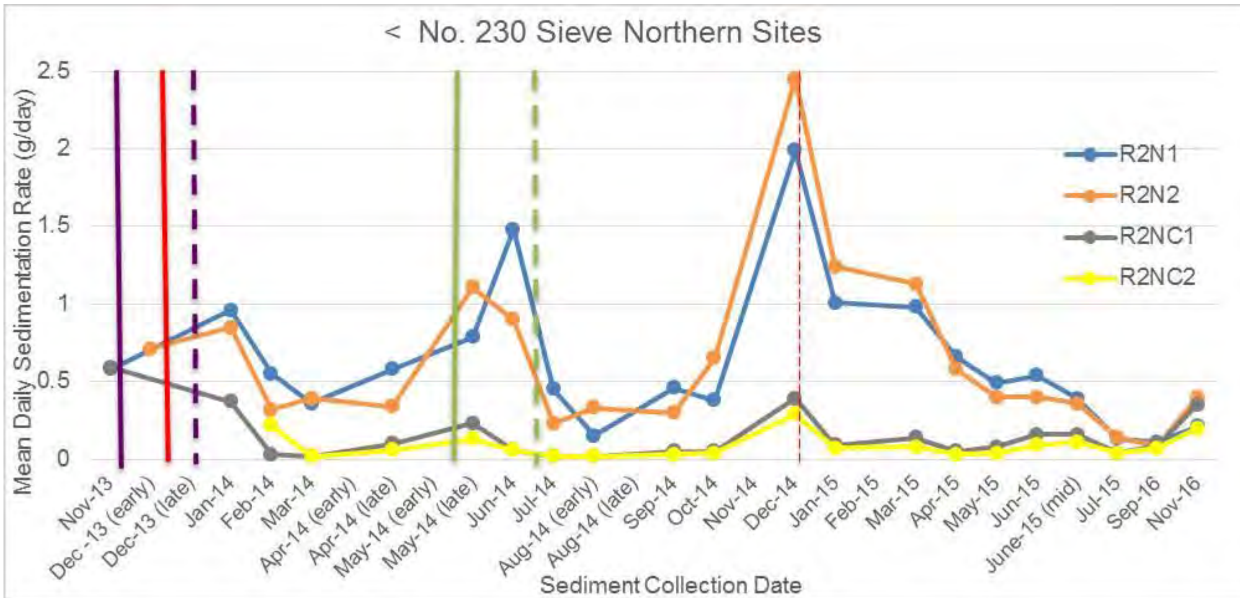


Figure 27. **Daily sedimentation rates at northern middle reef sites for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for Dredge Texas (12/23/2014).**

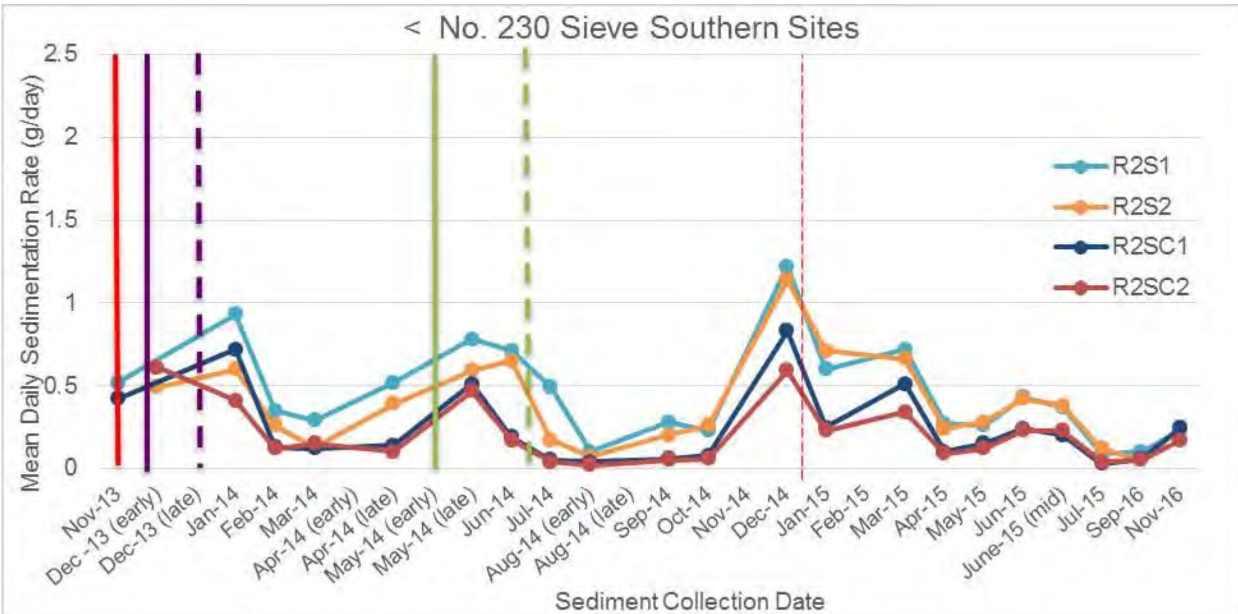


Figure 28. Daily sedimentation rates at southern middle reef sites for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for Dredge Texas (12/23/2014).

3.2.3 Outer Reef

Similar to hardbottom and middle reef sedimentation rates, the north side of the outer reef experienced greater sedimentation rates when compared to the south-side (Figure 29-32). During the initial sampling period of impact assessment surveys, the sedimentation rates of both coarse-grain and fine-grain sediments were generally lower than baseline samples (Figure 29-32). Coarse-grain sedimentation rates were highest at R3N1-LR (0.09 g/day), and lowest at R3SC2-LR (0.01 g/day). Fine-grain sedimentation rates ranged from 0.02 g/day (R3SC2-LR) to 0.04g/day (R3SC3-SG). During impact assessment surveys, sedimentation rates were lower for both coarse and fine grained sediments at both north and south sites when compared to baseline results, except for R3N1-LR which had equivalent coarse grain sedimentation rates in baseline and impact assessment survey periods. Similar to the hardbottom and middle reef sites, the outer reef sites were documented as having greater average daily sedimentation rates of both coarse- and fine-grain sediments during the second sampling of the impact assessment period as a result of the sustained winter weather conditions and the passage of Hurricane Matthew on October 9, 2016.

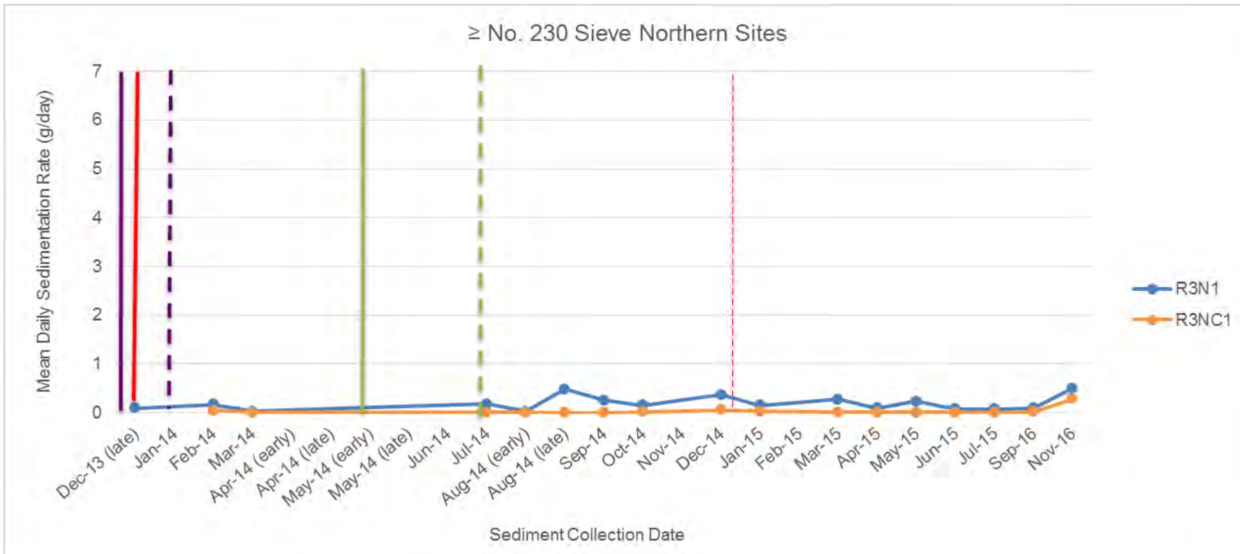


Figure 29. Daily sedimentation rates at northern outer reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore dredging for Dredge Texas (12/23/2014).

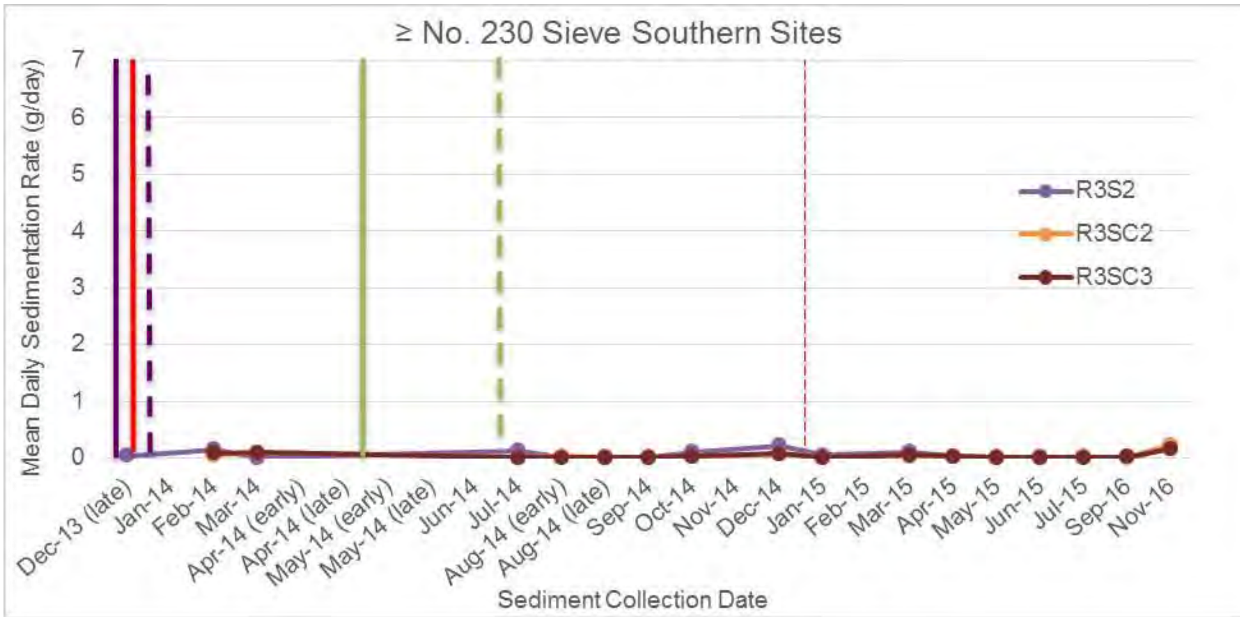


Figure 30. Daily sedimentation rates at southern outer reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day offshore dredging for Dredge Texas (12/23/2014).

Figure 31. Daily sedimentation rates at northern outer reef sites for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for Dredge Texas (12/23/2014).

Figure 32. Daily sedimentation rates at southern outer reef sites for fine-grain sediment (<#230 sieve) from baseline through impact assessment surveys. The solid purple line on November 20, 2013 represents the first day of maintenance dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of dredging for the Texas. The dotted purple line signifies the departure of the Terrapin Island (12/27/2013). The solid green line represents the first day of dredging for the Liberty Island (05/14/2014), and the green dotted line is the last day of dredging for the Liberty Island (07/03/2014). The red dash line represents the last day of offshore dredging for the Dredge Texas (12/23/2014).

3.3 Functional Group Percent Cover

Functional group percent cover is an indicator of the overall composition of various reef organisms according to their abundance within a site. Project-related sites were assessed in terms of the percent cover of corals, octocorals, sponges, zoanthids, macroalgae, CTB, sand, and other during baseline and impact assessment periods.

The functional group percent cover analysis from one-year post-construction impact assessment found that mean cover of dominant reef invertebrates was within a standard error of baseline values at 19 channel-side and control locations in all sampled habitats. The sand and CTB cover categories have been documented to be highly variable due to seasonality at control and channel-side sites (Figure 33). Impacts due to the project were documented as increased levels of sand cover and nearly reciprocal declines in CTB cover at channel-side locations that were greater than changes documented at control sites over the same time period. Increased sand cover was spatially restricted to middle reef and southern hardbottom channel-side sites between baseline and impact assessment surveys. The overall change in sand cover at channel-side sites was an estimated increase in mean sand cover from 13.6% documented during baseline surveys to the present mean sand cover of 29.3% documented during the impact assessment survey (an increase of 15.7%) (Table 8). A corresponding decline in the mean cover of CTB was also measured between baseline and impact assessment periods with a decline in mean CTB cover from 70.5% measured in baseline surveys to 54.8% during impact assessment surveys (decline of 15.7%) at channel-side locations (Table 8). Sand cover was found to vary considerably at both channel-side and control locations over the course of project monitoring. At control locations, the range average in sand cover over the course of the project was 40.0% (minimum 19.8% and maximum 63.8%, see also Section 3.3.2). The increase in sand cover documented at channel-side sites during the impact assessment period is within the range of seasonal variability of the control sites. The increase in sand cover at channel-side sites is within the expected natural variability documented at control sites (Figure 33). Although sand has increased channel-side, no macrofaunal functional group (scleractinians, octocorals, sponges or zoanthids) declined significantly over the same time period. Sand and CTB percent cover are discussed more thoroughly in Section 3.3.2.

Figure 33. Photographs of HBNC1-CP during baseline period (left photo October 15, 2013, right photo November 12, 2013), before the commencement of dredging (November, 20, 2013). The photographs illustrate the ephemeral nature of CTB cover and the transition of that community to one covered in sand.

3.3.1 Overview

Mean cover of dominant reef invertebrates, including scleractinian, octocoral, sponge, and zoanthid cover, as measured during the impact assessment survey, was within a standard error of baseline values for permanent channel-side and control locations (Table 8, Figure 34 and 35). Mean coral cover was less than 1% at channel-side sites in the baseline period and less than 2% at control sites (Table 8). Coral cover declined at both channel-side and control locations between baseline and impact assessment surveys, whereas mean sponge and octocoral cover increased at channel-side locations and declined at control sites over the survey period (Table 8, Figure 36 and 37). The decline in coral cover at both channel-side and control sites is explained by the regional white plague disease event that has affected all reefs in Southeast Florida (Figure 16). At control locations sand cover remained fairly constant (11.3% in baseline and 11.9% during impact assessment surveys) and CTB cover increased slightly (64.6% in baseline to 68.3% during impact assessment surveys) (Table 8). Functional group cover is discussed in the succeeding sections with both an overall assessment of cover by reef-type and with a presentation of functional group cover at each permanent site between baseline and impact assessment surveys.

Table 8 Mean percent cover and standard error of benthic functional groups of all channel-side sites in comparison with permanent site controls between baseline and impact assessment surveys.

Functional Group	Channel-side				Controls			
	Baseline	SE	Impact Assessment	SE	Baseline	SE	Impact Assessment	SE
Scleractinians	0.88	0.14	0.62	0.18	1.90	0.43	1.45	0.38
Octocorals	9.27	1.68	9.97	1.81	14.78	1.91	12.62	1.70
Sponges	4.48	0.58	4.70	0.61	4.87	1.16	3.31	0.39
Zoanthids	0.54	0.21	0.46	0.31	1.73	1.11	1.91	1.20
Macroalgae	0.18	0.09	0.00	0.00	0.42	0.26	0.45	0.22
Coralline, Turf, Bare	70.48	5.44	54.76	4.86	64.62	3.59	68.33	3.22
Sand	13.62	5.56	29.33	5.19	11.26	3.59	11.92	2.56
Other	0.56	0.25	0.15	0.09	0.42	0.17	0.02	0.02

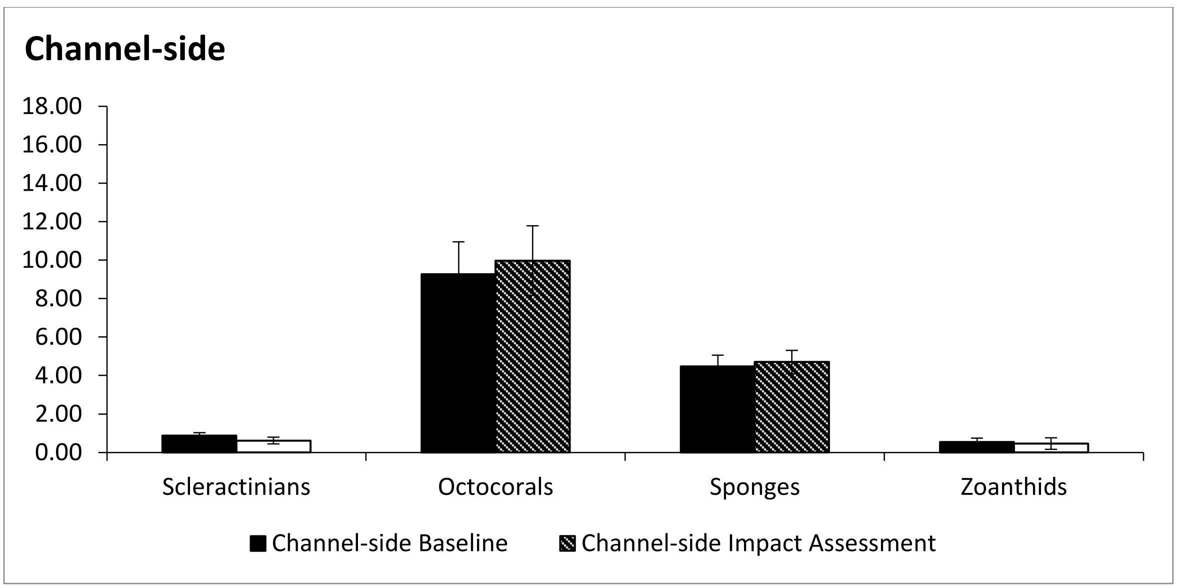


Figure 34. Mean cover ± standard error of dominant reef invertebrate categories during baseline and impact assessment surveys for all nine channel-side sites.

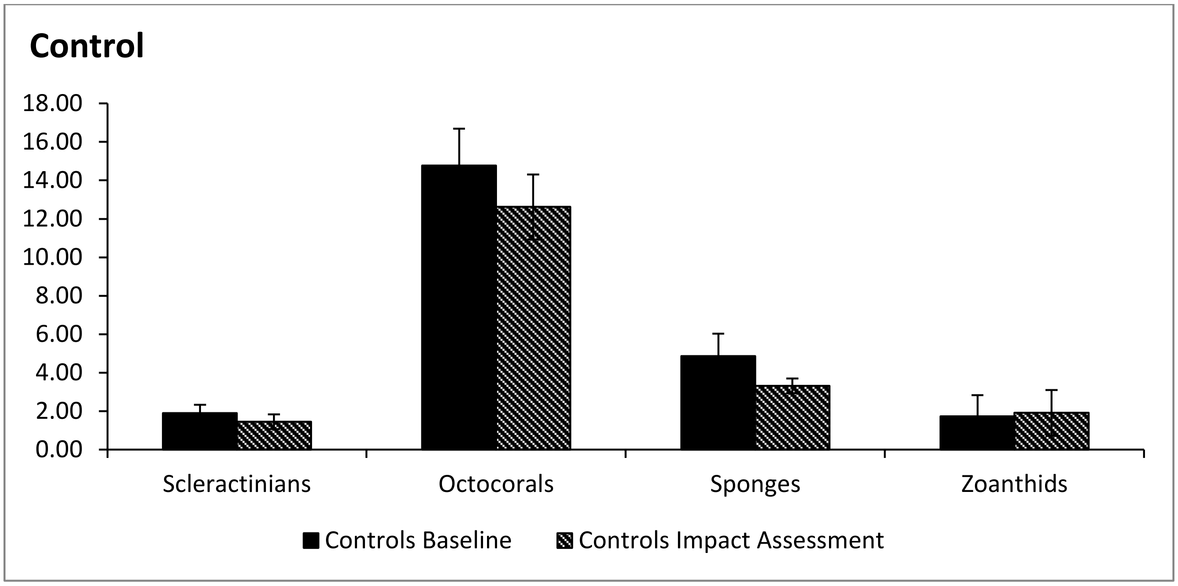


Figure 35. Mean cover ± standard error of dominant reef invertebrate categories during baseline and impact assessment surveys for all ten control sites.

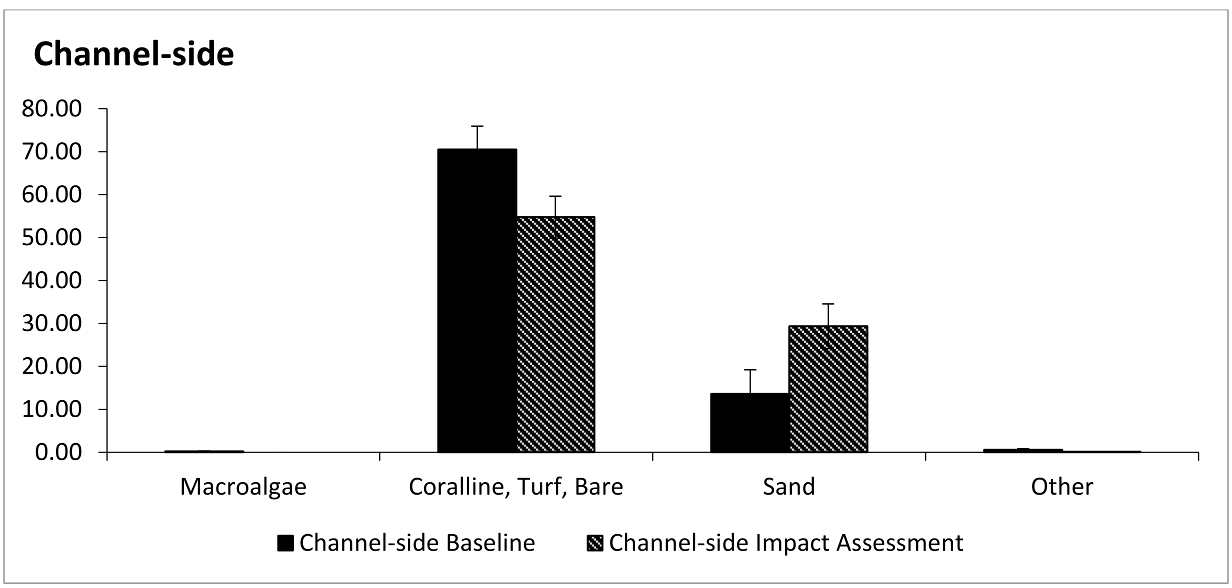


Figure 36. Mean cover ± standard error of non-invertebrate categories during baseline and impact assessment surveys for all nine channel-side sites.

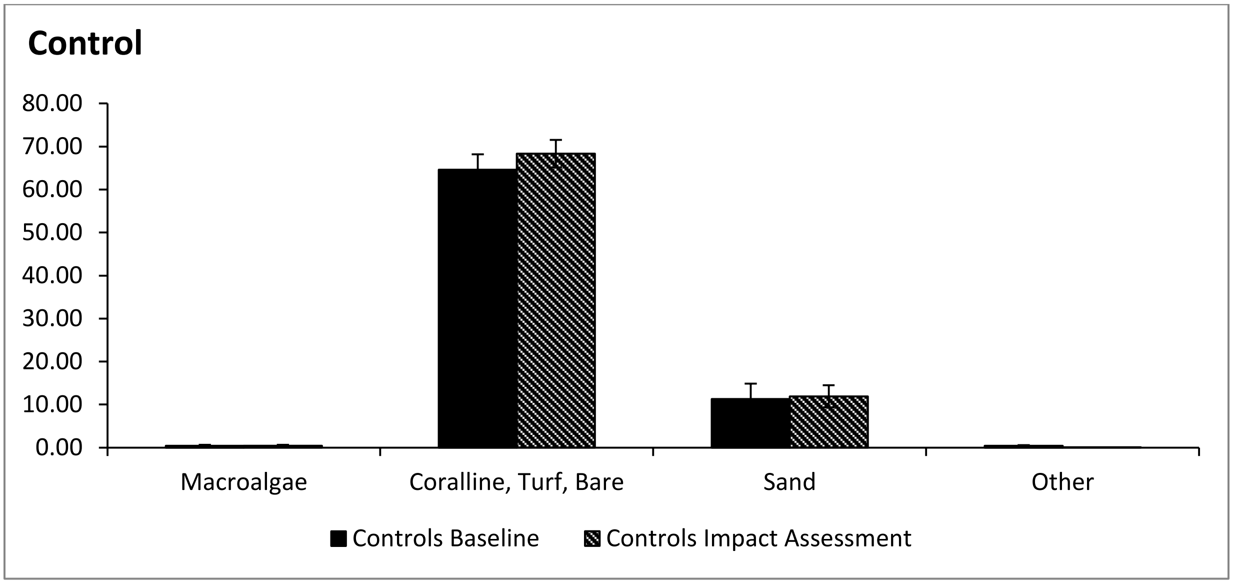


Figure 37. Mean cover ± standard error of non-invertebrate categories during baseline and impact assessment surveys for all ten control sites.

3.3.1.1 Hardbottom

Functional group cover of hardbottom monitoring sites were consistent with the overall trends observed at all channel-side and control locations discussed previously (Figure 34-37). Mean cover of dominant reef invertebrates, including scleractinian, octocoral, sponge, and zoanthid cover, as measured during the impact assessment survey, was within a standard error of baseline values for hardbottom channel-side and control locations (Table 9, Figure 34 and 35). Coral cover declined at both channel-side and control locations, whereas mean sponge cover increased at both channel-side and control sites, and octocoral density declined slightly at channel-side locations and increased at control sites over the survey period (Table 9, Figure 34 and 35). As a result of the project, mean sand cover increased at channel-side locations from 28.6% during baseline surveys to 41.8% during impact assessment surveys (an increase of 13.2%). A corresponding decline in the CTB category was also observed at channel-side locations with mean CTB cover of 54.1% in baseline declining to 41.5% during impact assessment surveys (a decline of 12.6%) (Table 9). The increased sand cover was localized to the two southern hardbottom channel-side sites HBS3-CP and HBS4-CR as discussed below. At control locations sand cover remained fairly constant (20.6% in baseline and 21.8% during impact assessment surveys) and CTB cover decreased slightly (56.8% in baseline to 54.0% during impact assessment surveys) (Table 9).

Table 9. Mean percent cover and standard error of benthic functional groups of all hardbottom channel-side sites in comparison with permanent site controls between baseline and impact assessment surveys.

Functional Group	Channel-side				Controls			
	Baseline	SE	Impact Assessment	SE	Baseline	SE	Impact Assessment	SE
Scleractinians	0.88	0.32	0.51	0.29	1.93	1.49	1.65	1.18
Octocorals	10.01	2.77	9.18	3.09	16.71	8.11	17.41	5.11
Sponges	5.01	1.23	5.78	0.84	2.28	0.51	4.19	0.26
Zoanthids	1.13	0.42	1.13	0.87	0.00	0.00	0.11	0.11
Macroalgae	0.08	0.08	0.00	0.00	1.45	1.17	0.89	0.89
Coralline, Turf, Bare	54.08	10.86	41.51	5.66	56.83	16.97	53.97	3.08
Sand	28.64	11.92	41.85	7.78	20.63	12.21	21.83	1.31
Other	0.17	0.14	0.03	0.03	0.18	0.18	0.00	0.00

At individual hardbottom monitoring sites, the functional group percent cover of dominant invertebrate categories (corals, octocorals, sponges, and zoanthids) remained fairly consistent between the baseline, post-construction and impact assessment surveys at all sites (Figure 38-42). The largest relative change of dominant invertebrate categories (corals, sponges, octocorals, or zoanthids) was the decline of octocorals at HBNC1-CP from 24.8% cover at baseline to 22.52% (a decline of 2.3%) during the impact assessment survey (Figure 39). The largest change of biological categories between baseline and impact assessment surveys at any channel-side site was the decline of the octocoral category from 5.1% to 3.58% at HBN3-CP (a decline of 1.56%). Since this decline at the northern channel-side sites was less than the respective northern hardbottom control (HBNC1-CP), this change was not attributed to local dredge-related impacts. It is important to note that power to detect change using functional group percent cover declines with the total cover of a category. As a result, changes in mean coral cover due to the regional disease event may not be reliably detected using functional group percent cover analysis due to the initially low cover of the category (less than 3.4% at all hardbottom monitoring sites). The results from the tagged colony analysis (Section 3.4) is a more accurate documentation of changes in the scleractinian coral community.

The largest changes in the hardbottom benthic community over time were based on the relative changes in the CTB and sand cover categories at the hardbottom monitoring sites. At the northern hardbottom monitoring sites, the relative percent cover of sand decreased at both HBN3-CP and HBNC1-CP between baseline and impact assessment surveys (Figures 38 and 39) and the percent cover of CTB increased. During baseline surveys, nearshore sand covered northern hardbottom sites (HBN1-CR and HBN2-CR). Sand builds up on the north side of the inlet in winter and covers hardbottom habitat, sediment moves off this area in the spring and summer months, which may explain the decreased sand values in impact assessment survey period (summer v. fall/winter survey periods). At the southern hardbottom monitoring sites, the percent cover of sand increased from 24.2% to 55.5% (an increase of 31.3%) at HBS4-CR and from 10.6% to 28.5% (an increase of 18%) at HBS3-CP between baseline and impact assessment surveys (Figures 40 and 41). Percent cover of sand at the hardbottom southern control also increased but to a lesser

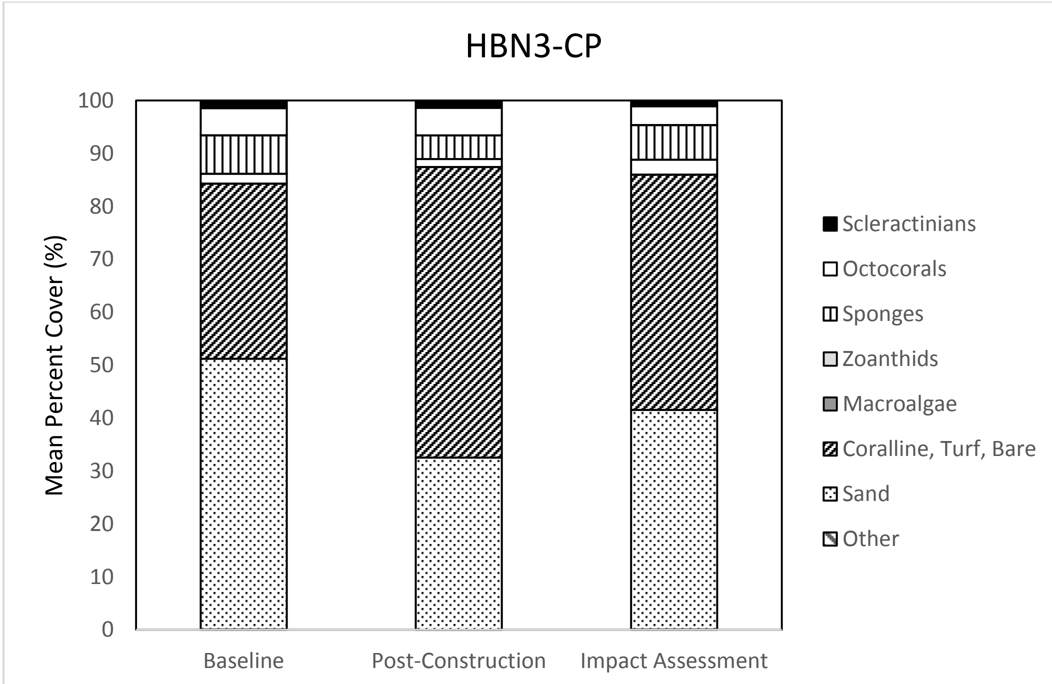


Figure 38. Functional group percent cover for HBN3-CP during baseline, post-construction, and impact assessment surveys.

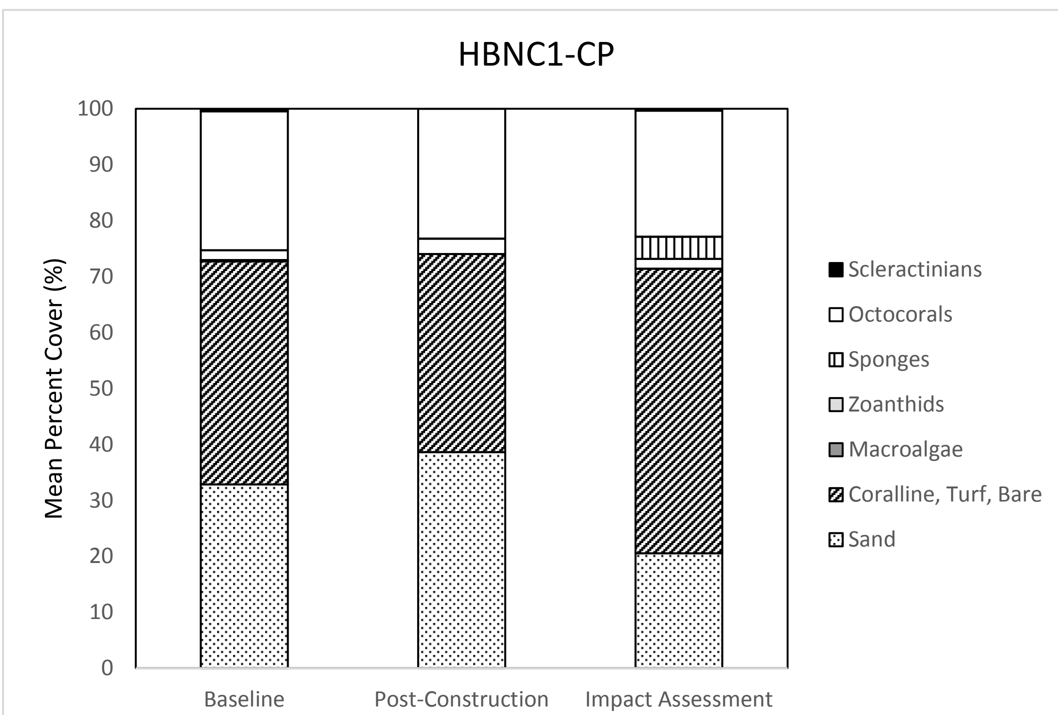


Figure 39. Functional group percent cover for HBNC1-CP during baseline, post-construction, and impact assessment surveys.

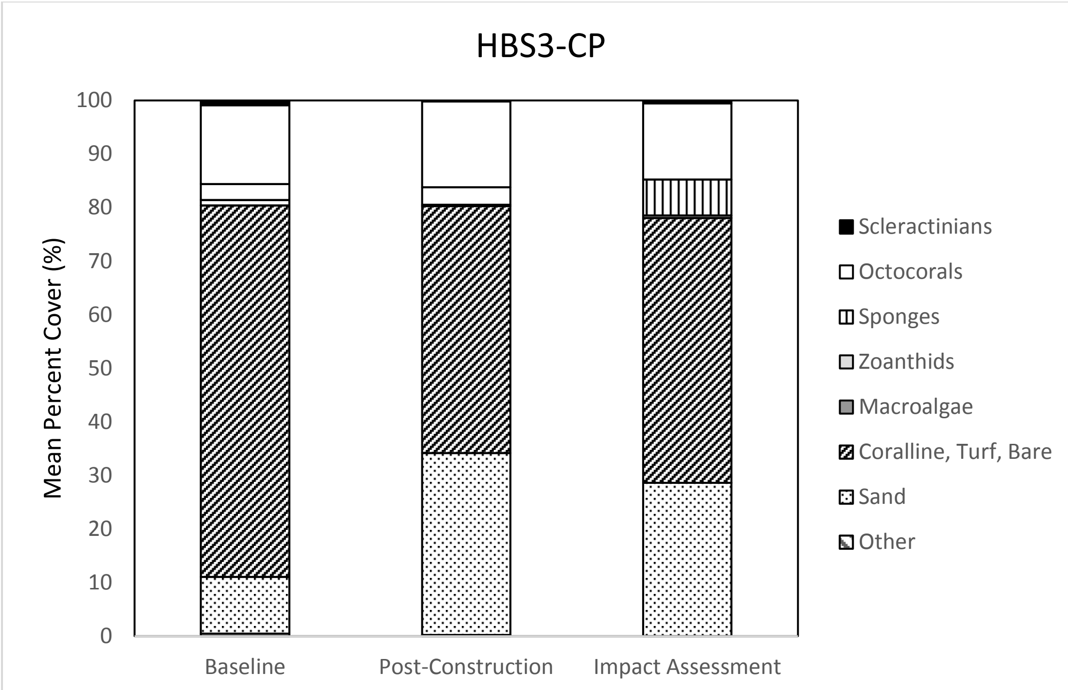


Figure 40. Functional group percent cover for HBS3-CP during baseline, post-construction, and impact assessment surveys.

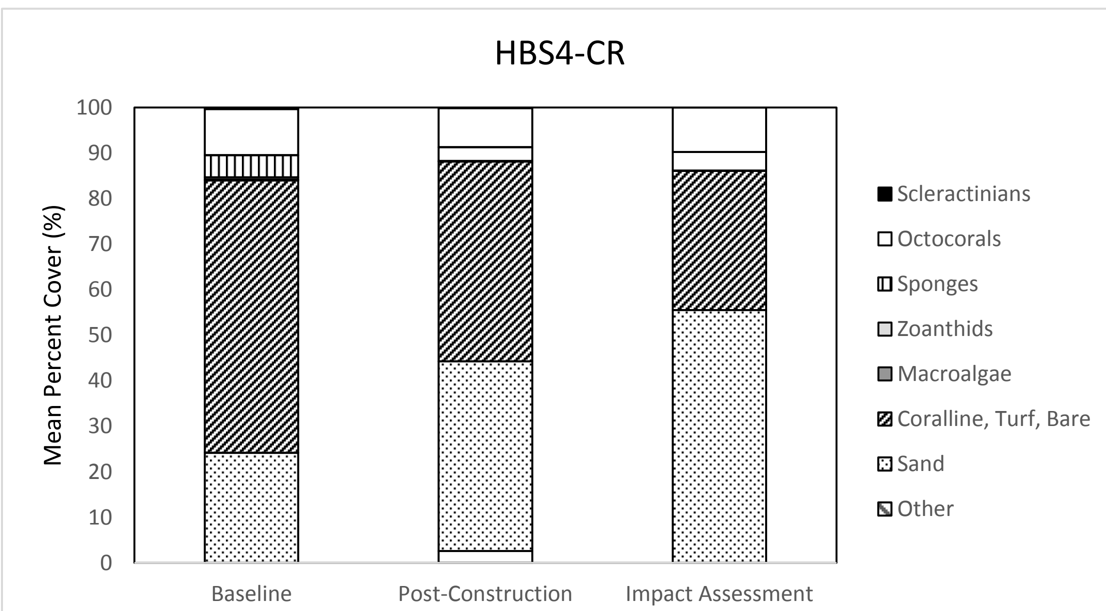


Figure 41. Functional group percent cover for HBS4-CR during baseline, post-construction, and impact assessment surveys.

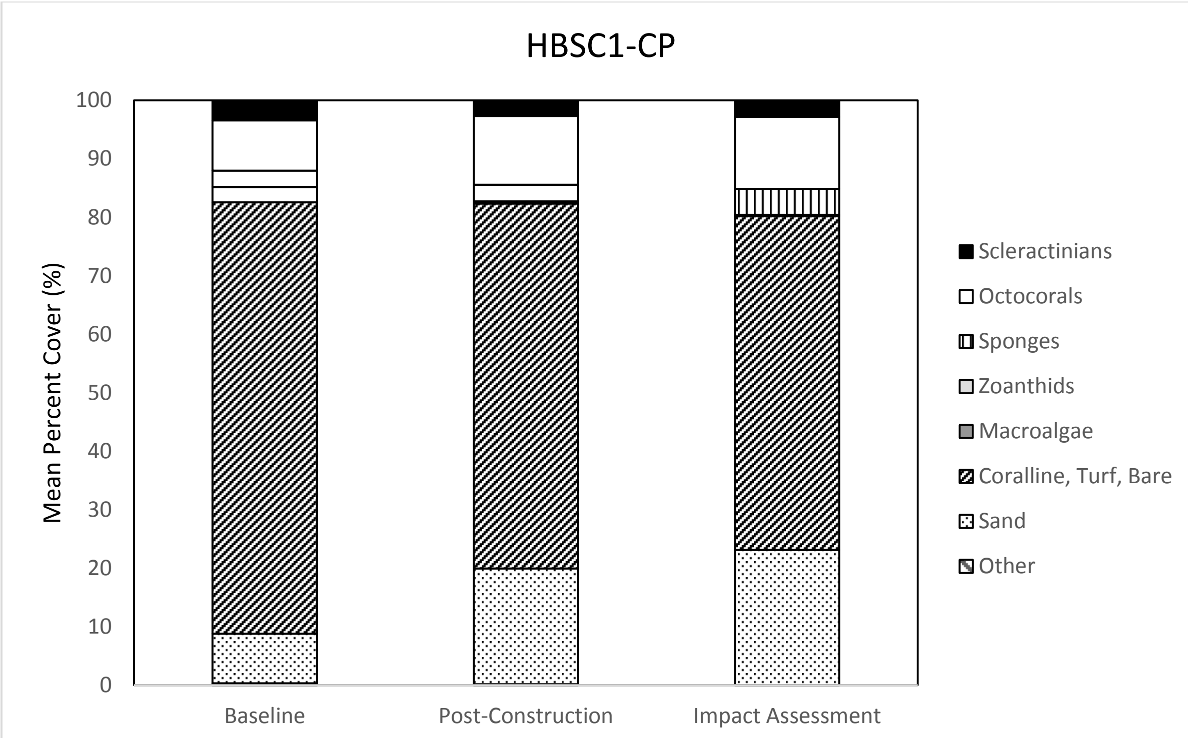


Figure 42. Functional group percent cover for HBSC1-CP during baseline, post-construction, and impact assessment surveys.

degree from 8.4% to 23.14% (an increase of 14.7%) over the same time period. Although the changes in CTB and sand categories were as much as 31.3% between baseline and impact assessment surveys, no dominant reef invertebrate category declined more than 1.5% at hardbottom channel-side sites (Figures 38-42).

3.3.1.2 Middle Reef

Functional group cover of middle reef monitoring sites were consistent with the overall trends observed at all channel-side and control locations discussed previously. Mean cover of dominant reef invertebrates, including scleractinian, octocoral, sponge, and zoanthid cover, as measured during the impact assessment survey, was within a standard error of baseline values for middle reef channel-side and control locations (Table 10). Coral cover declined at both channel-side and control locations, whereas mean sponge cover increased slightly at both channel-side and control locations and octocoral cover remained the same channel-side despite a decline in octocoral cover at middle reef controls over the survey period (Table 10). As a result of the project, mean sand cover increased at channel-side locations from 5.47% during baseline surveys to 29.4% during impact assessment surveys (an increase of 23.9%). It should be noted that sand cover values at channel-side sites declined between the immediate post-construction period and the one-year post-construction surveys. A corresponding decline in the CTB category was also observed at channel-side locations with mean CTB cover of 80.6% in baseline declining to 56.2% during impact assessment surveys (a decline of 24.4%) (Table 10). At control locations sand cover increased slightly (12.4% in baseline and 14.5% during impact assessment surveys) and CTB cover also increased slightly (63.2% in baseline to 67.8% during impact assessment surveys) (Table 10).

Table 10. Mean percent cover and standard error of benthic functional groups of all middle reef channel-side sites in comparison with permanent site controls between baseline and impact assessment surveys.

Functional Group	Channel-side				Controls			
	Baseline	SE	Impact Assessment	SE	Baseline	SE	Impact Assessment	SE
Scleractinians	0.99	0.24	0.85	0.34	2.53	0.56	1.52	0.65
Octocorals	8.60	3.28	8.60	2.90	15.18	2.80	10.44	1.95
Sponges	3.68	0.53	4.52	1.14	3.01	0.50	3.43	0.55
Zoanthids	0.22	0.17	0.16	0.10	3.30	2.06	1.79	2.27
Macroalgae	0.02	0.02	0.00	0.00	0.06	0.03	0.15	0.31
Coralline, Turf, Bare	80.58	3.67	56.15	5.68	63.20	3.17	67.86	4.38
Sand	5.47	5.01	29.40	5.50	12.40	4.74	14.54	3.93
Other	0.44	0.16	0.32	0.17	0.31	0.29	0.28	0.04

At individual middle reef monitoring sites, the functional group percent cover of dominant invertebrate categories (corals, octocorals, sponges, and zoanthids) remained fairly consistent between the baseline, post-construction and impact assessment surveys at all sites (Figure 43-51). The largest relative change of dominant invertebrate categories (corals, sponges, octocorals, or zoanthids) between baseline and impact assessment surveys was the decline of octocorals at R2NC3-LR from 17.2% to 8.2% (a decline of 9.0%) (Figure 47). The largest change of biological categories between baseline and impact assessment surveys at any middle reef channel-side site was a relative increase in the sponge category from 3.3% to 7.4% (an increase of 4.04%) at R2S1-RR (Figure 48). The largest decline in percent cover of a dominant reef invertebrate category at a middle reef channel-side site was a 3.1% decline in the sponge category at R2S2-LR (sponge cover changed from 4.97% at baseline to 1.84% during the impact assessment survey). It is important to note that power to detect change using functional group percent cover declines with the total cover of a category. As a result, changes in mean coral cover due to the regional disease event may not be reliably detected using functional group percent cover analysis due to the initially low cover of the category (less than 3.9% at all middle reef monitoring sites). The results from the tagged colony analysis (Section 3.4) is a more accurate documentation of changes in the scleractinian coral community.

The largest changes in the benthic community between baseline and impact assessment surveys at the individual middle reef sites were relative changes in the CTB and sand cover categories. At the middle reef channel-side sites, sand increased in terms of relative percent cover and CTB decreased in all cases. Relative increases in sand ranged from 0.9% at R2N2-LR to an increase of 42.8% at R2S2-LR. At the middle-reef control sites, relative changes in the sand category ranged from a decline of 11.9% at R2NC3-LR to an increase of 7.25% at R2NC2-RR between the two surveys. Although the changes in CTB and sand categories were as much as 42.8% between baseline and impact assessment surveys at middle reef channel-side sites, no dominant reef invertebrate category declined more than 3.13% at the same sites (Figure 43-51).

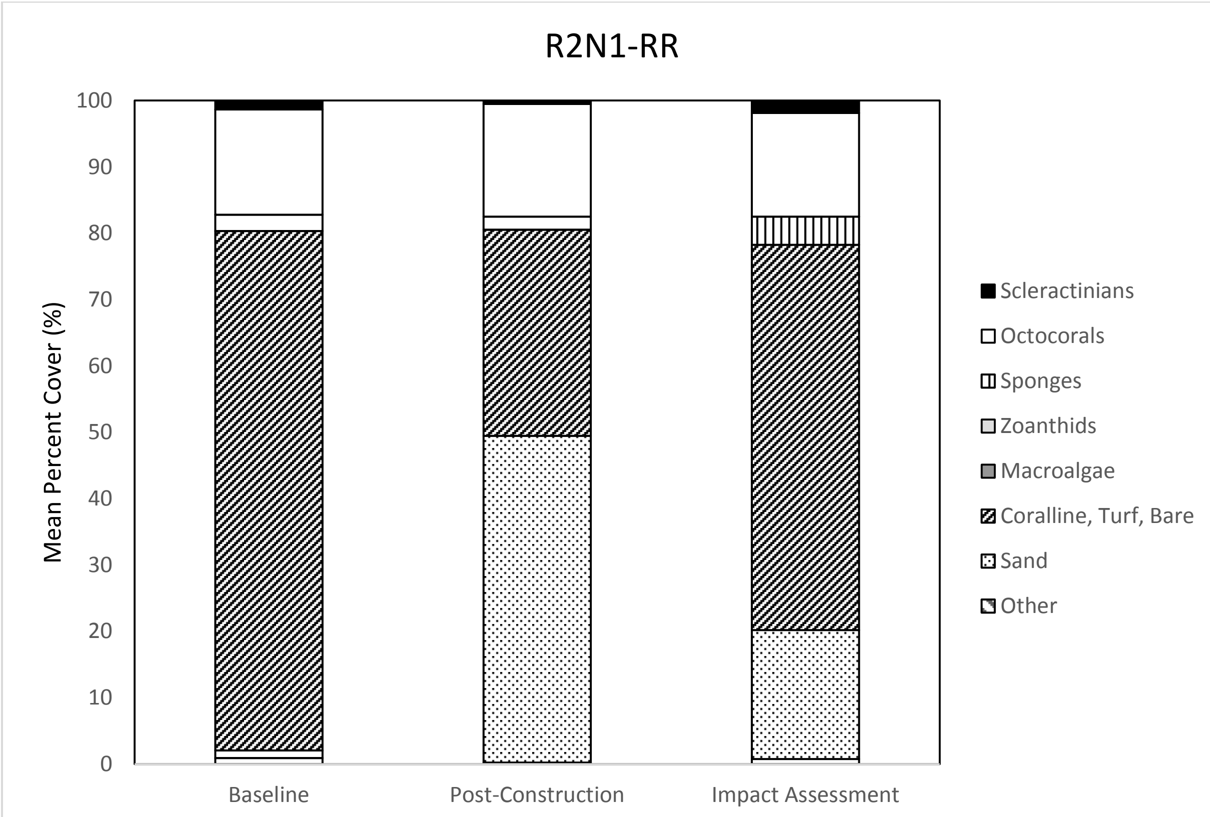


Figure 43. Functional group percent cover for R2N1-RR during baseline, post-construction, and impact assessment surveys.

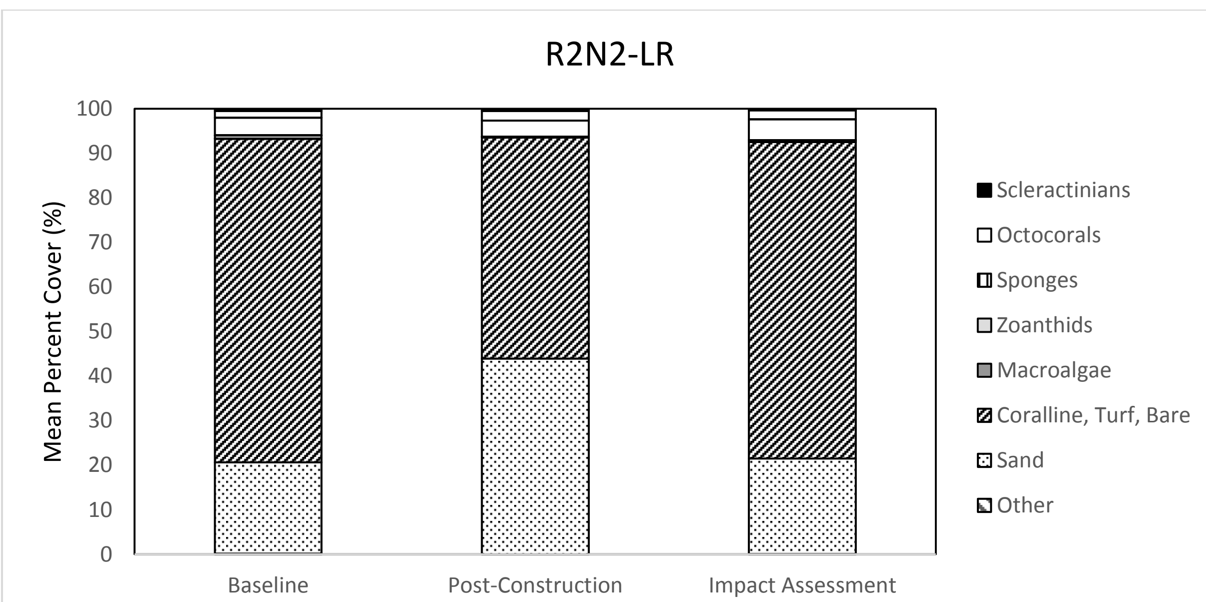


Figure 44. Functional group percent cover for R2N2-LR during baseline, post-construction, and impact assessment surveys

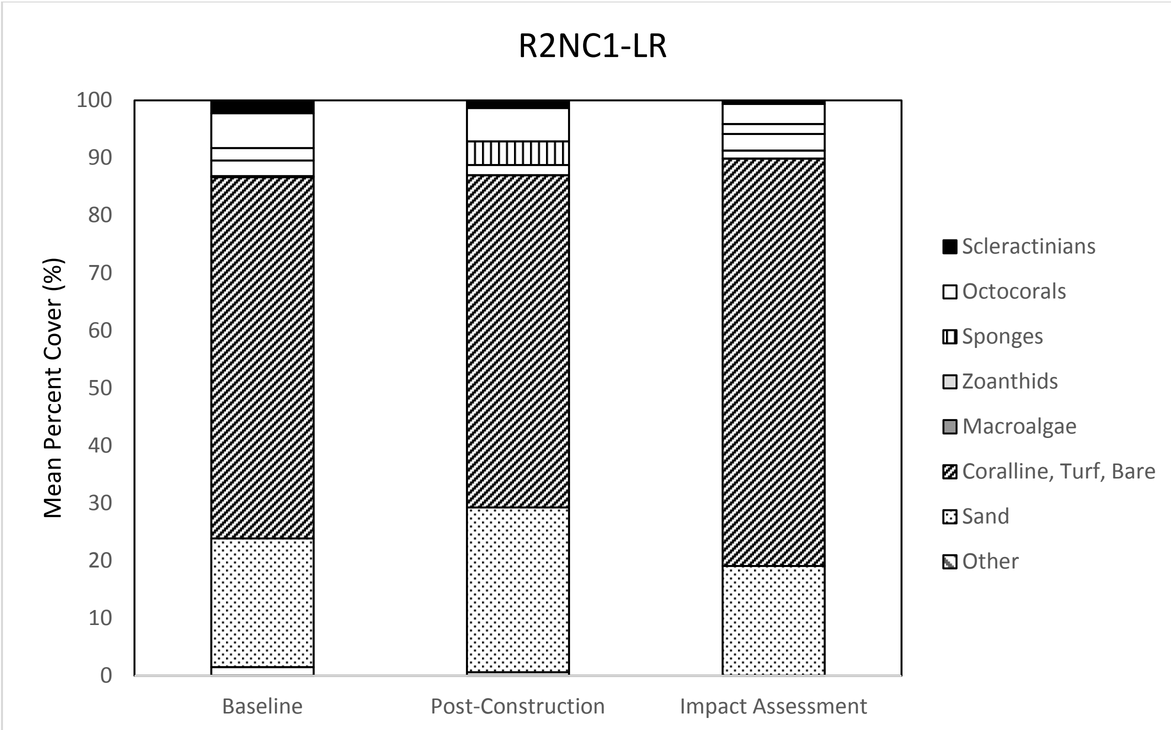


Figure 45. Functional group percent cover for R2NC1-LR during baseline, post-construction, and impact assessment surveys.

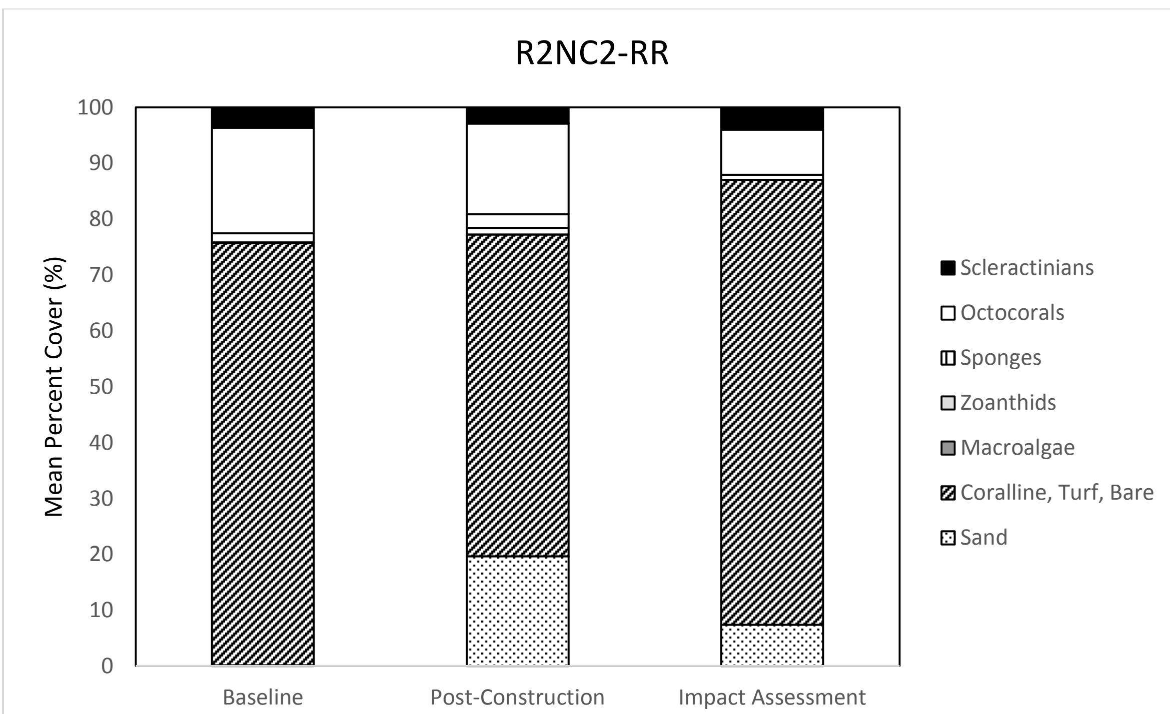


Figure 46. Functional group percent cover for R2NC2-RR during baseline, post-construction, and impact assessment surveys.

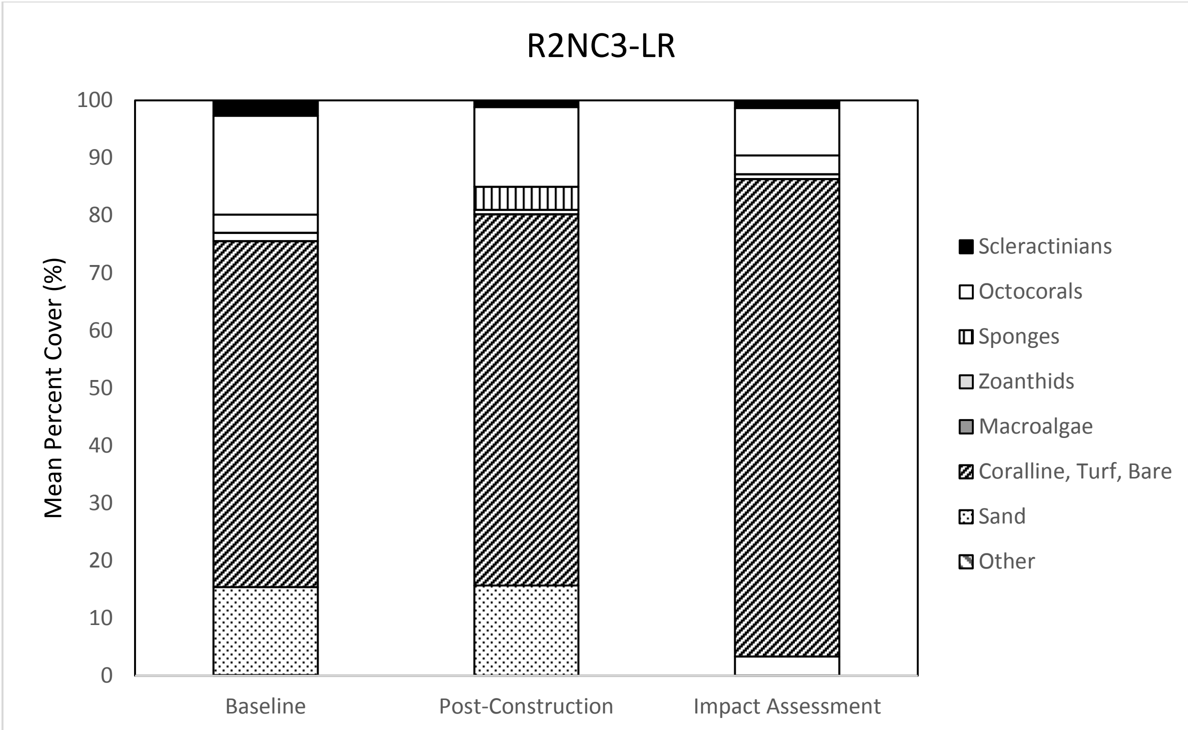


Figure 47. Functional group percent cover for R2NC3-LR during baseline, post-construction, and impact assessment surveys.

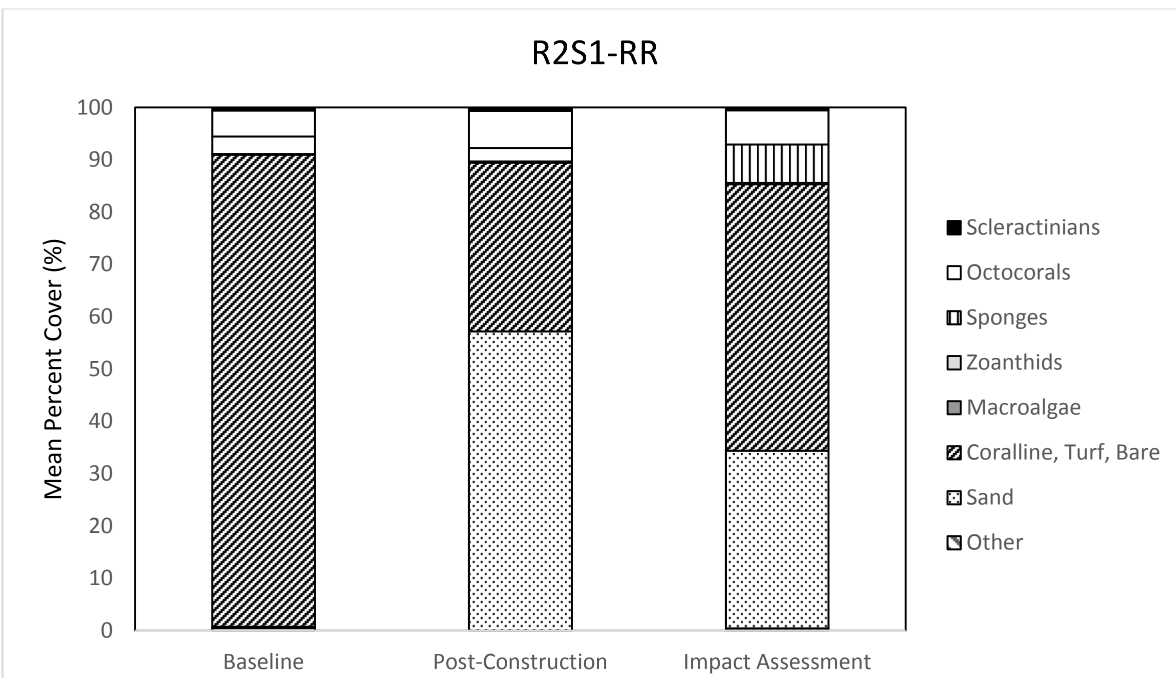


Figure 48. Functional group percent cover for R2S1-RR during baseline, post-construction, and impact assessment surveys.

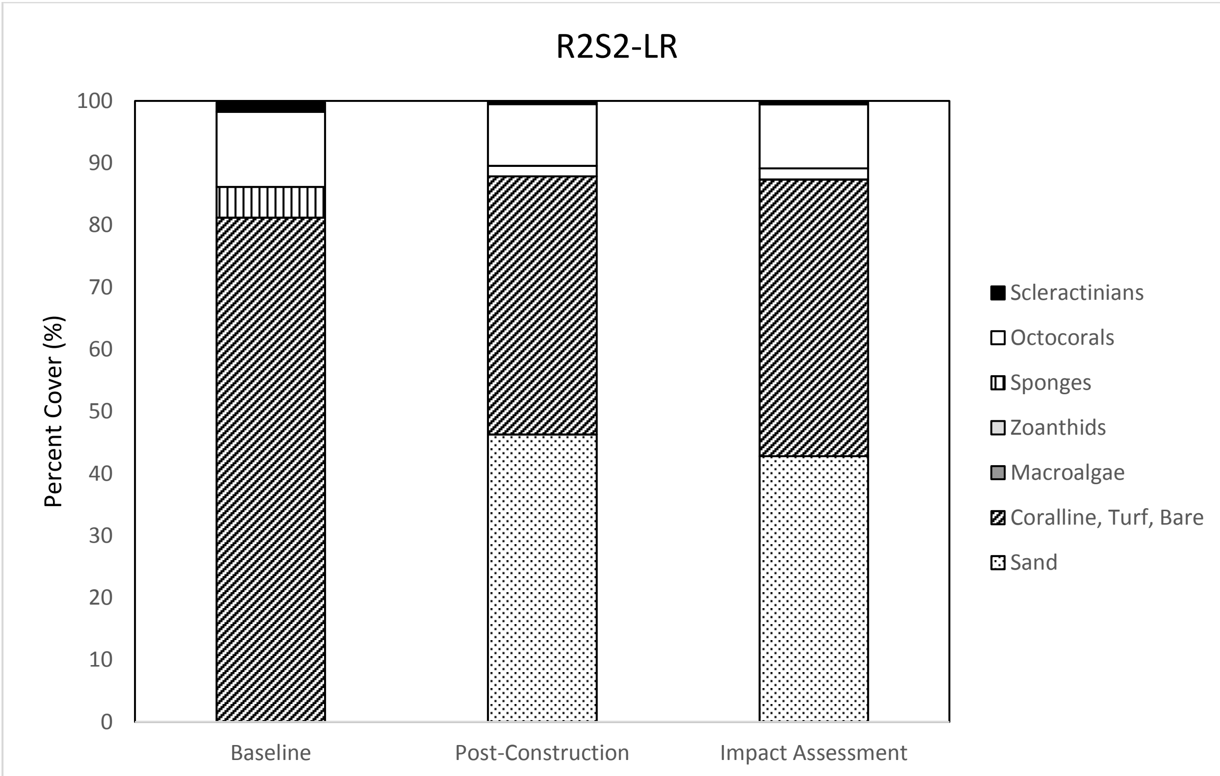


Figure 49 Functional group percent cover for R2S2-LR during baseline, post-construction, and impact assessment surveys.

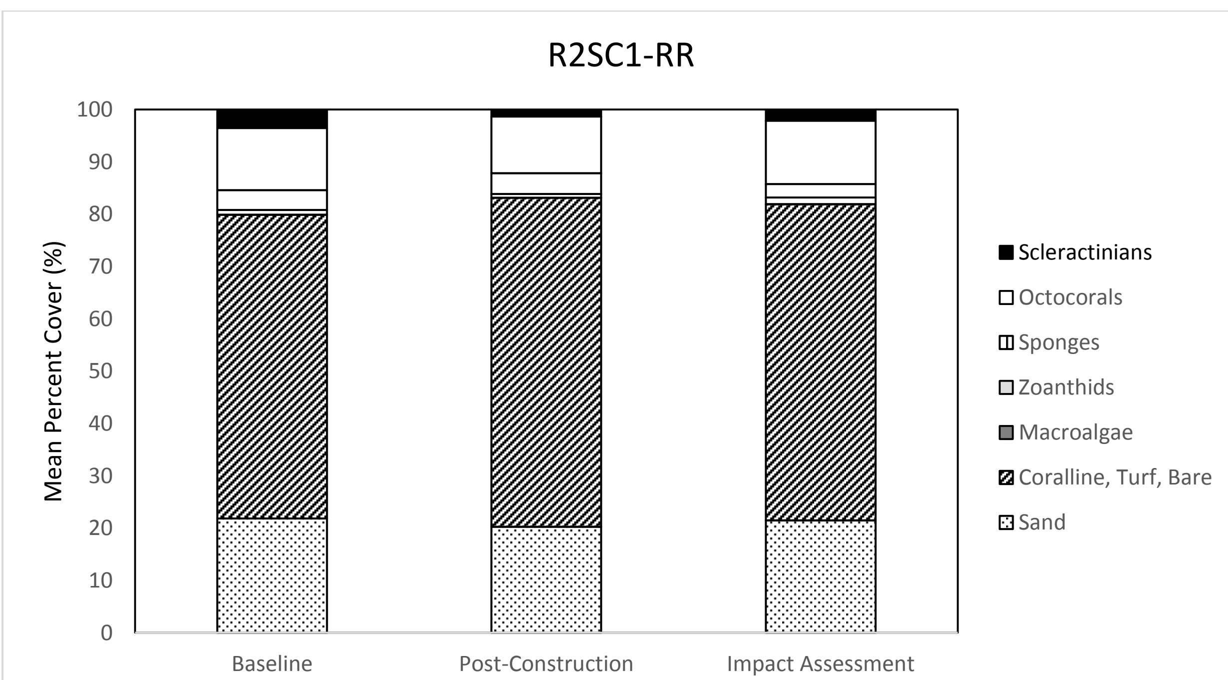


Figure 50. Functional group percent cover for R2SC1-RR during baseline, post-construction, and impact assessment surveys.

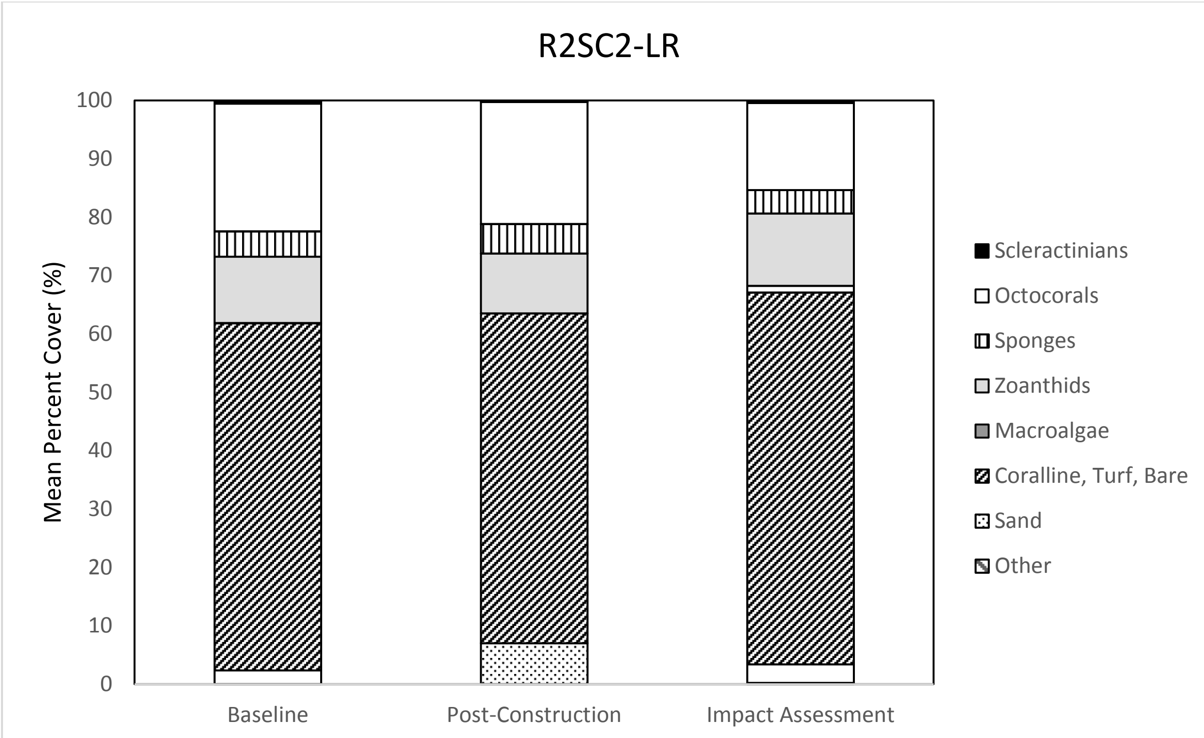


Figure 51. Functional group percent cover for R2SC2-LR during baseline, post-construction, and impact assessment surveys.

3.3.1.3 Outer Reef

Functional group cover of outer reef monitoring sites were the same for dominant invertebrate cover groups, but significantly less sediment was documented at outer reef channel-side sites since baseline surveys (Figure 52-56). Mean cover of dominant reef invertebrates, including scleractinian, octocoral, sponge, and zoanthid cover, as measured during the impact assessment survey, was within a standard error of baseline values for outer reef channel-side and control locations (Table 11). Coral cover declined at both channel-side and control locations, whereas mean sponge cover declined slightly at both channel-side and control locations and octocoral cover increased at both channel-side and control locations over the survey period (Table 11). Mean sand cover increased at channel-side locations from 7.4% during baseline surveys to 10.4% during impact assessment surveys (an increase of 3%). A corresponding decline in the CTB category was also observed at channel-side locations with mean CTB cover of 74.8% in baseline declining to 71.8% during impact assessment surveys (a decline of 3.0%) (Table 11). At control locations, sand cover also increased (3.1% in baseline and 6.6% during impact assessment surveys, similar to the channel-side increase) and CTB cover remained stable (Table 10).

Table 11. Mean percent cover and standard error of benthic functional groups of all outer reef channel-side sites in comparison with permanent site controls between baseline and impact assessment surveys.

Functional Group	Channel-side				Controls			
	Baseline	SE	Impact Assessment	SE	Baseline	SE	Impact Assessment	SE
Scleractinians	0.64	0.02	0.32	0.00	0.84	0.23	0.52	0.15
Octocorals	9.50	3.59	13.87	4.42	12.81	1.85	16.11	2.00
Sponges	5.26	1.92	3.47	0.33	9.68	1.66	3.68	0.39
Zoanthids	0.28	0.14	0.05	0.05	0.27	0.27	0.14	0.10
Macroalgae	0.65	0.05	0.00	0.00	0.34	0.34	0.05	0.05
Coralline, Turf, Bare	74.88	2.33	71.88	0.18	72.18	3.68	72.88	1.28
Sand	7.40	5.23	10.42	3.95	3.12	2.32	6.62	0.42
Other	1.39	1.06	0.00	0.00	0.76	0.22	0.00	0.00

At individual outer reef monitoring sites, the functional group percent cover of dominant invertebrate categories remained fairly consistent between the baseline, post-construction and impact assessment surveys at all sites (Figure 52-56). The largest relative change of dominant reef invertebrate categories between baseline and impact assessment surveys was the decline of sponges at R3SC3-SG from 13.0% to 3.5% (a relative decline of 9.5%) (Figure 56). The largest change of dominant reef invertebrate categories between baseline and impact assessment surveys at any outer reef channel-side site was a relative increase in the octocoral category from 13.1% to 18.3% (a change of 5.2%) at R3S2-LR (Figure 54). The largest decline in percent cover of a dominant invertebrate category at an outer reef channel-side site was a 3.4% decline in the sponge category at R3N1-LR (sponge cover changed from 7.2% at baseline to 4.4% during the impact assessment survey). A slightly larger decline in the sponge category was also noted at the R3NC1-LR where sponges declined from 8.2% in baseline to 4.4% during impact assessment (a relative change of 3.8%) over the same time period. Noting the similarity in the channel-side and control decline in the sponge category, it is likely due to a regional decline rather than a local impact. It is important to note that power to detect change using functional group percent cover declines with the total cover of a category. As a result, changes in mean coral cover due to the regional disease event may not be reliably detected using functional group percent cover analysis due to the initially low cover of the category (less than 1.3% at all outer reef monitoring sites). The results from the tagged colony analysis (Section 3.4) is a more accurate documentation of changes in the scleractinian coral community.

The largest changes in the benthic community between baseline and impact assessment surveys at the outer reef were relative changes in the CTB and sand cover categories. At the outer reef channel-side sites, sand increased in terms of relative percent cover from 12.6% to 14.4% (1.74% increase) at R3N1-LR and from 2.2% to 6.5% (4.28% increase) at R3S2-LR between baseline and impact assessment surveys. At outer reef control sites, relative changes in the sand category ranged from a decline of 0.35% at R3NC1-LR to an increase of 6.66% at R3SC2-LR.

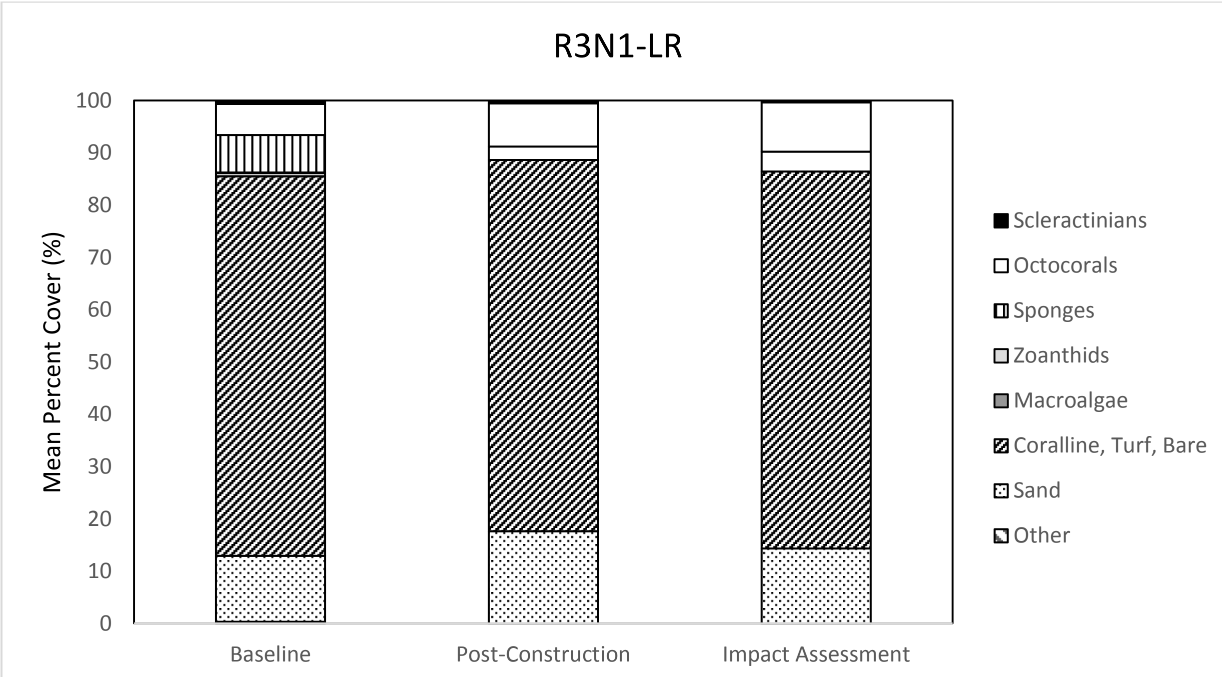


Figure 52. Functional group percent cover for R3N1-LR during baseline, post-construction, and impact assessment surveys.

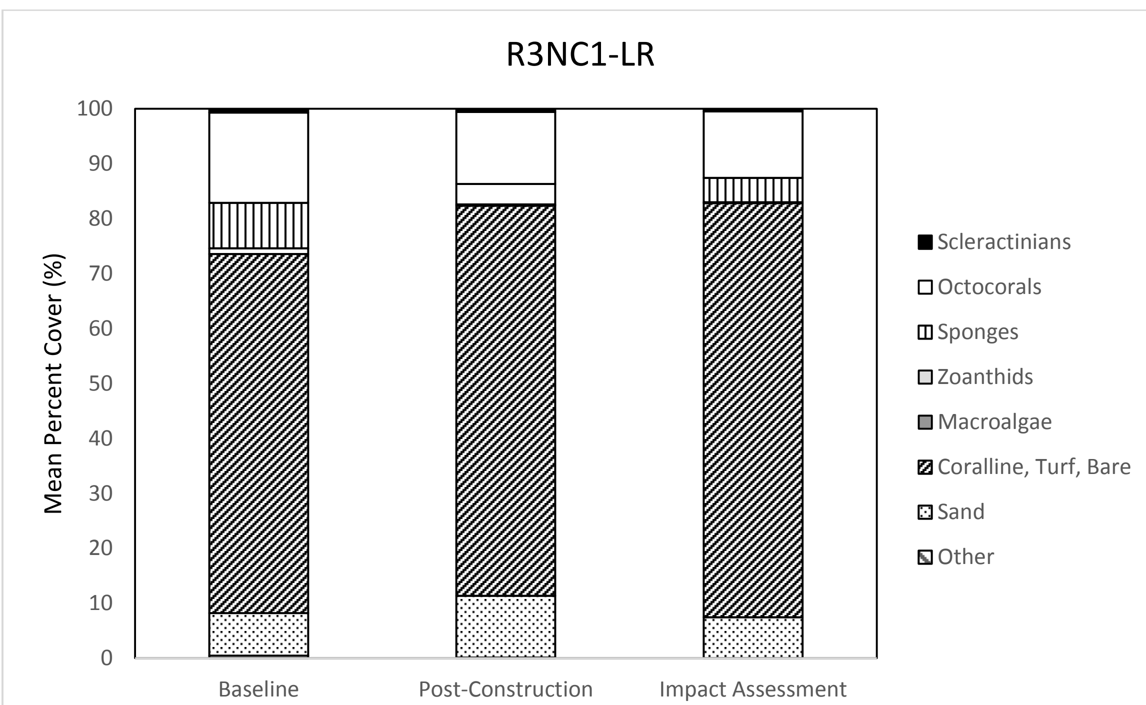


Figure 53. Functional group percent cover for R3NC1-LR during baseline, post-construction, and impact assessment surveys.

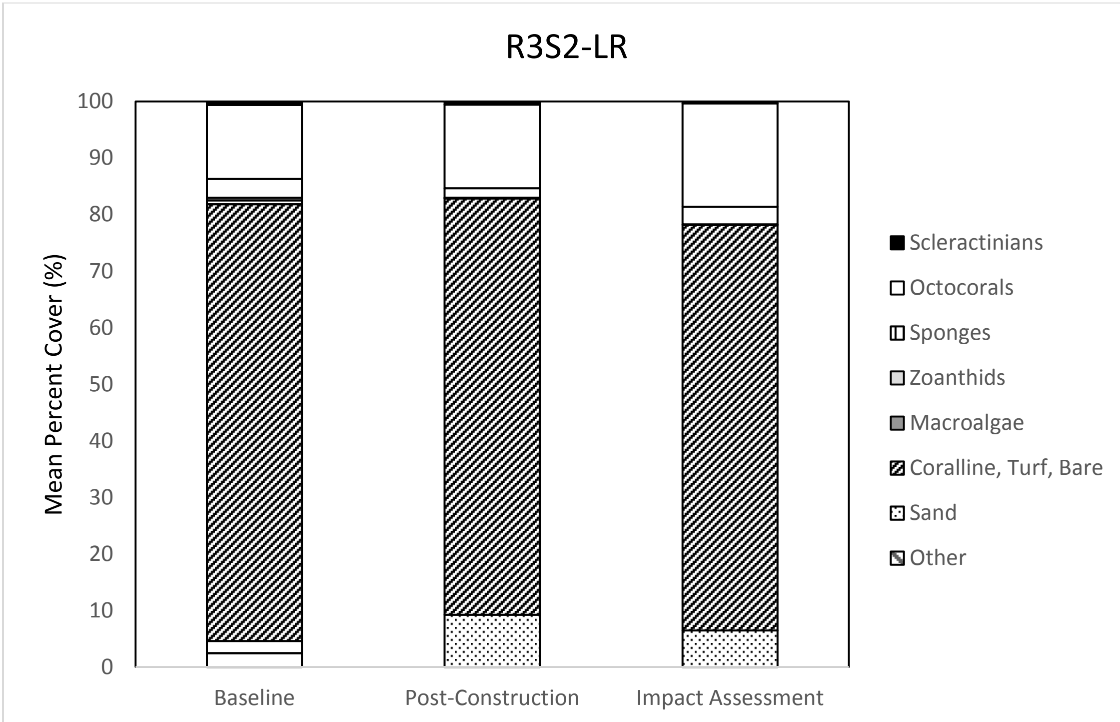


Figure 54. Functional group percent cover for R3S2-LR during baseline, post-construction, and impact assessment surveys.

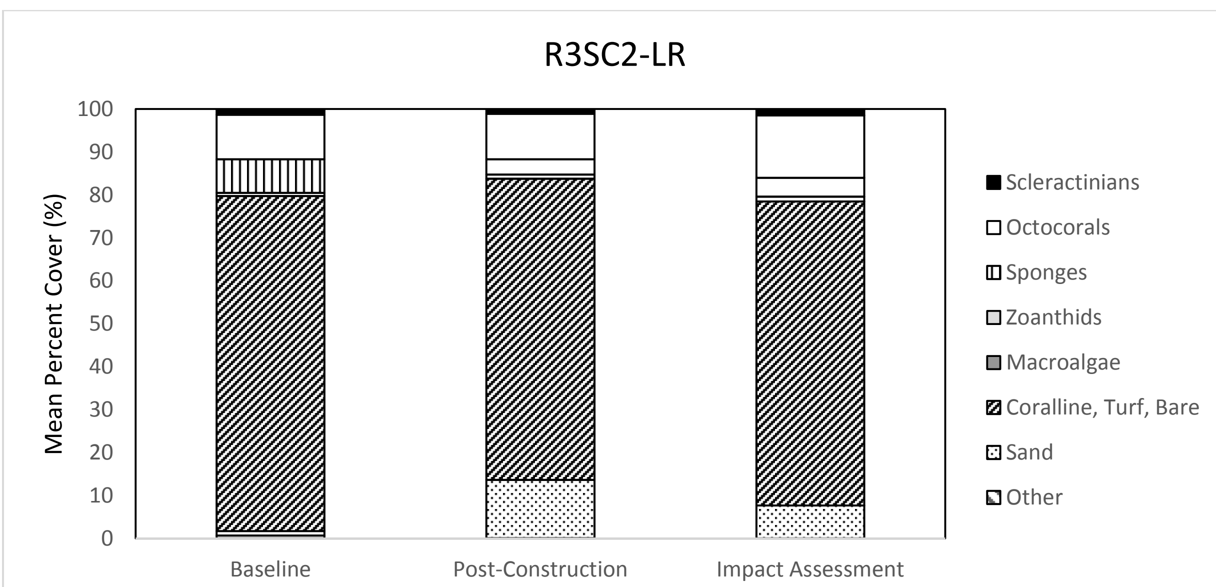


Figure 55. Functional group percent cover for R3SC2-LR during baseline, post-construction, and impact assessment surveys.

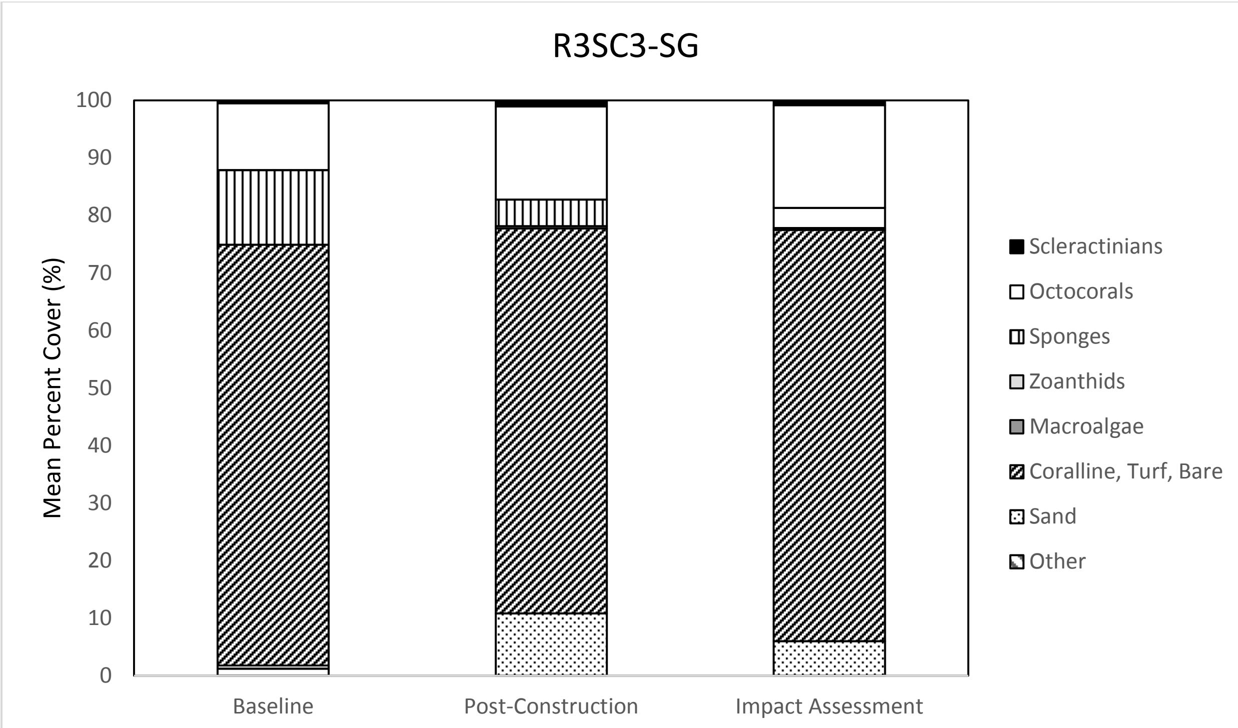


Figure 56. Functional group percent cover for R3SC3-SG during baseline, post-construction, and impact assessment surveys.

3.3.2 CTB vs. Sand

As discussed in the functional group percent cover section, two functional groups – sand and CTB were the most sensitive to project activities and have been used to record relative levels of sediment at channel-side and control sites from baseline through impact assessment surveys. Although levels of sand may have increased, this has not caused a decrease in living functional groups such as octocorals, sponges and scleractinian corals (Section 3.3). Unlike functional group percent cover data of dominant invertebrate categories that have remained fairly consistent over the survey period, CTB and sand have shown significant temporal variability at both channel-side and control locations. Sand and CTB cover were found to vary due to seasonal weather conditions, dominant current patterns, and spatial relationship to dredging operation over the course of project monitoring. The variability of these categories indicates that the effects of sedimentation and the extent of sediment cover are not fixed at any point in time at either channel-side or control locations. At control locations, the maximum sand cover measured during the project ranged from 19.8-68.97% above baseline, with a mean of 40% change. The following data show the temporal variability in sand and CTB cover at all permanent monitoring sites. Table 12 presents CTB and sand functional group data for baseline, and impact assessment surveys as well as maximum sand cover values measured at each project monitoring site. The maximum sand cover as measured during compliance monitoring is provided to show the range of sediment cover variability over the length of project monitoring and the relationship between maximum sand cover and current values. The current level of sand cover during the impact assessment is less than the maximum value recorded during project monitoring for all channel-side and control sites (Table 12).

Table 12. Mean CTB (crustose, turf, and bare) and sand benthic cover based on functional group analysis from video transect data. Maximum sand is the greatest cover value for sand documented between baseline and impact assessment surveys, including the construction period.

Sites	Baseline CTB	Impact Assessment CTB	Baseline Sand	Impact Assessment Sand	Max Sand	Change (Max-Baseline Sand)
HBN3-CP	33.07	44.46	51.15	41.43	79.67	28.52
HBNC1-CP	39.86	50.89	32.84	20.53	72.68	39.84
HBS3-CP	69.4	49.5	10.58	28.59	77.22	66.64
HBS4-CR	59.79	30.56	24.19	55.52	82.02	57.83
HBSC1-CP	73.8	57.05	8.42	23.14	68.7	60.28
R2N1-RR	78.27	58.08	1.2	19.46	81.22	80.02
R2N2-LR	72.63	71.03	20.47	21.4	82.92	62.45
R2NC1-LR	62.82	70.84	22.4	19.05	43.14	20.74
R2NC2-RR	75.49	79.6	0.15	7.4	19.96	19.81
R2S1-RR	90.21	50.94	0.21	34	87.42	87.21
R2S2-LR	81.2	44.55	0	42.78	85.77	85.77
R2SC1-RR	58.04	60.42	21.85	21.52	68.78	46.93
R2SC2-LR	59.51	63.7	2.31	3.15	50.7	48.39
R3N1-LR	72.55	73.11	12.63	11.08	86.89	74.26
R3NC1-LR	65.38	79.85	7.77	3.6	41.27	33.5
R3S2-LR	77.21	69.81	2.18	3.66	71.15	68.97
R3SC2-LR	78.04	71.49	1.02	1.81	64.89	63.87
R3SC3-SG	73.13	76.08	0.59	1.15	63.42	62.83

3.3.2.1 Hardbottom

Levels of sand cover were lower during the impact assessment survey than the estimated maximum sand cover at all hardbottom monitoring sites (Table 12). While CTB values were highly variable throughout the construction period, CTB values were 11% higher than baseline values during impact assessment surveys at both the northern channel-side sites, HBN3-CP, and the corresponding control site, HBNC1-CP (Figure 57 and 58).

At the southern hardbottom monitoring sites CTB values had decreased by 17% (HBSC1-CP), 20% (HBS3-CP) and 29% (HBS4-CR) with respect to baseline CTB values. Although CTB values decreased between the baseline and impact assessment periods, CTB values appear to have been steadily increasing since January 2015 and are on the trajectory to return to baseline levels at both HBS3-CP and HBSC1-CP (Figures 57-61). Sand cover at HBS4-CR increased since the post-construction survey performed in July, 2015 due to the fact that it was the only site sampled after the passage of Hurricane Matthew on October 9, 2016 and the subsequent passage of several cold fronts in November of 2016.

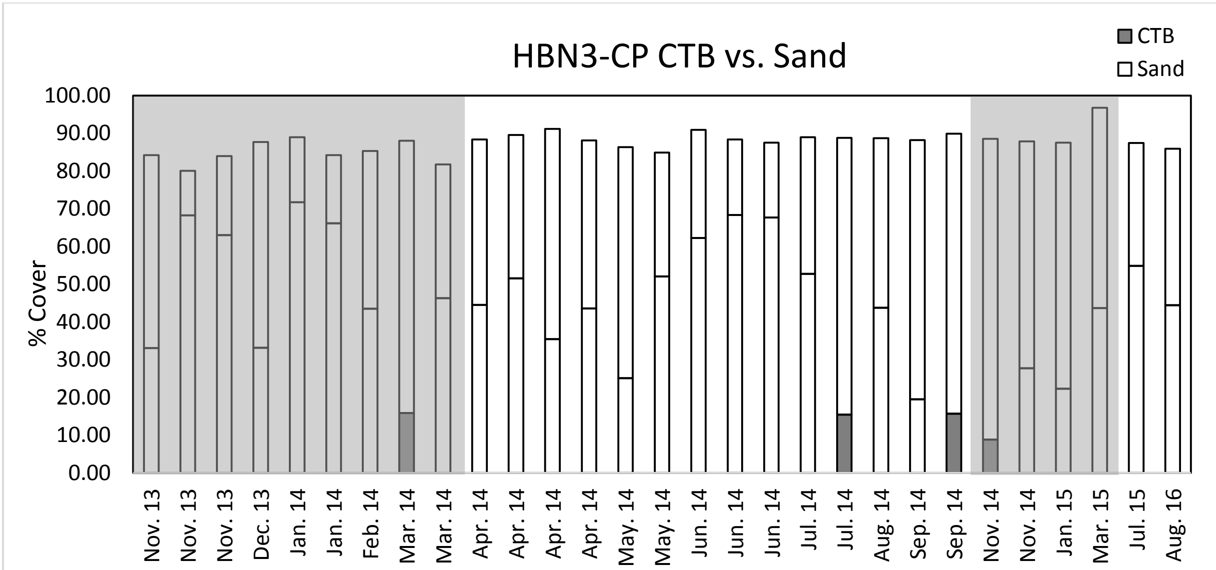


Figure 57 HBN3-CP CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

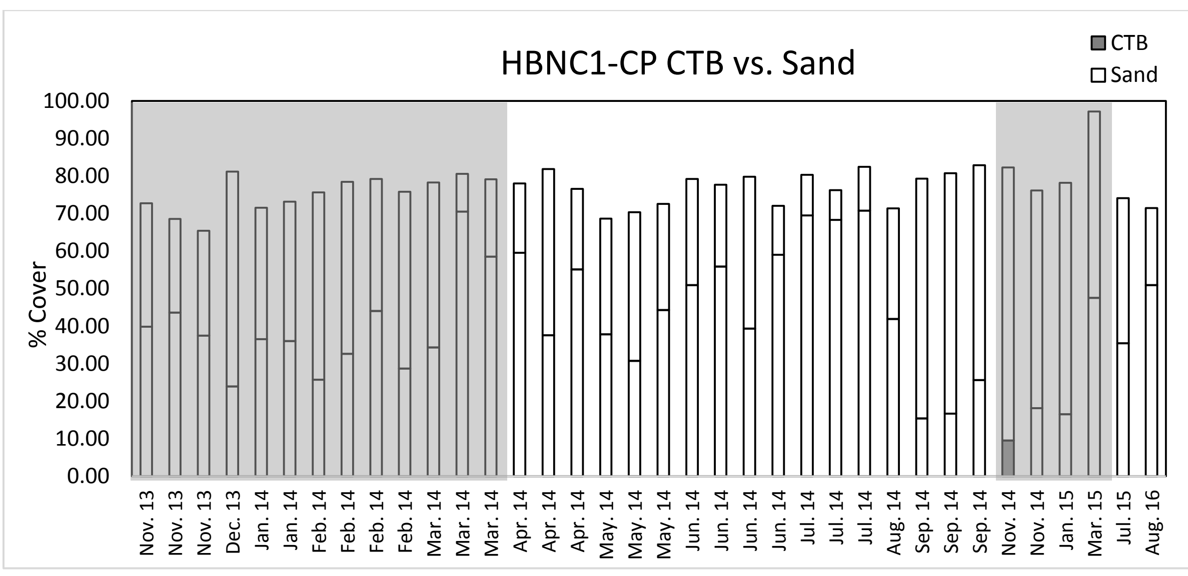


Figure 58. HBNC1-CP CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31).

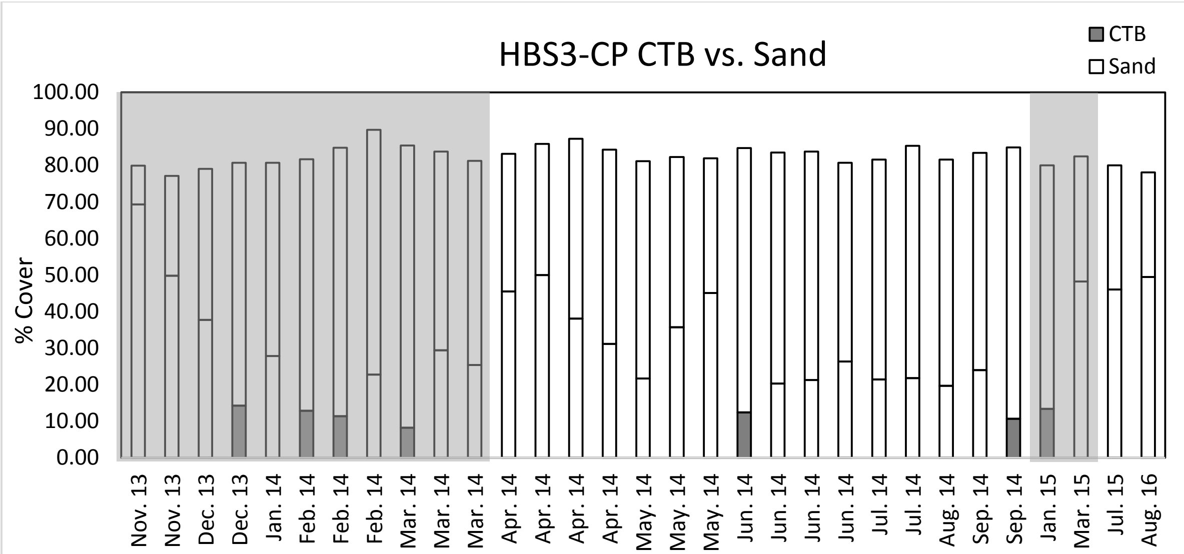


Figure 59. **HBS3-CP CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)**

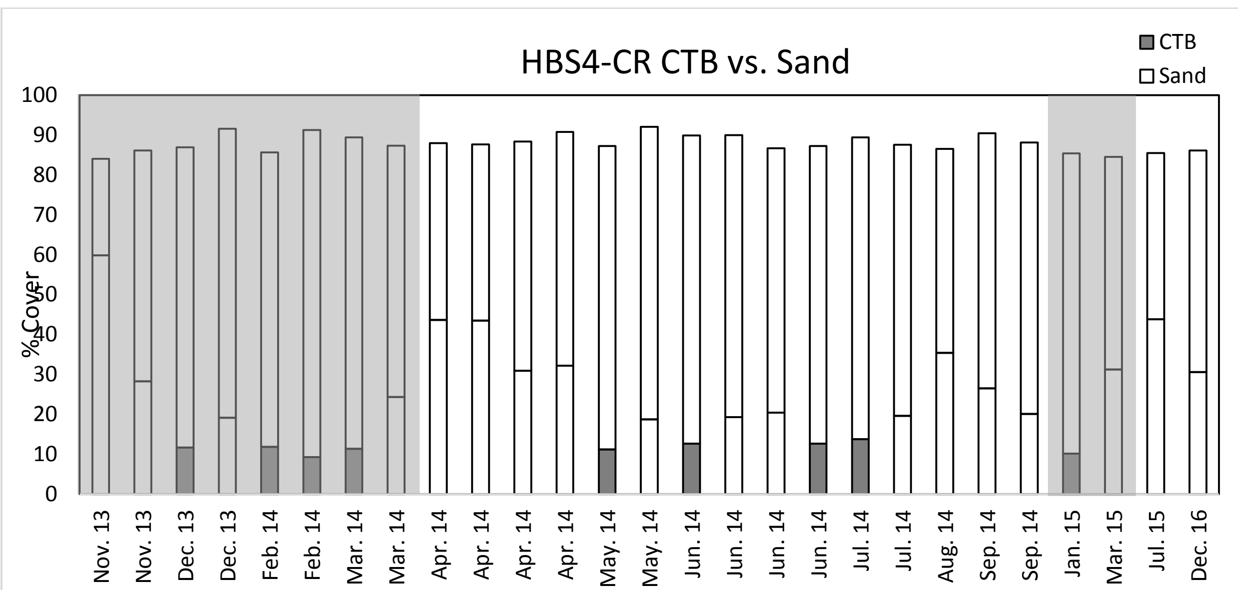


Figure 60. **HBS4-CR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through December 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)**

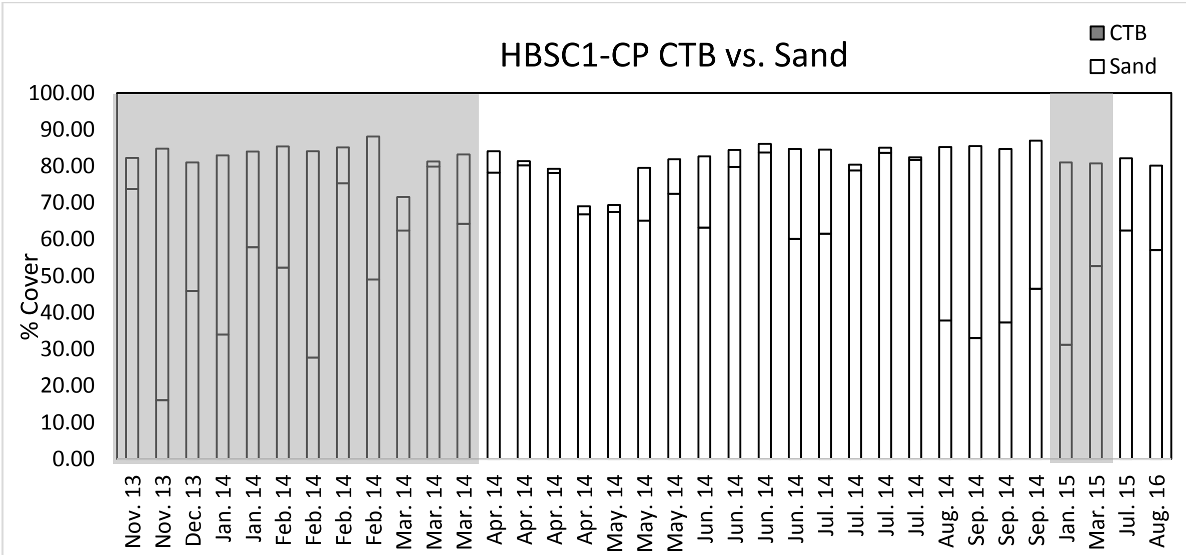


Figure 61. HBSC1-CP CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

3.3.2.2 Middle Reef

Levels of sand cover were lower during the impact assessment survey than the estimated maximum sand cover during project construction at all middle reef monitoring sites (Table 12). While CTB values were highly variable throughout the construction period, the proportion of CTB had decreased by 1% (R2N2-LR) to 20% (R2N1-RR) at middle reef channel-side sites and had increased from 4% (R2NC2-RR) to 8% (R2NC1-LR) at middle reef controls when compared to baseline values (Figures 62-69).

For the southern middle reef sites, CTB values have increased since the post-construction period at all sites (Figures 66-69). During the impact assessment period, the southern middle reef channel-side sites displayed decreases of 37% (R2S2-LR) to 39% (R2S1-RR) in CTB cover compared to baseline levels, while CTB values at the south control sites were within 2%-4% of initial baseline values (Figures 66-69) Despite the observed declines in CTB cover over the construction period, CTB cover has been increasing since March 2015 at all middle reef channel-side sites.

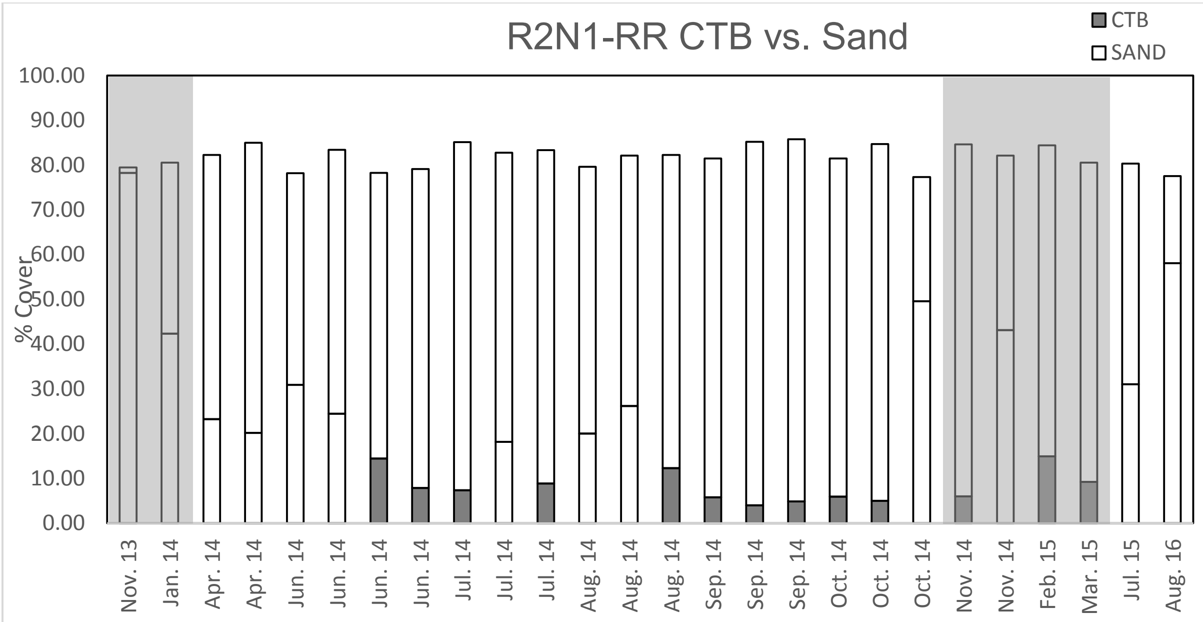


Figure 62. **R2N1-RR CTB and sand data analysis based on video transect analysis.Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31).**

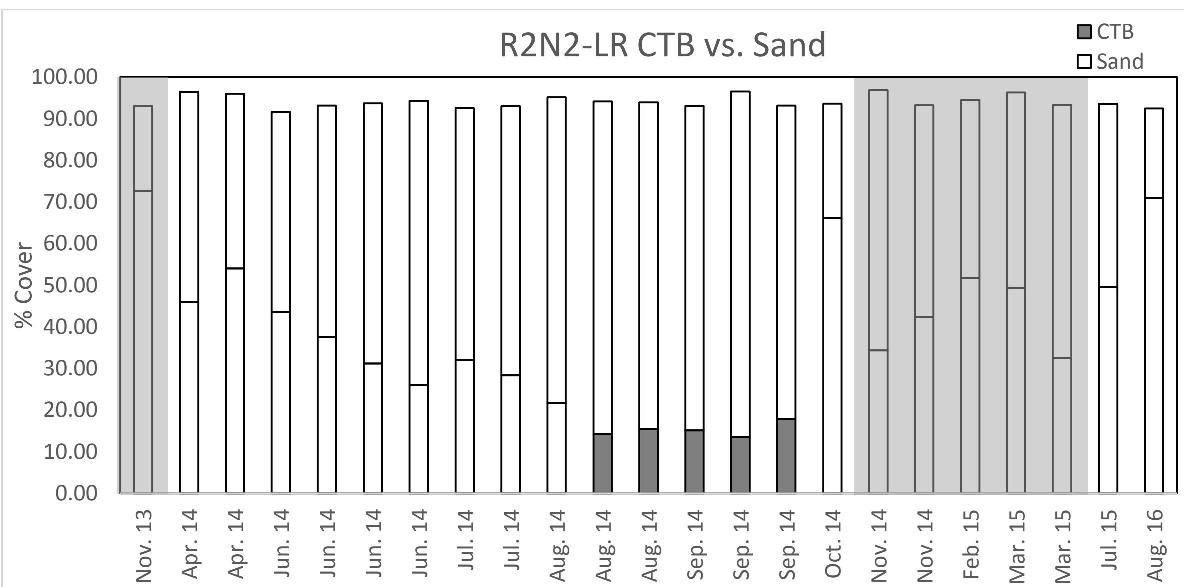


Figure 63. **R2N2-LR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys**

(post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

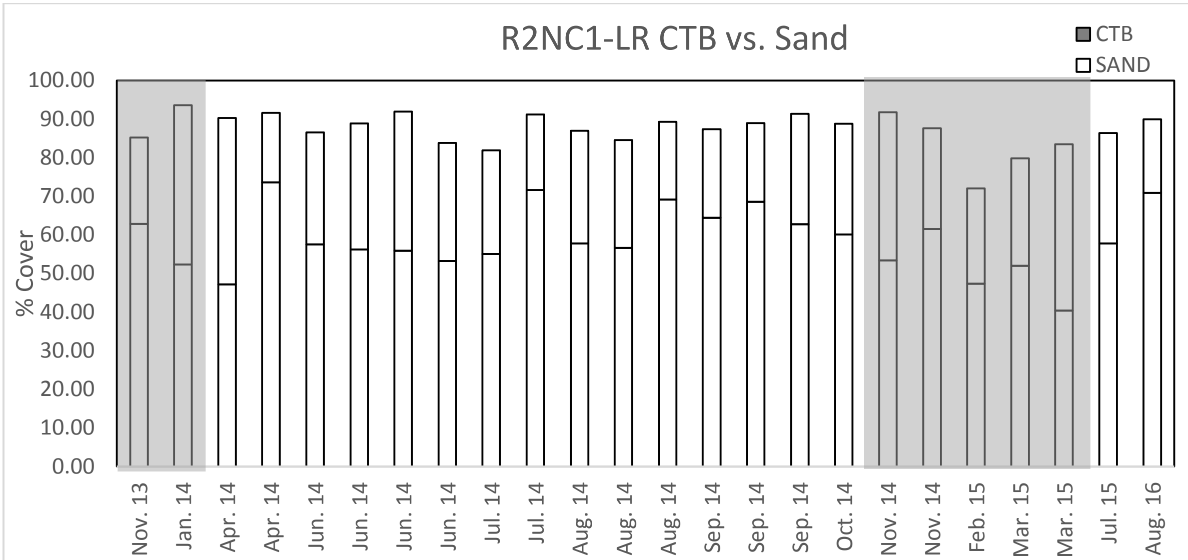


Figure 64. R2NC1-LR CTB and sand data analysis based on video transect analysis.Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

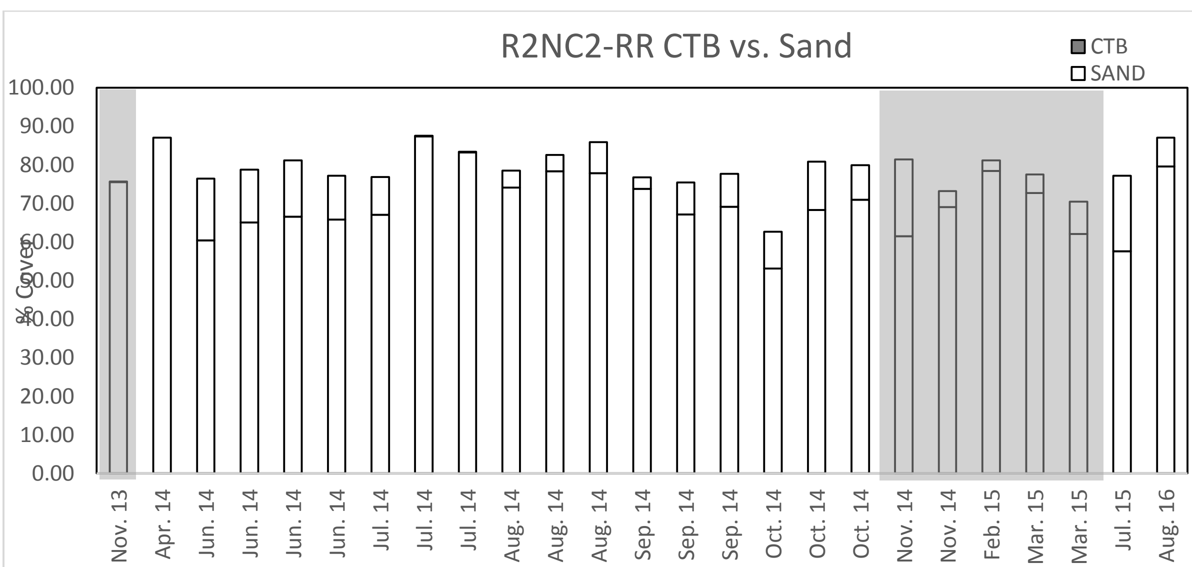


Figure 65. R2NC2-RR CTB and sand data analysis based on video transect analysis.Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys

(post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

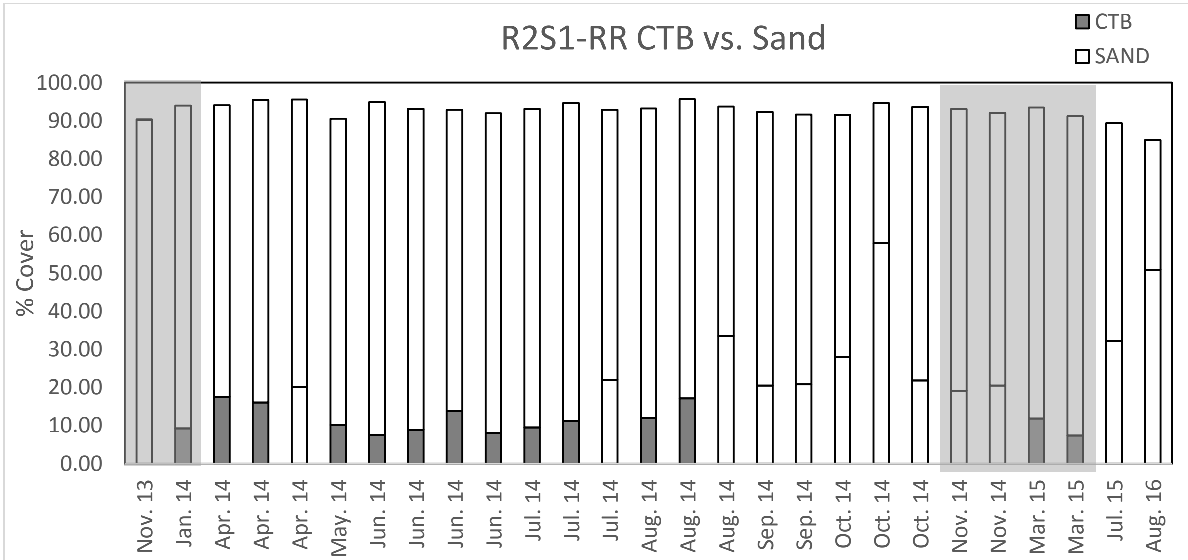


Figure 66. R2S1-RR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

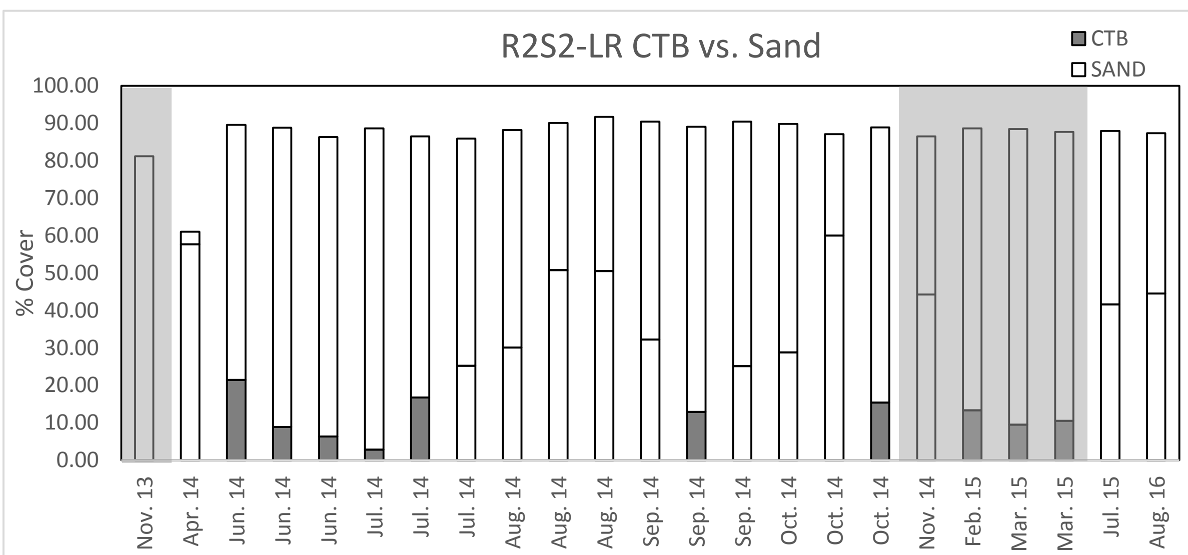


Figure 67. R2S2-LR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents baseline analysis, and the last column on the figure

represents impact assessment analysis. Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

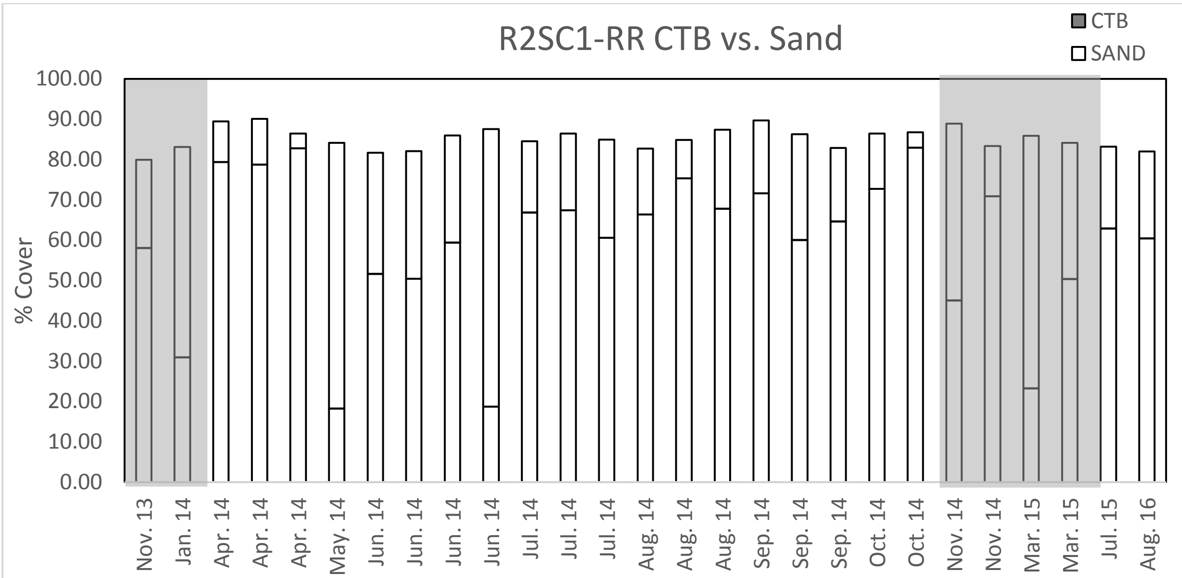


Figure 68. R2SC1-RR CTB and sand data analysis based on video transect analysis.Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

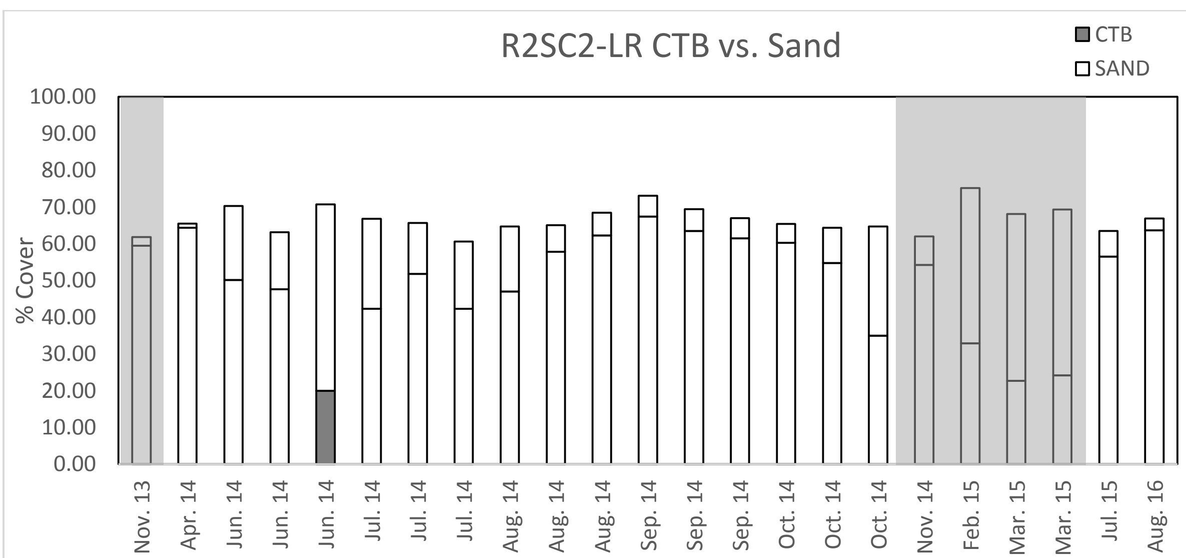


Figure 69. R2SC2-LR CTB and sand data analysis based on video transect analysis.Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two

columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31).

3.3.2.3 Outer Reef

Levels of sand cover were lower during the impact assessment survey than the estimated maximum sand cover during project construction at all outer reef monitoring sites (Table 12). Similar to the hardbottom and middle reef sites, CTB values fluctuated throughout the construction period. However, at outer reef sites, impact assessment CTB cover was the same as baseline surveys at R3N1-LR (73%) and CTB had increased from 65% to 80% at R3NC1-LR, a 15% increase compared to baseline surveys (Figure 70 and 71).

For the southern outer reef sites during the impact assessment period, CTB cover was 70% at R3S2-LR, 71% at R3SC2-LR, and 76% at R3SC3-SG. These values were within 3% to 7% of those measured during initial baseline surveys (Figures 72-74). Despite the observed declines in CTB cover over the construction period, data collected during impact assessment surveys displayed upward trends in CTB abundance across all outer reef sites.

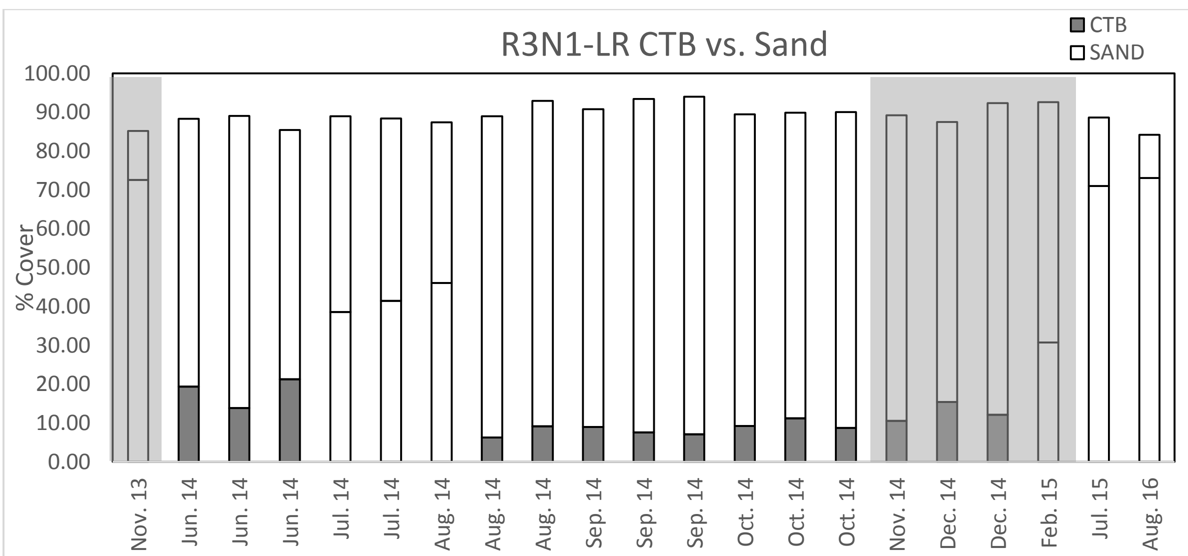


Figure 70. R3N1-LR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

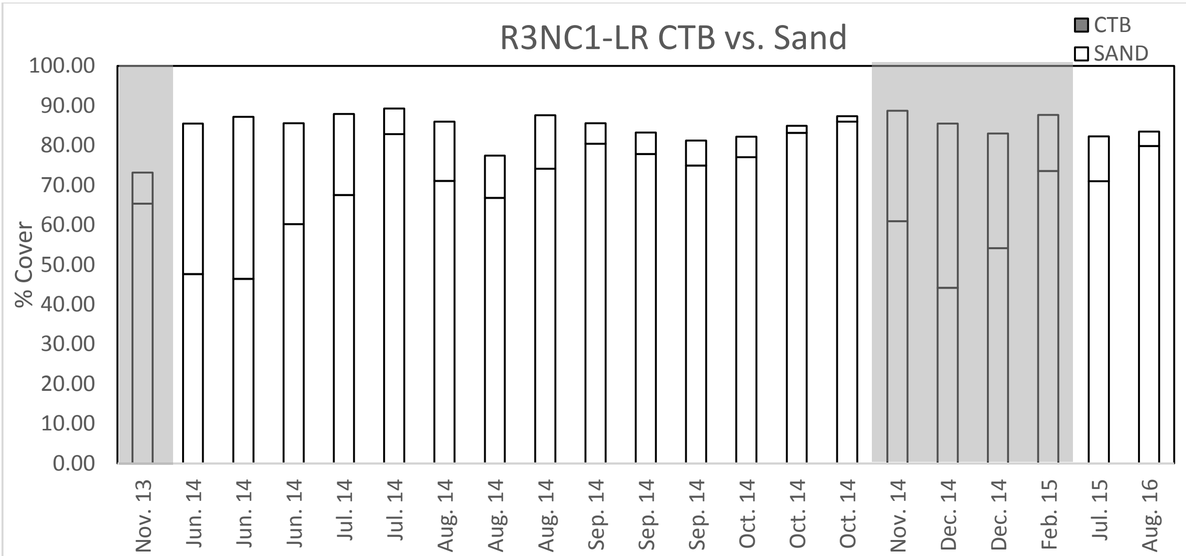


Figure 71. R3NC1-LR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

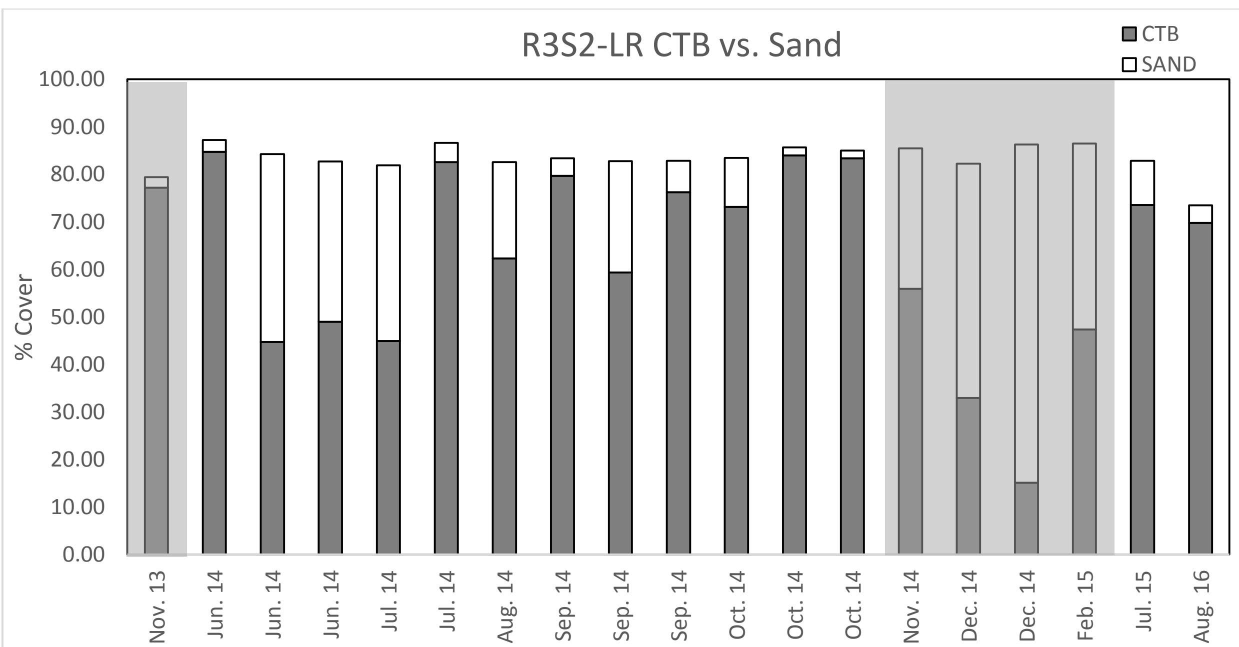


Figure 72. R3S2-LR CTB and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys

(post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

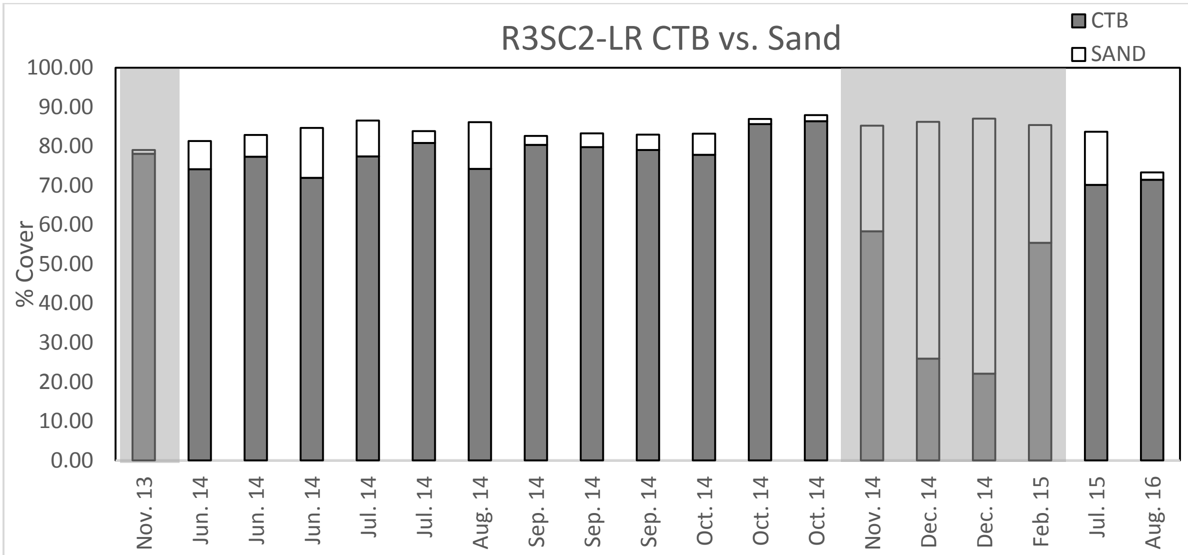


Figure 73. R3SC2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

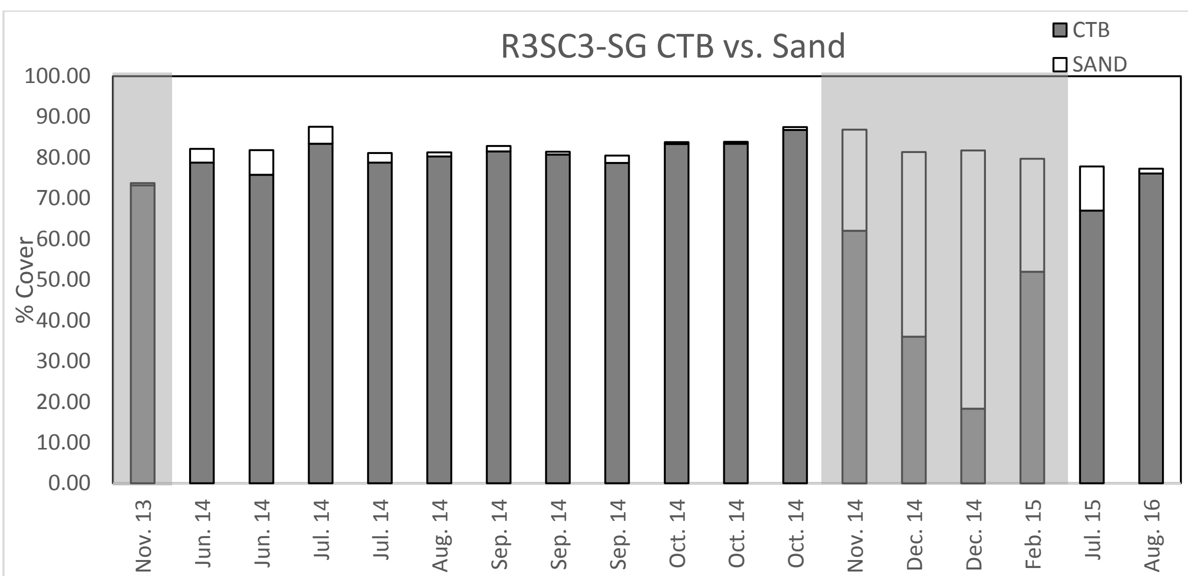


Figure 74. R3S3-SG CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. Percent cover data are presented from November 2013 through August 2016. The first column of the figure represents the baseline analysis (pre-

dredging) and the two columns at the end represent the post-construction and impact assessment surveys (post-dredging). Gray shading highlights season (November 1-April 1), and white highlights April 2-October 31)

3.4 Tagged Scleractinian Mortality- Overview

A total of 476 coral colonies were tagged during baseline surveys and monitored through construction monitoring at the 19 permanent monitoring sites presented in this report. Channel-side sites and their paired control site were monitored as often as twice a week when dredging was occurring within 750m of the permanent monitoring station. As a consequence, monitoring was very frequent when active dredging occurred and absent when dredge activity was outside the 750m boundary established by the FDEP permit. A four-week post-construction monitoring survey was conducted after the conclusion of dredge activity and this impact assessment survey was conducted approximately one year following the collection of post-construction survey data. The total number of tagged scleractinian corals that died at each permanent monitoring site between baseline and impact assessment surveys and the corresponding percent mortality for each site are presented in Table 13. Photographs of all monitored corals between baseline and impact assessment are available in Appendix B. The causes of coral mortality were estimated in baseline through post-construction surveys. Due to the high frequency of monitoring events between baseline and post-construction surveys, the estimated causes of coral mortality were enumerated with high confidence. The large gap between the post-construction and impact assessment surveys (approximately 13 months) prevented our ability to definitively assign causation to the mortality observed between these two surveys. As a result, only corals that showed distinct indications of cause (primarily white-plague disease infection) at either survey period were assigned causation for the death of the tagged coral. All other mortality was defined as "unidentified" between post-construction and impact assessment surveys (Table 13).

Table 13. Total coral mortality at selected monitoring sites from baseline through impact assessment surveys. Distinctions in the cause of coral mortality were made through post-construction and only colonies with visible disease signs were assigned a cause during the impact assessment, otherwise due to the length of time between surveys, they were assigned an unidentified cause of death during the impact assessment. The "sediment" mortality data are the same values as previously reported in the post-construction reports.

Survey Zone	Area	Site	Scleractinian Mortality (Baseline through Impact Assessment)											
			N (not including missing)	Sediment	Bleaching	Competition	White-band Disease	Unidentified	WP & Concurrent Diseases	Active Disease	% Sediment Mortality	% WP Mortality**	Total Mortality	% of Tagged Dead
Hardbottom	North	HBN3-CP	23	1	1	0	0	3	3	0	4.35	13.04	8	34.78
Hardbottom	North	HBNC1-CP CP	12	0	0	0	0	2	4	0	0.00	33.33	6	50.00
Hardbottom	South	HBS3-CP	26	0	0	0	0	0	17	0	0.00	65.38	17	65.38
Hardbottom	South	HBS4-CR	24	1	0	0	0	7	13	0	4.17	54.17	21	87.50
Hardbottom	South	HBSC1-CP	30	0	0	1	0	1	8	1	0.00	26.67	10	33.33
e	North	R2N1-RR	30	0	0	0	0	0	13	2	0.00	43.33	13	43.33

Survey Zone	Area	Site	Scleractinian Mortality (Baseline through Impact Assessment)											
			N (not including missing)	**Sediment**	**Bleaching**	**Competition**	**White-band Disease**	**Unidentified**	**WP & Concurrent Diseases**	**Active Disease**	**% Sediment Mortality**	**% WP Mortality****	**Total Mortality**	**% of Tagged Dead**
		R2N2-LR	24	2	0	1	0	1	5	0	8.33	20.83	9	37.50
		R2NC1-LR	28	0	0	0	0	1	4	1	0.00	14.29	5	17.86
		R2NC2-RR	30	0	0	0	0	0	5	4	0.00	16.67	5	16.67
		R2NC3-LR	29	0	0	0	0	4	4	5	0.00	13.79	8	27.59
	South	R2S1-RR	27	0	0	0	0	1	7	1	0.00	25.93	8	29.63
		R2S2-LR	24	0	0	0	0	0	13	0	0.00	54.17	13	54.17
		R2SC1-RR	30	0	0	0	0	0	9	0	0.00	30.00	9	30.00
		R2SC2-LR	25	0	0	0	3	2	11	0	0.00	44.00	16	64.00
Outer Reef	North	R3N1-LR	21	2	0	0	0	1	0	1	9.52	0.00	3	14.29
		R3NC1-LR	24	0	0	0	0	2	6	0	0.00	25.00	8	33.33
	South	R3S2-LR	25	0	0	0	0	2	4	3	0.00	16.00	6	24.00
		R3SC2-LR	20	0	0	0	0	0	9	0	0.00	45.00	9	45.00
		R3SC3-SG	24	0	0	0	0	0	9	0	0.00	37.50	9	37.50
Totals			476	6	1	2	3	27	144	18	1.26	30.25	183	38.45

During construction monitoring a white-plague disease event began affected tagged control and channel-side corals in the fall of 2014. A study conducted by Precht et al. (2016) documenting the regional extent and impact of the white-plague disease event on Southeast Florida coral populations is provided as Appendix E. As a result of the 13 month period between post-construction and impact assessment surveys, many of the corals marked as “unidentified” mortality during the impact assessment survey period were likely killed as a result of the continued white-plague disease event that has affected coral populations throughout south Florida. Although no project-monitoring occurred between the post-construction and impact assessment surveys, 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 2015, 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 (Figure 16, Florida Reef Resilience Program, 2015). High levels of coral disease (>10%) were also noted in the Broward-Miami sub region in 2016 along with Martin, the Upper Keys, Lower Keys, and Dry Tortugas sub regions (Florida Reef Resilience Program, 2016). Recent data released from the SECREMP monitoring program for Miami-Dade, Broward, and Martin County show a similar pattern of disease and disease-related mortality region-wide (Hayes et al. 2017). In addition, white-plague disease was present in both the post-construction and impact assessment surveys of permanent monitoring sites (channel-side and controls), demonstrating that white-plague disease was still active at permanent site locations.

Of the 27 corals that died and were assigned to the “unidentified” category, 23 (85.2%) were white-plague disease susceptible species. A table of the species that were documented with mortality of “unidentified” cause is provided below (Table 14). Of the four corals that were non-white-plague susceptible species, two *Porites astreoides* were killed, one at R3S2-LR (channel-side site) and one at R2NC1-LR (control site) and in both cases the coral suffered significant coral bleaching that led to partial mortality. The eventual mortality of both corals maybe related to the earlier bleaching but cannot be definitively stated due to the lag between bleaching and total colony mortality. One *Agaricia agaricites* and one *Siderastrea siderea* colony at R2SC2-LR (control) also died without apparent cause between post-construction and impact assessment surveys.

Table 14. The number of corals of each species that were documented as "unidentified" as the source of coral mortality during project monitoring. White-plague susceptible species as assessed in the regional white-plague surveys (Precht et al., 2016; Appendix E) are marked with an *.

Coral Species	Mortality
Agaricia agaricites	1
*Colpophyllia natans**	1
*Dichocoenia stokesi**	8
*Montastrea cavernosa**	3
Porites astreoides	2
*Pseudodiploria strigosa**	1
Siderastrea siderea	1
*Solenastrea bournoni**	10
Total	**27**

As previously noted in the post-construction report, the unknown *Solenastrea bournoni* and *Oculina* diseases may be related to the regional white-plague disease outbreak, as the timing and locations of the disease coincide with the outbreak of white-plague. Due to the overlapping time-frame, and similarity of mortality patterns, the previously documented Unknown *Solenastrea* Disease and Unknown *Oculina* Disease have been combined with our enumeration of white-plague and concurrent disease category for this report (Table 13).

The following section provides an overview of patterns of mortality across channel-side and control sites. Sediment impacts to corals are addressed specifically in the following section.

3.4.1 Patterns in Coral Mortality- All sites

One-hundred eighty-three out of 476 tagged corals (38.44%) died during project monitoring (Table 13). The overwhelming majority of identifiable mortality (77%) died from white-plague and other concurrent diseases (Figure 75). If combined, the white-plague and concurrent diseases category and the unidentified mortality category, account for 93% of all coral mortality observed during the project (Figure 75). Sediment burial (3%), *Acropora* specific White-band disease (2%), Competition (1%), and Bleaching (<1%) explained the remaining coral mortality throughout the project area.

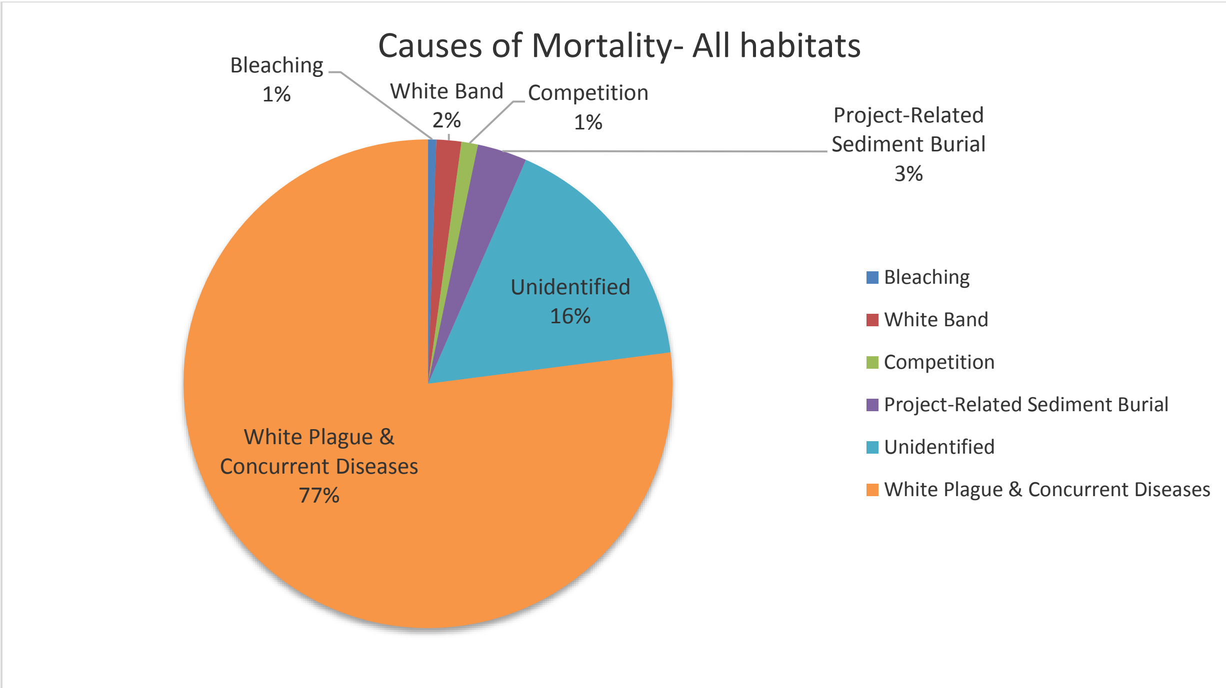


Figure 75. Percentage of causes of total scleractinian mortality across all 19 permanent monitoring sites evaluated during the impact assessment survey.

Levels of total coral mortality were not significantly different between channel-side and control sites. Mean percent coral mortality was 35.5% at the selected control sites during impact assessment surveys and was 43.4% at the selected channel-side sites (Figure 76). An independent-sample t-test was performed on the percent coral mortality from all channel-side site locations and compared to all control site locations. There was not a significant difference in percent coral mortality from channel-side (mean percent coral mortality 43.75%, SD 22.5) when compared to control locations (mean percent coral mortality 35.5%, SD 14.5); $t(17) = 2.10$, $p = 0.37$. These results suggest that levels of total coral mortality at sites located directly near dredge operations were not significantly higher than those away from dredge activity and demonstrate the significant influence of the regional white-plague disease event on the mortality of all tagged corals regardless of location.

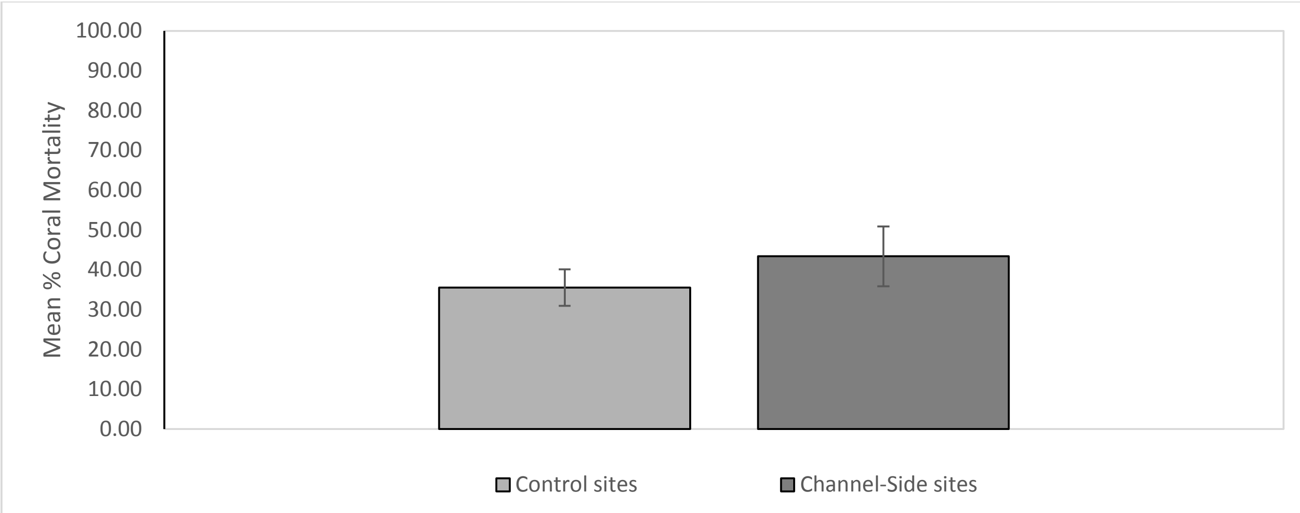


Figure 76. Comparison of mean % coral mortality of the nine channel-side sites and ten control sites surveyed during the impact assessment survey. Differences in % coral mortality at channel-side sites are due to a higher degree of white-plague disease susceptibility at channel-side sites where mean predicted susceptibility was 48.7% at channel-side sites versus 41.3% at control sites, and sediment related mortality which affected 2.7% of channel-side corals.

3.4.2 Patterns in Coral Mortality- Controls

Eighty-five (85) out of 252 tagged coral colonies at control sites (33.7%) died during project monitoring. The overwhelming majority of identifiable mortality (81%, 69 out of 85) died from white-plague and other concurrent diseases (Figure 77). If combined, the white-plague and concurrent diseases category and the unidentified mortality category, account for 95% of all coral mortality observed during the project at control sites (Figure 77). W white-band disease (4%, 3 out of 85), competition (1%, 1 out of 85) explained the remaining coral mortality throughout the control sites.

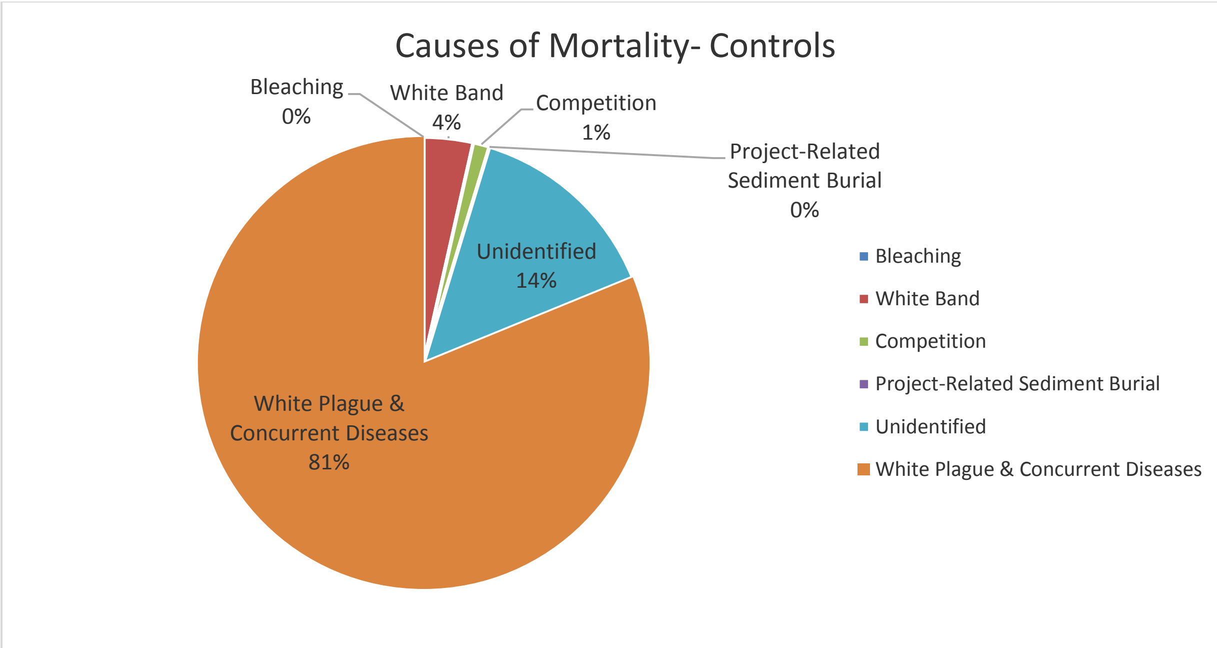


Figure 77. Percentage of causes of total scleractinian mortality across all 10 control sites evaluated during the impact assessment survey.

3.4.3 Patterns in Coral Mortality- Channel-side

Ninety-eight out of 224 (43.7%) of tagged coral colonies at channel-side sites died during project monitoring. The overwhelming majority of identifiable mortality (74%, 72 out of 98) died from white-plague and other concurrent diseases at channel-side sites (Figure 78). If combined, the white-plague and concurrent diseases category and the unidentified mortality category, account for 92% of all coral mortality observed during the project (Figure 78). Project-related sediment burial (6%, 6 out of 98), competition (1%, 1 out of 98), and bleaching (1%, 1 out of 98) explained the remaining coral mortality throughout the channel-side sites.

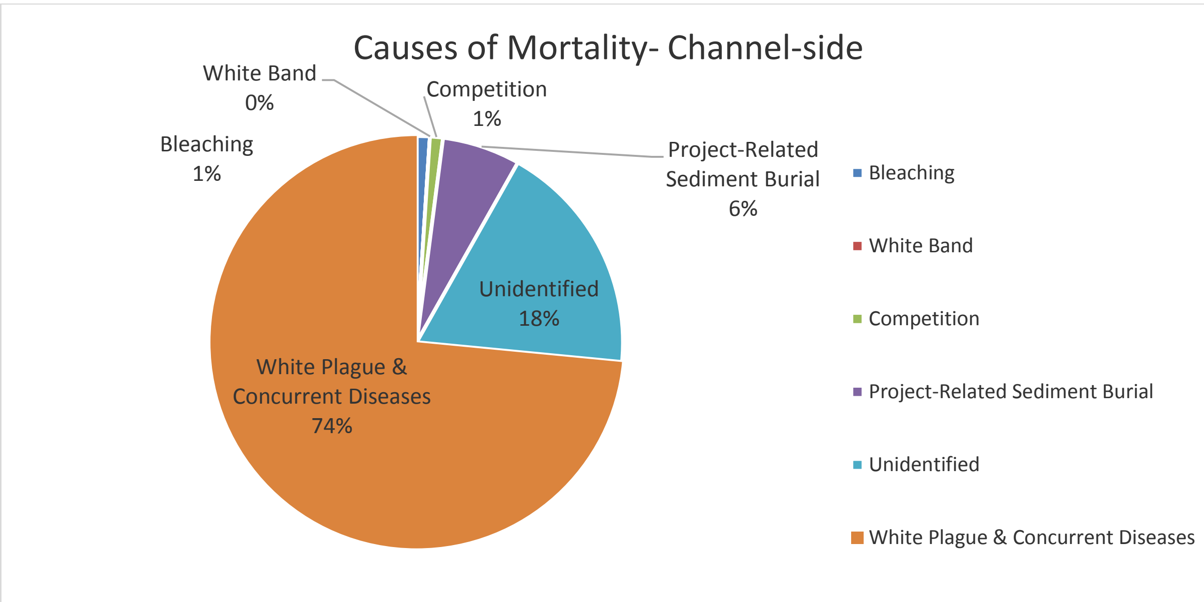


Figure 78. Percentage of causes of total scleractinian mortality across all 9 channel-side sites evaluated during the impact assessment survey.

3.4.4 Total Mortality due to Sedimentation

At the 19 sites surveyed during the impact assessment a total of 6 out of 224 channel-side corals were determined to be killed through direct sediment burial due to project activities. In most cases, corals that were naturally located within a depression, or in an orientation that prohibited water movement, were more susceptible to sedimentation mortality than corals located in higher-relief areas of the reef. . All six of the corals that died from sediment burial died between baseline and post-construction surveys. All six corals were from channel-side locations and the mortality of these corals is equivalent to 2.7% (6 out of 224 tagged channel-side corals) of all channel-side tagged corals. In total, two corals from each reef survey zone, hardbottom, middle, and outer reef, were killed from sediment burial (Table 13). There were no significant differences in the proportion of corals killed as a result of sedimentation at any of the affected sites when compared with the paired control site. Therefore this mortality does not represent a change to the function of the habitat.

3.4.4.1 Hardbottom

In total, two corals across the hardbottom monitoring sites surveyed during the impact assessment died from sediment burial.

A colony of *Dichocoenia stokesi* at HBS4-CR (Transect 3, Coral #1) was documented as dead due to burial during Compliance Week 22 (April 17, 2014). The colony was first documented as buried in Week 18 (March 20, 2014). Conditions documented prior to the burial included sediment accumulation, polyps extended, and mucus production.. A Fisher's exact test was used to determine if the proportion of corals killed due to sedimentation at HBS4-CR was significantly different than those of the paired control HBSC1-CP. The proportion of corals that died as a result of sedimentation at HBS4-CR (colony of 0.04; 1 out of 24) was not significantly different than those at HBSC1-CP (0.00; 0 out of 30) ($Z=1.02$, $p=0.444$).

A *Siderastrea siderea* at HBN3-CP (Transect 2 Coral #5) colony was documented as dead during the second week of post-construction surveys (June 29, 2015). The burial and associated mortality of this colony was likely due to a combination of project-related and natural factors. The colony was located in a depression at the site and experienced complete burial twice during compliance surveys (Week 16 – March 6, 2014, and Week 43 – September 11, 2014). The colony was documented as buried for a third time during Week 1 of post-construction surveys (June 23, 2015), and then identified as dead the following week (June 29, 2015). A Fisher's exact test was used to determine if the proportion of corals killed due to sedimentation at HBN3-CP was significantly different than those of the paired control HBNC1-CP. The proportion of corals that died as a result of sedimentation at HBN3-CP (0.04; 1 out of 23) was not significantly different than those at HBNC1-CP (0.00; 0 out of 12) ($Z=1.02$, $p=1.000$).

3.4.4.2 Middle Reef

Two *Siderastrea siderea* colonies at R2N2-LR (Transect 1, Coral #4; Transect 3 Coral #6) colonies experienced mortality due to burial at R2N2-LR (Table 13). The burial and associated mortality of this colony was likely due to a combination of project-related and natural factors. This particular study site was located in a depression with higher relief surrounding the majority of the site. The surrounding high relief at the site likely reduced the water movement and allowed sediment to accumulate within the site longer than at other study sites. A Fisher's exact test was used to determine if the proportion of corals killed due to sedimentation at R2N2 was significantly different than those of the paired control R2NC1-LR. The proportion of corals that died as a result of sedimentation at R2N2 (0.08; 2 out of 24) was not significantly different than those at R2NC1-LR (0.00; 0 out of 28) ($Z=1.48$, $p=0.208$).

3.4.4.3 Outer Reef

One *Porites. porites* colony (Transect 2, Coral #2) and one *P. astreoides* colony (Transect 2, Coral #4) experienced sediment related mortality at R3N1-LR (Table 13). The burial and associated mortality of this colony was likely due to a combination of project-related and natural factors. While the site was relatively flat, there were several depressions (holes) and a few sand channels. The *P. porites* colony was located within a reef depression approximately 15 cm in diameter and 10 cm deep. Any sediment that the colony was able to remove from itself would remain in the hole as water movement could not clear the sediment from the pocket. The second *P. astreoides* colony was located on a high spot and was documented as partially buried with mucus in Compliance Week 39 (August 13, 2014) and buried in Week 40 (on August 25, 2014). In Compliance Week 43 (September 16, 2014) the colony was identified as buried and bleached, and in Compliance Week 44 the colony was first identified as dead. A Fisher's exact test was used to determine if the proportion of corals killed due to sedimentation at R3N1-LR was significantly different than those of the paired control R3NC1-LR. The proportion of corals that died as a result of sedimentation at R3N1-LR (0.09; 2 out of 21) was not significantly different than those at R3NC1-LR (0.00; 0 out of 24) (Z=0.09, p=0.212).

One coral, a *Solenastrea bournoni* colony at R3N1-LR (Transect #3, Coral #8), was noted as buried and dead during the post-construction survey but was located alive during the impact assessment survey (Figure 79). This coral is no longer counted as dead in the impact assessment survey report.

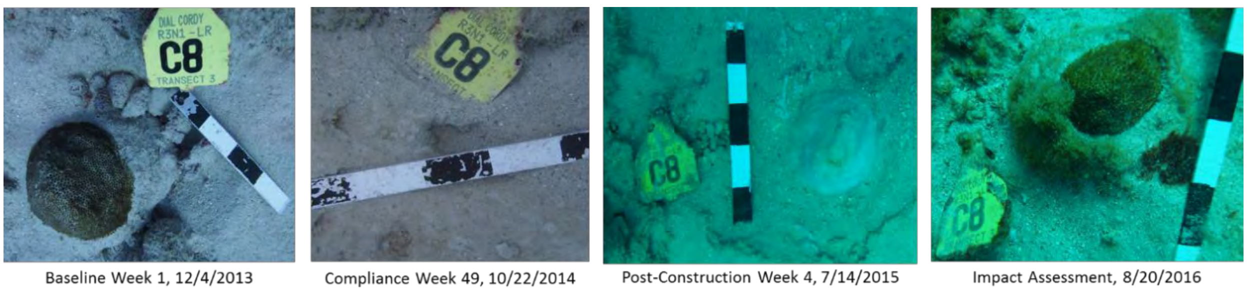


Figure 79. *Solenastrea bournoni* colony from R3N1-LR (Transect 3 C#8) was assumed dead during Post-Construction Week 4 due to previous sediment burial but was found alive during the impact assessment survey on 8/20/2016.

3.4.5 Partial Scleractinian Mortality Due to Sedimentation

Partial mortality due to sedimentation was noted at both control and channel-side sites over the course of project monitoring. Mean partial mortality due to sedimentation from baseline through post-construction affected 64.8% of tagged coral colonies at the nine sampled channel-side locations compared to 19.4% at surveyed control sites (DCA 2015d). Partial mortality due to sedimentation as measured in the impact assessment period was less than the cumulative value from baseline through post-construction at all sites (Table 15). Low levels of partial mortality recorded during the impact assessment surveys suggest that partial mortality associated with sediment was related to an active dredging period and that the effects have greatly diminished compared to the construction and immediate post-construction time period.

Of the coral stress indicators evaluated during compliance monitoring, several were specifically targeted to evaluate the effect of sedimentation on corals (see Table 4 in Methods). Partial mortality (PM) however was an indicator of permanent impacts of sediment stress to coral colonies. These "halos" of partial mortality have been previously described for dredging projects in south Florida (Courtnenay et al. 1974; Marszalek 1981).

In addition, the partial mortality (PM) indicator is a term applied to describe an ephemeral condition. To remain consistent with baseline through post-construction surveys, partial mortality due to sediment was only recorded by divers in the impact assessment if recently dead skeleton was visible in areas of the colony near current sediment pools. Areas that had previously sustained partial mortality due to sedimentation and had been grown-over with turf algae or other benthic organisms or could not be distinguished from disease or other related mortality near the base of the coral were not assessed with the PM indicator. As a result, the current level of PM measured during the impact assessment should be viewed as the number of corals with fresh sediment related mortality. The values of PM assessed from baseline through post-construction is the cumulative number of corals that were observed with recent partial mortality due to sediment at *any* survey point throughout project monitoring (Table 15).

Due to the high rates of white-plague disease-related mortality documented across middle and outer reefs (DCA 2015a), the cumulative sediment-related partial mortality data from baseline through post-construction are presented in Table 15 in two formats: one that includes all tagged corals at compliance monitoring sites, and again with all dead corals removed from the total number of corals sampled. The removal of dead corals from the sediment-related partial mortality values changed the total number of corals sampled at some compliance monitoring sites. Impact assessment values of partial mortality due to sedimentation are presented without missing or dead corals.

Table 15. Sediment related partial mortality as presented in the post-construction report with cumulative values from baseline through post-construction and during the impact assessment. Scleractinians at compliance monitoring sites were assigned a "0" or "1" depending on the presence/absence of sediment- related partial mortality. Corals with no evidence of sediment-related partial mortality were assigned a "0", while corals exhibiting sediment-related partial mortality (PM) were assigned a "1". Data are presented both for the total number of corals marked at a given site "All corals" and with dead corals removed "without dead corals". N= number, Prop = proportion, SD = standard deviation. Data collected for during the impact assessment does not include missing or dead colonies. **N/A sites were redundant control sites and data was not collected at these locations during construction monitoring.**

Partial Mortality Due to Sedimentation														
Zone	Area	Site	Baseline to Post-Construction (cumulative)								Impact Assessment			
			All Corals				Without Dead Corals				Without Dead Corals			
			#PM	N	Prop	SD	#PM	N	Prop	SD	#PM	N	Prop	SD
Hardbottom	North	HBN3-CP	19	24	0.79	0.41	15	19	0.50	0.42	0	15	0.00	0.00
		HBNC1-CP	7	12	0.58	0.51	6	9	0.67	0.50	2	6	0.33	0.12
	South	HBS3-CP	21	26	0.81	0.40	7	8	0.88	0.35	2	9	0.22	0.07
		HBS4-CR	16	24	0.67	0.48	9	11	0.82	0.40	0	3	0.00	0.00
		HBSC1-CP	7	30	0.23	0.43	5	23	0.22	0.42	0	21	0.00	0.00
Middle Reef	North	R2N1-RR	28	30	0.93	0.25	17	18	0.94	0.24	0	17	0.00	0.00
		R2N2-LR	15	24	0.63	0.49	12	20	0.60	0.50	1	15	0.07	0.06
		R2NC1-LR	2	28	0.07	0.25	2	24	0.08	0.27	0	23	0.00	0.00
		R2NC2-RR	2	30	0.07	0.25	2	28	0.07	0.26	0	25	0.00	0.00
		R2NC3-LR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	21	0.00	0.00
	South	R2S1-RR	17	27	0.63	0.49	14	20	0.70	0.47	1	19	0.05	0.06

Partial Mortality Due to Sedimentation															
Zone	Area	Site	Baseline to Post-Construction (cumulative)								Impact Assessment			
			All Corals				Without Dead Corals				Without Dead Corals			
			#PM	N	Prop	SD	#PM	N	Prop	SD	#PM	N	Prop	SD
		R2S2-LR	15	24	0.63	0.49	6	12	0.50	0.52	0	11	0.00	0.00
		R2SC1-RR	9	30	0.30	0.47	8	21	0.38	0.50	2	21	0.10	0.06
		R2SC2-LR	2	25	0.08	0.28	1	11	0.10	0.32	0	9	0.00	0.00
Outer Reef	North	R3N1-LR	15	21	0.71	0.46	14	18	0.78	0.43	1	17	0.06	0.10
Outer Reef	North	R3NC1-LR	7	24	0.29	0.46	5	18	0.28	0.46	1	16	0.06	0.08
Outer Reef	South	R3S2-LR	1	25	0.04	0.20	0	20	0.00	0.00	0	19	0.00	0.00
Outer Reef	South	R3SC2-LR	0	20	0.00	0.00	0	12	0.00	0.00	0	11	0.00	0.00
Outer Reef	South	R3SC3-SG	3	24	0.13	0.34	2	15	0.13	0.35	0	15	0.00	0.00
Total			186	448			125	307			10	293		

3.4.5.1 Hardbottom

During the impact assessment evidence of recent partial mortality due to sedimentation was low throughout the hardbottom habitat. No more than two corals at any site were noted with this condition (Table 15). The only two hardbottom sites with any recent partial mortality due to sediment during the impact assessment were HBNC1-CP and HBS3-CP (Table 15). At HBS3-CP, where partial mortality due to sediment was highest from baseline to post-construction (88%) partial mortality has declined to 22% during the impact assessment survey. Rates of partial mortality due to sedimentation documented during the impact assessment were significantly less at every hardbottom site when compared to the cumulative partial mortality assessed from baseline through post-construction (Table 15).

The cumulative assessment of partial mortality (PM) from baseline through post-construction surveys indicated that 60% of all scleractinian corals at the selected hardbottom sites (42 out of 70) at one time or another (compliance and/or post-construction) suffered partial mortality due to sediment (Table 15). Partial mortality occurred across channel-side sites and control sites (Table 15). HBS3-CP recorded the highest percentage of corals affected by partial mortality (88%) of the selected sites, while HBN1-CR had the lowest (50%).

The reduction in partial mortality due to sedimentation documented during the impact assessment, including HBS3-CP where it was highest during construction monitoring, suggests that accumulation of sediment is no longer a significant cause of coral mortality at the hardbottom sites.

The dredge-related impact that was documented in the post-construction report should be considered the greatest extent of the partial coral mortality impact since no additional corals were documented with fresh colony mortality due to sedimentation during the impact assessment. As a result, HBS3-CP was the most impacted hardbottom site with seven out of eight living corals (88%) were noted with partial mortality due to sedimentation during post-construction. The corresponding level of partial mortality at the southern hardbottom control site was that five out of 23 corals (22%) were noted with partial mortality due to sedimentation over the course of all tagged colony monitoring.

3.4.5.2 Middle Reef

During the impact assessment evidence of recent partial mortality due to sedimentation was low throughout the middle reef habitat. No more than two corals at any site were noted with this condition (Table 14). The middle reef site with the highest partial mortality due to sedimentation was the southern control site R2SC2-LR (Table 15). R2N2-LR and R2S1-RR each had one colony with recent evidence of partial mortality due to sediment (Table 15). No other tagged colonies at middle reef sites were documented with this stress condition. Rates of partial mortality due to sedimentation have declined significantly from the cumulative assessment provided as part of the post-construction report. At R2N1-RR, where partial mortality due to sediment was highest from baseline to post-construction (94%, Table 15), this indicator has declined to 0% during the impact assessment survey. Rates of partial mortality due to sedimentation documented during the impact assessment never exceeded 7% at the middle reef and were significantly less at all permanent monitoring sites when compared to baseline through post-construction values (Table 15).

The dredge-related impact that was documented in the post-construction report should be considered the greatest extent of the partial coral mortality impact since no additional corals were documented with fresh colony mortality due to sedimentation during the impact assessment. As a result, R2N1-RR was the most impacted middle reef site with 17 out of 18 living corals (94%) were noted with partial mortality due to sedimentation. The corresponding level of partial mortality at the northern middle reef control site was that two out of 28 corals (7%) were noted with partial mortality due to sedimentation over the course of all tagged colony monitoring.

3.4.5.3 Outer Reef

During the impact assessment evidence of recent partial mortality due to sedimentation was low throughout the outer reef habitat. No more than 1 coral at any site was noted with this condition (Table 15). R3N1-LR and R3NC1-LR each had a single coral observed with partial mortality due to sediment during the impact assessment (Table 15). No other tagged colonies at outer reef sites were documented with this stress condition. At R3N1-LR, where partial mortality due to sediment was highest from baseline to post-construction (78%, Table 15), this indicator has declined to 6% during the impact assessment survey. Rates of partial mortality due to sedimentation documented during the impact assessment never exceeded 6% at the outer reef and were significantly less at all permanent monitoring sites when compared to baseline through post-construction values (Table 15).

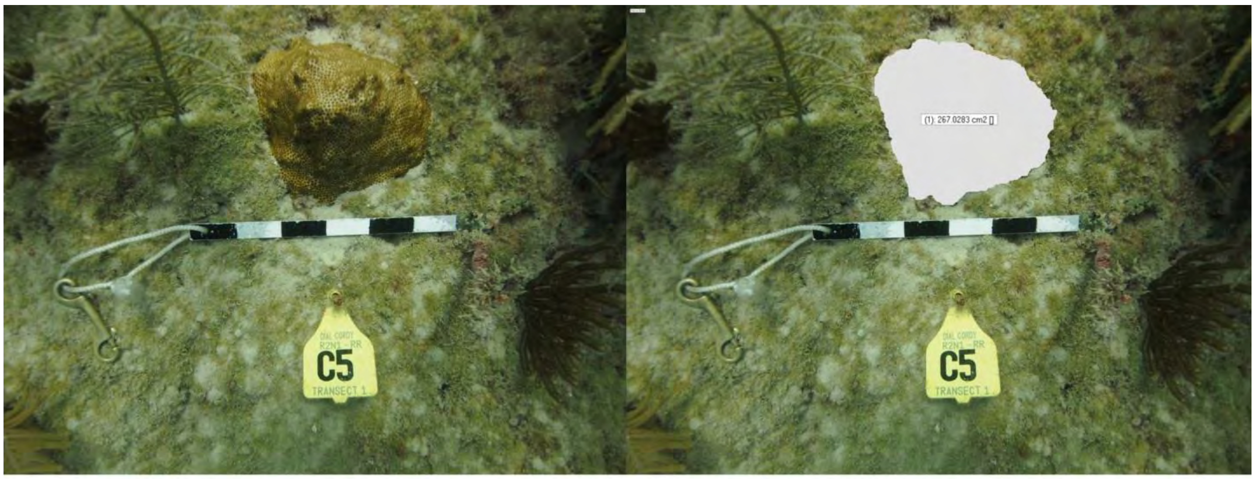
The lack of partial mortality due to sedimentation during the impact assessment at most sites including R3N1-LR where PM was the highest during construction monitoring, suggests that accumulation of sediment is no longer a significant cause of coral mortality at the outer reef sites.

The dredge-related impact that was documented in the post-construction report should be considered the greatest extent of the partial coral mortality impact since no additional corals were documented with fresh colony mortality due to sedimentation during the impact assessment. As a result, R3N1-LR was the most impacted middle reef site with 14 out of 18 living corals (78%) were noted with partial mortality due to sedimentation during post-construction. The corresponding level of partial mortality at the northern middle reef control site was that 5 out of 18 corals (28%) were noted with partial mortality due to sedimentation over the course of all tagged colony monitoring.

3.4.5.4 Live tissue lost due to partial mortality

The proportion of tagged corals that were affected by partial mortality due to sedimentation, recorded in Table 15, are an estimate of the number of corals at each site to have experienced some level of partial mortality due to sediment stress at any point between baseline and post-construction surveys. The extent of the partial mortality due to sediment stress in terms of percent tissue lost has not been previously documented.

To quantify the percentage of live tissue lost due to sediment-related partial mortality, planimetry measurements were performed on down-looking digital images of tagged colonies from baseline, post-construction, and impact assessment surveys (Figure 80). R2N1-RR and R2NC2-RR were chosen for analysis of partial mortality due to sedimentation due to the fact that R2N1-RR was the site with the highest proportion of tagged corals documented with partial mortality related to sedimentation from baseline through post-construction (94%) and R2NC2-RR had some of the lowest rates of partial mortality due to sedimentation of any control site (7%) (Table 15). As a result, R2N1-RR was considered the channel-side site most affected by sedimentation impacts (Table 15). Corals that suffered complete mortality between baseline and impact assessment surveys were removed from planimetry analysis as these affects were previously enumerated and discussed in Section 3.4. Coral disease is a confounding factor that also affected coral partial mortality during the impact assessment survey; corals that were documented with active disease during the impact assessment survey, 2 corals at R2N1-RR and 4 corals at R2NC2-RR, were removed from all planimetry comparisons. As a result, the same corals were assessed for percent live tissue at all time periods.



Baseline R2N1-RR T1 C5 Baseline R2N1-RR T1 C5, Measured

Figure 80. Example of coral before (left) and after planimetry measurement (right).

The total area of living coral tissue as measured by planimetry declined from baseline to impact assessment surveys by 12.28% at R2N1-RR. At R2NC1-RR, the paired control, total living tissue declined by 11.60% over the same time period. Of the 15 corals surveyed at R2N1-RR the average % tissue change from baseline to impact assessment was a gain of tissue of 1.3% (Table 16, Figure 81). At R2NC2-RR, the mean percent tissue change was a decline of 5.3% between baseline and impact assessment periods (Table 16, Figure 81). There was not a significant difference in percent tissue change in corals from baseline to impact assessment from R2N1-RR (mean % tissue change 1.3%, SD 35.54) when compared to control locations (mean % tissue change -5.3%, SD 24.53); $t(24)= 2.06$, $p = 0.54$. These results suggest that levels of partial coral mortality, as measured by change in colony area between baseline and impact assessment surveys, at R2N1-RR, the 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%).

Table 16. Mean percent live tissue change for corals that survived from baseline to impact assessment at R2N1-RR and R2NC2-RR using down-looking images at baseline, post-construction and impact assessment surveys. Calculation of percent live tissue

change was done through digitizing live tissue from baseline and post-construction images and from baseline and impact assessment images.

Site	N	Total Area Baseline (cm^2)	Total Area Post-construction (cm^2)	Total Area Impact Assessment (cm^2)	% Change Baseline-Impact	Mean % area change/colony Baseline-Impact	SE
R2N1-RR	15	3137.90	2783.66	2752.69	-12.28%	1.33%	9.2
R2NC2-RR	20	18534.78	18737.55	16378.10	-11.60%	-5.31%	5.5

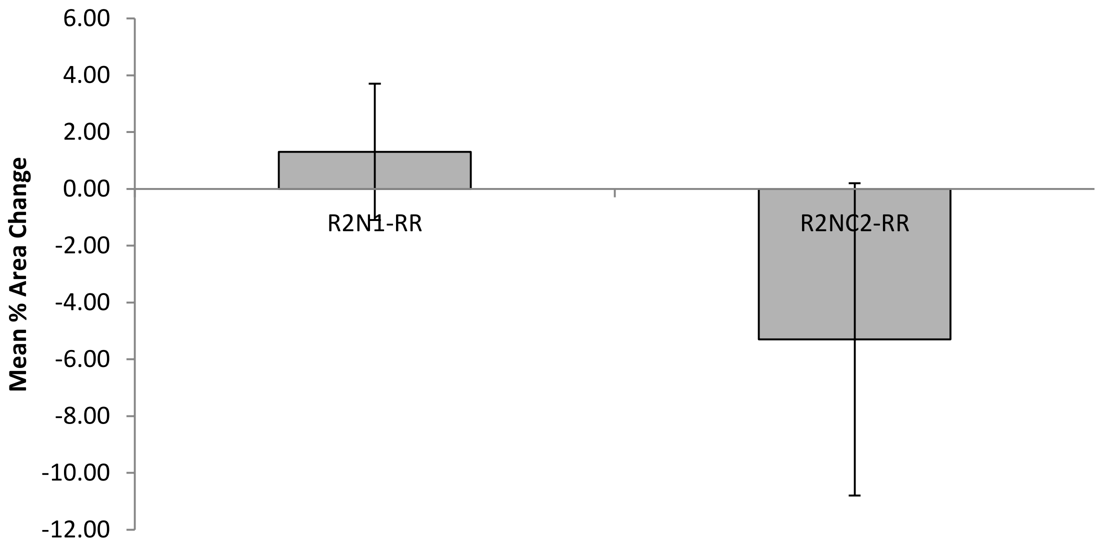


Figure 81. Mean percent area tissue change from baseline to impact assessment surveys at R2NC2-RR and R2N1-RR permanent monitoring sites.

3.4.6 Scleractinian Tissue Loss- Visual Estimation of % Colony Mortality

Visual estimation of partial mortality on tagged scleractinian coral colonies was conducted during the one-year impact assessment for PortMiami monitoring. Post-hoc visual estimation of partial mortality was conducted by comparing planar photographs taken during the initial baseline surveys in fall 2013 and photos taken during impact assessment surveys in 2016. Post-hoc visual estimation efforts took into account any partial mortality that was present during baseline surveys. Figure 6 was used as a guide for personnel tasked with post-hoc visual estimation of partial mortality. Examples of baseline and impact assessment photos used for visual estimation can be seen in Figures 82 and 83.

Figure 82. Comparison of tagged scleractinian coral R2SC1-RRT1-C6 from Baseline Week 1 (left) and 12-month Impact Assessment (right). The visual estimate of mortality for this coral was estimated to be 100% (dead).

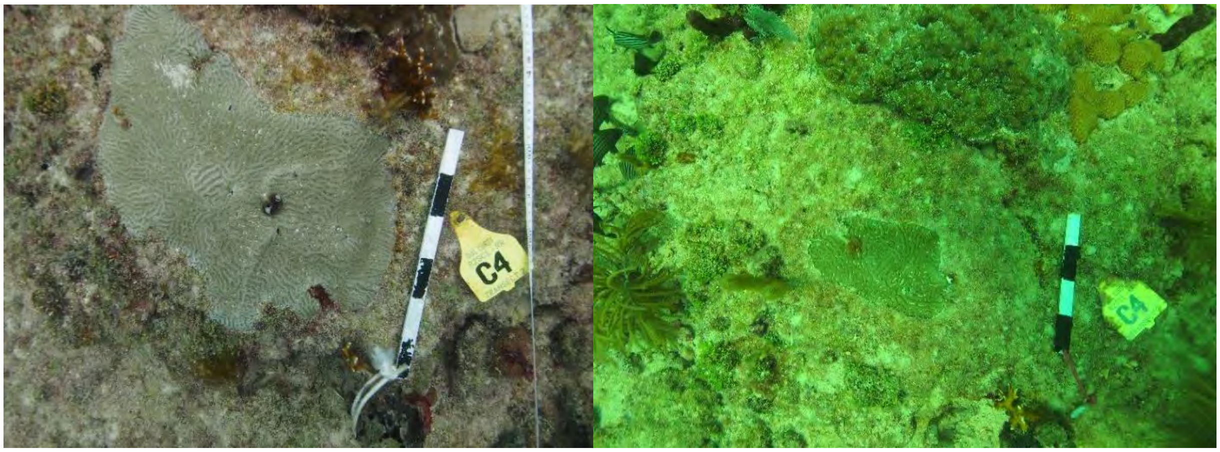


Figure 83. Comparison of tagged scleractinian coral R2SC1-RR T2-C4 from Baseline Week 1 (left) and 12-month Impact Assessment (right). The visual estimate of mortality for this coral was estimated to be 85%.

Levels of visually estimated coral mortality were not significantly different between channel-side and control sites. Mean visually estimated coral mortality was 54.1% at the selected control sites during impact assessment surveys and was 49.3% at the selected channel-side sites. An independent-sample t-test was performed on the mean visually estimated coral mortality from channel-side and control site locations. There was not a significant difference in percent coral mortality from channel-side (mean percent coral mortality 54.1%, SD 15.9) when compared to control locations (mean percent coral mortality 49.2%, SD 17.6); $t(17)= 2.11$, $p = 0.53$. These results suggest that levels of visually estimated mortality which include both total colony mortality and partial mortality, at sites located directly near dredge operations were not significantly higher than controls (away from dredge activity) and indicate the significant influence of the regional disease event on the mortality of all tagged corals regardless of location.

3.4.6.1 Hardbottom

Visually estimated mortality at hardbottom sites ranged from 39.1 (HBN3-CP) to 91.5% (HBS4-CR) (Table 17). Northern hardbottom average visually estimated mortality was greater at HBNC1-CP than HBN3-CP. The southern hardbottom channel-side sites had greater mean visually estimated mortality than the southern hardbottom control site, HBSC1-CP. No distinction was made in this analysis to the cause of total or partial mortality. However, total colony mortality, which has devastated tagged coral populations, was the primary driver of visually estimated mortality. These patterns were a reflection of disease susceptibility as well as location. However, disease susceptibility was found to be significantly higher for HBS3-CP and HBS4-CR and suggests disease-related mortality would also be greater at these sites than paired controls. Due to the disease-related mortality bias of HBS3-CP and HBS4-CR, a strict comparison of test vs. controls is not applicable at these sites (see Section 3.5).

Table 17. Average visually estimated mortality for all hardbottom sites from baseline to impact assessment.

Site	Baseline to Impact Assessment		
	N	Estimated Mortality	
		Mean	SE
HBN3-CP	27	39.1	48.0
HBNC1-CP	14	60.0	44.9
HBS3-CP	29	77.9	38.4
HBS4-CR	25	91.5	28.2
HBSC1-CP	30	46.3	45.6

3.4.6.2 Middle Reef

Visually estimated mortality at middle reef sites ranged from 27.6 (R2NC2-RR) to 69.4 (R2SC2-LR) (Table 18). Average visually estimated mortality was greater at the northern middle reef channel-side sites compared to corresponding control sites. Across the southern middle reef sites, mean visually estimated mortality was greater at R2S2-LR (×=62.9) and R2SC2-LR (×=69.4) than R2S1-RR (×=37.7) and R2SC1-RR (×=52). Interestingly, a larger portion of tagged coral mortality was attributed to white-plague disease at R2S2-LR (46%) and R2SC2-LR (44%) compared to R2S1-RR (26%) and R2SC1-RR (27%). While no distinction was made in this analysis to the cause of total or partial mortality, total colony mortality largely affected tagged coral populations and was the primary driver of visually estimated mortality. As previously stated, patterns of partial and total coral mortality was a function of disease susceptibility as well as location. Compared to hardbottom and outer reef sites, middle reef sites had the greatest number of white-plague disease susceptible scleractinian coral species and thus the highest documented coral mortality, particularly at the south channel-side and control sites. White-plague disease was the only source of coral mortality recorded during the construction and post-construction periods at R2N1-RR, R2S1-RR, and R2NC2-RR and the primary cause of total coral mortality (11 of 12) at R2S2-LR. Comparatively, white-plague disease affected fewer corals at R2N2-LR (8%), R2NC1-LR (11%), and R2NC2-RR (7%). Due to the disease-related mortality differences between middle reef sites, a strict comparison of test vs. controls is not applicable at these sites.

Table 18. Average visually estimated mortality for all middle reef sites from baseline to impact assessment.

Site	Baseline to Impact Assessment		
	N	Estimated Mortality	
		Mean	SE
R2N1-RR	30	51.6	46.3
R2N2-LR	25	50.2	47.3
R2NC1-LR	30	33.7	44.8
R2NC2-RR	30	27.6	41.8
R2NC3-LR	30	45.5	42.4
R2S1-RR	28	37.7	47.7
R2S2-LR	24	62.9	47.0
R2SC1-RR	30	52.0	44.2
R2SC2-LR	25	69.4	45.3

3.4.6.3 Outer Reef

Visually estimated mortality at outer reef sites ranged from 31.5 (R3N1-LR) to 60.3 (R3SC2-LR) (Table 19). Average visually estimated mortality was greater at the outer reef control sites compared to channel-side sites. While no distinction was made in this analysis to the cause of total or partial mortality, total colony mortality largely affected tagged coral populations and was the primary driver of visually estimated mortality. As previously stated, patterns of partial and total coral mortality is a function of disease susceptibility as well as location. Across the outer reef sites, the site with the lowest visually estimated mortality, R3N1-LR, also was least affected by white-plague disease (0%) and the site with the greatest visually estimated mortality, R3SC2-LR, was largely affected by white-plague (40%). Due to the disease-related mortality differences between outer reef sites, a strict comparison of test vs. controls is not applicable at these sites.

Table 19. Average visually estimated mortality for all outer reef sites from baseline to impact assessment.

Site	Baseline to Impact Assessment		
	N	Estimated Mortality	
		Mean	SE
R3N1-LR	23	31.5	38.9
R3NC1-LR	24	49.5	44.9
R3S2-LR	25	44.4	43.1
R3SC2-LR	23	60.3	42.4
R3SC3-SG	25	48.3	45.6

3.5 Scleractinian Mortality-White-plague Disease

White-plague disease and other concurrent coral diseases were responsible for between 77-93% of all tagged colony mortality (Figure 75, 77, and 78). All three types of white-plague disease (WPL I, II, and III), are characterized by a sharp line between apparently healthy coral tissue and recently dead coral skeleton with differences between types of white-plague disease being based on rate of advance or progression of the disease over time (Sutherland et al. 2004). The migrating disease line associated with white-plague diseases can progress rapidly, as fast as 2 cm/day, and most often results in total colony mortality (Richardson et al. 1998). Thirty two Caribbean coral species are susceptible to white-plague disease (Weil et al. 2002), and outbreaks following summer bleaching events have caused significant declines in total coral cover (Brandt & McManus 2009; Miller et al. 2009; see numerous other references in Precht et al. 2016; Appendix E). Based upon these previous examples, Miller and Precht (2013) predicted the likely occurrence of coral disease epizootics following on the heels of future coral bleaching events for the reefs of Southeast Florida. Unbeknownst to them their prediction would come true approximately one year later.

The first evidence of mortality due to white-plague disease noted in the permanently tagged corals occurred at the middle reef southern control site (R2SC2-LR) during compliance week 45 on September 26, 2014. The middle reef southern control site is located 1.27 km south of the channel (Table 1) and was not documented as affected by excess sedimentation in any impact assessment survey of project-monitoring sites. The first coral with signs of white-plague following the 2014 summer bleaching was still bleached from high summer temperatures but recent tissue loss was evident and subsequent visits confirmed signs of white-plague disease (Figure 84). By 10/17/2014 (compliance Week 48) two additional corals had the appearance of white-plague disease at R2SC2-LR.White plague disease was not noted at any channel-side sites until 10/18/2014, twenty two days after the first occurrence of white-plague at the southern middle reef control when a tagged coral at R2S2-LR was documented with signs of the disease. Due to poor conditions offshore, few sites were visited between compliance week 48 and 51 when several colonies were also found at R2N1-RR with the appearance of white-plague disease. The first reporting of white-plague disease as a significant source of coral mortality within permanent monitoring sites occurred in compliance monitoring week 52 (11/12/14-11/18/2014) monitoring report. At the time, a total of seven coral colonies had died from white-plague disease (1.2% of all tagged colonies).

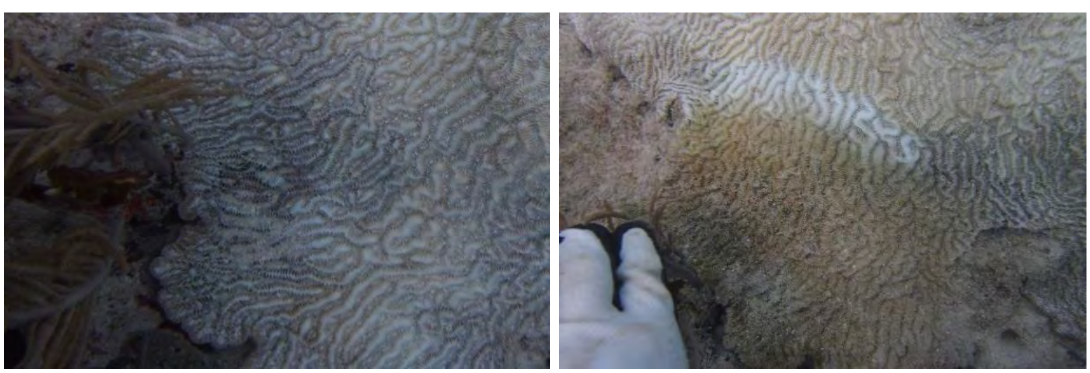


Figure 84. Initial observation of partial mortality and white tissue from tagged coral located at R2SC2-LR (T2, C#1) September 26, 2014 (left) and with tell-tale white-plague disease line on October 8, 2014. This was the first coral documented with active white-plague disease at any of the 26 permanent monitoring stations.

Between Compliance Week 52 (November 2014), when the mortality of several corals with white-plague disease was first reported within the project study area, and the post-construction surveys (June 2015), white-plague disease had spread from primarily affecting middle reef sites, to both the outer reef and hardbottom habitats. Active white-plague disease was still recorded on a number of colonies at hardbottom, middle and outer reef sites during Week 4 of post-construction surveys.

In the post-construction report, the hardbottom habitat was the least affected by white-plague disease with the total mortality of 17.7% (33 out of 186 marked corals, excluding missing) and has affected (either killed or is actively causing mortality) 25.8% of marked corals within all hardbottom monitoring sites (DCA 2015d). At the time of the post-construction report white-plague disease has caused the total mortality of 23.5% (94 out of 400 marked corals) and has affected (either killed or is actively causing mortality) of 30.5% of marked corals throughout all middle and outer reef sites. At the middle and outer reef, nearly equivalent levels of mortality had occurred at channel-side and control sites at the writing of the post-construction report. At middle and outer reef channel-side sites, 23.6% of all tagged corals (46 out of 195) had died from white-plague disease whereas 23.4% of all tagged corals (48 out of 205) had died from white-plague at middle and outer reef control sites (DCA 2015d). *M. meandrites* and *D. stokesi* were the most affected species. Total colony mortality of *P. strigosa, P. clivosa, S. bournoni, M. cavernosa* and *C. natans* have also been documented as a result of white-plague disease across most compliance and all control sites, including hardbottom, middle and outer reefs.

The white-plague disease outbreak documented above followed a period of bleaching (summer/fall 2014) due to thermal stress across the region (Manzello 2015). 2014 was the hottest year on record in Southern Florida and caused wide-spread bleaching (Manzello 2015). Figure 85 displays the proportion of corals surveyed that exhibited bleaching and white-plague disease during compliance monitoring. The proportion of bleached corals was highest in September 2014, when approximately 28% of corals surveyed were bleached. White-plague disease started to appear across all monitoring sites, as early as November 2014, when 4% of surveyed corals showed signs of white-plague. White plague prevalence kept increasing to reach its highest documented level in March 2015, when 15% of tagged corals surveyed had white-plague disease.

More than a year passed between the post-construction survey of July 2015 and the impact assessment survey of August-December 2016. During that time, the cause of tagged coral mortality was only noted if signs of that mortality (typically evidence of disease) was documented in either the post-construction or impact assessment survey or photographs. If no direct evidence was noted, the coral was documented as having died from “unidentified causes”. Despite a lack of photographic documentation of disease, high levels of white-plague disease were noted in the Broward-Miami region during both the summer of 2015 and 2016 (Baker 2015, Florida Reef Resilience Program, 2015; Florida Reef Resilience Program, 2016; CSi 2016; DERM 2016; Hayes et al. 2017). Our surveys have also documented that white-plague disease is still present more than two years after the initial onset of the disease within the permanent monitoring sites. At the time of the impact assessment survey, 18 corals were noted with active signs of disease (6.1% of all tagged corals) suggesting that levels had not yet declined to baseline levels (<1% of tagged corals) (Table 15). In addition, levels of disease-related mortality are estimated to have killed between 77-93% of all tagged corals between baseline and impact assessment surveys (Figure 75).

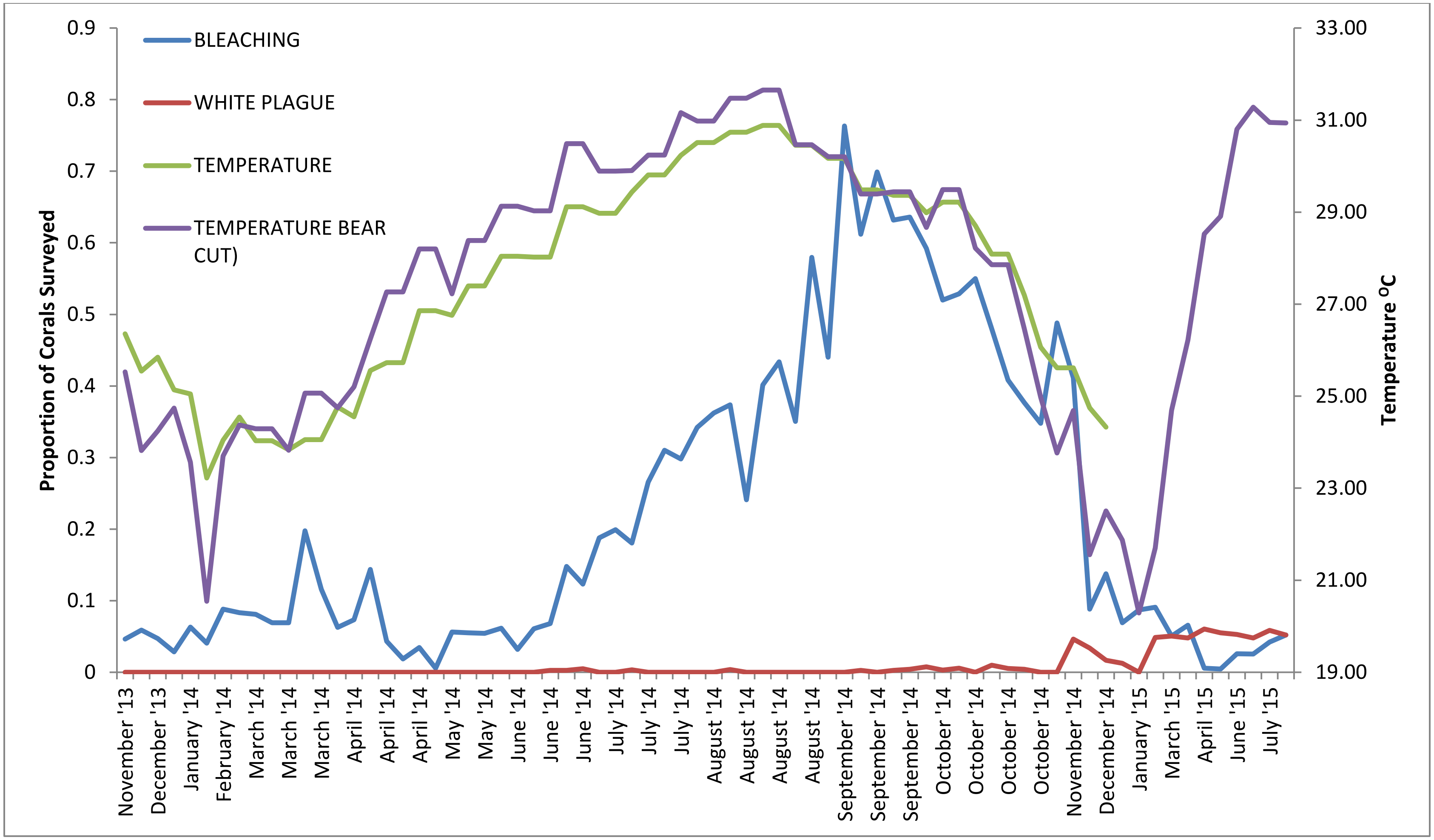


Figure 85. **Proportion of corals surveyed across all compliance monitoring sites (hardbottom, middle and outer reef sites) showing signs of bleaching or white-plague disease across all monitoring weeks.**

Comparison of project monitoring results to regional mortality from white-plague disease

Significant coral mortality occurred throughout the project area at both channel-side and control sites between baseline and impact assessment surveys. When examining all coral mortality at channel-side sites (all categories included), mortality ranged from 14.29% mortality at R3N1-LR to 87.5% at HBS4-CR. All coral mortality at control-sites ranged from 16.67% mortality at R2NC2-RR to 64.0% mortality at R2SC2-LR.

Four channel-side sites had higher mortality than their respective controls, four channel-side sites had lower mortality than their respective control, and one channel-side site had equivalent levels of mortality between baseline and impact assessment periods. In the southern hardbottom and northern side of the middle reef, channel-side sites HBS3-CP, HBS4-CR, R2N1-RR, and R2N2-LR had higher coral mortality than their respective controls (Table 20). However, total colony mortality was greater at habitat control sites at the northern hardbottom (HBNC1-CP), southern middle reef site (R2SC2-LR), and both the northern (R3NC1-LR) and southern portions of the outer reef (R3SC2-LR), than their respective channel-side comparison. Mortality was only slightly higher at the R2SC1-RR when compared to its channel-side comparison. As a result, no clear pattern of coral mortality related to location, be it channel-side or control, was observed throughout the project area.

Table 20. Coral colonies were replaced with the regional species-level prediction of white-plague related mortality from Precht et al.(2016) (Appendix E) at each permanent monitoring site. Missing corals were excluded from the analysis. Mean predicted mortality as well as the upper and lower bounds of the 95% confidence interval calculated for each permanent site are provided. Percent observed mortality and active disease are also provided.

Transect	Coral #	HBN3	HBNC1	HBS3	HBS4	HBSC1	R2N1	R2N2	R2NC1	R2NC2	R2NC3	R2S1	R2S2	R2SC1	R2SC2	R3N1	R3NC1	R3S2	R3SC2	R3SC3
1	1	69	97	69	98	0	0	0	0	38	0	38	38	0	98	38	0	0	0	97
	2	69	69	93	0	38	84	38	97	38	69	98	38	84	0	69	0	0	84	98
	3	69	69	98	97	0	84	38	0	38	0	38	38	98	0	38	0	69	98	0
	4	69		98	69	38	97	0	38	97	38	0	93	38	98	0	84	0		0
	5	69	97	98	69	97	69	97	0	38	69	97	38	69	97	38	98	0		0
	6	97	69	97	97	84	38	69	0	97	98	0	38	97	0	0	98	69	84	0
	7	0		0	97	38	69	0	0	0	0	0	69	13	98		69	69	84	0
	8	69		0	97	38	0	69	0	38	69	0	97	0						
	9			97	0	38	38	0	0	97	38	98		84						
	10					0	98		0	38	38	69		0						
2	1	0	69	97	0	38	69	0	38	69	38	97	98	69	98		69	69	98	0
	2			0	97	38	0	38	0	69	93	0	0	38	97	0	0	0	0	69
	3	69	69	97	97	0	69	38	69	0		97	0	69	98	38	69	0	0	0
	4			97	69	38	98	38	0	38	69	0	38	0	0	0	0	0	84	0
	5	0		97	69	97	69	69	0	38	69	97	97	0	0	0	0	0	0	
	6	69		98		97	69	0	0	38	38	98	84	38	0	0	0	69	0	69
	7	69		97	97	0	0		0	38	69	38	0	69	98	69	98	0	0	0
	8			0	97	69	84		0	38	38	0	69	0	0	0		98		0
	9	97		97		97	69			38	0	69		69						98
	10	0				0	98		0	38	38			0						
3	1	0	0	98	97	84	38	0	98	38	98		93	69	0	0	0	0	0	0
	2	0	97	0	97	97	69	38	0	38	38	97	0	13	0	0	0	69	0	0
	3	69	69		69	69	69	69		0	38	0	93	0	0	0	69	98	38	98
	4	69	0	98	97	0	98	38	0	38	0	69	0	69	0	38	93	0	0	93
	5	97	97	97	97	0	98	38	0	0	38	0	0	97	0	38	98	0	69	84
	6			97	69	0	98	0	38	0	0	0	98	69	93	0	0	0	0	38
	7	0		97	97	97	0	0	0	38	97	69	98	38	38	0	0	83	98	84
	8	0		97	97	97	0	38	97	0	0	0	38	84	0	69	0	0	69	38
	9	0				38	38	97	0	0	97	69		69	98		0	0		84
	10			97		0	0		0	38	38			97	84		0	0		
Mean Predicted Mortality		45.7	66.8	77.3	77.9	44.2	57.0	33.8	17.0	37.1	45.3	45.9	52.3	48.0	43.8	20.7	35.2	27.7	40.3	39.6
95% CI (Upper)		62.3	88.3	93.1	91.6	58.7	70.8	47.3	29.8	47.5	58.1	62.7	68.7	61.7	63.6	32.7	53.6	43.6	60.5	57.8
95% CI (Lower)		29.0	45.3	61.6	64.2	29.7	43.2	20.4	4.2	26.7	32.6	29.0	35.9	34.3	24.0	8.7	16.9	11.9	20.1	21.4
Observed Mortality		34.8	50.0	65.4	87.5	33.3	43.3	37.5	17.9	16.7	27.6	29.6	54.2	30.0	64.0	14.3	33.3	24.0	45.0	37.5
Observed Mortality & Active Disease		34.8	50.0	65.4	87.5	36.7	50.0	37.5	21.4	30.0	41.4	33.3	54.2	30.0	64.0	19.0	33.3	36.0	45.0	37.5

Since patterns in observed coral mortality throughout the nineteen sites surveyed during the impact assessment were not explained by channel-side or control-site distinctions, the coral composition of all project monitoring sites was analyzed to determine if species composition and the susceptibility of corals to the white-plague disease epidemic could explain the variability observed in mortality at the various project monitoring sites. Precht et al., (2016) documented 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.* Similar data has been recorded in a number of other regional studies (e.g. CSi 2016; DERM 2016; Hayes et al. 2017). Precht et al. (2016) (Appendix E) noted that since all corals infected with white-plague disease had since died, that the estimates of disease infection could also be used as estimated rates (a proxy) of colony mortality throughout the region.

As a consequence of the species-specific susceptibility to white-plague disease documented region-wide, project sites would be expected to show significantly different rates of disease-related mortality depending on the composition of the tagged coral community. Sites dominated by corals that were not susceptible to white-plague disease such as *Porites astreoides, Stephanocoenia intercepta,* or *Siderastrea siderea* would be expected to experience lower rates of mortality than sites that were dominated by highly susceptible species such as *Meandrina meandrites* or *Dichocoenia stokesi* (Table 5).

To determine the amount of white-plague mortality expected at each permanent monitoring site due to species-susceptibility alone, we used the regional species-level data on the percentage of colonies infected with white-plague disease plus recently dead in-place published in Precht et al. (2016) (Appendix E) as an estimate of predicted white-plague disease-related mortality for each species within the project area. The 10 sites sampled in Precht et al. (2016) (Appendix E) span the length of Miami-Dade County and represent an independent source of disease prevalence and disease-related mortality estimates that occurred throughout south Florida reefs during project-related monitoring activities. Using the regional species-specific percent infection plus recently dead in place value as a proxy for the predicted likelihood of mortality of each coral colony at a given site, a mean percent predicted mortality and 95% confidence interval for each permanent monitoring site was calculated (Table 20). The mean predicted mortality was based solely on the species composition of each site and the regional estimates of % mortality provided in Precht et al. (2016) (Appendix E). Our method of prediction was identical for control and channel-side sites. The site-level predictions of coral mortality and the corresponding 95% confidence intervals are presented as the shaded region in Figure 86. The percentage of colonies that have died plus active white-plague disease infection are shown as the solid black line of the same graph (Figure 86). Percent observed mortality (all causes) is the dotted black line (Figure 86).

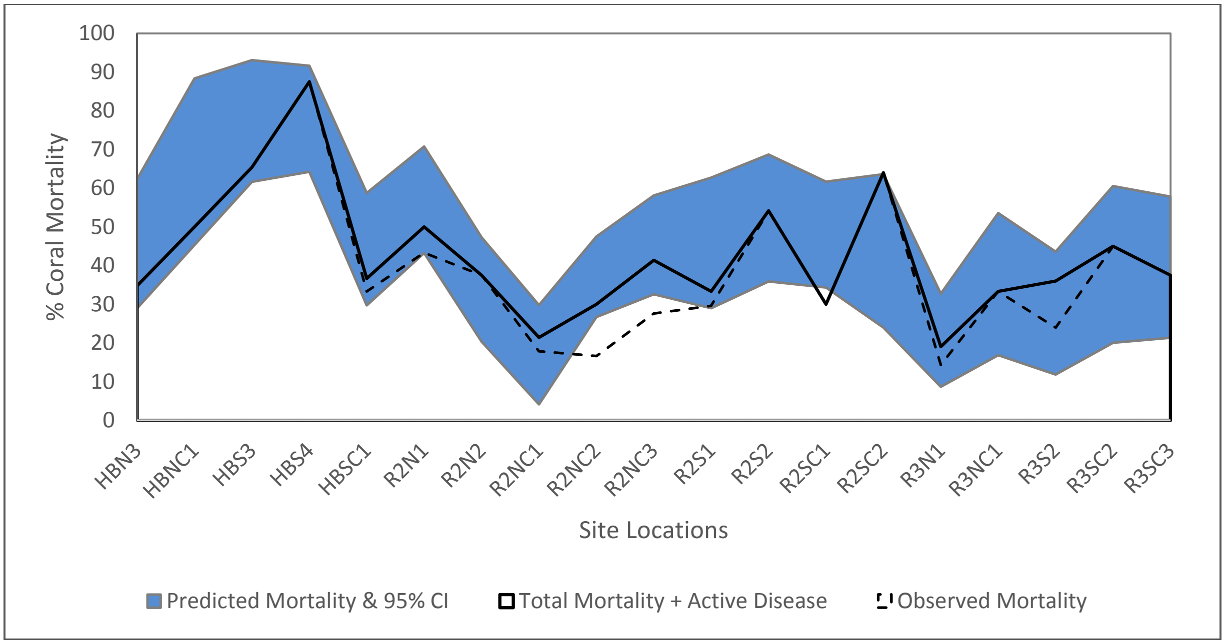


Figure 86. The predicted mortality and 95%CI for each permanent monitoring site based on white-plague disease prevalence/mortality estimates for observed and dead in place corals published in Precht et al. (2016) (grey shaded region). Total observed mortality plus active disease documented during the impact assessment survey are depicted by the solid black line. Observed mortality only is denoted by the black dotted line.

The levels of coral mortality and active white-plague disease at the time of the impact assessment monitoring survey were within the range of those predicted using the region-wide disease mortality information from Precht et al. (2016) (Appendix E) for 17 out of 19 permanent monitoring stations. While observed levels of coral mortality are lower than predicted at R2NC2-RR and R2NC3-LR, these were the two sites with the highest levels of active white-plague disease during the impact assessment surveys. Four tagged colonies (13.3% of tagged colonies) were documented at R2NC2-RR with active white-plague disease and four additional colonies (13.7% of tagged colonies) were documented at R2NC3-LR with active white-plague disease during the impact assessment survey. The observed mortality and active disease at R2SC1-RR (30.0%) was the only permanent monitoring station that had lower mortality than the predicted range (34.3%-64.6%). The cause of this discrepancy is currently unknown but could be attributed to the lower than predicted mortality of *Solenastrea bournoni* colonies at the site where only 25% (two of eight tagged colonies) of colonies died from disease compared to the regional estimate of 69%. Observed mortality was slightly higher than predicted at R2SC2-LR (64.00% mortality) where the regional mortality prediction ranged from 23.9% to 63.6%. At this site three colonies of *Acropora cervicornis* died from white-band disease, during a similar but unrelated disease event. White-band disease is a coral disease that affects only acroporid corals (Aronson and Precht 2001). The mortality of all three colonies of this species at R2SC2-LR (100%) was significantly higher than the species-specific rate of 0% documented by Precht et al. 2016 (Appendix E) for white-plague disease and resulted in a higher than predicted level of coral mortality at R2SC2-LR. *Acropora cervicornis* was only tagged at two permanent monitoring sites; one colony is still living at R2SC1-RR and the other three have died from white-band disease at R2SC2-LR. Thus, in our study, the effect of white-band disease mortality was restricted to data from R2SC2-LR only.

Disease-related mortality was not significantly influenced by proximity to dredge activity as purported in Miller et al. (2016). No channel-side sites experienced levels of coral mortality during the project monitoring period that were outside the 95% confidence intervals predicted based on community composition and regional white-plague disease mortality data. In addition, both the highest and lowest values of predicted mortality among the 19 surveyed sites corresponded to the highest and lowest levels of observed mortality. HBS4-CR was the permanent monitoring site with the highest observed mortality (87.5%) as well as the site with the highest mean predicted mortality (77.9%; 95%CI 64.2-91.6%) (Table 21). Conversely, R2NC1-LR is the site with the lowest observed coral mortality (17.9%) was also the site to have the lowest mean predicted mortality (17.0%; 95%CI 4.2-29.8%) (Table 21). The differences in the levels of mortality observed are explained by the different susceptibilities of the two coral communities to white-plague disease. HBS4-CR, the site with highest tagged colony mortality, had only 3 of 24 corals with a 0% probability of suffering from white-plague disease mortality whereas R2NC1-LR, the site with the lowest tagged colony mortality, had 21 out of 28 corals with 0% probability of white-plague disease mortality according to the regional estimates.

The ability to effectively use control and test site monitoring to evaluate the effects of local impacts is dependent on both the control and test sites being representative of the overall benthic community. The use of channel-side and control site monitoring during this project was invaluable for detecting the presence of a regional disease event that also affected project-related resources. However, the effects of white-plague disease on project resource mortality was found to be highly dependent on the community composition of the site and posed a potential violation to the assumption that control and test site comparisons are representative of the same community.

To test for significant differences in disease susceptibility between channel-side and control pairs, a t-test was performed for each site pair based on the predicted mortality values of the coral community at each site. Results of the t-test comparisons are provided in Table 21. Four out of the nine channel-side vs. control site comparison had significantly different levels of disease susceptibility than their paired control (Table 20). Channel-side sites HBS3-CP, HBS4-CR, R2N1-RR, and R2N2-LR all had significantly higher predicted disease susceptibility than their respective control sites. These results indicate that significantly higher rates of coral disease mortality are likely to occur at these sites due to the abundance of disease-susceptible species when compared to their paired control site and not based on location. These results show that in four of nine cases, the channel-side and control communities are not representative of each other due to differences in disease susceptibility. In these cases, evaluation of coral mortality should not be made on a control and test-site basis as the expectation of no differences in coral communities has been violated. The result of this pre-disposition to disease-related mortality due to community composition means that it should be considered inaccurate to expect equal levels of mortality from R2N2-LR that had a predicted level of coral mortality of 57% and R2NC1-LR that had a predicted percent mortality rate of 17.0%.

Table 21. Results of one-tailed t-test on predicted mortality values of each channel-side and control site comparison. Sites where channel-side sites were found to have significantly higher levels of predicted coral mortality are shown in bold.

Channel-side site	Control Comparison	t	p value
HBN3-CP	HBNC1-CP	-1.67	0.05
HBS3-CP	HBSC1-CP	3.18	0.00
HBS4-CR	HBSC1-CP	3.47	0.00
R2N1-RR	R2NC2-RR	2.36	0.01
R2N2-LR	R2NC1-LR	1.87	0.03
R2S1-RR	R2SC1-RR	-0.20	0.42
R2S2-LR	R2SC2-LR	0.68	0.25
R3N1-LR	R3NC1-LR	-1.37	0.09
R3S2-LR	R3SC2-LR	-1.01	0.16

The significantly different levels of disease susceptibility at nearly half of the channel-side sites when compared to their paired controls indicates that data should be pooled to reduce the impact of site-specific differences. No significant differences were found between levels of predicted mortality when all channel-side sites were pooled and compared to all pooled control sites. Mean predicted coral mortality was 48.7% across the selected channel-side sites and was 41.7% at the selected control sites (Figure 87). An independent-sample t-test was performed on the predicted coral mortality from the selected channel-side sites verses all of the selected control site locations. There was not a significant difference in predicted coral mortality from channel-side (mean predicted coral mortality 48.7%, SD 20.6) when compared to control locations (mean predicted coral mortality 41.7%, SD 12.4); $t(17) = 2.11$, $p = 0.37$. These results suggest that comparisons of coral mortality at the level of all channel-side site locations verses all control site locations are not significantly different due to the disease-susceptibility of the corals within each group.

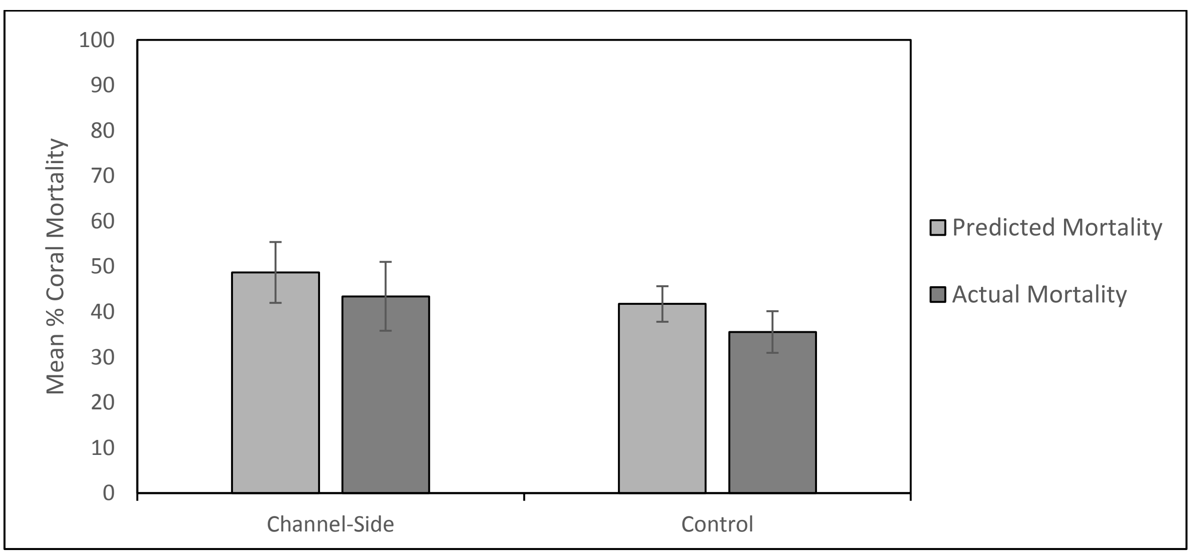


Figure 87. Comparison of Mean % coral mortality and predicted % coral mortality from all nine selected channel-side sites and ten control sites surveyed during the impact assessment.

As shown previously in Section 3.1, mean total colony mortality was not significantly different when comparing mortality at all surveyed channel-side verses all surveyed control sites. In addition, we also show that the percent mortality predicted using region-wide estimates is not significantly different than the mean observed mortality for either the group of channel-side sites or the group of control sites (Figure 87). Mean predicted coral mortality for all surveyed channel-side sites was 48.7% compared to 43.4% observed mortality (Figure 87). An independent-sample t-test was performed on the predicted verses actual mean percent coral mortality for all sampled channel-side locations. There was not a significant difference in predicted coral mortality at channel-side locations (mean predicted coral mortality 48.7%, SD 20.6) when compared to actual mortality (mean coral mortality 43.4%, SD 22.5); $t(16)= 2.12$, $p = 0.61$. Mean predicted coral mortality for all surveyed control sites was 41.7% compared to 35.5% observed mortality (Figure 87). An independent-sample t-test was performed on the predicted verses actual mean % coral mortality for all sampled control locations. There was not a significant difference in predicted coral mortality at control locations (mean predicted coral mortality 41.7%, SD 12.4) when compared to actual mortality (mean coral mortality 35.5%, SD 14.7); $t(18)= 2.10$, $p = 0.32$.These results suggest that not only were there no significant differences in control verses channel-side levels of total colony mortality, but also that neither the channel-side or control sites were distinguishable from regional levels of colony mortality.

The comparison of permanent site data with regional estimates of disease-related mortality show that the mortality levels observed at all permanent monitoring sites follow the trends predicted due to the coral community composition of that site and their white-plague disease susceptibility without reference to location, either close to, or far away from dredge activity. This result is in direct contrast to patterns described by Miller et al. (2016) in which they document significantly greater coral mortality at channel-side sites when compared to control sites from data derived from PortMiami monitoring from baseline through post-construction surveys. It is important to note that the scope of the Miller et al. (2016) analysis was restricted to the two channel-side and two control sites from the northern middle reef as opposed to the entire twenty-six site dataset that was assembled as part of the baseline, construction, and post-construction monitoring or the nineteen sites analyzed here as part of the impact assessment survey. In addition, the northern middle reef sites that were analyzed were also two of the channel-side sites in which significantly higher predicted mortality was documented when compared to the respective middle reef controls due to the species composition of the channel-side sites (Table 19). Therefore, it is unsurprising that Miller et al. (2016) found significantly higher rates of coral mortality at the middle reef north channel-side sites, since they are much more susceptible to the regional disease event than their paired control sites, however their conclusion that all differences in coral mortality are related to location, without considering the species-specific nature of the regional disease event is flawed. If location were the only driver for rates of coral mortality, higher rates of coral mortality would have been documented at all of the surveyed channel-side sites when compared to their respective controls. However, this was only the case for four channel-side permanent monitoring sites out of nine surveyed, all of which had significantly higher rates of disease-susceptibility than their paired control sites. The fact that the trends documented in Miller et al. (2016) are not applicable to all channel-side and control comparisons suggests that their sample was too small to adequately address the question of regional vs. local mortality. In contrast, by examining the coral composition of all nineteen sites, levels of mortality and current coral disease observed were within those predicted from regional data for 17 out of 19 sites.

The predictability of the extent of coral mortality at the 19 permanent monitoring sites shows that levels documented throughout the channel-side and control sites were within the same range as the mortality documented throughout Miami-Dade County from the fall of 2014 to the summer of 2015. It is important to note that this result does not mean that white-plague disease was the only cause of coral mortality during project monitoring. Surveys documented cases of sediment burial (related to project activities), competitive mortality, bleaching mortality, and other coral diseases (Section 3.4). However, the relative contribution of each of these factors was not greater than 3% of the total tagged colony mortality (Figure 75) or 6% of all channel-side tagged colony mortality (Section 3.4, Figure 76). Compared to the 77-93%of disease-related mortality documented across all permanent monitoring sites (Figure 75), the impact of non-disease disturbances are greatly overshadowed by the impact of the regional white-plague disease event on tagged coral populations.

Overall, the coral mortality from the nine channel-side and ten control permanent monitoring sites agree with published mortality estimates from the Southeast Florida white-plague disease event. White-plague and other concurrent diseases were the dominant source of mortality at the permanent monitoring sites and mortality occurred in a predictable manner based on the disease susceptibility of the species observed at a given site. Finally, species composition was a significant factor in the level of coral disease observed at a given site to the extent that strict test vs. control comparisons would violate the assumption of uniform susceptibility to disease stressors. As a result, the pooled data were compared for all channel-side sites and all control site locations and found no significant differences in mean colony mortality.

3.6 Quantitative Benthic Sampling Comparison: Scleractinians

3.6.1 Scleractinian Density

Scleractinian density of corals >3cm declined at 18 out of 19 surveyed sites across all reef habitats. Mean coral densities declined in all habitats and were consistent between channel-side and control locations when compared by reef type (Table 22). In the hardbottom habitat mean coral density declined by 51.8% (from 0.83 to 0.40 corals/m^2) at channel-side locations compared with 51.5% (from 0.83 to 0.40 corals/m^2) at hardbottom controls (Table 22). In the middle reef mean coral density declined by 22.2% (from 1.11 to 0.86 corals/m^2) at channel-side locations compared with 33.0% (from 1.80 to 1.21 corals/m^2) at middle reef controls (Table 22). At the outer reef mean coral density declined by 30.8% (from 1.40 to 0.97 corals/m^2) at channel-side locations compared with 33.1% (from 2.37 to 1.58 corals/m^2) at outer reef controls (Table 22). The declines of corals throughout the region have been linked to a high-mortality coral disease event documented throughout South Florida from 2014 through 2016 (Precht et al. 2016; Appendix E).

A two-way repeated measures ANOVA comparing coral densities between sites and over the survey period did not reveal any significant interaction of site and time at either the middle or outer reef habitat. As a result, no significant project effects to coral density were detected between baseline and impact assessment surveys in the middle or outer reef. In the hardbottom, the effect of time was not the same across all hardbottom sites with HBS3-CP, HBS4-CR and HBSC1-CP having significantly lower mean coral densities during the impact assessment survey when compared to baseline values. As part of the tagged coral monitoring results it was shown that coral communities at HBS3-CP and HBS4-CR had significantly higher disease-susceptibility than their paired control. The higher susceptibility to disease at HBS3-CP and HBS4-CR is likely the reason for significantly lower coral densities at these sites between survey periods as opposed to local project effects. The results of the scleractinian density comparison between baseline and impact assessment periods are consistent with those of the tagged colony data in which a regional disease event has resulted in the decline of coral densities in all surveyed habitats.

Coral recruit (3cm and smaller) densities were found to be less than paired controls at four channel-side sites, higher than paired control sites at four channel-side sites and have equivalent recruit densities at one paired channel-side and control site. Since data on recruit density was not collected prior to the impact assessment survey there is no way to determine if these densities have changed due to project-related effects.

Table 22. Mean scleractinian coral densities as measured at channel-side and control locations in hardbottom, middle, and outer reef types. Mean densities and standard error are provided for baseline and impact assessment time periods.

Site	Channel-side				Controls			
	Baseline		IA		Baseline		IA	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Hardbottom	0.83	0.04	0.40	0.05	0.83	0.06	0.40	0.05
Middle Reef	1.11	0.07	0.86	0.12	1.80	0.14	1.21	0.11
Outer Reef	1.40	0.08	0.97	0.17	2.37	0.17	1.58	0.09

3.6.1.1 Hardbottom

Mean scleractinian site density was lower at all surveyed sites during the impact assessment period when compared to the baseline survey. Mean scleractinian site density ranged from 0.23 (HBNC1-CP) to 0.62 colonies/m^2 (HBN3-CP) across all hardbottom sites during the impact assessment period (Table 23). Scleractinian density data are reported from tagged and non-tagged scleractinian corals >3cm collected during baseline (4 weeks), post-construction (4 weeks), and impact assessment periods (1 week) within a one meter belt transect at each of three transects and are reported by site (Figure 88). It is important to note that in Figure 88 the error bars of the impact assessment surveys show the variability of the one week sample compared to the 4 week samples of the baseline and impact assessment surveys. The decline in coral density ranged from a decline of approximately 30% at HBN3-CP where mean coral density declined from 0.89 to 0.62 corals/m^2 to the nearly 80% decline at HBS4-CR where mean coral density declined from 0.74 corals/m^2 to 0.15 corals/m^2 (Table 23).

Table 23. Mean scleractinian density (with standard deviation and standard error) among nine hardbottom sites across three permanent transects from baseline through impact assessment surveys. Mean coral densities from the baseline and post-construction surveys are based on a 4 week sample and the impact assessment densities were calculated from a single sampling event. N/A sites were not part of the FDEP required impact assessment protocol.

Site	Baseline			Post Construction			Impact Assessment		
	Avg	SD	SE	Avg	SD	SE	Avg	SD	SE

Site	Baseline			Post Construction			Impact Assessment		
	Avg	SD	SE	Avg	SD	SE	Avg	SD	SE
HBN1-CR	0.54	0.32	0.09	1.05	0.21	0.06	N/A	N/A	N/A
HBN2-CR	0.41	0.18	0.05	0.48	0.11	0.03	N/A	N/A	N/A
HBN3-CP	0.89	0.19	0.05	0.68	0.12	0.03	0.62	0.20	0.12
HBNC1-CP	0.79	0.22	0.06	0.42	0.22	0.06	0.23	0.06	0.03
HBS1-CP	0.42	0.16	0.05	0.40	0.15	0.04	N/A	N/A	N/A
HBS2-CP	0.53	0.17	0.05	0.42	0.11	0.03	N/A	N/A	N/A
HBS3-CP	0.86	0.13	0.04	0.49	0.11	0.03	0.43	0.08	0.04
HBS4-CR	0.74	0.11	0.03	0.36	0.09	0.03	0.15	0.00	0.00
HBSC1-CP	0.86	0.20	0.06	0.69	0.12	0.03	0.57	0.13	0.07

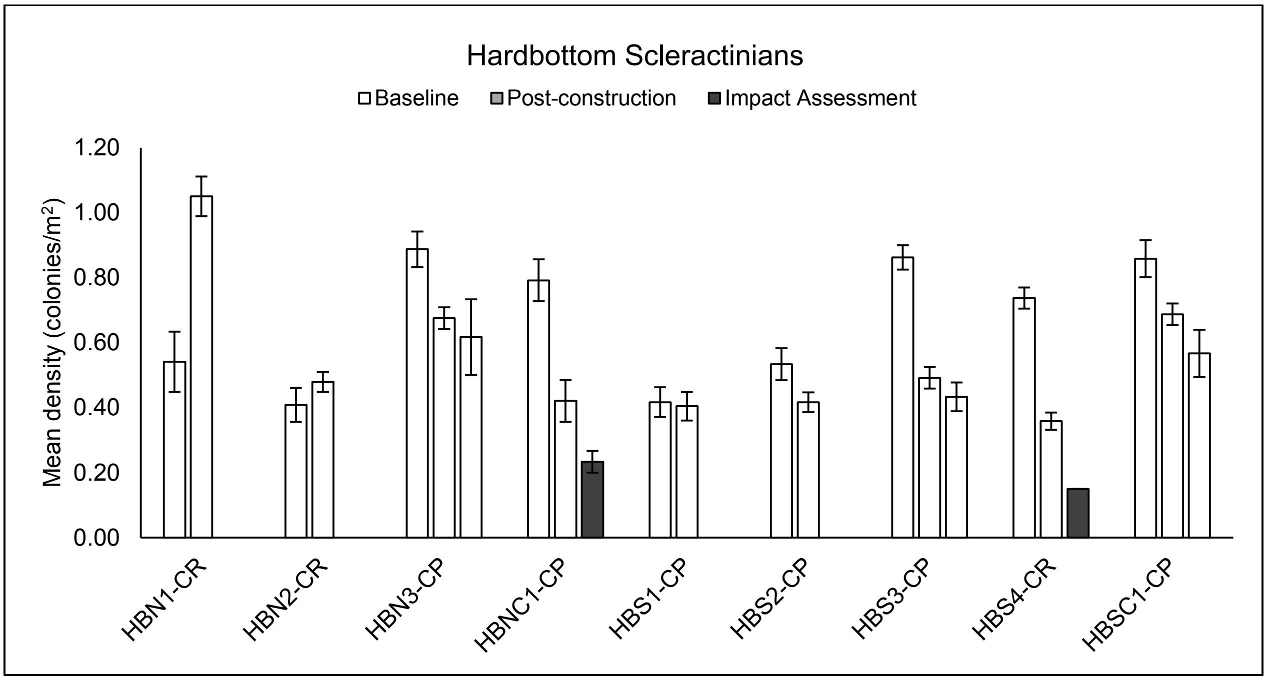


Figure 88. Mean density of scleractinian colonies at nearshore hardbottom sites throughout the baseline, post-construction, and impact assessment surveys. Error bars represent the standard error for each site. Mean densities from the baseline and post-construction surveys are based on 4 week sample and the impact assessment densities were calculated from a single sampling event.

For significance testing, a single week of density measurements from the baseline survey (week 1) were compared to scleractinian density estimates from the impact assessment survey. A two-way repeated measures ANOVA was used to determine if the effect of time period was the same across all hardbottom sites when measured by mean coral density. Data were collected over three transects during a single sampling event for each assessment period (Baseline week 1 and the impact assessment period). Mean site densities were normally distributed (Anderson Darling Test, $p > 0.05$), in all cases. There was a significant interaction between site and time period between the five surveyed sites ($F = 4.11$, $p = 0.032$). Significant differences were also detected in mean coral density between assessment periods (F = 65.40, *p* = 0.000), but no significant difference was detected based on site (F=1.62, *p*= 0.245)(Table 24).

The finding of a significant interaction between site and time period indicated that the effect of time was not the same across all hardbottom sites. Since there was a significant interaction between site and period, additional one-way ANOVAs were performed on both of the main factors, site and period. No significant differences were found between hardbottom locations based on site (Table 25). All five sites saw a decrease in coral density between baseline and impact assessment surveys. However, significant differences were found in mean coral density at all hardbottom sites except HBN3-CP (Table 26). HBN3-CP had the least severe decline with mean coral density changing from 0.89 to 0.62 corals/m^2 (decline of 30%). At the remaining four hardbottom sites, changes in mean coral density ranged from a loss of 34% at HBSC1-CP (0.86 to 0.57 corals/m^2) to a nearly 80% decline at HBS4-CR (0.74 to 0.15 corals/m^2). Of the three channel-side sites surveyed, HBS3-CP and HBS4-CR had mean coral densities that were significantly different over the time period. While the paired control site HBSC1-CP also had a significant decline in mean coral density the % decline was higher at both channel-side sites with a 50% decline at HBS3-CP, 80% decline at HBS4-CR, and 34% decline at HBSC1-CP. The relative decline of these sites is related to the disease susceptibility of corals at each of these hardbottom sites. Not only were HBS3-CP and HBS4-CR the two sites of 19 surveyed with the highest levels of mortality between baseline and impact assessment surveys, they were also the two sites with the highest mean predicted mortality based on the species composition of the corals at each site (mean predicted mortality at HBS3-CP was 77.3 and 77.9% at HBS4-CR) due to the regional white-plague disease (see Section 3.5). In the tagged colony data, the coral mortality documented at HBS3-CP and HBS4-CR was not significantly different than the region-wide decline documented as part of the white-plague disease event (Section 3.5). The results of the scleractinian density comparison between baseline and impact assessment periods are consistent with those of the tagged colony data in which a regional disease event has resulted in the decline of coral densities at all hardbottom monitoring sites.

Recruit corals, defined in this report as corals 3 cm in diameter and smaller, were only surveyed in the impact assessment survey. On the northern side of the hardbottom habitat recruit density was 0.13 colonies/m^2 at HBN3-CP and 0.32 colonies/m^2 at HBNC1-CP. On the southern side of the hardbottom habitat, recruit density was lowest at HBSC1-CP (0.03 colonies/m^2) in comparison to the two channel-side sites (0.08 colonies/m^2 at HBS4-CR and 0.13 colonies/m^2 at HBS3-CP). Since corals 3cm and smaller were not required for collection in surveys conducted prior to the impact assessment, it is impossible to determine if these densities are higher or lower than during pre-dredging surveys.

Table 24. Two-way ANOVA results testing the effects of the two assessment periods (baseline and impact assessment), the effects of survey sites, and the interaction between the two effects on scleractinian density among the five hardbottom survey areas.

Source	DF	Mean Square	F Value	*p*
PERIOD	1	0.75208	65.40	0.000
SITE	4	0.05446	1.62	0.245
PERIOD*SITE	4	0.04729	4.11	0.032

Table 25. Tukey post-hoc comparisons of mean coral density differences among hardbottom sites. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons		
	N	Mean	Grouping
HBSC1-CP	6	0.73	A
HBN3-CP	6	0.73	A
HBNC1-CP	6	0.69	A
HBS3-CP	6	0.67	A
HBS4-CR	6	0.50	A

Table 26. Tukey post-hoc comparisons of mean coral density differences between baseline and impact assessment surveys for hardbottom sites (superscripts indicate a significant difference between survey periods, NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
HBNC1-CP	F=10.8, p=0.030	$Baseline^{A}$, Impact $Assessment^{B}$
HBN3-CP	NS	(trend) Baseline > Impact Assessment
HBS3-CP	F=21.00, p=0.044	$Baseline^{A}$, Impact $Assessment^{B}$
HBS4-CR	F=36.57, p=0.026	$Baseline^{A}$, Impact $Assessment^{B}$
HBSC1-CP	F=19.69, p=0.047	$Baseline^{A}$, Impact $Assessment^{B}$

3.6.1.2 Middle Reef

The average scleractinian site density across middle reef sites ranged from 0.43 (R2SC2-LR) to 1.92 (R2SC1-RR) colonies/m^2 during the impact assessment period (Table 27). Eight of nine middle reef sites showed a decline in mean coral density between baseline and impact assessment surveys. Only R2S1-RR saw a slight increase. Scleractinian density data are reported from tagged and non-tagged scleractinian corals >3cm collected during baseline (4 weeks), post-construction (4 weeks), and impact assessment periods (1 week) within a one meter belt transect at each of three transects and are reported by site (Figure 89). It is important to note that in Figure 89, the error bars of the impact assessment surveys show the variability of the one week sample compared to the 4 week samples of the baseline and impact assessment surveys. The decline in coral density ranged from slight increase at R2S1-RR (from 0.95 to 1.08 corals/m^2) to a 58% loss at R2SC2-LR where mean coral density declined from 1.05 corals/m^2 to 0.42 corals/m^2.

Table 27. Mean scleractinian density (with standard deviation and standard error) among eight outer reef sites across three permanent transects for baseline through impact assessment periods.Mean coral densities from the baseline and post-construction surveys are based on a 4 week sample and the impact assessment densities were calculated from a single sampling event.

Site	Baseline			Post Construction			Impact Assessment		
	Avg	SD	SE	Avg	SD	SE	Avg	SD	SE
R2N1-RR	1.37	0.27	0.08	0.73	0.15	0.04	0.78	0.24	0.14
R2N2-LR	1.09	0.29	0.08	0.96	0.10	0.03	0.77	0.15	0.09

Site	Baseline			Post Construction			Impact Assessment		
	Avg	SD	SE	Avg	SD	SE	Avg	SD	SE
R2NC1-LR	2.13	0.50	0.14	1.85	0.40	0.12	1.73	0.28	0.16
R2NC2-RR	1.61	0.27	0.08	1.05	0.14	0.04	0.77	0.08	0.04
R2NC3-LR	1.72	0.68	0.20	1.78	0.17	0.07	1.18	0.24	0.14
R2S1-RR	0.95	0.21	0.06	0.75	0.21	0.06	1.08	0.25	0.14
R2S2-LR	1.03	0.26	0.07	0.62	0.11	0.03	0.82	0.23	0.13
R2SC1-RR	2.49	0.58	0.17	2.74	0.54	0.15	1.92	0.30	0.17
R2SC2-LR	1.05	0.38	0.11	0.80	0.23	0.07	0.43	0.03	0.02

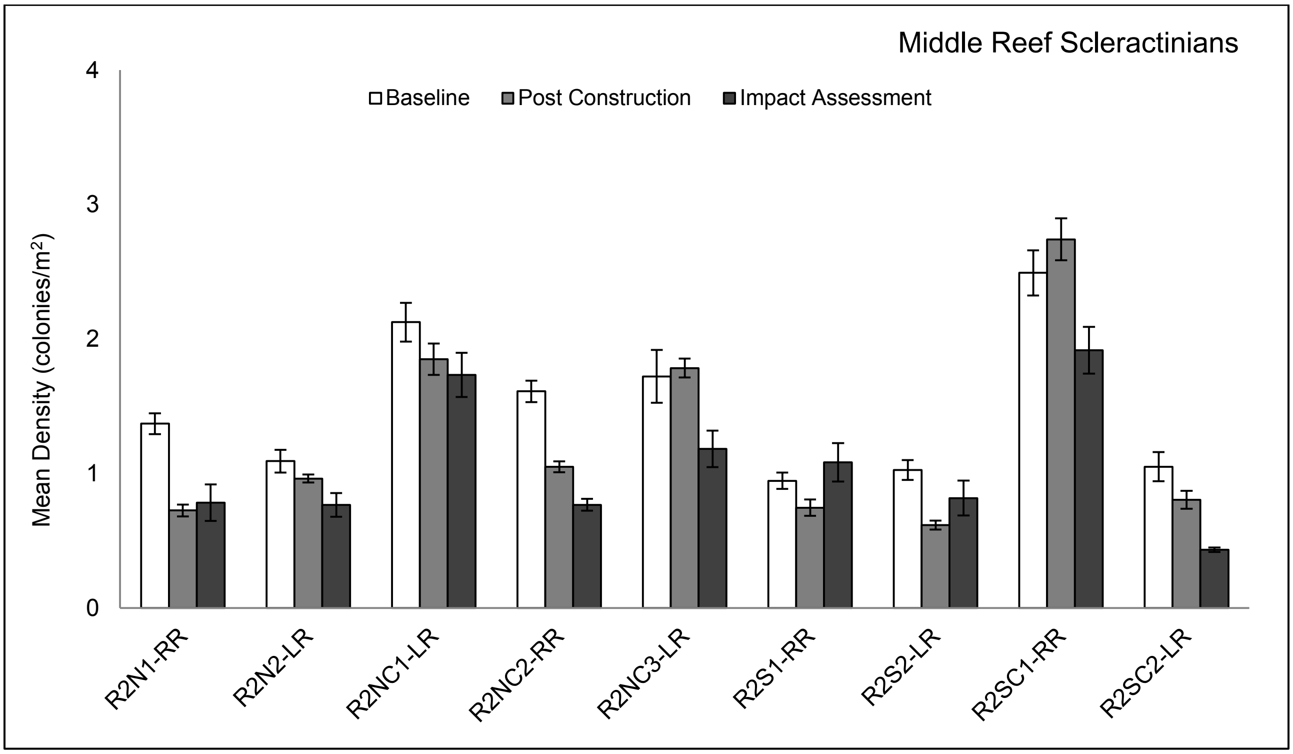


Figure 89. Mean density of scleractinian colonies at middle reef sites throughout baseline, post-construction, and impact assessment surveys. Error bars represent the standard error for each site. Mean coral densities from the baseline and post-construction surveys are based on 4 week sample and the impact assessment densities were calculated from a single sampling event.

For significance testing, a single week of density measurements from the baseline survey (week1) were compared to scleractinian density estimates from the impact assessment survey. Atwo-way repeated measures ANOVA was used to determine if the effect of survey period was the same across all middle reef sites when measured by mean coral density. Mean site densities were normally distributed (Anderson-Darling Test, p >0.05), in all cases. Significant differences were detected in mean coral density between assessment periods (F = 36.14, p = 0.000), and between sites (F=10.81, p= 0.00) but the interaction between period and site was not significant at the p< 0.05 level (F = 2.51, p = 0.050) (Table 28). The nearly significant interaction term indicates that the effect of time was likely not the same across all outer reef sites but a larger sample size may be needed to confirm the results. To investigate the interaction of site and period, additional one-way ANOVAs were performed on both of the main factors, site and period. Significant differences were detected between middle reef sites during the impact assessment period ($F = 10.81$, p=0.000, Table 28). Mean coral density was significantly higher at R2SC1-RR and R2NC1-LR than all other reef sites. In terms of mean coral density the paired channel-side and control sites R2S1-RR, R2SC1-RR, and R2N2-LR and R2NC1-LR were significantly different from each other at the site level. R2S2-LR, R2SC2-LR, and R2N1-RR and R2NC1-LR were not significantly different in terms of mean coral density at the site level (Table 29).

Table 28. Two-way ANOVA results testing the effects of the two time periods, baseline and impact assessment (PERIOD), the effects of coral site locations (SITE), and the interaction between the two effects on scleractinian density among the nine middle reef sites.

Source	DF	Mean Square	F Value	*p*
PERIOD	1	2.14005	36.14	0.000
SITE	8	1.07531	10.81	0.000
PERIOD*SITE	8	0.14848	2.51	0.050

Table 29. Tukey post-hoc comparisons of mean coral density differences among middle reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons				
	N	Mean	Grouping		
R2SC1-RR	6	2.04	A		
R2NC1-LR	6	1.79	A		
R2NC3-LR	6	1.52	A	B	
R2N2-LR	6	1.06		B	C
R2NC2-RR	6	1.03		B	C
R2S1-RR	6	1.02		B	C
R2N1-RR	6	0.97			C
R2S2-LR	6	0.94			C
R2SC2-LR	6	0.89			C

Mean density at the middle reef varied by location (Figure 89). Mean density increased slightly at R2S1-RR (not significant) over the time period and declined at all other middle reef sites (Table 28). Mean coral density was only significantly different at R2NC2-RR, R2NC3-LR, and R2SC2-LR between baseline and impact assessment surveys (Table 29). R2SC2-LR had the largest decline in mean density at the middle reef from 1.05 colonies/m^2 to 0.43 colonies/m^2 (58.7% loss). Mean coral density at R2NC2-RR declined from 1.61 colonies/m^2 to 0.77 colonies/m^2 (52.4% loss) and R2NC3-LR declined from 1.72 colonies/m^2 to 1.18 colonies/m^2 (31.2% loss) (Table 26). It is important to note that the mean densities presented in Figure 89 and Table 26 are based on a four week average of the baseline and post-construction periods compared to the single survey during the impact assessment. As a result, visual differences presented in Figure 89 may not reflect the differences of the one week sample used for significance testing of mean densities between baseline and impact assessment surveys. No significant differences in mean coral density were measured at any channel-side locations between baseline and impact assessment surveys. The overall decline in mean coral density measured at eight of the nine middle reef sites are consistent with the evaluation of tagged colony data in which coral mortality was documented at all middle reef sites, largely due to the effects of the regional white-plague disease event.

Recruit corals, defined in this report as corals 3 cm in diameter and smaller, were only surveyed in the impact assessment survey. On the northern side of the middle reef habitat recruit density was 0.0 colonies/m^2 for both the R2N1-RR channel-side site and its paired control R2NC2-RR. R2N2-LR had 0.08 colonies/m^2 compared to its paired control site R2NC1-LR which had 0.22 colonies/m^2. Although R2N2-LR had slightly lower recruit density than its paired control, the second northern middle reef control (R2NC3-LR) had 0.07 recruit colonies/m^2 which is consistent with the channel-side site for the same habitat. On the southern side of the middle reef habitat, recruit density was lowest at the two control sites R2SC1-RR (0.03 colonies/m^2) and R2SC2-LR (0.02 colonies/m^2) when compared to the channel-side sites (R2S1-RR 0.13 colonies/m^2 and R2S2-LR 0.12 colonies/m^2. Since corals 3cm and smaller were not required for collection in surveys conducted prior to the impact assessment, it is impossible to determine if these densities are higher or lower than during pre-dredging surveys.

Table 30. Tukey post-hoc comparisons of mean coral density differences between baseline and impact assessment surveys for middle reef sites (superscripts indicate a significant difference between survey periods, NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
R2N1-RR	NS	(trend) Baseline > Impact Assessment
R2N2-LR	NS	(trend) Baseline > Impact Assessment
R2NC1-LR	NS	(trend) Baseline > Impact Assessment
R2NC2-RR	F=30.12, p=0.005	Baseline^A, Impact Assessment^B
R2NC3-LR	F=17.15, p=0.014	Baseline^A, Impact Assessment^B
R2S1-RR	NS	(trend) Baseline > Impact Assessment
R2S2-LR	NS	(trend) Baseline > Impact Assessment
R2SC1-RR	NS	(trend) Baseline > Impact Assessment
R2SC2-LR	F=12.71, p=0.023	Baseline^A, Impact Assessment^B

3.6.1.3 Outer Reef

The average scleractinian site density across outer reef sites ranged from 0.58 (R3NC1-LR) to 2.4 (R3SC3-SG) colonies/m^{2}during the impact assessment period (Table 31). All five surveyed outer reef sites showed a decline in mean coral density between baseline and impact assessment surveys. Scleractinian density data are reported from tagged and non-tagged scleractinian corals >3cm collected during baseline (4 weeks), post-construction (4 weeks), and impact assessment periods (1 week) within a one meter belt transect at each of three transects and are reported by site (Figure 90). It is important to note that in Figure 90 the error bars of the impact assessment surveys show the variability of the one week sample compared to the 4 week samples of the baseline and impact assessment surveys. The decline in coral density ranged from a 24% decline at R3SC2-LR (from 2.35 to 1.77 corals/m^2) to a 58% loss at R3NC1-LR where mean coral density declined from 1.24 corals/m^2 to 0.58 corals/m^2.

Table 31. Mean scleractinian density (with standard deviation and standard error) among eight outer reef sites across three permanent transects for baseline through impact assessment periods. Mean coral densities from the baseline and post-construction surveys are based on a 4 week sample and the impact assessment densities were calculated from a single sampling event. N/A sites were not part of the FDEP

required impact assessment protocol.

Site	Baseline			Post Construction			Impact Assessment		
	Avg	SD	SE	Avg	SD	SE	Avg	SD	SE
R3N1-LR	1.03	0.19	0.06	0.75	0.12	0.04	0.67	0.03	0.02
R3NC1-LR	1.24	0.24	0.10	1.32	0.19	0.06	0.58	0.06	0.03
R3S1-CP	1.07	0.19	0.06	0.93	0.35	0.10	N/A	N/A	N/A
R3S2-LR	1.76	0.30	0.10	1.53	0.44	0.13	1.27	0.55	0.32
R3S3-SG	1.27	0.46	0.15	1.43	0.38	0.11	N/A	N/A	N/A
R3SC1-CP	2.01	0.44	0.18	2.19	0.53	0.15	N/A	N/A	N/A
R3SC2-LR	2.35	0.62	0.25	2.84	0.67	0.19	1.77	0.33	0.19
R3SC3-SG	3.51	0.38	0.15	3.70	0.54	0.16	2.40	0.10	0.06

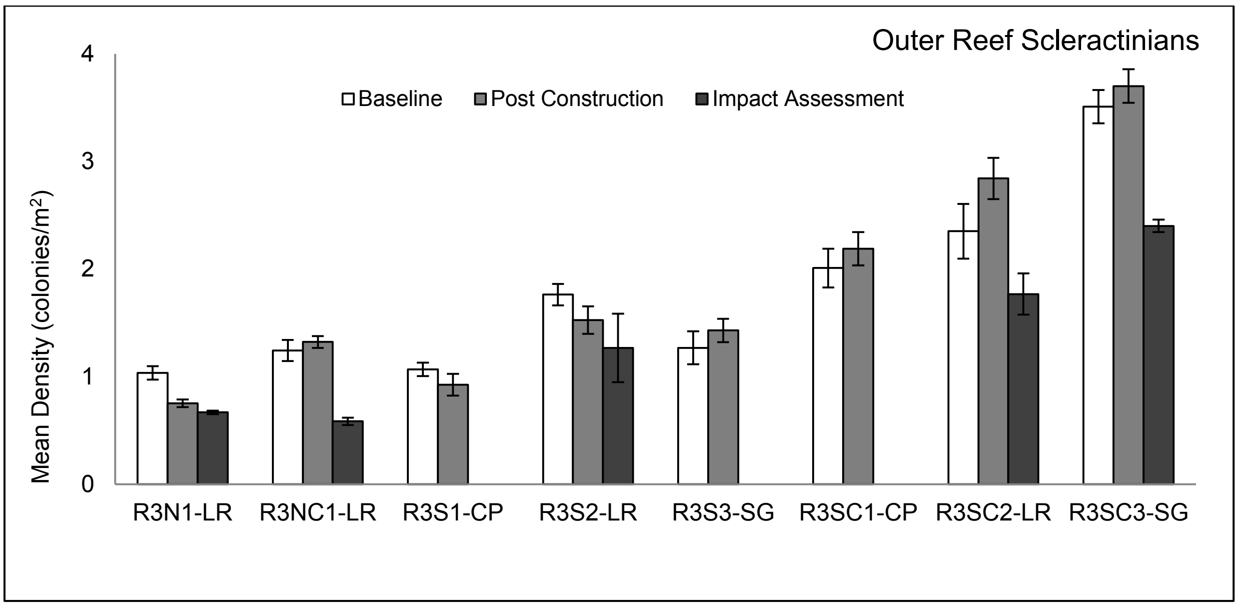


Figure 90. Mean density of scleractinian colonies at middle reef sites throughout baseline, post-construction, and impact assessment surveys. Error bars represent the standard error for each site. Mean coral densities from the baseline and post-construction surveys are based on 4 week sample and the impact assessment densities were calculated from a single sampling event.

For significance testing, a single week of density measurements from the baseline survey (Week 1) were compared to scleractinian density estimates from the impact assessment survey. Atwo-way repeated measures ANOVA was used to determine if the effect of survey period was the same across all outer reef sites when measured by mean coral density. Mean site densities were normally distributed (Anderson-Darling test, $p > 0.05$), in all cases. There was a significant interaction between site and time period ($F = 4.41$, $p = 0.026$) (Table 31) as well as between assessment periods ($F = 70.67$, $p = 0.000$), and between sites ($F = 28.56$, $p = 0.000$).

The finding of a significant interaction between site and time period indicates that the effect of time was not the same across all outer reef sites. Since there was a significant interaction between site and period, additional one-way ANOVAs were performed on both of the main factors, site and period. Significant differences were detected between outer reef sites during the impact assessment period (F = 70.67, *p*=0.000, Table 32). Mean coral density was significantly higher at R3SC3-SG than all other reef sites. Paired test sites R3N1-LR and R3NC1-LR and R3S2-LR and R3SC2-LR were not significantly different from each other but mean coral density was different between the paired groups (Table 33).

Mean density declined at all five outer reef sites (Figure 90). However, mean coral density was only significantly different at R3N1-LR, R3NC1-LR and R3SC3-SG between baseline and impact assessment surveys (Table 34). At R3N1-LR mean coral density declined 35%, from 1.03 colonies/m^2 to 0.67 colonies/m^2 compared to a 53% decline at the paired control site R3NC1-LR over the same time period (from 1.24 colonies/m^2 to 0.58 colonies/m^2). Although R3S2-LR had a slightly higher decline than its paired control (28.1% versus 24.8%) neither of these changes were significantly different over the time period (Table 24). As a result, there was no increased loss of coral density found at channel-side sites when compared with their paired control at the outer reef. These results coincide with the evaluation of tagged colony data in which significant coral mortality was documented at all outer reef sites, largely due to the effects of the regional white-plague disease event (Section 3.4).

The cause of change in mean coral density between baseline and impact assessment surveys cannot be determined for untagged corals but likely follows the patterns documented in the tagged coral samples in which white plague and concurrent diseases was the predominant cause of mortality in all surveyed reef types (Section 3.4).

Recruit corals, defined in this report as corals 3 cm in diameter and smaller, were only surveyed in the impact assessment survey. On the northern side of the outer reef habitat mean recruit density was 0.03 colonies/m^2 for R3N1-LR and 0.07 colonies/m^2 at R3NC1-LR. On the southern side of the outer reef, mean recruit density was 0.03 colonies/m^2 at R3N2-LR which was lower than at the outer reef control R3SC2-LR which had 0.18 colonies/m^2. The additional southern outer reef channel-side site R3SC3-SG had mean recruit density that was similar to channel-side values (0.03 colonies/m^2). Since corals 3cm and smaller were not required for collection in surveys conducted prior to the impact assessment, it is not possible to determine if these densities are higher or lower than during pre-dredging surveys.

Table 32. Two-way ANOVA results testing the effects of the two time periods, baseline and impact assessment (PERIOD), the effects of coral site locations (SITE), and the interaction between the two effects on scleractinian density among the five outer reef sites.

Source	DF	Mean Square	F Value	*P*
PERIOD	1	3.71008	70.67	0.000
SITE	4	5.37387	28.56	0.000
PERIOD*SITE	4	0.23154	4.41	0.026

Table 33. Tukey post-hoc comparisons of mean coral density differences between outer reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons		
	N	Mean	Grouping

Site	Tukey Pairwise Comparisons				
	N	Mean	Grouping		
R3SC3-SG	6	3.07	A		
R3SC2-LR	6	2.15		B	
R3S2-LR	6	1.52		B	
R3NC1-LR	6	0.86			C
R3N1-LR	6	0.83			C

Table 34. Tukey post-hoc comparisons of mean coral density differences between baseline and impact assessment surveys for outer reef sites (superscripts indicate a significant difference between survey periods,NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
R3N1-LR	F=10.00, p=0.034	$Baseline^{A}$, Impact $Assessment^{B}$
R3NC1-LR	F= 135.13, p = 0.000	$Baseline^{A}$, Impact $Assessment^{B}$
R3S2-LR	NS	(trend) Baseline>Impact assessment
R3SC2-LR	NS	(trend) Baseline>Impact assessment
R3SC3-SG	F= 53.34, p=0.002	$Baseline^{A}$, Impact $Assessment^{B}$

3.6.2 Scleractinian Colony Size

Maximum diameter data were collected for all scleractinian colonies greater than 3 cm along all transects at hardbottom, middle and outer reef sites during Week 1 of baseline, Week 3 of post-construction, and during impact assessment surveys. Size measurements were only collected for tagged colonies at HBS3-CP, HBS4-CR, and HBSC1-CP during baseline surveys so these sites were excluded from temporal size class comparisons. Scleractinian corals ranged from 3 cm to more than 35 cm. Overall, size class distributions did not shift between baseline and impact assessment surveys for either channel-side or control site locations (Figure 91). Corals in the size class of 6-15cm was the dominant size class for channel-side and control sites during both time periods.

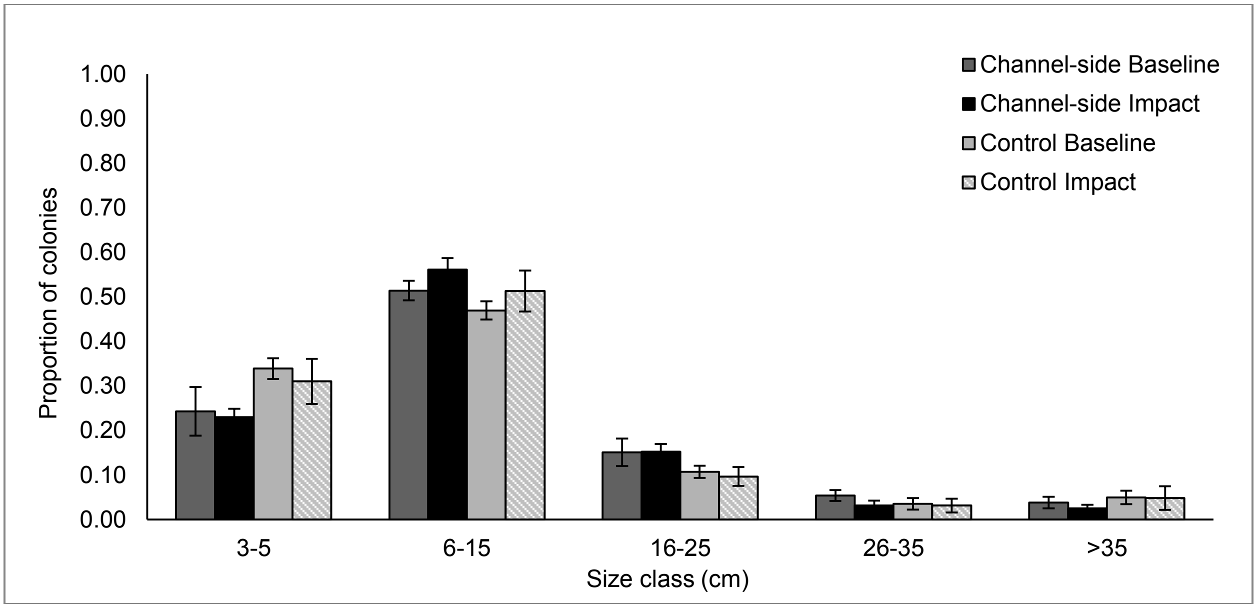


Figure 91. Mean proportion of scleractinian coral colonies by size class at all channel-side locations (except HBS3-CP and HBS4-CR) during baseline and impact assessment surveys and all control sites (except HBSC1-CP) during baseline and impact assessment surveys. Mean proportions ± one standard error are presented.

3.6.2.1 Hardbottom

The majority of scleractinian corals at northern hardbottom sites, including control sites were 15 cm or less in maximum diameter during baseline, post-construction, and impact assessment surveys. Throughout the three survey periods, HBNC1-CP had the greatest number of scleractinians in the smallest size class (3-5 cm) across the northern hardbottom sites. Unlike HBN3-CP, HBNC1-CP did not have any scleractinians larger than 25 cm in size during the baseline, post-construction, or impact assessment periods. Across the northern hardbottom sites, the group of corals in the smallest size class (3-5 cm) increased slightly between baseline and impact assessment surveys, while the corals within the 6-15 cm size class declined slightly between the baseline and impact assessment periods. The larger size classes (>16 cm) increased slightly (HBN3-CP) or did not change from baseline values. An explanation for the increase in small size class corals at northern hardbottom sites may be due to sampling timing. Baseline surveys were conducted in the fall/winter when northern hardbottom sites were under the influence of the natural sand wave which may have obscured or buried scleractinians that were exposed in post-construction and impact assessment surveys (summers of 2015 and 2016, respectively) (Figure 92-96).

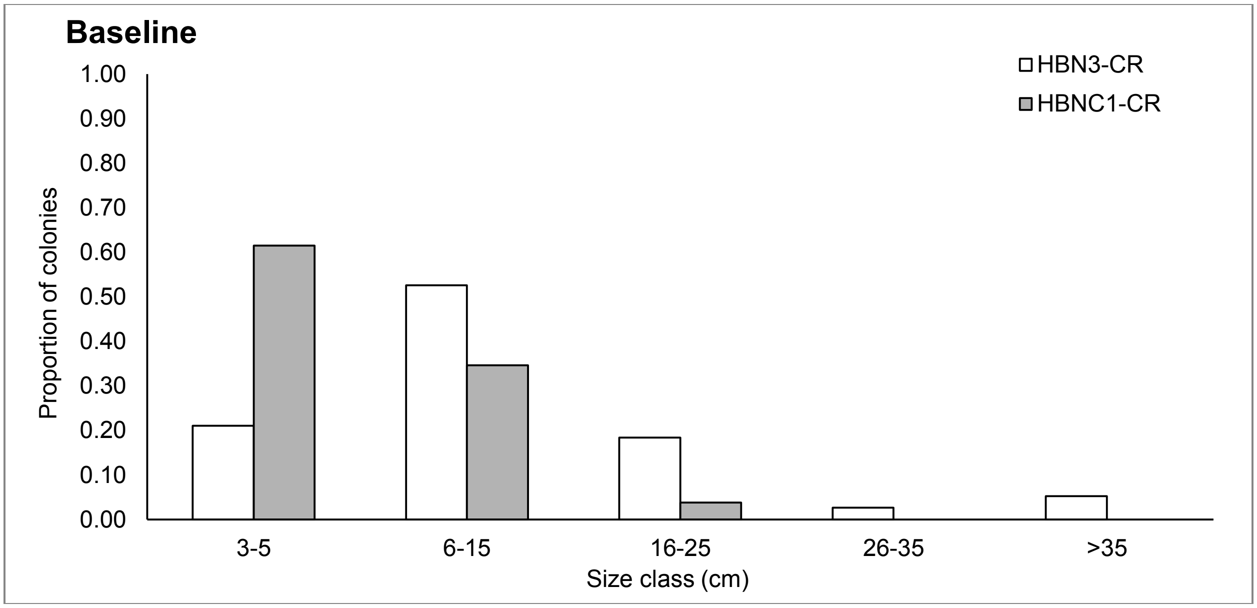


Figure 92 Proportion of scleractinian coral colonies by size class at northern hardbottom sites during baseline surveys.

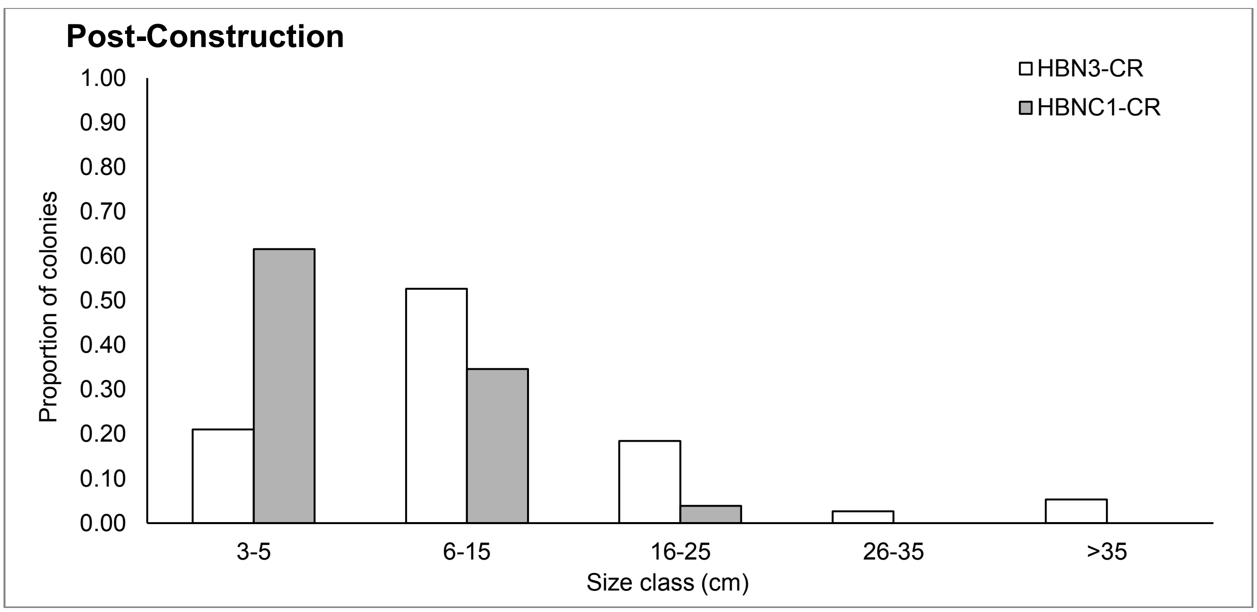


Figure 93. Proportion of scleractinian coral colonies by size class at northern hardbottom sites during post-construction surveys.

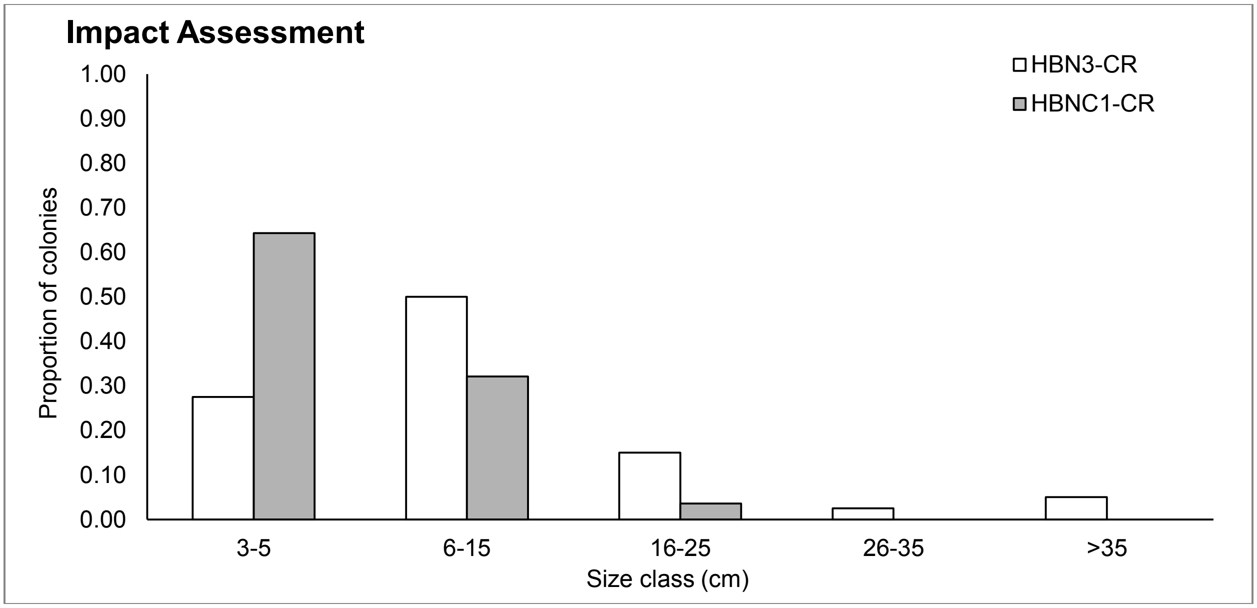


Figure 94. Proportion of scleractinian coral colonies by size class at northern hardbottom sites during impact assessment surveys.

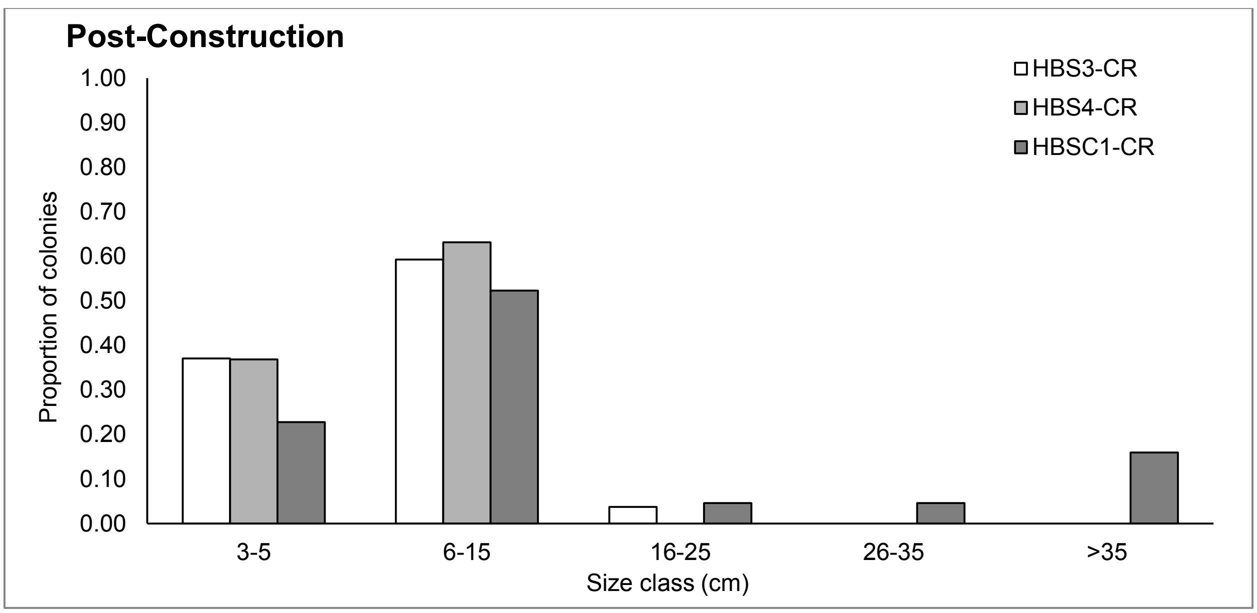


Figure 95. Proportion of scleractinian coral colonies by size class at southern hardbottom sites during post-construction surveys.

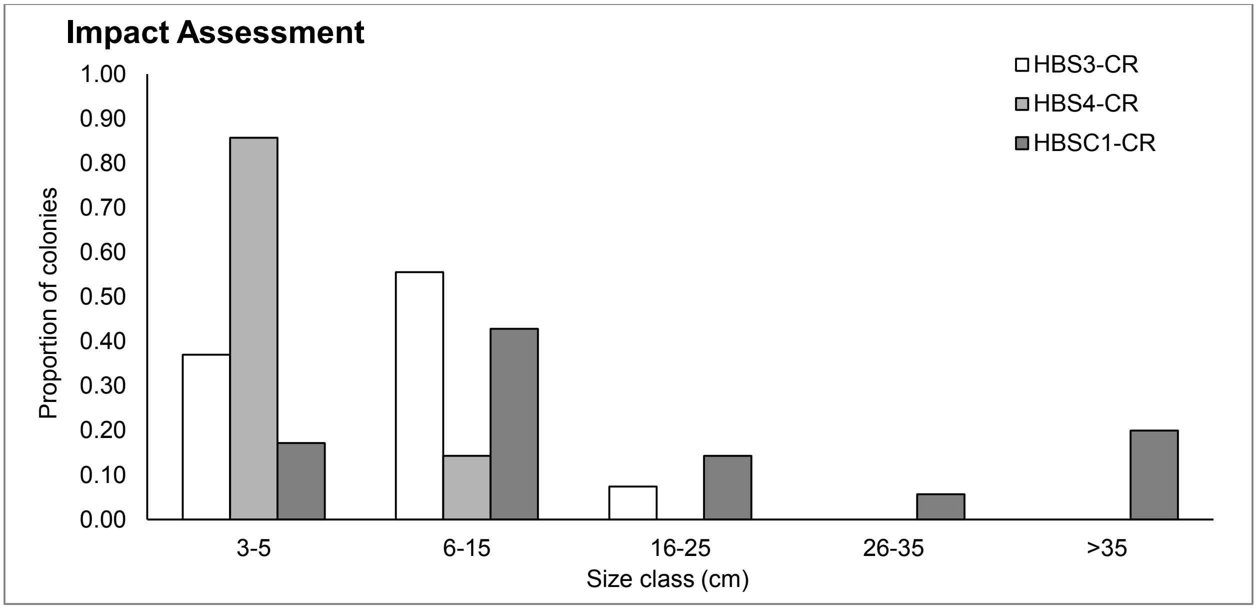


Figure 96. Proportion of scleractinian coral colonies by size class at southern hardbottom sites during impact assessment surveys.

Like the northern hardbottom sites, the majority of coral colonies at the southern hardbottom sites fell within the two smallest size classes, ranging from 3-15 cm in size. Coral size information was only collected for tagged coral colonies during baseline surveys at the southern hardbottom monitoring sites. As a result, size class data for southern hardbottom monitoring sites is only presented for post-construction and impact assessment time periods (Figure 95 and 96). Between the post-construction and impact assessment surveys, HBS4-CR displayed a shift in coral colony sizes, with a 49% increase in the abundance of scleractinians between 3-5 cm and a 49% decrease in colonies between 6-15 cm in size. The reason for the shift in coral colony size is related to the white-plague disease related mortality at this site. Between post-construction and impact assessment surveys, the number of tagged colonies that died at HBS4-CR increased from 13 to 21 coral colonies.

3.6.2.2 Middle Reef

Scleractinian colony size ranged from 3 cm to greater than 35 cm across the middle reef sites. Coral colony size-class data, presented as a proportion (total number of individuals within a size class/total number of colonies per site), revealed that the majority of coral colonies across the middle reef sites were between 6-15 cm in diameter, followed by the 3-5 cm size class (Figures 97-102) for baseline through impact assessment surveys. Between baseline and impact assessment surveys, the number of corals in the smallest size class (3-5 cm) decreased at all northern middle reef sites, ranging from a 1% (R2NC3-LR) to 22% (R2NC2-RR) reduction, while the number of corals between 16-25 cm in size increased across all northern middle reef sites by 1% (R2NC1-LR) to 12% (R2NC2-RR). All northern middle reef sites except R2N1-RR saw an increase in the proportion of scleractinians with a maximum diameter greater than 35 cm.

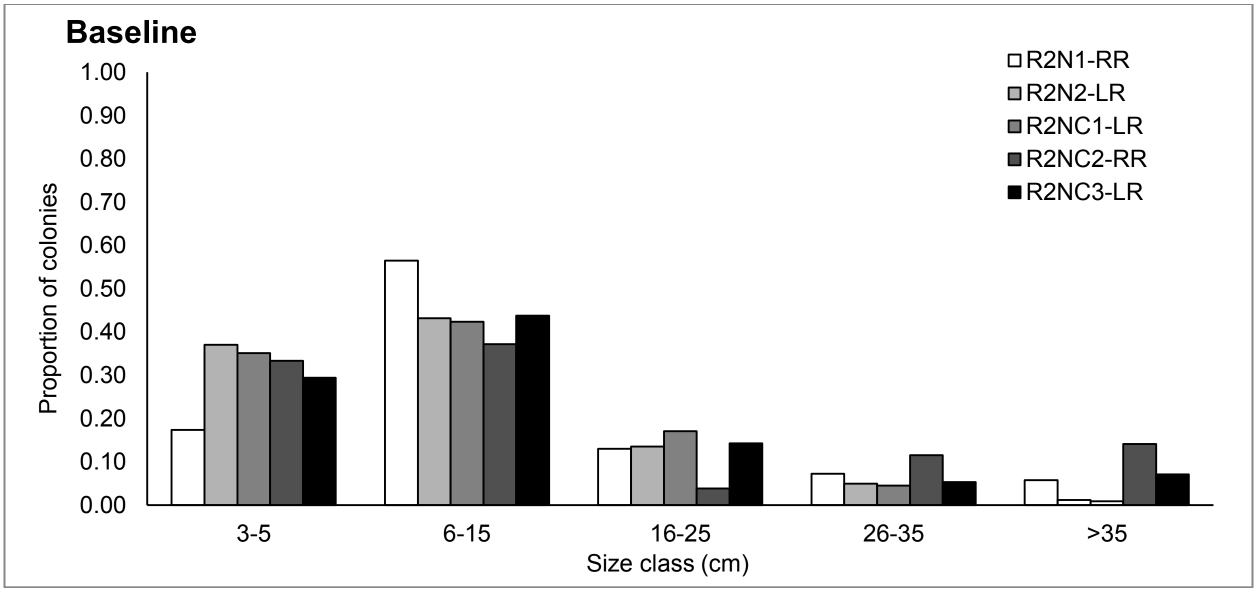


Figure 97. Proportion of scleractinian coral colonies by size class at northern middle reef sites during baseline surveys.

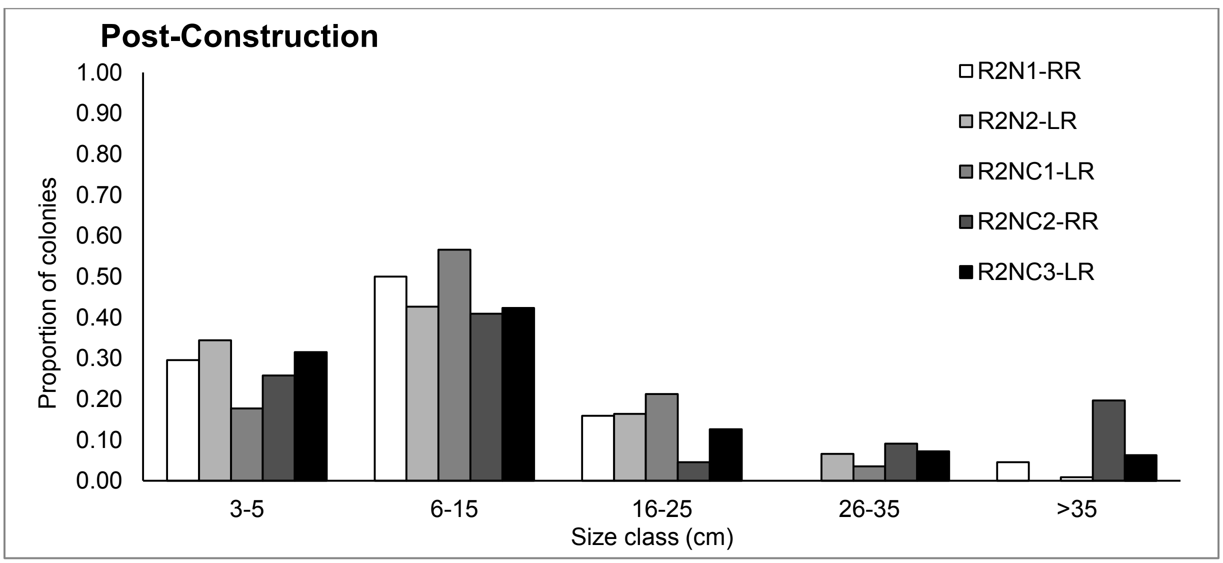


Figure 98. Proportion of scleractinian coral colonies by size class at northern middle reef sites during post-construction surveys.

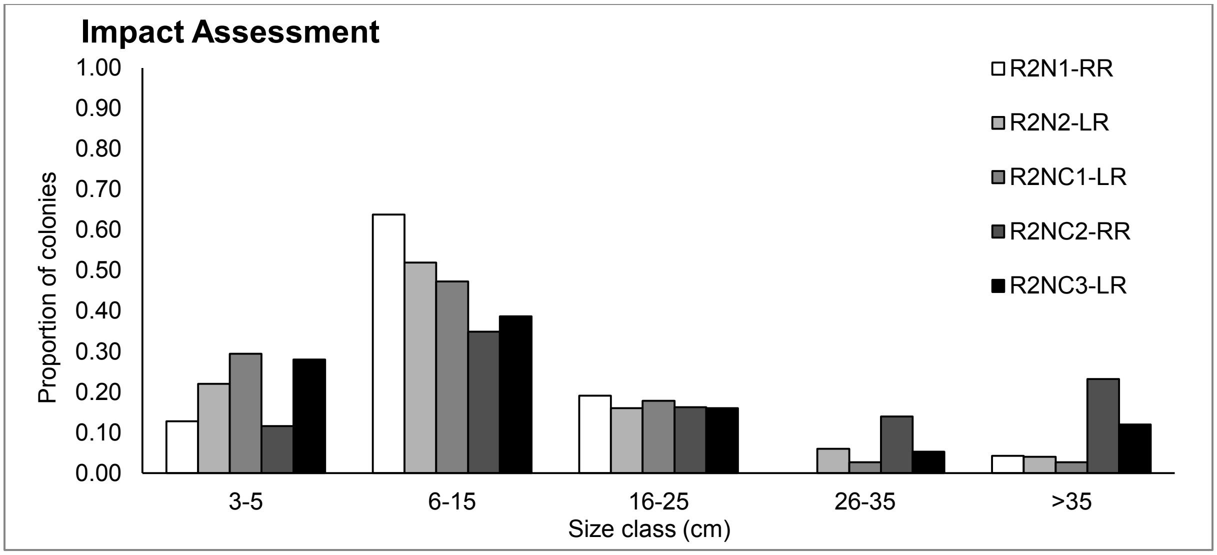


Figure 99. Proportion of scleractinian coral colonies by size class at northern middle reef sites during impact assessment surveys.

Different patterns were apparent between the southern middle reef sites throughout the three survey periods (Figures 100-102). At R2S1-RR, the smallest size class (3-5 cm) of corals increased from 0 to 26% between the baseline and impact assessment periods, while the abundance of scleractinians between 16-25 cm in size decreased by 23%. In contrast, the proportion of corals in the smallest size class declined at all other southern middle reef sites, ranging from a 1% (R2S2-LR) to 8% (R2SC1-RR) reduction. Between baseline and impact assessment surveys, the abundance of corals between 6-15 cm in size increased across all southern middle reef sites, while the number of corals in the largest size class (>35 cm) decreased.

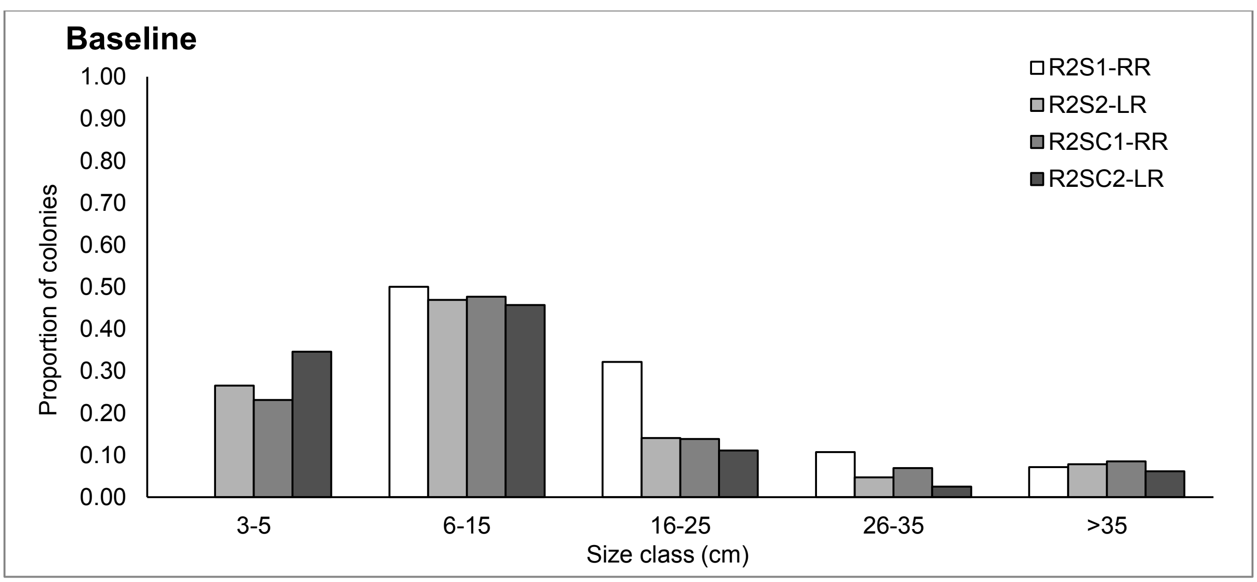


Figure 100. Proportion of scleractinian coral colonies by size class at southern middle reef sites during baseline surveys.

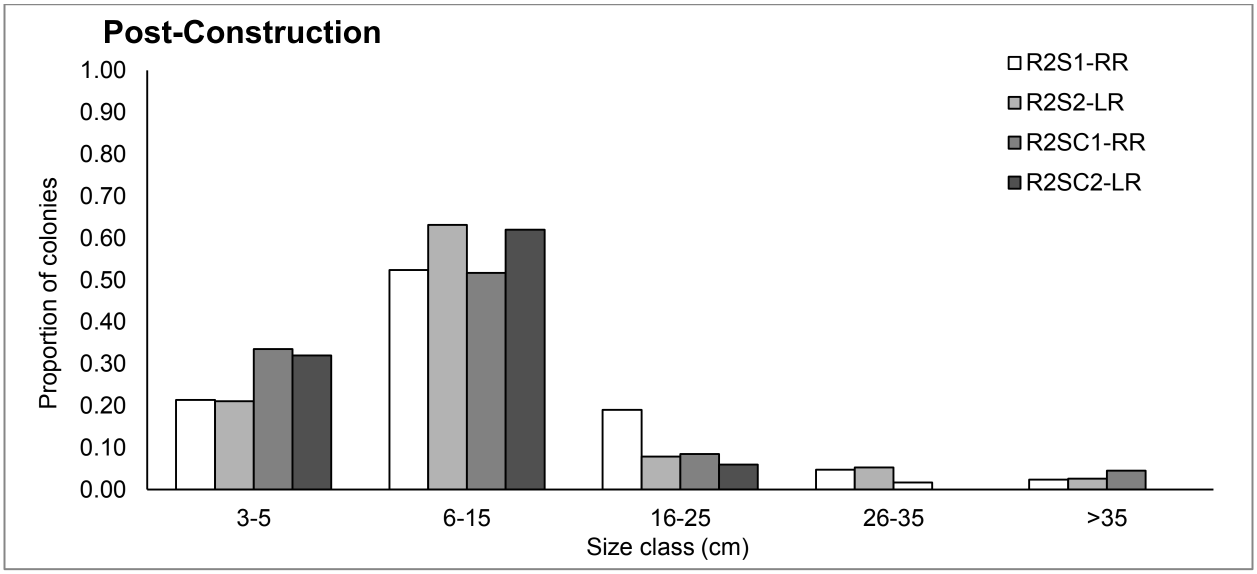


Figure 101. Proportion of scleractinian coral colonies by size class at southern middle reef sites during post-construction surveys.

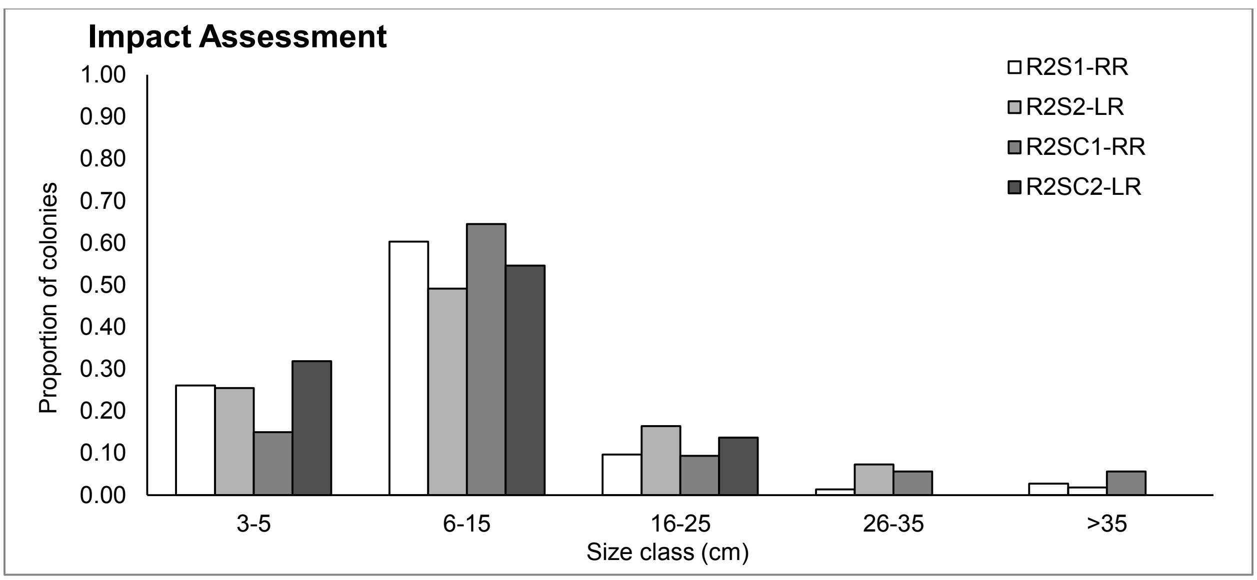


Figure 102. Proportion of scleractinian coral colonies by size class at southern middle reef sites during impact assessment surveys.

3.6.2.3 Outer Reef

Like the hardbottom and middle reef sites, northern outer reef sites had similar patterns of size class distribution between baseline and impact assessment surveys, with the greatest proportion of corals surveyed being grouped into the two smallest size classes, between 3 and 15 cm in maximum diameter (Figure 103-108). Between the baseline and impact assessment periods, the abundance of corals between 3 and 5 cm in size increased by 9% at R3N1-LR, but decreased by 9% at R3NC1-LR, while the number of corals in the middle size class (16-25 cm) increased by 11% at R3N1-LR, but decreased by 7% at R3NC1-LR.

During impact assessment surveys, the abundance of corals in the smallest size class group decreased across all southern outer reef sites, while the percentage of corals between 6 and 15 cm in size increased.

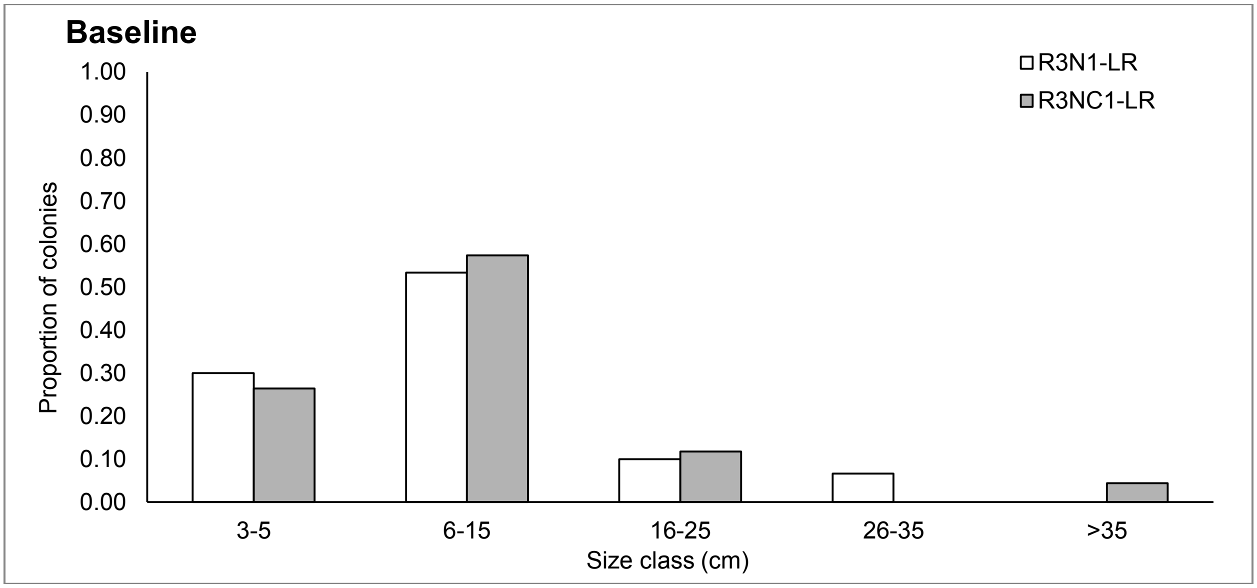


Figure 103. Proportion of scleractinian coral colonies by size class at northern outer reef sites during baseline surveys.

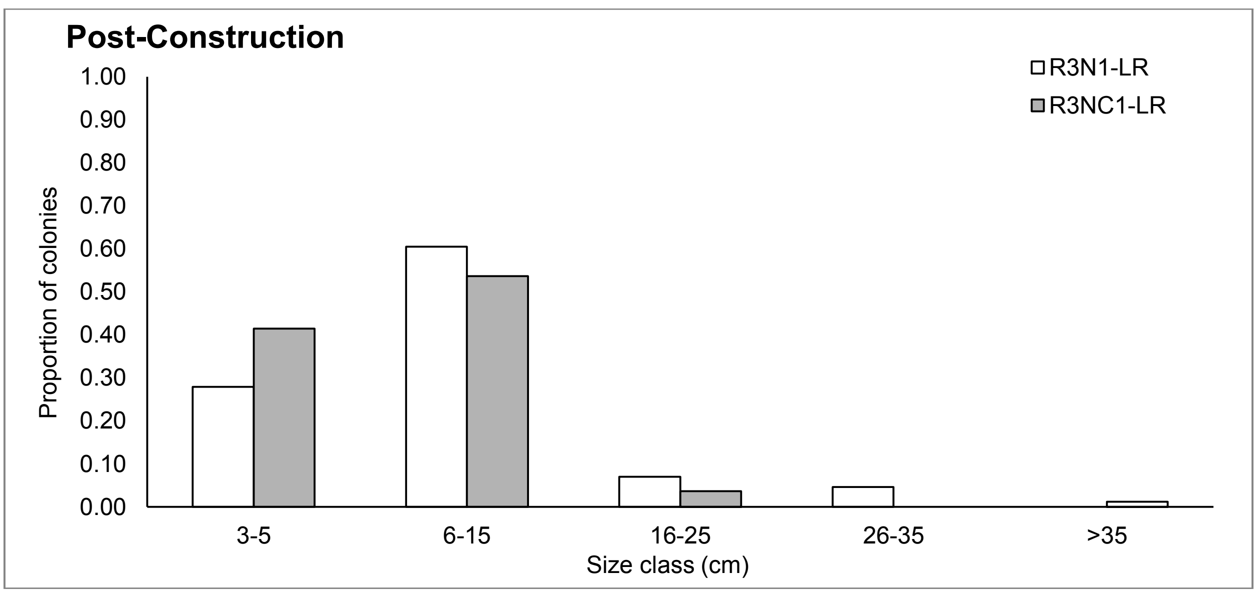


Figure 104. Proportion of scleractinian coral colonies by size class at northern outer reef sites during post-construction surveys.

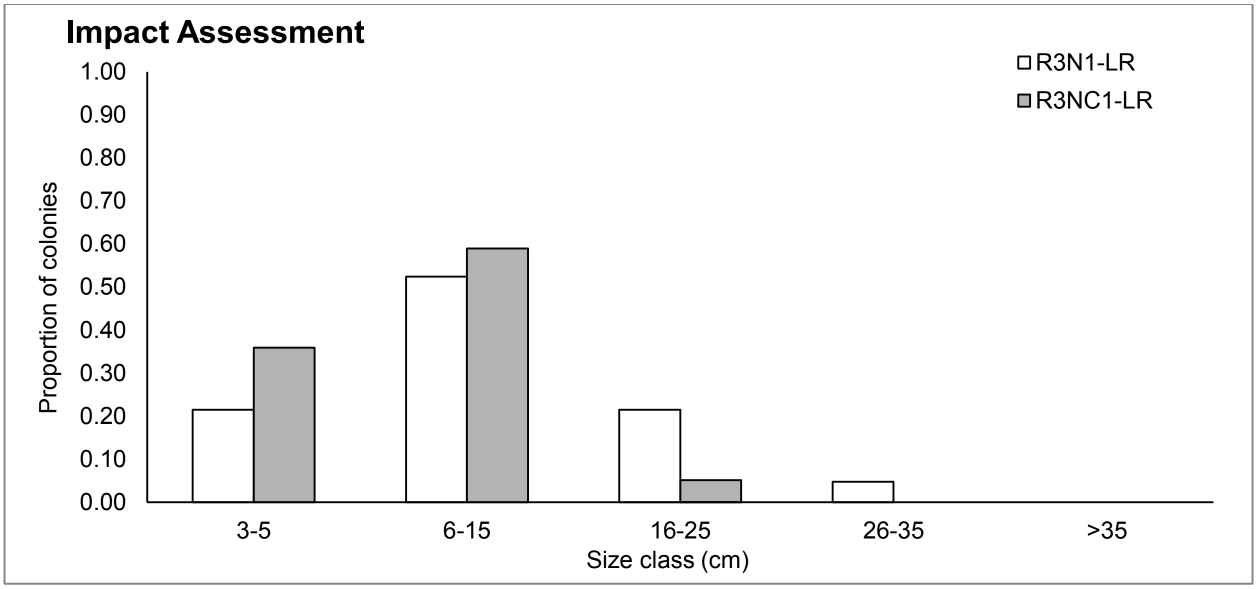


Figure 105. Proportion of scleractinian coral colonies by size class at northern outer reef sites during impact assessment surveys.

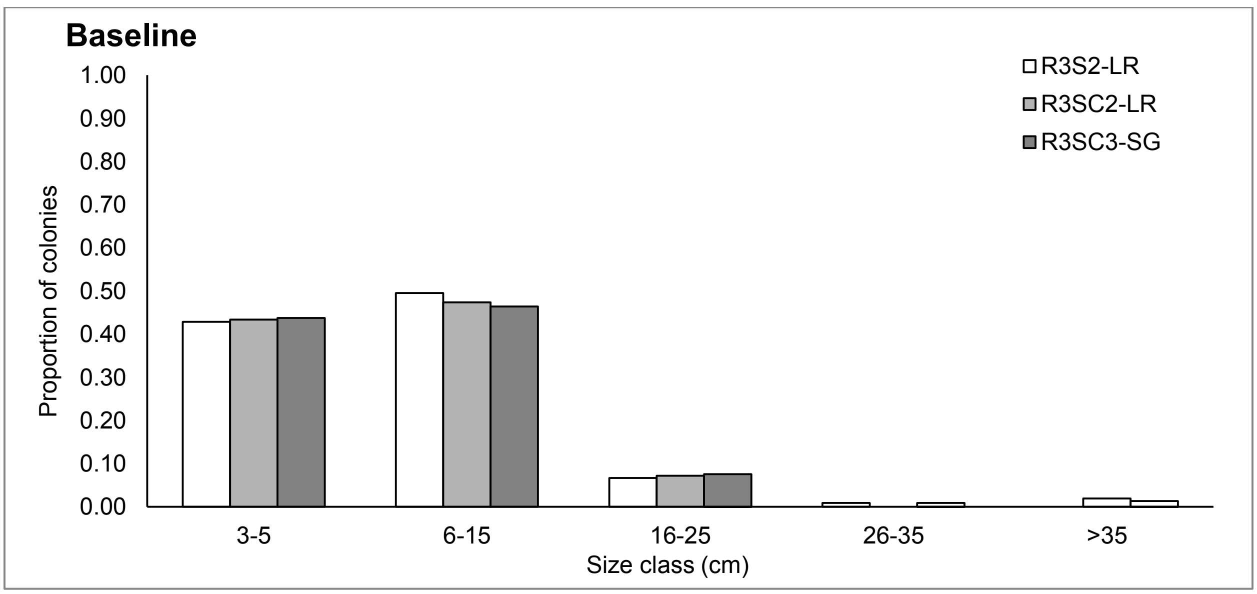


Figure 106. Proportion of scleractinian coral colonies by size class at southern outer reef sites during baseline surveys.

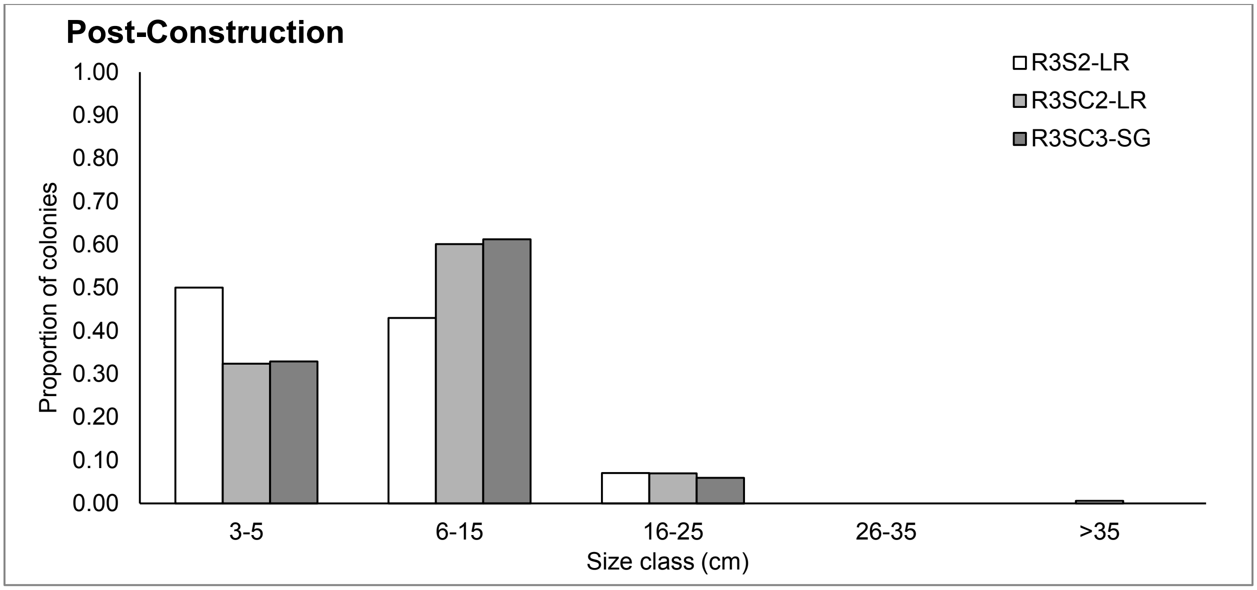


Figure 107. Proportion of scleractinian coral colonies by size class at southern outer reef sites during post-construction surveys.

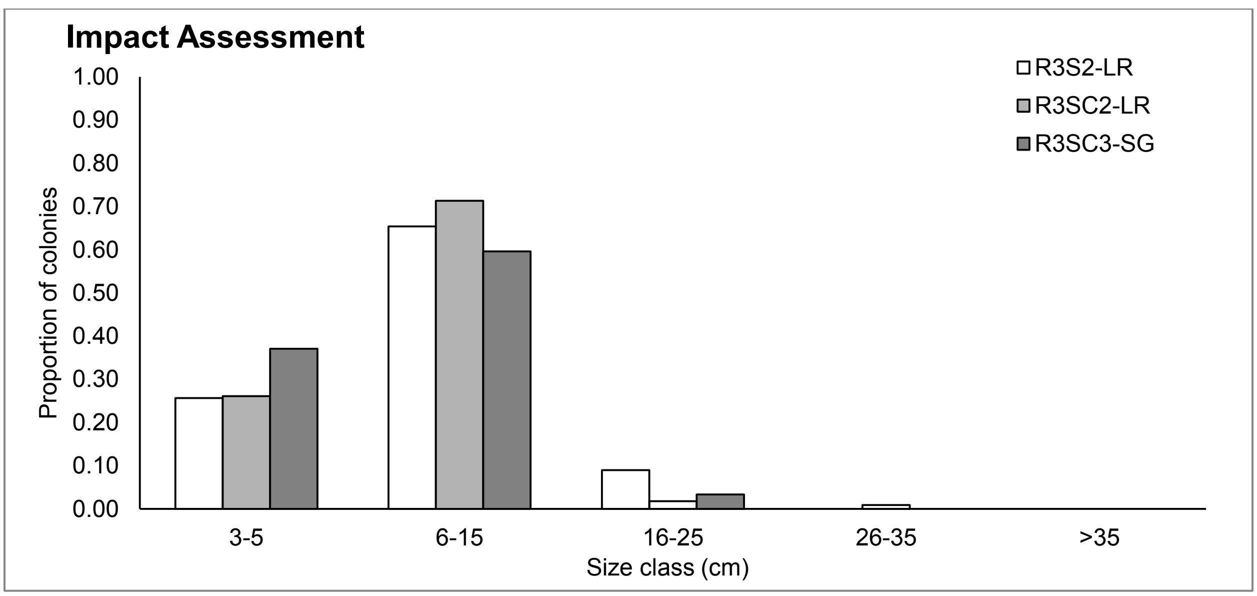


Figure 108. Proportion of scleractinian coral colonies by size class at southern outer reef sites during impact assessment surveys.

3.6.3 Total Scleractinian Condition

Condition was assessed on all tagged corals during baseline, post-construction, and impact assessment. Conditions included sediment and non-sediment related stress conditions. The mean proportion of stressed corals at each site is presented for all four weeks of baseline and post construction as well as the single impact assessment sample in Table 35, 37, and 39 for hardbottom, middle and outer reef habitats. Criteria defined in the FDEP permit, condition categories, and other stress conditions including sediment stress, bleaching, paling, diseases, fish bites, mucus production, disease, and extended polyps, are described in the methods section of this report (Table 4 in Methods). Although total mean scleractinian stress remained elevated above baseline levels in middle and outer reef habitats, levels of scleractinian sediment stress were at or below baseline levels for all surveyed channel-side sites (Table 35). As a result, no impact due to current levels of sedimentation was detected during impact assessment surveys.

The total stress of corals at each outer reef site is a cumulative assessment of all sediment stress, bleaching, competitive mortality, fish bites, disease, and several other factors. Since many of these factors are seasonal (particularly levels of coral bleaching), or were not present during baseline surveys (outbreak levels of disease), it is difficult to compare levels of coral stress that were not taken at the same time of year. To reduce the variability associated with this metric, levels of sediment stress only were also compared between baseline and impact assessment surveys. Sediment stress is defined as any coral showing signs of sediment accumulation (SA), partial burial due to sediment (PBUR), or burial (BUR) from sedimentation during each survey period.

3.6.3.1 Hardbottom

In the hardbottom community mean levels of scleractinian stress have declined to baseline or near baseline levels at three sites, HBN3-CP, HBNC1-CP, and HBS4-CR (Table 35). Both HBS3-CP and HBSC1-CP remained elevated from baseline levels, however mean scleractinian stress was higher at the hardbottom control than at the channel-side location (Mean condition score of HBS3-CP was 0.55 during impact assessment compared to mean condition score of 0.76 at HBSC1-CP)(Table 35).

The mean proportion of corals exhibiting sediment stress was equivalent to or below baseline values for all surveyed hardbottom sites (Table 36).

Table 35. Mean (and standard deviation) of colony condition score over four weeks of baseline and post construction sampling and during the one-time impact assessment sampling at selected hardbottom sites. For the post-construction and impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Post-construction		Impact Assessment	
	Mean	SD	Mean	SD	Mean	SD
HBN3-CP	0.42	0.14	0.92	0.05	0.4	0.17
HBNC1-CP	0.52	0.11	0.88	0.05	0.55	0.19
HBS3-CP	0.2	0.08	0.94	0.04	0.55	0.19
HBS4-CR	0.27	0.06	0.91	0.05	0.25	0.35
HBSC1-CP	0.33	0.1	0.78	0.1	0.76	0.16

Table 36. Mean (and standard deviation) of the proportion of coral colonies exhibiting sedimentation stress over four weeks of baseline and post construction sampling and during the one-time impact assessment sampling at selected hardbottom sites. Sediment stress is the combined proportion of corals with sediment accumulation, partial burial and burial during each survey period. For the post-construction and impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Impact Assessment	
	Mean	SD	Mean	SD
HBN3-CP	0.09	0.00	0.06	0.10
HBNC1-CP	0.02	0.04	0.00	0.00
HBS3-CP	0.00	0.00	0.00	0.00
HBS4-CR	0.01	0.02	0.00	0.00
HBSC1-CP	0.03	0.02	0.00	0.00

3.6.3.2 Middle Reef

In the middle reef community, mean levels of scleractinian stress have remained elevated above baseline values for all sites except R2N2-LR (Table 37). However, all middle reef channel-side sites with the exception of R2S1-RR have equivalent or lower levels of mean scleractinian condition than their paired control site. At R2S1-RR, mean scleractinian condition was 0.79 during impact assessment, whereas its paired control site R2SC1-RR had mean scleractinian condition of 0.60. The elevated levels of scleractinian condition at all middle reef sites is due to the continued presence of white plague disease and other diseases that were not present during baseline surveys combined with seasonal variability in coral condition.

Table 37. Mean (and standard deviation) of colony condition score over four weeks of baseline and post construction sampling and during the one-time impact assessment sampling at all middle-reef sites. For the post-construction and impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Post-construction		Impact Assessment	
	Mean	SD	Mean	SD	Mean	SD
R2N1-RR	0.53	0.02	0.83	0.38	0.72	0.25
R2N2-LR	0.44	0.03	0.75	0.44	0.44	0.19
R2NC1-LR	0.55	0.02	1.00	0.00	0.82	0.07
R2NC2-RR	0.35	0.04	0.89	0.31	0.72	0.05
R2NC3-LR	0.34	0.02	0.78	0.42	0.8	0.12
R2S1-RR	0.62	0.02	0.75	0.44	0.79	0.21
R2S2-LR	0.87	0.20	0.75	0.45	0.75	0.25
R2SC1-RR	0.42	0.02	0.82	0.39	0.6	0.13
R2SC2-LR	0.29	0.03	0.73	0.47	0.83	0.24

The mean proportion of corals exhibiting sedimentation stress during impact assessment surveys was below baseline levels for all channel-side sites (Table 38).

Table 38. Mean (and standard deviation) of the proportion of coral colonies exhibiting sedimentation stress over four weeks of baseline and during the one-time impact assessment sampling at selected middle reef sites. Sediment stress is the combined proportion of corals with sediment accumulation, partial burial and burial during each survey period. For the impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Impact Assessment	
	Mean	SD	Mean	SD
R2N1-RR	0.41	0.25	0.22	0.25
R2N2-LR	0.45	0.23	0.22	0.10
R2NC1-LR	0.04	0.04	0.12	0.13
R2NC2-RR	0.09	0.02	0.07	0.06
R2NC3-LR	0.03	0.03	0.10	0.09
R2S1-RR	0.20	0.16	0.16	0.03
R2S2-LR	0.63	0.28	0.17	0.29
R2SC1-RR	0.08	0.07	0.13	0.13
R2SC2-LR	0.07	0.04	0.00	0.00

3.6.3.3 Outer Reef

In the outer reef community, mean levels of scleractinian stress have remained elevated above baseline values for all sites (Table 39). R3N1-LR (0.83) had slightly higher mean coral condition values than its paired control R3NC1-LR (0.73) during the impact assessment surveys. R3S2-LR (0.84) had nearly equivalent levels of mean coral condition when compared to its paired control R3SC2-LR (0.86) during the impact assessment.

The mean proportion of corals exhibiting sedimentation stress during impact assessment surveys was below baseline levels for all outer-reef channel-side sites (Table 40).

Table 39. Mean (and standard deviation) of colony condition score over four weeks of baseline and post construction sampling and during the one-time impact assessment sampling at all middle-reef sites. For the post-construction and impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Post-construction		Impact Assessment	
	Mean	SD	Mean	SD	Mean	SD
R3N1-LR	0.65	0.09	0.65	0.09	0.83	0.15
R3NC1-LR	0.60	0.05	0.58	0.02	0.73	0.28
R3S2-LR	0.45	0.06	0.47	0.04	0.84	0.16
R3SC2-LR	0.45	0.05	0.43	0.02	0.86	0.15
R3SC3-SG	0.32	0.16	0.27	0.08	0.92	0.14

Table 40. Mean (and standard deviation) of the proportion of coral colonies exhibiting sedimentation stress over four weeks of baseline and impact assessment sampling at selected outer reef sites. Sediment stress is the combined proportion of corals with sediment accumulation, partial burial and burial during each survey period. For the impact assessment periods, mean proportion of stress is presented without missing or dead corals.

Site	Baseline		Impact Assessment	
	Mean	SD	Mean	SD
R3N1-LR	0.42	0.13	0.30	0.30
R3NC1-LR	0.10	0.15	0.13	0.23
R3S2-LR	0.19	0.14	0.16	0.01
R3SC2-LR	0.30	0.11	0.27	0.23
R3SC3-SG	0.15	0.09	0.26	0.07

3.7 Quantitative Benthic Sampling Comparison: Octocorals and Sponges

3.7.1 Octocoral Density

A two-way repeated measures ANOVA comparing octocoral densities between sites and over the survey period did not reveal any significant interaction of site and time at any of the three reef types. As a result, no significant project effects to octocoral density were detected between baseline and impact assessment surveys. Trends in mean octocoral density were consistent between channel-side and control sites of the same reef type. Mean density of octocorals declined in the hardbottom and middle reef habitat and increased at outer reef sites between baseline and impact assessment surveys (Table 41).

Table 41. Mean octocoral densities as measured at channel-side and control locations in hardbottom, middle, and outer reef types. Mean densities and standard error are provided for baseline and impact assessment (IA) time periods.

Site	**Channel-side**				**Controls**			
	Baseline		IA		Baseline		IA	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Hardbottom	5.88	0.29	5.63	0.33	14.88	1.47	14.52	1.21
Middle Reef	6.39	1.41	4.90	0.79	12.53	2.25	9.72	0.87
Outer Reef	2.33	1.41	3.86	1.12	6.15	0.60	7.06	0.37

3.7.1.1 Hardbottom

Overall octocoral density was lower channel-side (mean baseline density 5.88 octocorals/m^2) when compared to the control site locations (mean baseline density 14.88 octocorals/m^2)(Table 41). During baseline surveys there was also a general trend of lower octocoral densities at the four sites closest to the channel jetty (HBN1-CR, HBN2-CR, HBS1-CP, and HBS2-CP octocoral density ≤3.5 colonies/m^2 (Table 42). The decline in octocoral density closest to the channel jetty is possibly a function of stronger currents closer to the jetties. This trend was also noted for scleractinian corals.

Table 42. Mean octocoral density (with standard deviation and standard error) among nine hardbottom sites across three permanent transects. **N/A sites were not part of the FDEP required impact assessment protocol.**

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
HBN1-CR	0.0	0.0	0.00	0.0	0.0	0.00	N/A	N/A	N/A
HBN2-CR	0.2	0.1	0.07	0.2	0.1	0.06	N/A	N/A	N/A
HBN3-CP	2.2	0.6	0.34	1.8	0.2	0.10	1.60	0.28	0.16
HBNC1-CP	22.5	4.0	2.31	28.0	0.7	0.42	19.02	2.30	1.33
HBS1-CP	3.5	0.3	0.15	2.9	0.3	0.16	N/A	N/A	N/A
HBS2-CP	1.0	0.5	0.29	1.0	0.1	0.07	N/A	N/A	N/A
HBS3-CP	10.0	0.3	0.16	8.5	1.0	0.60	9.18	0.59	0.34
HBS4-CR	5.5	0.7	0.38	4.1	0.2	0.14	6.12	0.83	0.48
HBSC1-CP	7.2	1.1	0.62	9.6	1.6	0.94	10.02	1.90	1.10

A two-way repeated measures ANOVA was used to determine if mean octocoral density was different among the five surveyed hardbottom sites between the baseline and impact assessment periods. Data were collected one time for the baseline and impact assessment periods. Octocoral density data were normally distributed in all cases (Anderson-*Darling* $p>$ 0.05, in all cases). Significant effects among the sites were detected (F = 136.89,p= 0.000; Table 43) but no significant effect was detected based on time period (F = 0.645,p =0.674), or based on the interaction between period and site (F = 2.29,p = 0.131) (Table 44).

Table 43. Two-way ANOVA results testing the effects of the two assessment periods (baseline and impact assessment), the effects of octocoral locations, and the interaction between the two effects on the mean density of octocorals among the five hardbottom survey areas.

Source	DF	Mean Square	F Value	*P*
PERIOD	1	0.645	0.19	0.674
SITE	4	299.006	136.89	0.000
PERIOD*SITE	4	7.857	2.29	0.131

Table 44. Tukey post-hoc comparisons of mean coral density differences among middle reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons					
	N	Mean	Grouping			
HBNC1-CP	6	20.78	A			
HBS3-CP	6	9.57		B		
HBSC1-CP	6	8.63		B	C	
HBS4-CR	6	5.82			C	
HBN3-CP	6	1.88				D

Of the five hardbottom sites revisited during the impact assessment period, there was no significant difference between time periods with mean octocoral density at all five sites declining slightly from 9.5 octocorals/m^2 to 9.2 octocorals/m^2 from baseline to impact assessment period. Significant differences were detected between the sites during the impact assessment period due to differences in octocoral densities. Mean octocoral densities were significantly different at the site with the highest (HBNC1-CP) and lowest (HBN3-CP) octocoral density from the remaining four sites (Table 44). HBS3-CP and HBS4-CR were also significantly different from each other but not from the southern hardbottom control (HBSC1-CP) (Table 44). At hardbottom channel-side sites, octocoral density declined slightly at HBS3-CP (from 10.0 to 9.18 octocorals/m^2) and increased at HBN3-CP and HBS4-CR between baseline and impact assessment surveys. HBNC1-CP octocoral density declined from 22.5 to 19.02 octocorals/m^2 and HBSC1-CP increased from 7.2 to 10.02 octocorals/m^2 (Table 42, Figure 109).

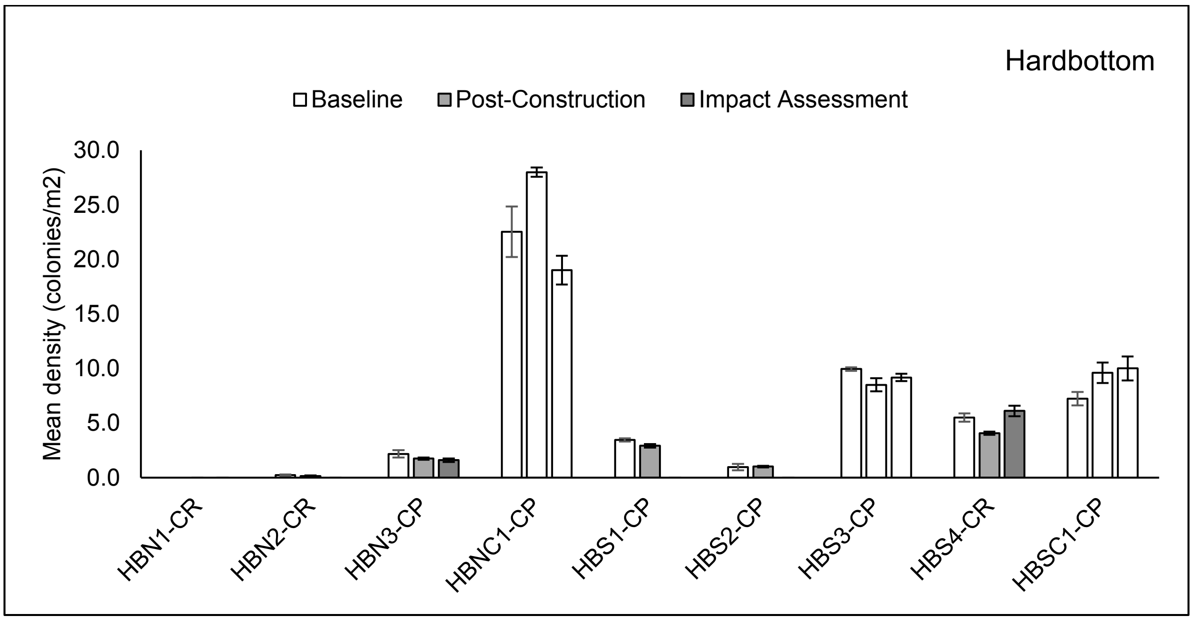


Figure 109. Mean density of octocoral colonies at nearshore hardbottom sites, collected in Week 1 of baseline, Week 3 of post-construction, and impact assessment surveys. Error bars represent the standard error.

3.7.1.2 Middle Reef

A two-way repeated measures ANOVA was used to determine if mean octocoral density was different among the nine middle reef sites between the baseline and impact assessment periods. Data were collected one time for the baseline and impact assessment periods (Table 45, Figure 110). Octocoral density data were normally distributed in all cases (Anderson-*Darling* p> 0.05). Significant effects among the sites were detected (F = 12.82,p= 0.000; Table 46) for time period (F = 7.04,p=0.016), but there was no significant interaction between period and site (F = 1.55,p = 0.208) (Table 46). Figure 110 shows the similarity in octocoral community at channel-side site R2N1-RR between baseline and impact assessment periods, demonstrating little change to these organisms at a channel-side location.

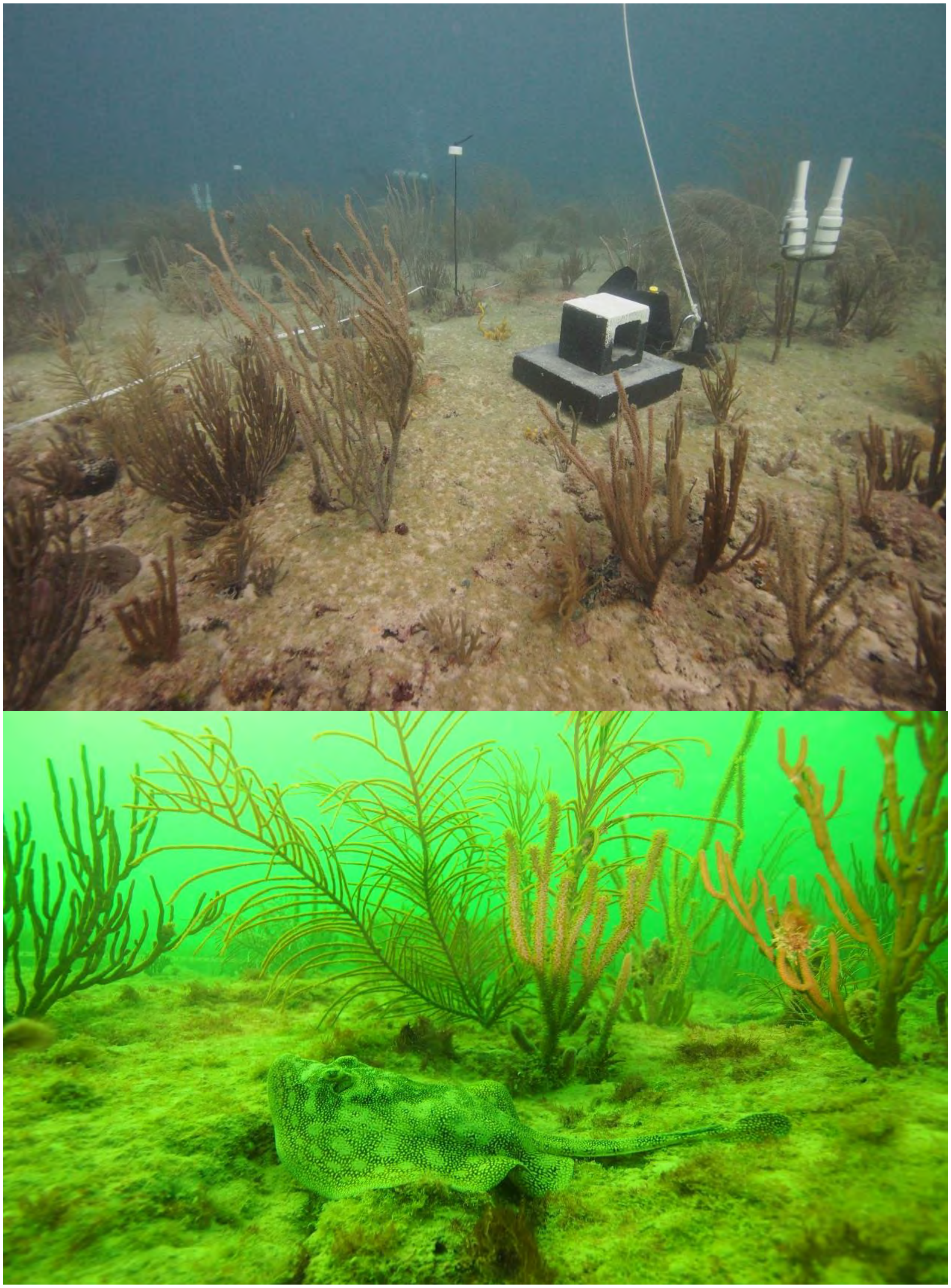


Figure 110. Baseline (top) and impact assessment (bottom) period photos at R2N1-RR show similar octocoral communities.

Seven of the nine sites (R2N1-RR, R2N2-LR, R2NC1-LR, R2NC2-RR, R2NC3-LR, R2S2-LR and R2SC2-LR) had declines in mean octocoral density (Table 45) compared to R2S1-RR and R2SC1-RR that showed increased octocoral density since baseline. At the middle reef, there was a significant effect of time period (Table 46). Mean octocoral density over all sites declined from 9.8 octocorals/m^2 to 7.6 octocorals/m^2. Since there was not a significant interaction between site and time period, the changes in density were not statistically significant at the surveyed sites over the time period. The large decline in octocoral density at R2NC2-RR between baseline and post-construction surveys was attributed to documented damage from lobster fishing during construction monitoring (Figure 111).

Table 45. Mean octocoral density (with standard deviation and standard error) among nine middle reef sites across three permanent transects.

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
R2N1-RR	11.6	1.88	1.09	9.95	0.72	0.42	8.02	0.53	0.30
R2N2-LR	1.83	1.03	0.59	1.72	0.98	0.57	0.95	0.52	0.30
R2NC1-LR	7.32	1.58	0.91	6.18	0.79	0.46	6.25	0.79	0.45
R2NC2-RR	25	9.42	5.44	15.22	0.86	0.5	15.35	3.31	1.91
R2NC3-LR	11.88	5.86	3.39	15.85	2.68	1.54	9.90	1.98	1.14
R2S1-RR	2.60	0.71	0.41	2.47	0.4	0.23	2.88	0.33	0.19
R2S2-LR	9.52	6.13	3.54	8.67	5.66	3.27	7.73	4.13	2.38
R2SC1-RR	7.08	0.37	0.21	10.48	1.35	0.78	8.33	1.17	0.68
R2SC2-LR	11.37	2.29	1.32	12.12	0.58	0.34	8.75	0.31	0.18

Table 46. Two-way repeated measures ANOVA results testing the effects of the two assessment periods (baseline and impact assessment), the effects of octocoral locations, and the interaction between the two effects on the mean density of octocorals among the five hardbottom survey areas.

Source	DF	Mean Square	F Value	Pr > F
PERIOD	1	67.00	7.04	0.016
SITE	8	174.754	12.82	0.000
PERIOD*SITE	8	14.784	1.55	0.208

Figure 111. Lobster long-line traps were documented to sheer and topple benthic organisms at control site on the northern middle reef. These effects may explain documented declines between baseline and impact assessment periods for octocorals and sponges at R2NC2-RR.

During the impact assessment period, mean octocoral density ranged from 0.95 colonies/m^2 (R2N2-LR) to 15.35 colonies/m^2 (R2NC2-RR) (Table 45). Significant differences were detected between the sites during the impact assessment period and Tukey post-hoc comparisons were performed to determine significant differences. During impact assessment surveys, R2NC2-RR was the middle reef site with the highest mean octocoral density (15.35 colonies/m^2), which was statistically different from all other middle reef sites (Table 47). R2N2-LR was the middle reef site with the lowest mean octocoral density, which was not significantly different from other low density sites (R2S1-RR, R2NC1-LR, and R2SC1-RR) but was significantly different from all other middle reef sites (Table 47, Figure 112).

Table 47. Tukey post-hoc comparisons of mean coral density differences among middle reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons					
	N	Mean	Grouping			
R2NC2-RR	6	20.17	A			
R2NC3-LR	6	10.89		B		
R2SC2-LR	6	10.06		B		
R2N1-RR	6	9.81		B		
R2S2-LR	6	8.63		B	C	
R2SC1-RR	6	7.71		B	C	D
R2NC1-LR	6	6.78		B	C	D
R2S1-RR	6	2.74			C	D
R2N2-LR	6	1.40				D

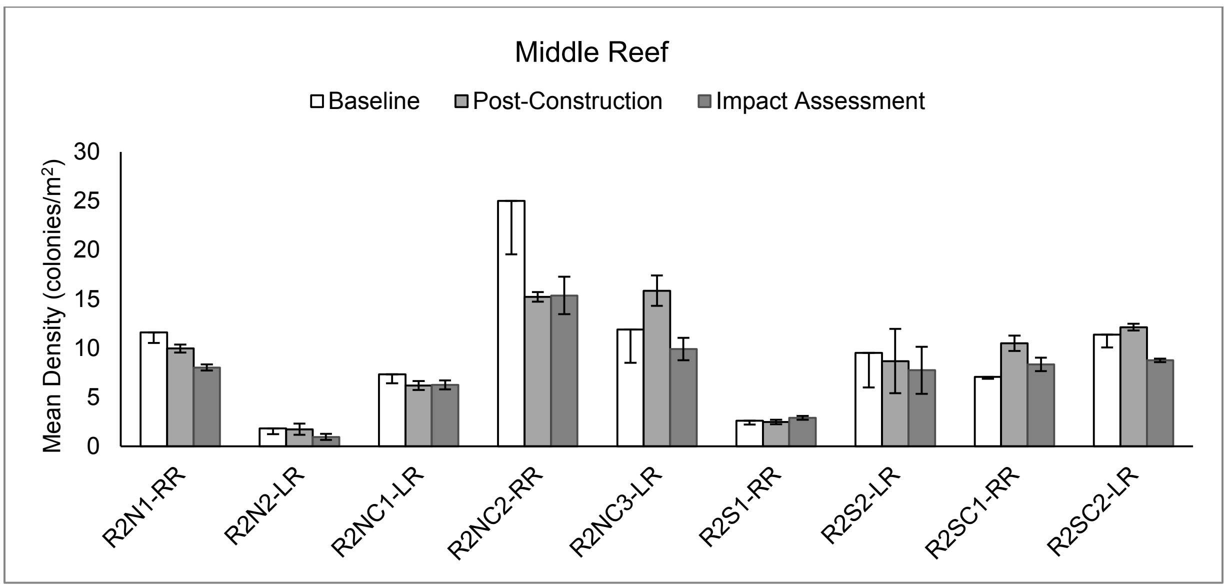


Figure 112. Mean density of octocoral colonies at middle reef sites documented in Week 1 of baseline, Week 3 of post-construction, and during impact assessment surveys. Error bars represent the standard error.

3.7.1.3 Outer Reef

A two-way repeated measures ANOVA was used to determine if mean octocoral density was different among the five outer reef sites between the baseline and impact assessment periods. Data were collected one time for the baseline and impact assessment periods (Table 48, Figure 113. Octocoral density data were normally distributed in all cases (Anderson-*Darling p*> 0.05). Significant effects among the sites were detected (F = 17.51,*p*= 0.000; Table 49) and over the time period (F = 11.21, *p*= 0.007), but there was no significant interaction between period and site (F = 3.27,*p* = 0.108) (Table 49).

Table 48. Mean octocoral density (with standard deviation and standard error) among eight outer reef sites across three permanent transects. **N/A sites were not part of the FDEP required impact assessment protocol.**

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
R3N1-LR	1.98	0.25	0.15	1.72	0.38	0.22	2.38	1.57	0.91
R3NC1-LR	5.9	0.65	0.38	9.48	1.4	0.81	8.30	0.53	0.30
R3S1-CP	1.4	0.09	0.05	1.52	0.54	0.31	N/A	N/A	N/A
R3S2-LR	2.67	0.57	0.33	3.27	0.9	0.52	5.33	2.30	1.33
R3S3-SG	3.05	0.8	0.46	3.38	0.81	0.47	N/A	N/A	N/A
R3SC1-CP	3.67	1.03	0.59	4.63	1.02	0.59	N/A	N/A	N/A
R3SC2-LR	4.65	1.26	0.73	5.68	1.09	0.63	5.68	0.57	0.33
R3SC3-SG	7.9	1.21	0.7	8.55	0.85	0.49	7.20	0.83	0.48

Table 49. Two-way ANOVA results testing the effects of the two assessment periods (baseline and impact assessment), the effects of octocoral locations, and the interaction between the two effects on the mean density of octocorals among the five outer reef survey areas.

Source	DF	Mean Square	F Value	Pr > F
PERIOD	1	10.0920	11.21	0.007
SITE	4	29.5108	17.51	0.000
PERIOD*SITE	4	2.9478	3.27	0.108

At the outer reef, there was a significant effect of time period (Table 49). Mean octocoral density over all outer reef sites increased from 4.62 octocorals/m^2 to 5.78octocorals/m^2. Since there was not a significant interaction between site and time period, the changes in density were not statistically significant at the surveyed sites over the time period. Four of the five outer reef sites (R3N1-LR, R3NC2, R3S2-LR, and R3SC2-LR) increased in mean octocoral density (Table 48) compared to R3SC3-SG that slightly declined from baseline surveys.

During the impact assessment period, mean octocoral density ranged from 2.38 colonies/m^2 (R3N1-LR) to 8.3 colonies/m^2 (R3NC1-LR) (Table 48). Significant differences were detected between the sites during the impact assessment period and Tukey post-hoc comparisons were performed to determine the relationships. The outer reef sites with the highest mean octocoral density during the impact assessment, R3SC3-SG, (7.5octocorals/m^2) and R3NC1-LR (7.1 octocorals/m^2) were statistically different than all other middle reef sites (Table 49). R3N1-LR had the lowest mean octocoral density among outer reef sites (2.38 octocorals/m^2) and was significantly different from other low density sites (R3S2-LR, and R3SC2-LR) (Table 50, Figure 113). Mean octocoral densities between R3SC2-LR and R3S2-LR were not significantly different.

Table 50. Tukey post-hoc comparisons of mean coral density differences among middle reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons				
	N	Mean	Grouping		
R3SC3-SG	6	7.50	A		
R3NC1-LR	6	7.10	A		
R3SC2-LR	6	5.17		B	
R3S2-LR	6	4.00		B	
R3N1-LR	6	2.18			C

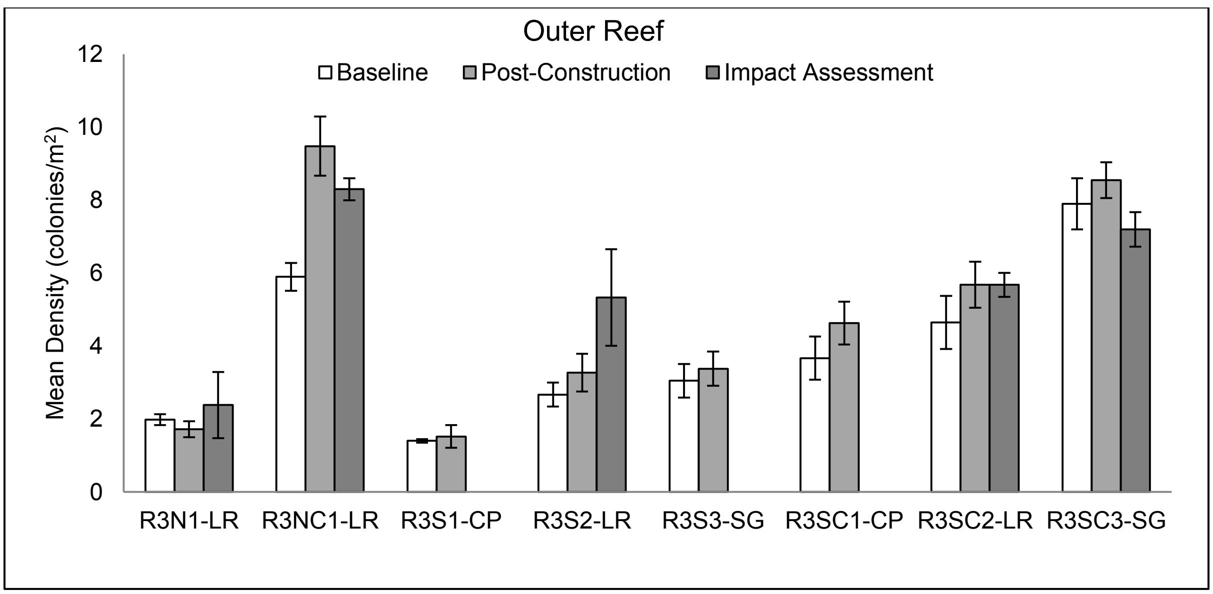


Figure 113. Mean density of octocoral colonies at outer reef sites documented in Week 1 of baseline, Week 3 of post-construction, and during impact assessment surveys. Error bars represent the standard error.

3.7.2 Octocoral Colony Size

Maximum diameter data were collected for all octocorals along all transects at middle and outer reef sites during Week 1 of baseline, Week 3 of post-construction, and impact assessment, as well as at hardbottom sites during the impact assessment period. Maximum diameter was defined as the maximum linear extent of a colony (cm), height for erect or branching varieties, or diameter for encrusting varieties. Overall, the proportion of colonies in each size class shifted slightly between baseline and impact assessment surveys. Octocorals in the smallest size class (3-5cm) declined slightly and octocorals in the 21-35cm size class increased between baseline and impact assessment periods. The shift in octocoral size distribution was observed for both channel-side and at control locations (Figure 114). Since the changes in size distribution were the same at channel-side and control locations, the differences noted in octocoral size distribution are not attributable to project effects.

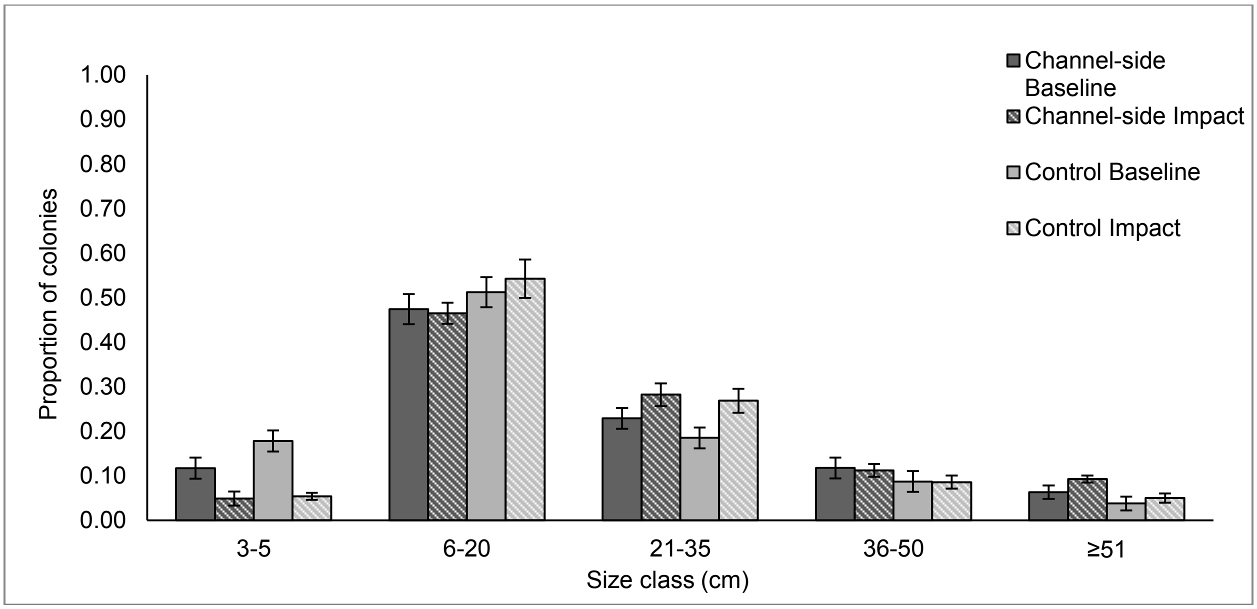


Figure 114. Mean proportion of octocoral colonies by size class at all channel-side locations during baseline and impact assessment surveys and all control sites during baseline and impact assessment surveys. Mean proportions ± one standard error are presented.

3.7.2.1 Hardbottom

Maximum diameter data were collected for all octocorals along all transects at hardbottom sites during impact assessment surveys. These data were not collected during baseline surveys so temporal comparisons for hardbottom sites were not possible. Size class distribution varied by site, but generally octocorals from 6-35 cm were the predominant size octocorals across hardbottom channel-side and control sites (Figures 115 and116). The least number of octocorals fell into the smallest size class (3-5 cm) across both channel-side and control sites.

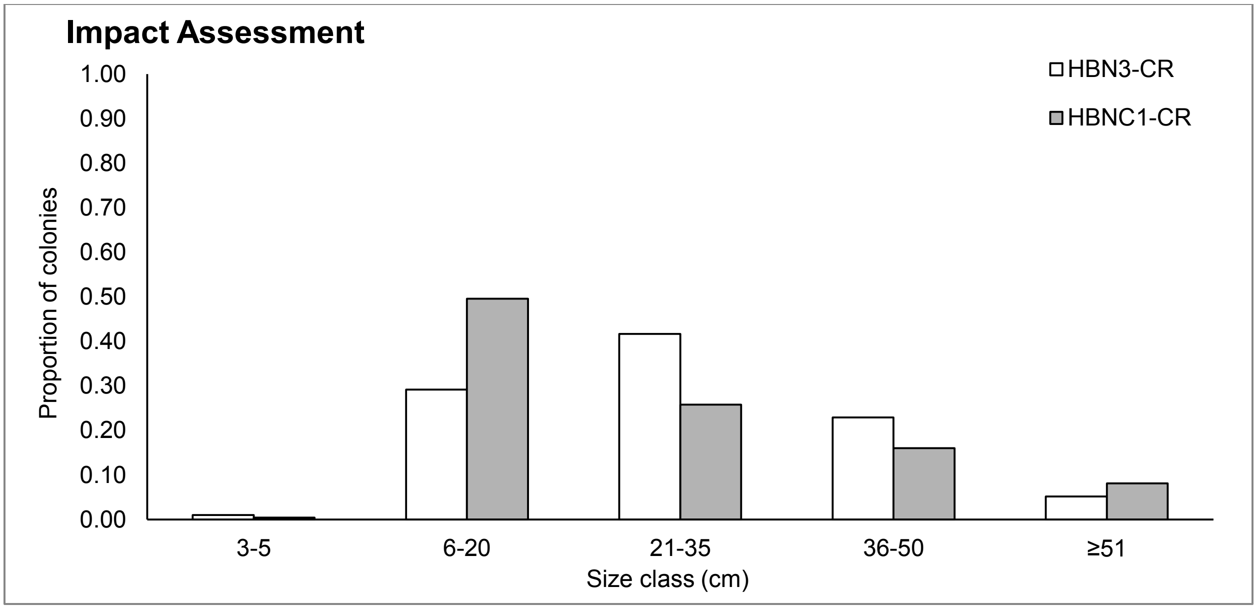


Figure 115. Proportion of octocoral colonies by size class for northern hardbottom sites during impact assessment surveys.

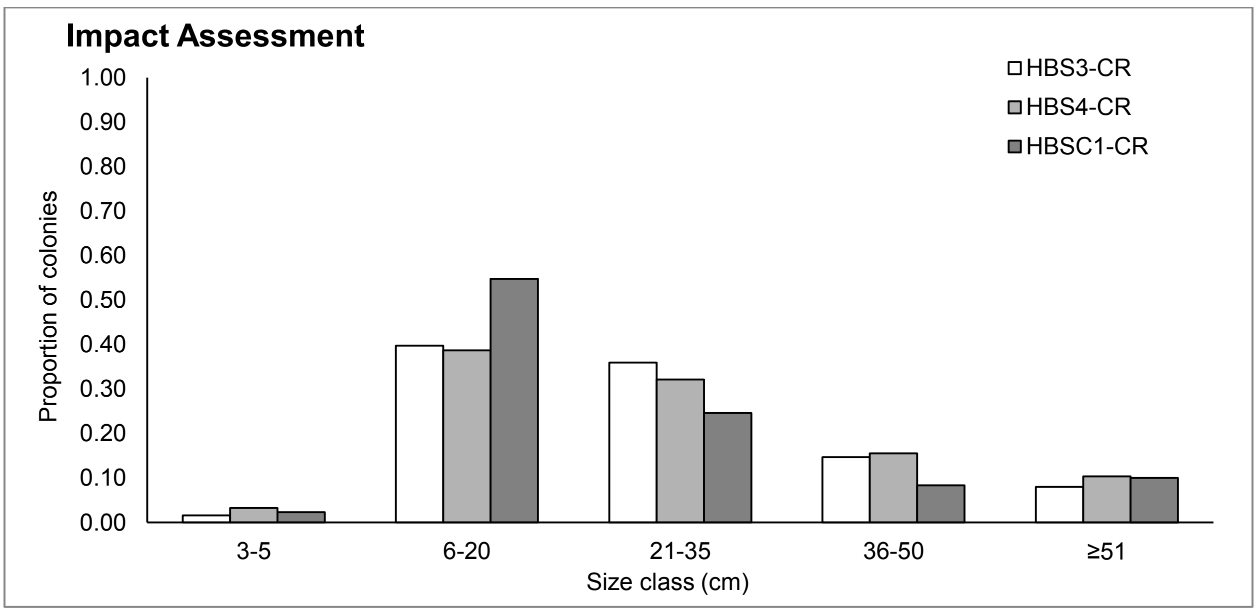


Figure 116. ***Proportion of octocoral colonies by size class for southern hardbottom sites during impact assessment surveys.***

3.7.2.2 Middle Reef

Throughout the three survey periods, the majority of octocorals observed at the northern middle reef control and channel-side sites fell into the 6 - 20 cm size class, accounting for 48% to 72% of octocorals during baseline, 47% to 66% during post-construction, and 43 to 68% during the impact assessment period. Compared to the other northern middle reef sites, R2N1-RR had fewer small octocorals (3-5 cm) and a greater abundance of larger octocorals (>21 cm) from baseline through post-construction surveys. During impact assessment surveys, 43% to 46% of octocorals at northern middle reef channel-side sites and 61% to 68% of octocorals from the corresponding control sites were grouped into the 6-20 cm size class. At the northern middle reef sites, 16% to 31% of the octocorals documented ranged from 21-35 cm and only 1% to 16% of the observed octocorals were 3-5 cm or greater than 35 cm in size (Figures 117-119).

From baseline to impact assessment periods, the majority (43% to 60%) of octocorals surveyed at the southern middle reef control and channel-side sites fell into the 6-20 cm size class. About 17% to 35% of octocorals measured between 21-35 cm, and only 3% to 14% were 3-5 cm or larger than 35 cm in size (Figures 120-122).

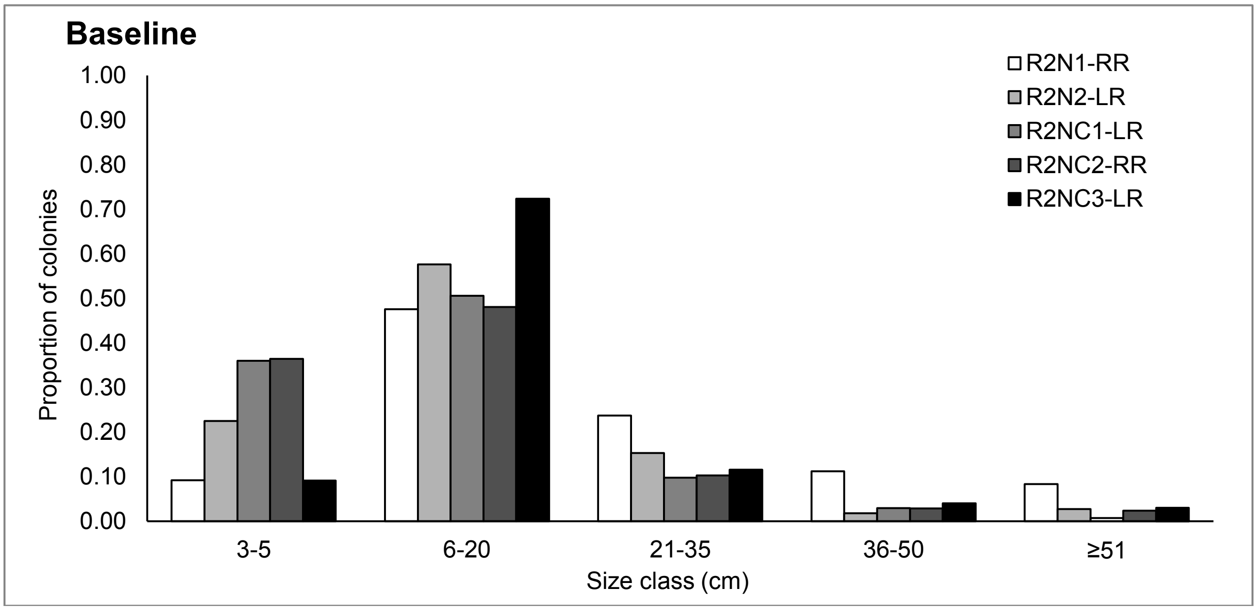


Figure 117. Proportion of octocoral colonies by size class for northern middle reef sites during baseline surveys.

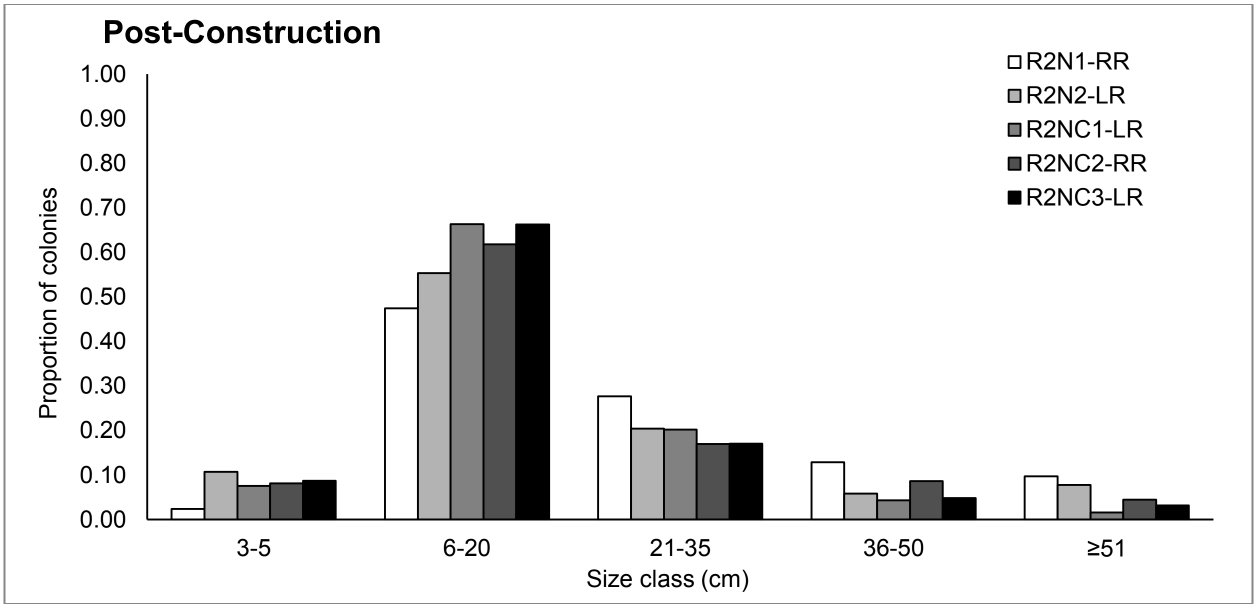


Figure 118. Proportion of octocoral colonies by size class for northern middle reef sites during post-construction surveys.

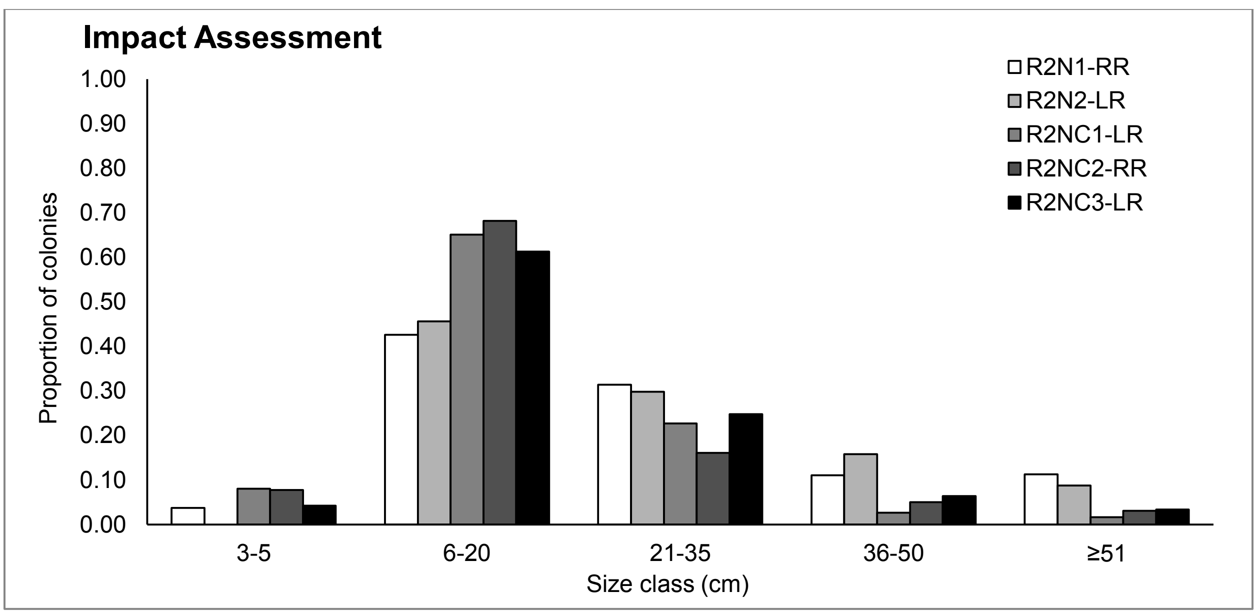


Figure 119. Proportion of octocoral colonies by size class for northern middle reef sites during impact assessment surveys.

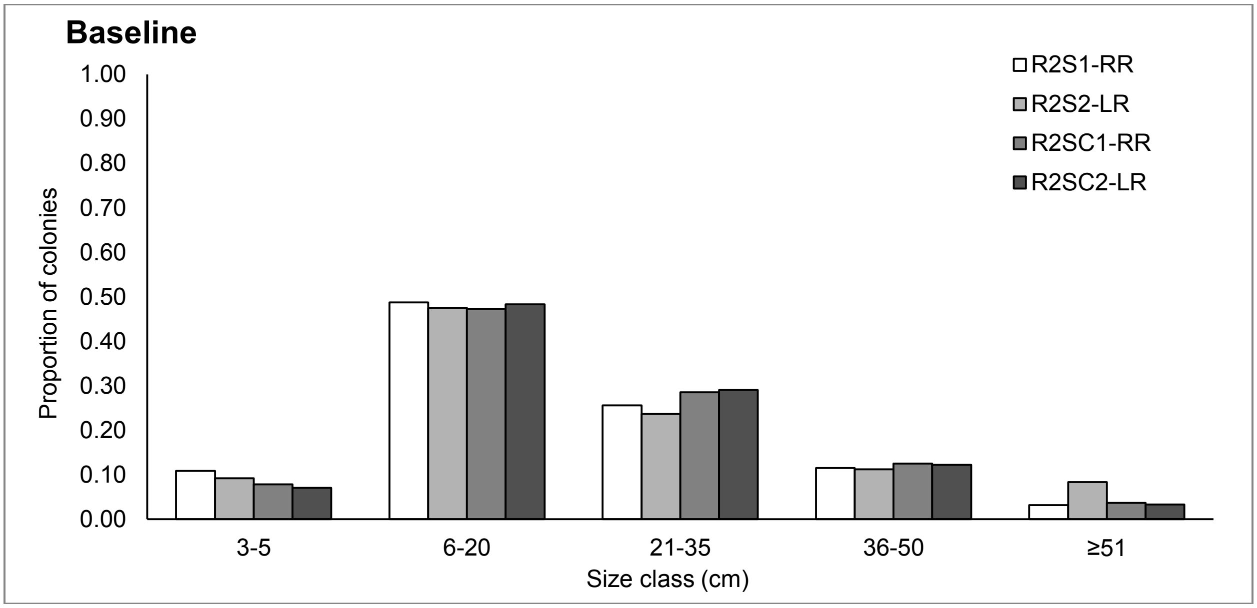


Figure 120. Proportion of octocoral colonies by size class for southern middle reef sites during baseline surveys.

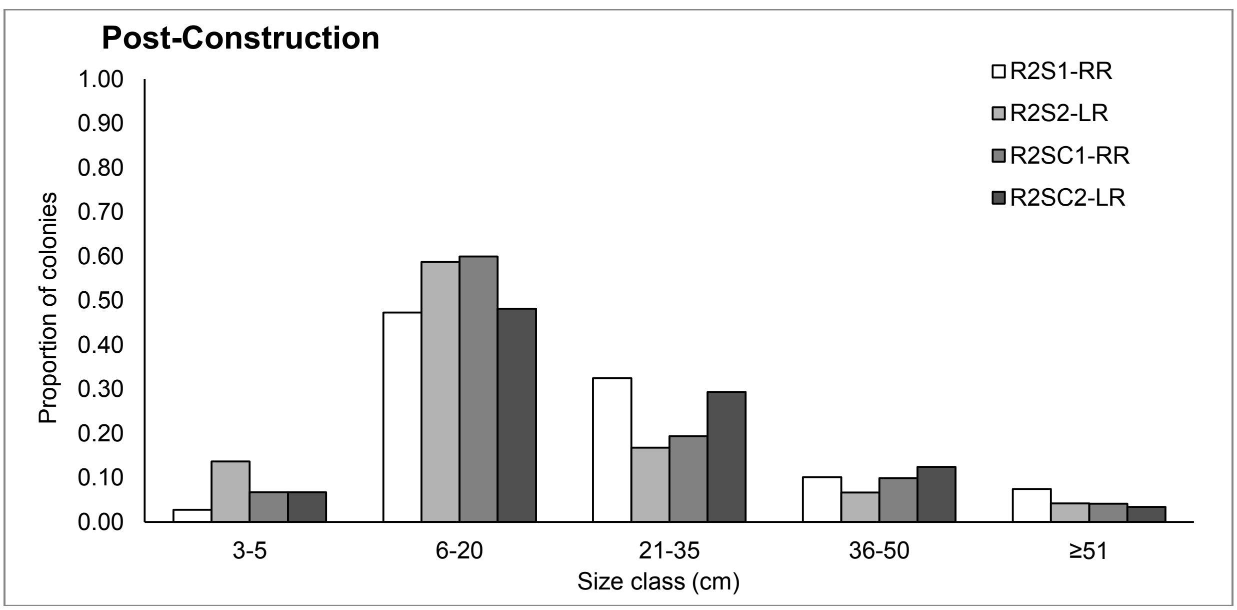


Figure 121. Proportion of octocoral colonies by size class for southern middle reef sites during post-construction surveys.

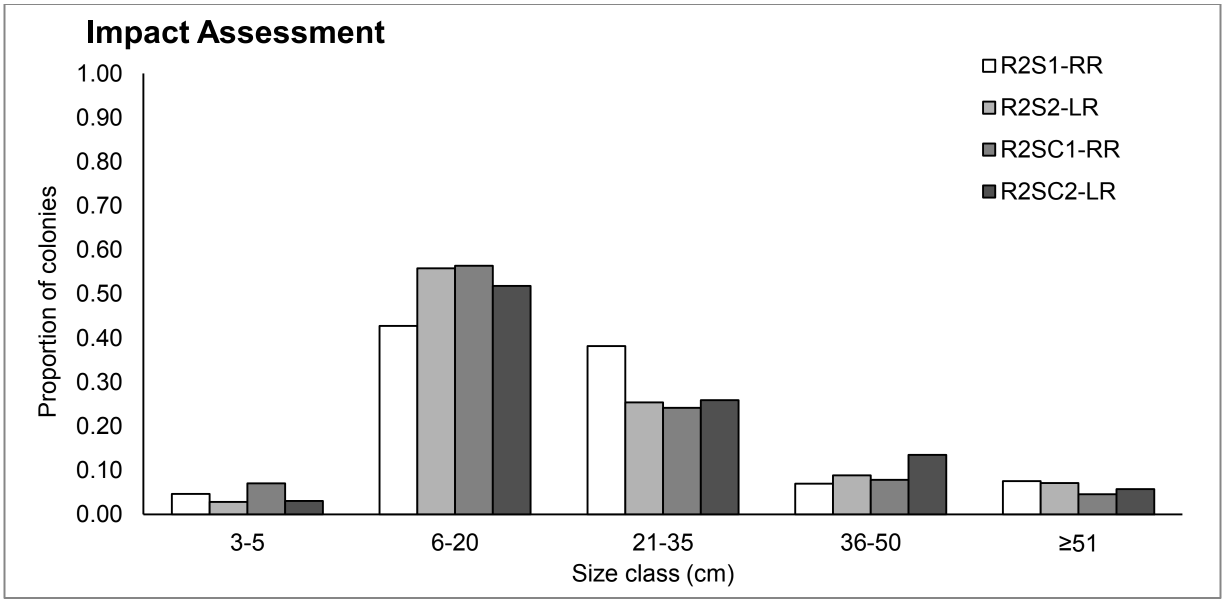


Figure 122. Proportion of octocoral colonies by size class for southern middle reef sites during impact assessment surveys.

3.7.2.3 Outer Reef

The number of octocorals in the smallest size class (3-5 cm) increased at R3NC1-LR between baseline (1%) and impact assessment (6%), while the percentage of octocorals in the larger size classes (>21 cm) declined. At R3N1-LR, the percentage of octocorals in the smallest class size (3-5 cm) and some of the larger size classes (21-35 cm and ≥51 cm) increased from baseline to impact assessment (Figure 123-125).

Between baseline and impact assessment surveys, the percentage of octocorals in the smallest size class category (3-5 cm) declined at the southern outer reef control sites (R3SC2-LR and R3SC3-SG), but increased at the channel-side site (R3S2-LR). The percentage of octocorals in the largest size class (≥51 cm) remained the same at R3S2-LR (12%) but increased by 6% at (R3SC2-LR and R3SC3-SG) between the baseline and impact assessment periods (Figure 126-128).

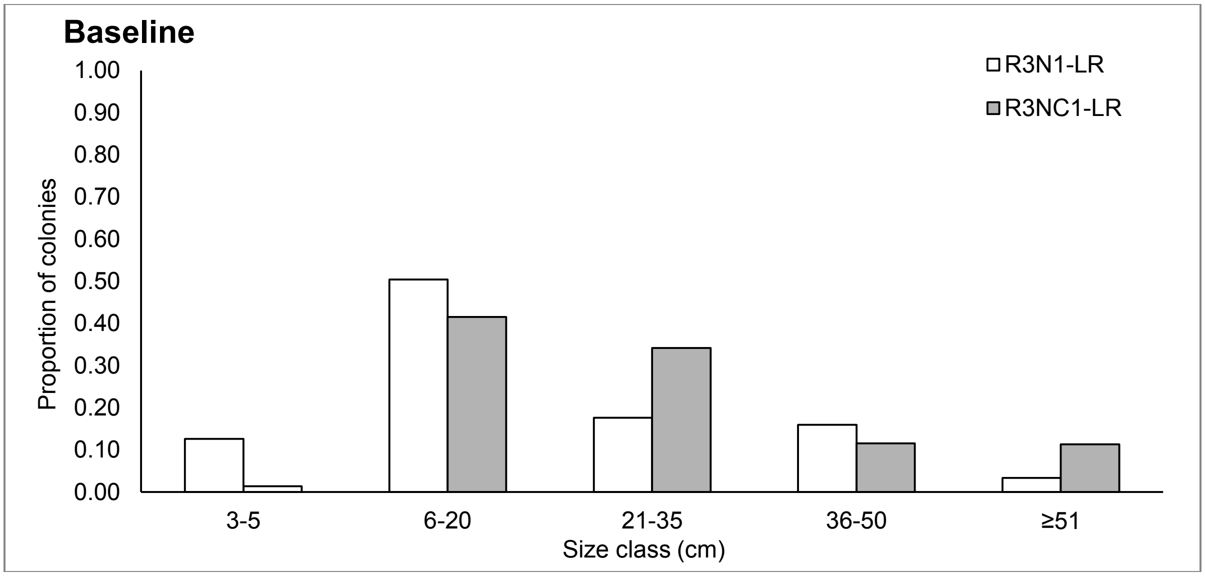


Figure 123. Proportion of octocoral colonies by size class for northern outer reef sites during baseline surveys.

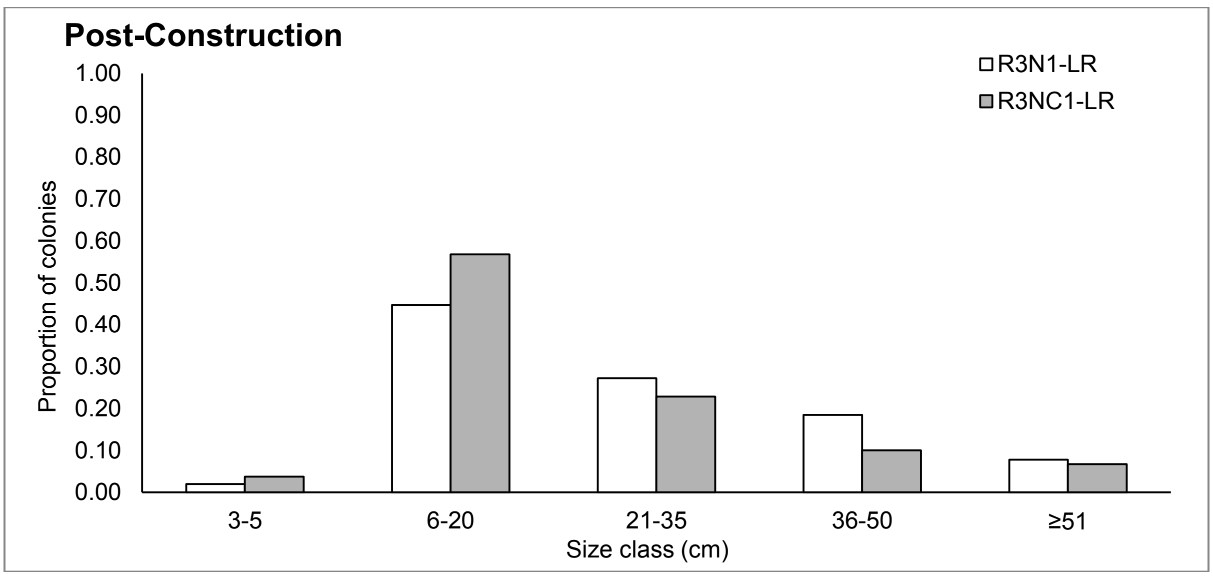


Figure 124. Proportion of octocoral colonies by size class for northern outer reef sites during post-construction surveys.

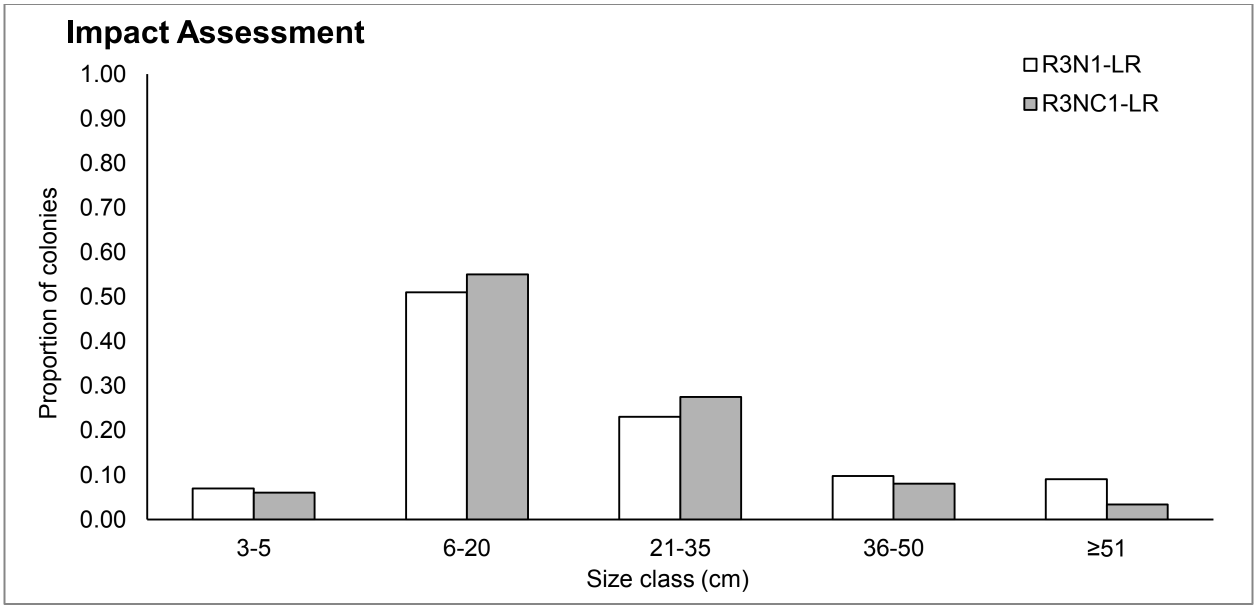


Figure 125. Proportion of octocoral colonies by size class for northern outer reef sites during impact assessment surveys.

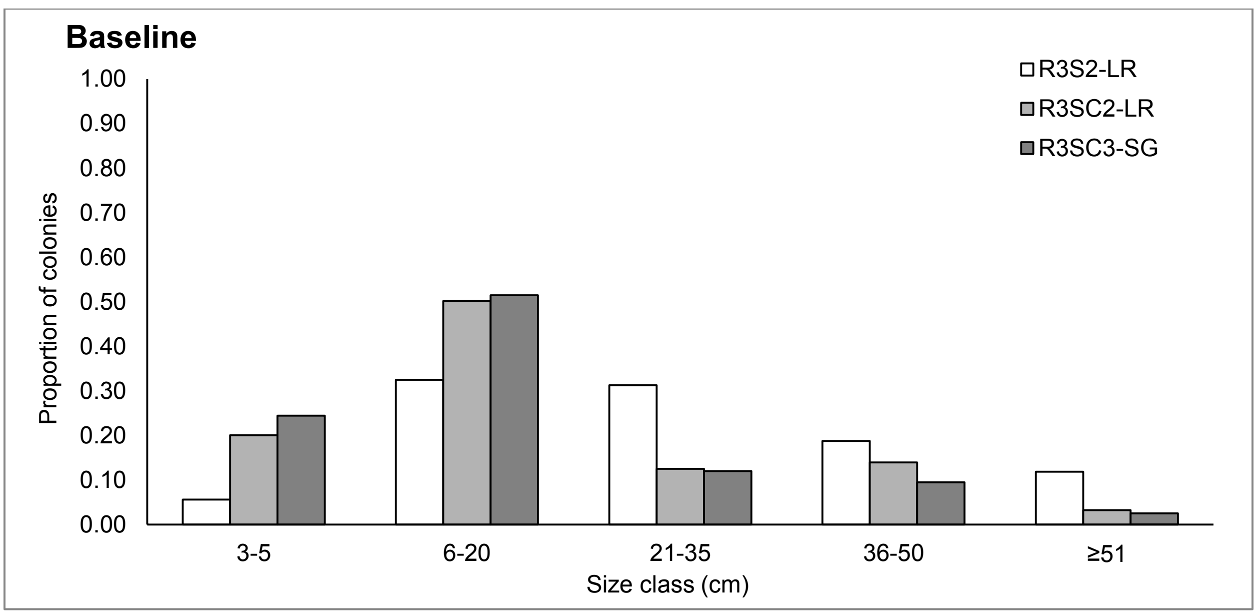


Figure 126. Proportion of octocoral colonies by size class for southern outer reef sites during baseline surveys.

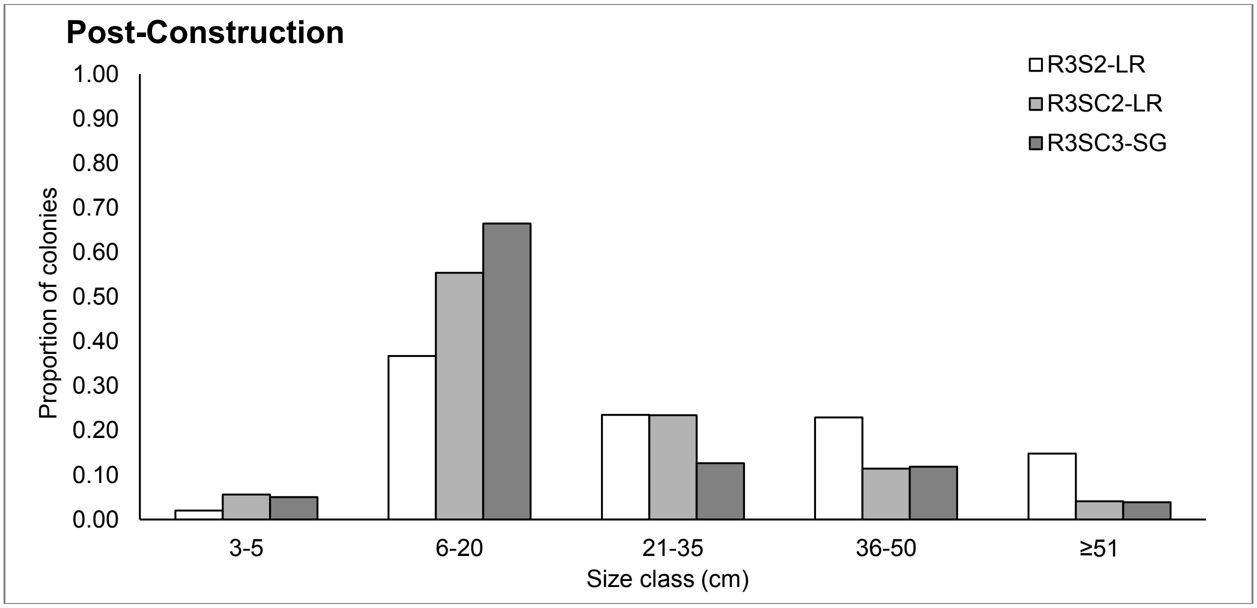


Figure 127. Proportion of octocoral colonies by size class for southern outer reef sites during post-construction surveys.

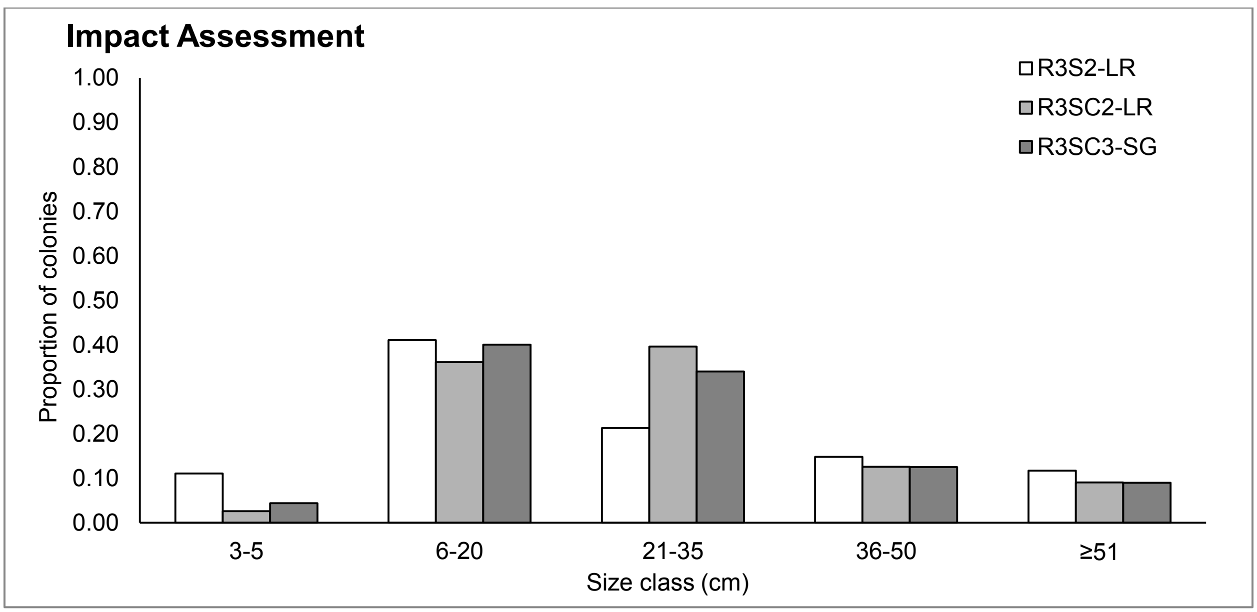


Figure 128. Proportion of octocoral colonies by size class for southern outer reef sites during post-construction surveys.

3.8 Sponges

3.8.1 Sponge Density

Sponge density was not assessed during baseline or post-construction surveys at hardbottom sites and therefore temporal analysis is not available for sponge density in this habitat (Table 51). However, mean hardbottom sponge density as measured in the impact assessment (8.24 sponges/m^2) was higher than channel-side sites at either the middle or outer reef habitats and higher than sponge density at hardbottom control sites (Table 51).

Of the nine middle reef sites surveyed, sponge density declined at six sites, three channel-side and three control sites. At the outer reef, five sites were surveyed and sponge density declined at one channel-side and one control site. Overall, mean sponge density declined at middle reef channel-side sites from 10.65 sponges/m^2 to 4.65 sponges/m^2 compared to a decline from 8.50 to 7.53 sponges/m^2 at middle reef controls (Table 51). A two-way repeated measures ANOVA that compared sponge density at each middle reef site over the survey period indicated that a significant decline in sponge density occurred at R2N2-LR between baseline and impact assessment surveys that was significantly different than its paired control site and are likely due to project activities. Examination of sponge counts at R2N2-LR showed that sponge losses were primarily of encrusting and finger morphotypes over the time period whereas large conspicuous sponge morphotypes were largely unaffected. This may have been a result of sediment burial, that could be expected to affect low lying morphotypes, such as encrusting and finger morphotypes. Functional group percent cover of sponges at R2N2-LR did not decline between baseline and impact assessment surveys (Section 3.3). No other middle reef channel-side site was documented with significant declines in sponge density over the time period. At the outer reef, sponge density increased at both channel-side and control locations between baseline and impact assessment periods and no significant interactions were documented at outer reef sites between baseline and impact assessment periods (Table 51).

Table 51. Mean sponge densities as measured at channel-side and control locations in hardbottom, middle, and outer reef types. Mean densities and standard error are provided for baseline and impact assessment time periods.

Site	Channel-side				Controls			
	Baseline		IA		Baseline		IA	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Hardbottom	N/A	N/A	8.24	0.85	N/A	N/A	5.96	0.53
Middle Reef	10.65	2.15	4.65	1.01	8.50	0.69	7.53	0.84
Outer Reef	6.26	0.65	7.02	0.75	4.88	0.45	6.92	0.30

3.8.1.1 Hardbottom

Sponge density ranked second behind octocorals as the most dominant functional group category and ranged from 4.68 sponges/m^2 (HBSC1-CP) to 10.50sponges/m^2 (HBN3-CP) individuals per m^{2}during the impact assessment survey (Figure 129). Sponge density data were not required for baseline or post-construction surveys at hardbottom sites so no temporal comparisons are available (Table 52).

Table 52. Sponge density values for hardbottom sites during baseline, post-construction, and impact assessment surveys. SE represents standard error of the mean.

N/A sites were sites in which sponge density was not required as part of FDEP protocol.

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
HBN1-CR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HBN2-CR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HBN3-CP	N/A	N/A	N/A	N/A	N/A	N/A	10.50	3.36	1.94
HBNC1-CP	N/A	N/A	N/A	N/A	N/A	N/A	7.23	1.27	0.73
HBS1-CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HBS2-CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HBS3-CP	N/A	N/A	N/A	N/A	N/A	N/A	6.37	0.50	0.29
HBS4-CR	N/A	N/A	N/A	N/A	N/A	N/A	7.85	0.54	0.31
HBSC1-CP	N/A	N/A	N/A	N/A	N/A	N/A	4.68	0.56	0.32

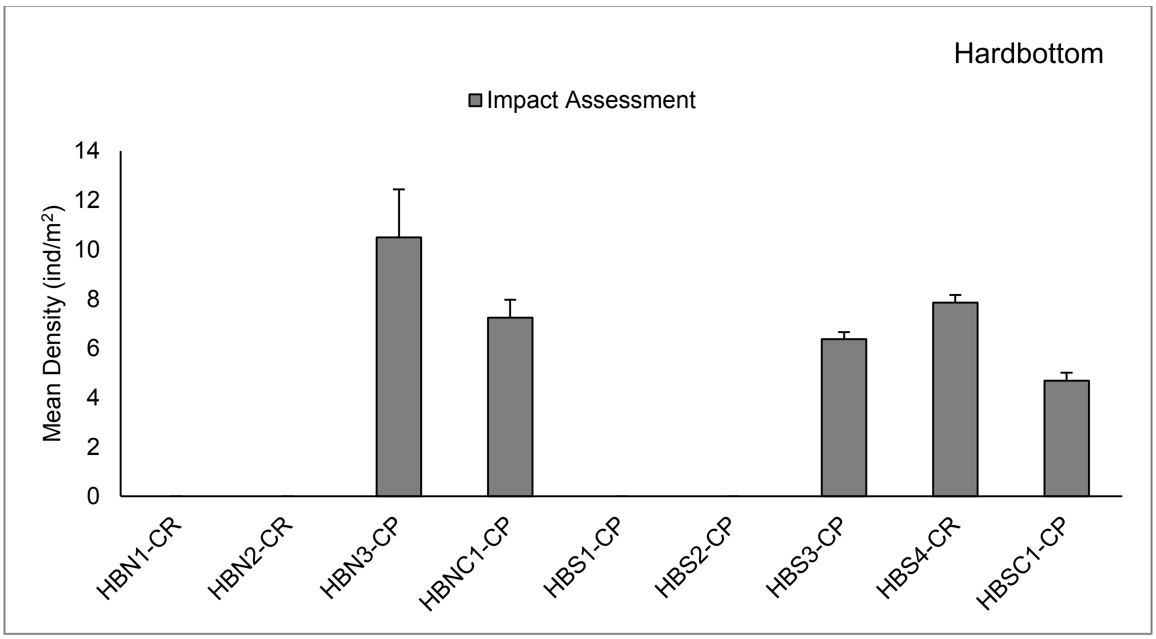


Figure 129. Sponge density values for hardbottom sites were only collected during impact assessment surveys, so no baseline data is available. Error bars represent the standard error of the mean.

3.8.1.2 Middle Reef

Sponge density ranked second behind octocorals as the most dominant functional group category and ranged from 3.73 (R2NC2-RR) to 11.72 (R2SC2-LR) individuals per m^2during the impact assessment survey (Table 53). During the post-construction assessment period mean sponge density ranged from 3.7 individuals/m^2 (R2NC2-RR) to 11.72 individuals/m^2 (R2SC2-LR) (Table 53). Sponge density decreased at six middle reef sites and increased at three middle reef sites between baseline and impact assessment surveys (Figure 130).

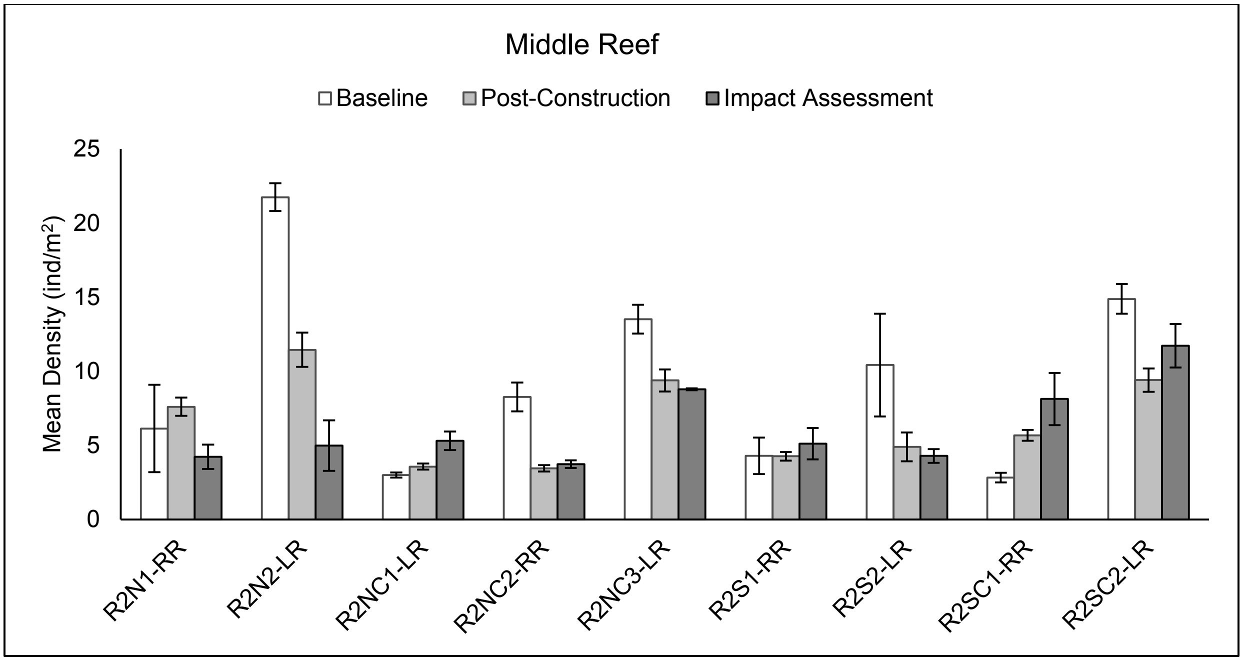


Figure 130. Sponge density values for middle reef sites during baseline, post-construction, and impact assessment surveys. Error bars represent the standard error of the mean.

Table 53. Mean sponge density (with standard deviation and standard error) among nine middle reef sites across three permanent transects during baseline, post-construction and impact assessment surveys. SD represents standard deviation and SE represents standard error.

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
R2N1-RR	6.13	5.11	2.95	7.60	1.06	0.61	4.23	1.41	0.82
R2N2-LR	21.75	1.63	0.94	11.45	2.00	1.16	4.98	2.95	1.70
R2NC1-LR	3.00	0.30	0.17	3.57	0.34	0.20	5.30	1.08	0.63
R2NC2-RR	8.27	1.68	0.97	3.45	0.36	0.21	3.73	0.45	0.26
R2NC3-LR	13.52	1.69	0.97	9.38	1.30	0.75	8.78	0.13	0.07
R2S1-RR	4.30	2.13	1.23	4.27	0.50	0.29	5.12	1.83	1.06
R2S2-LR	10.42	6.01	3.47	4.90	1.69	0.98	4.28	0.80	0.46
R2SC1-RR	2.82	0.56	0.32	5.67	0.63	0.37	8.13	3.05	1.76
R2SC2-LR	14.88	1.73	1.00	9.40	1.37	0.79	11.72	2.53	1.46

A two-way ANOVA was used to determine if mean sponge density was different among the nine middle reef sites between the baseline and impact assessment periods. Mean site densities were normally distributed in all cases (Anderson-Darling test,$p > 0.05$). A significant interaction among the sites between the assessment periods was detected ($F = 11.66$, $p = 0.000$). Significant differences were also found between assessment periods ($F = 27.09$, $p = 0.000$), and between sites ($F = 11.65$, $P < 0.001$) (Table 54).

Table 54. Two-way ANOVA results testing the effects of the two time periods, baseline and impact assessment (PERIOD), the effects of site locations (SITE), and the interaction between the two effects on sponge density among the five outer reef sites.

Source	DF	Mean Square	F Value	*p*
PERIOD	1	138.240	27.09	0.000
SITE	8	83.258	11.65	0.000
PERIOD*SITE	8	59.512	11.66	0.000

The significant interaction indicates that the effect of time was different across middle reef sites as measured by mean sponge density. Additional Tukey post-hoc comparisons were performed to determine significant differences of mean sponge density between middle reef sites and among individual sites between the baseline and impact assessment periods (Table 55 and 56).

Table 55. Tukey post-hoc comparisons of mean sponge density differences between middle reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons				
	N	Mean	Grouping		
R2N2-LR	6	13.37	A		
R2SC2-LR	6	13.30	A		
R2NC3-LR	6	11.15	A	B	
R2S2-LR	6	7.35		B	C
R2NC2-RR	6	6.00			C
R2SC1-RR	6	5.47			C
R2N1-RR	6	5.18			C
R2S1-RR	6	4.70			C
R2NC1-LR	6	4.15			C

Table 56. Tukey post-hoc comparisons of mean sponge density differences between baseline and impact assessment surveys for middle reef sites (superscripts indicate a significant difference between survey periods, NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
R2N1-RR	NS	(trend) Baseline> Impact Assessment
R2N2-LR	F=468.32 (p=0.002)	Baseline^{A}, Impact Assessment^{B}
R2NC1-LR	NS	(trend) Impact Assessment > Baseline
R2NC2-RR	NS	(trend) Baseline> Impact Assessment
R2NC3-LR	F=26.98 (p=0.035)	Baseline^{A}, Impact Assessment^{B}
R2S1-RR	NS	(trend) Impact Assessment > Baseline
R2S2-LR	NS	(trend) Baseline> Impact Assessment
R2SC1-RR	NS	(trend) Impact Assessment > Baseline
R2SC2-LR	F=31.89 (*p*=0.0127)	Baseline^{A}, Impact Assessment^{B}

Patterns in sponge density were not clear based on location at middle reef sites. The northern middle reef control sites, R2NC1-LR and R2NC3-LR are controls of the same reef type and yet

R2NC1-LR saw increased sponge density (from 3.0 sponges/m^2 to 5.3 sponges/m^2) between baseline and impact assessment surveys whereas R2NC3-LR had significant declines (from 13.52 sponges/m^2 to 8.78 sponges/m^2) (Table 53). Similarly, the southern middle reef channel-side sites had one site that had an increase in sponge density between baseline and impact assessment surveys (R2S1-RR) and one site that declined in mean sponge density (R2S2-LR). The lack of consistent patterns in sponge density at control sites of the same reef type as well as nearby channel-side sites over the same time period indicated that patterns of sponge density over time were driven by mostly non-project related factors.

Significant differences were detected between the sites during the impact assessment period (Table 56). High sponge density sites R2N2-LR and R2SC2-LR were significantly different than all other sites with respect to mean sponge density. In addition low density sites R2NC1-LR, R2S1-RR, R2N1-RR, R2SC1-RR and R2NC2-RR were significantly different than the remaining middle reef sites. Three sites were found to have significantly different mean sponge density from baseline to impact assessment surveys. R2N2-LR, R2NC3-LR, R2SC2-LR all had significant declines in sponge density from baseline to impact assessment surveys. R2N2-LR had the largest decline in sponge density from 21.75 sponges/m^2 during the baseline surveys to 4.98 sponges/m^2 (Table 53). The paired control site of R2NC1-LR had increased sponge density from 3.0 to 5.30 sponges/m^2 over the same time period.

The significant decline in sponge density at R2N2-LR between baseline and impact assessment periods is likely an effect of sedimentation impacts from construction activities. However, the change in sponge density was not reflected in the overall abundance of sponges at R2N2-LR as the percentages of sponges documented at R2N2-LR increased in terms of functional group percent cover over the time period. Sponge cover increased from baseline surveys from 3.96% cover to 4.6% as assessed in the functional group analysis at R2N2-LR (Section 3.3). Examination of sponge counts from R2N2-LR at baseline and impact assessment surveys helps to explain these conflicting trends in sponge abundance as the losses between surveys was primarily experienced by encrusting and finger morphotypes (Table 57) that are likely difficult to view in planar video frames used in the percent cover analysis. As a result, it is likely that small and encrusting sponges that formed a large numerical part of the sponge community were affected by construction activities but that the sustained presence of large conspicuous sponges suggests that the total sponge cover was not adversely affected between surveys.

Table 57. Sponge counts by morphotype as documented at baseline and impact assessment surveys at R2N2-LR. Counts were summed over three 20m survey transects.

Sponge Type	Baseline	Impact Assessment
Ball	34	37
Cliona	6	9
Encrusting	457	45
Finger	668	57
Tube	85	104
Vase	47	34
Xestospongia	8	13
Totals	1305	299

3.8.1.3 Outer Reef

Sponge density ranked second behind octocorals as the most dominant functional group category and ranged from 4.90 (R3SC2-LR) to 10.6 (R3N1-LR) individuals per m^2during the impact assessment survey (Table 58). Sponge density increased at all surveyed sites during impact assessment surveys except R3N1-LR and R3SC3-SG (Figure 131).

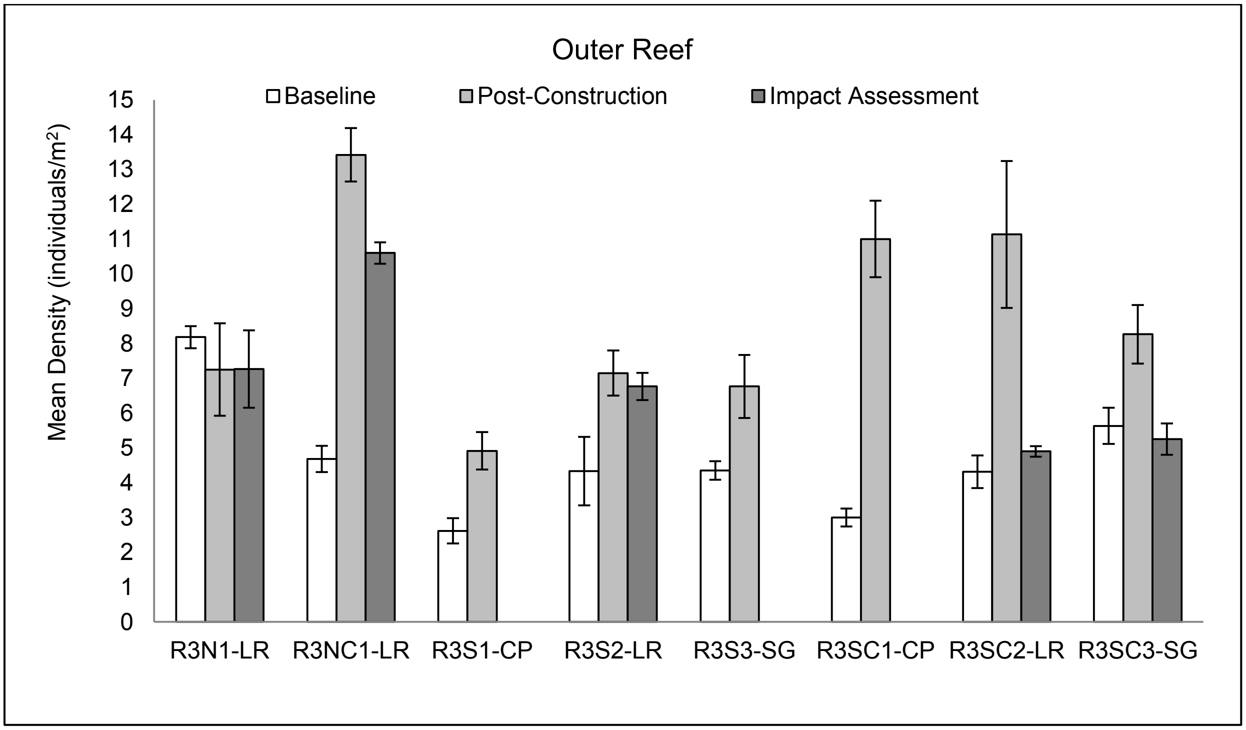


Figure 131. Sponge density values for outer reef sites during Week 1 of baseline, Week 3 of Post-Construction, and during impact assessment surveys. Error bars represent the standard error of the mean.

Table 58. Mean sponge density (with standard deviation and standard error) among nine outer reef sites across three permanent transects. **N/A sites were not part of the FDEP required impact assessment protocol.**

Site	Baseline			Post-Construction			Impact Assessment		
	Mean Density	SD	SE	Mean Density	SD	SE	Mean Density	SD	SE
R3N1-LR	8.18	0.55	0.32	7.25	2.30	1.33	7.27	1.92	1.11
R3NC1-LR	4.68	0.65	0.38	13.42	1.33	0.77	10.60	0.53	0.31
R3S1-CP	2.62	0.63	0.36	4.92	0.93	0.54	N/A	N/A	N/A
R3S2-LR	4.33	1.70	0.98	7.15	1.13	0.65	6.77	0.68	0.39
R3S3-SG	4.35	0.46	0.26	6.77	1.57	0.90	N/A	N/A	N/A
R3SC1-CP	3.00	0.44	0.26	11.00	1.91	1.10	N/A	N/A	N/A
R3SC2-LR	4.32	0.81	0.47	11.13	3.65	2.11	4.90	0.26	0.15
R3SC3-SG	5.63	0.89	0.52	8.27	1.46	0.84	5.25	0.78	0.45

A two-way repeated-measures ANOVA was used to determine if mean sponge density responded differently among the five surveyed outer reef sites between the baseline and impact assessment periods (Table 59). Mean site densities were normally distributed in all cases (Anderson-Darling test,$p > 0.05$). A significant interaction between site and period was detected ($F=11.27$, $p=0.001$) as well as between sites ($F=11.67$, $p=0.001$) and over the time period ($F=17.16$, $p= 0.002$). The significant interaction indicates that the effect of time was different across outer reef sites as measured by mean sponge density. Additional Tukey post-hoc comparisons were performed to determine significant differences of mean sponge density between outer reef sites and among individual sites between the baseline and impact assessment periods (Table 60). R3SC2-LR and R3SC3-SG were significantly different than the other outer reef sites based on sponge density. Only R3NC1-LR had significantly different mean sponge density between baseline and impact assessment surveys (Table 61). At R3NC1-LR, mean sponge density increased from 4.68 sponges/m^2 to 10.6 sponges/m^2. Changes in channel-side sites were not significantly different over the time period; R3N1-LR sponge density decreased slightly from 8.18 sponges/m^2 to 7.27sponges/m^2 whereas sponge density increased at R3S2-LR from 4.33 sponges/m^2 to 6.77 sponges/m^2.

Table 59. Two-way ANOVA results testing the effects of the two time periods, baseline and impact assessment (PERIOD), the effects of coral site locations (SITE), and the interaction between the two effects on scleractinian density among the five outer reef sites.

Source	DF	Mean Square	F Value	*p*
PERIOD	1	17.480	17.16	0.002
SITE	4	11.67	11.67	0.001
PERIOD*SITE	4	11.476	11.27	0.001

Table 60. Tukey post-hoc comparisons of mean coral density differences between outer reef sites for the impact assessment period. Sites with the same letter grouping are not significantly different.

Site	Tukey Pairwise Comparisons			
	N	Mean	Grouping	
R3SC3-SG	6	7.73	A	
R3SC2-LR	6	7.64	A	
R3S2-LR	6	5.55		B
R3NC1-LR	6	5.44		B
R3N1-LR	6	4.6		B

Table 61. Tukey post-hoc comparisons of mean coral density differences between baseline and impact assessment surveys for outer reef sites (superscripts indicate a significant difference between survey periods,NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
R3N1-LR	NS	(trend) Baseline>Impact assessment
R3NC1-LR	F= 1658.22, p = 0.001	Baseline[A], Impact Assessment[B]
R3S2-LR	NS	(trend) Impact Assessment>Baseline
R3SC2-LR	NS	(trend) Impact Assessment>Baseline
R3SC3-SG	NS	(trend) Baseline>Impact assessment

4.0 SUMMARY

The one-year post-construction impact assessment report for permanent sites documents the permanent and temporary impacts of the Miami Harbor Phase III Project. The project was permitted through the Florida Department of Protection (FDEP), under Permit No. 0305721-001-BI. This report is responsive to Specific Condition 32 a ii. d of the permit. In order to characterize impacts of the dredging project at channel-side sites, 19 of the originally established 26 permanent monitoring sites were selected by FDEP for follow-up monitoring. These sites included nine (9) impacted channel-side sites and their respective controls. The seven (7) sites that were eliminated from this impact assessment report were those that were deemed by FDEP to have been unaffected by the dredging operations and their controls.

Baseline surveys established information on the sedimentation environment, percent cover of benthic resources, and population dynamics of corals, octocorals, and sponges that dominate the benthic communities adjacent to the Federal Navigation Channel. These baseline results were used as a point of comparison for the impact assessment survey to document changes attributable to dredging one year after the completion of construction activities while considering other environmental and/or anthropogenic factors that influence benthic resources in the area. Changes in the benthic habitats between baseline and impact assessment surveys were attributable to a number of factors, including regional stress events (bleaching and disease), natural environmental conditions, and project related activities.

Sediment Monitoring Results

The sedimentation environment varied substantially at both channel-side and control locations over the course of project monitoring. During the one-year post-construction impact assessment surveys, sediment accumulation rates were found to be equal to or below baseline values at all channel-side sites, except during rare weather events such as the passage of a hurricane near project sites (Hurricane Matthew October 9, 2016). Mean sediment accumulation rates measured over all channel-side locations were below baseline values during the one-year post-construction impact assessment survey. The sedimentation accumulation results indicate that the sedimentation environment has returned to levels observed prior to dredging activities.

Biological Monitoring Results

Functional group percent cover data describe the overall composition of benthic organisms and abiotic cover at a site. Project-related sites were assessed in terms of the percent cover of corals, octocorals, sponges, zoanthids, macroalgae, CTB (crustose coralline algae, turf and bare), sand, and other during baseline and impact assessment periods. The mean percent cover of benthic invertebrates was approximately 17% of the bottom at channel-side sites during baseline surveys: scleractinians (0.88%), octocorals (10.01%), sponges (5.01%) and zoanthids (1.13%), while CTB and sand comprised the remaining 83% of the benthic cover. During impact assessment surveys the mean percent cover of benthic invertebrates was again 17% of the bottom at channel-side sites: scleractinians (0.51%), octocorals (9.18%), sponges (5.78%) and zoanthids (1.13%), while CTB and sand comprised the remaining 83% of the bottom at channel-side sites. The functional group percent cover analysis documented that mean cover of corals, octocorals, sponges and zoanthids was within a standard error of baseline values at channel-side and control locations in each of the sampled habitats.

Temporary impacts due to the project were documented as increased levels of sand cover and nearly reciprocal declines in CTB cover at channel-side locations that were greater than changes documented at control sites over the time period. Overall, mean sand cover increased at channel-side sites from 13.6% to 29.3% (15.7% increase) from baseline to impact assessment surveys in comparison to a 0.6% increase in mean sand cover at control sites. A corresponding decline in the mean cover of CTB was also measured between baseline and impact assessment periods with a decline in mean CTB cover declining from 70.5% to 54.8% (-15.7%) at channel-side locations compared to a 3.7% increase in mean CTB cover at control sites. Increased sand cover was spatially restricted to middle reef and southern hardbottom channel-side sites during the impact assessment survey. These increases in sand cover documented at channel-side sites were within the variability of sand cover documented over time at control sites. At control locations, sand cover varied as much as 68.3% over the course of project monitoring due to seasonal variability. The range mean sand cover at control site locations was 40.0% over the course of the project. The increased sand cover documented at channel-side sites during the impact assessment survey is within the range of control site variability. The increase in sand cover channel-side is expected to be temporary, as sand cover at channel-side sites has declined since construction and continues to trend towards baseline values.

Repeated Measures Coral Monitoring Results

A total of 476 scleractinian corals were tagged and monitored at control and channel-side sites as often as twice per week during construction activities. Over the course of project monitoring, six tagged channel-side scleractinian corals were buried and died as a direct result of sediment accumulation during dredging. The mortality of these six corals is considered a permanent impact of the project. These six corals represent 2.7% (6 out of 224 channel-side corals) of all tagged corals at the channel-side site locations.

In addition to the coral mortality associated directly with sediment burial, significant coral mortality was observed at channel-side and control locations over the course of project monitoring. Following a regional coral bleaching event in the summer of 2014, white-plague disease was documented at both control and channel-side locations during project monitoring. In the summer of 2015, the Florida Reef Resilience Program (FRRP) documented high levels (>10%) of coral disease in Broward-Miami, Biscayne, Upper and Lower Keys sub-regions. In the summer of 2016 FRRP documented high levels of coral disease in Martin, Broward-Miami, Upper, Lower, and Dry Tortugas sub regions. The location of the project in the Broward-Miami subregion was within the affected disease areas in both 2015 and 2016.

Eighty-five (85) out of 252 tagged coral colonies at the surveyed control sites (33.7%) died during project monitoring. The overwhelming majority of identifiable mortality (81%, 69 out of 85) died from white-plague and other concurrent diseases, followed by unidentified mortality (14% 12 out of 85), white-band disease (4%, 3 out of 85), competition (1%, 1 out of 85). Ninety-eight out of 224 (43.7%) of tagged coral colonies at channel-side sites died during project monitoring. The overwhelming majority of identifiable mortality (74%, 72 out of 98) died from white-plague and other concurrent diseases followed by unidentified mortality (18%, 18 out of 98), sediment burial (6%, 6 out of 98), competition (1%, 1 out of 98), and bleaching (1%, 1 out of 98) explained the remaining coral mortality throughout the project area. Declines in scleractinian density between baseline and impact assessment surveys at channel-side and control locations were directly linked to the white-plague disease event.

<u>Implication of Regional Coral Disease Outbreak</u>

Precht et al. (2016) (Appendix E) documented 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.* The comparison of permanent site coral mortality with regional estimates of disease-related mortality show that the mortality levels observed at all permanent monitoring sites follow the trends predicted due to the coral community composition of that site and their white-plague disease susceptibility without reference to location, either close to, or far away from dredge activity. Taking disease-susceptibility into account, no channel-side sites had higher levels of coral mortality than would be predicted from regional white-plague disease mortality information.

<u>Partial Coral Mortality</u>

Partial mortality associated with sediment affected 64.8% of corals across the nine channel-side sites and 19.4% of corals at the ten control sites during the impact assessment. The difference of 45.4% in sediment related partial mortality at the channel-side sites is attributed to the dredging project. To measure the amount of tissue lost from sediment-related partial mortality, planimetry measurements were performed on non-diseased corals at the most affected site (R2N1-RR) and changes from baseline surveys were compared to live tissue measurements of non-diseased corals at the paired control site (R2NC2-RR) over the time period. There was no statistical difference in percent change in live coral tissue at R2N1-RR (-12.28%) when compared with its paired-control R2NC2-RR (-11.6%) between baseline and impact assessment surveys.

<u>Coral Recruit Monitoring Results</u>

Coral recruit (3cm and smaller) densities were found to be less than paired controls at four channel-side sites, higher than paired control sites at four channel-side sites and have equivalent recruit densities at one paired channel-side and control site. Since data on recruit density was not collected prior to the impact assessment survey there is no way to determine if these densities have changed due to project-related effects.

<u>Octocoral and Sponge Monitoring Results</u>

Analysis of octocoral and sponge density data between baseline and impact assessment surveys indicated that no significant changes in octocoral density were documented at channel-side sites when compared to paired-controls. In addition, no significant changes in sponge density were documented between baseline and impact assessment, except at R2N2-LR. The loss of sponges at R2N2-LR were primarily encrusting and finger sponges and are also a potential impact of dredge activities.

Project Mitigation

The FDEP permit authorized direct impact of 7.07 acres of reef, 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. Mitigation was completed during the project and a portion of the mitigation was completed before the direct impact occurred on the outer reef, representing a benefit to the overall ecosystem before any impacts occurred. No up-front mitigation was built for sediment accumulation associated impacts, as these effects were expected to be temporary.

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 a 2.32 acres of additional mitigation (9.28 acres were required) and may be considered advanced mitigation for other project related impacts. When considering the actual direct impact of 6.88 acres (instead of 7.07 acres permitted), the 2.32 acre of surplus mitigation represents an even greater functional gain. In addition, 157 *Acropora cervicornis* colonies from within 450 m of the channel were relocated to the RSMAS coral nursery by NOAA (October, 2014) as a part of the NEPA minimization process. From these colonies 1,059 fragments were created, grown, outplanted and monitored. In 2017, an additional 2,040 colonies were outplanted to the RSMAS coral nursery (personal communication to USACE; Tom Moore, NOAA). The addition of 3,099 outplanted *A. cervicornis* colonies may also be considered mitigation for additional project-related impacts.

Conclusions

Community structure and function at the one-year post-construction impact assessment survey were not significantly different from baseline surveys in terms of percent cover of major benthic organisms, density of sponges (8 out of 9 channel-side sites) and octocorals, and sediment accumulation levels.

The dredging impacts documented were the following:

- Permanent loss of 6/224 tagged scleractinians (2.7% of channel-side corals).
- Partial mortality due to sediment affected 64.8% of channel-side tagged corals as compared to paired controls (19.4%). No difference in tissue loss at one-year post-construction surveys was measured through planimetry.
- Temporary increase in sand cover and reduced cover of CTB at channel-side sites, which are trending back toward baseline values.
- Sponge density decline at R2N2-LR (1 out of 9 channel-side sites).

The majority of change seen in the coral community resulted from natural disturbances, including coral disease (30-50%), coral bleaching (<1%), and competitive mortality (<1%).

5.0 REFERENCES

Aronson, R.B., Edmunds, P.J., Precht, W.F., Swanson, D.W. and Levitan, D.R. 1994. Large-scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive techniques. Atoll Research Bulletin 421 pp. 1-19.

Aronson, R. B. & W. F. Precht, 2000. Herbivory and algal dynamics on the coral reef at Discovery Bay, Jamaica. Limnol. Oceanogr.45: 251–255.

Atlantic and Gulf Rapid Reef Assessment. 2013. AGRRA Training Aids. http://www.agrra.org/method/trainingid.html

Baker, A.C. 2015. Coral Reef Conservation Lab (CR2) Facebook Posting April 30, 2015. https://m.facebook.com/pages/Baker-Coral-Reef-Conservation-Research-Laboratory/147275378670311

Banks, K.W., Riegl, B.M, Shinn, E.A., Piller, W.E. and Dodge, R.E. 2007. Geomorphology of the southeast Florida continental reef tract (Miami–Dade, Broward, and Palm Beach Counties, USA). Coral Reefs 26 pp. 617-633.

Brandt, M. and McManus, J.W. 2009. Disease incidence is related to bleaching extent in reef-building corals. Ecology 90(10) 2859–2867.

Bruckner, A.W. 2001. Coral health and mortality: Recognizing signs of coral diseases and predators. In: Humann and Deloach (eds.), Reef Coral Identification. Jacksonville, FL: Florida Caribbean Bahamas New World Publications, Inc. pp. 240-271.

Coastal Systems International Inc. (CSi) 2016. Transplanted Corals to Artificial Reefs – 24 Month Post Transplant Monitoring Report. Prepared for Miami Harbor Phase III Federal Channel Expansion. Contract No. E12-SEA-03/Project No. 1999-027

Courtenay, W.R., Herrema, D.J., Thompson, M.J., Azzinaro, W.P., and van Montfrans, J. 1974. Ecological monitoring of beach erosion control projects, Broward County, Florida and adjacent areas. Technical Memo. No. 41. U.S. Army Corps of Engineers, Coastal Engineering Research Ctr., Fort Belvoir, VA. 90 pp.

CSA Ocean Sciences Inc. 2014a. Final Report for the 30-Day Post-Relocation Monitoring Survey for Acropora cervicornis Associated with the Miami Harbor Construction Dredging (Phase 3) Project.

CSA Ocean Sciences Inc. 2014b. Advanced Compensatory Mitigation Completion Report.

DERM Miami-Dade County Department Environmental Resource Management. 2016. PortMiami corals transplanted corals to hardbottoms (24 month report).

DCA (Dial Cordy and Associates Inc.) 2012. Miami Harbor Baseline Hardbottom Study. Prepared for U.S. Army Corps of Engineers Jacksonville District. Pp. 96.

DCA (Dial Cordy and Associates Inc.) 2013. Guide to Coral Condition at PortMiami (PPT).

DCA (Dial Cordy and Associates Inc.) 2014a. Quantitative Baseline for Hardbottom Benthic Communities. FDEP Final Order #0305721-001-BI. Florida Department of Environmental Protection, Tallahassee, FL.Revised March 2014. Pp. 109.

DCA (Dial Cordy and Associates Inc.) 2014b. Impact assessment on hardbottom (September 3, 2014 report).

DCA (Dial Cordy and Associates Inc.) 2014c. Baseline report on middle and outer reef (October 2014).FDEP Final Order #0305721-001-BI. 2012. PortMiami Phase III Federal Channel Expansion Project. 47pp. Florida Department of Environmental Protection, Tallahassee, FL.

DCA (Dial Cordy and Associates Inc.) 2015a. Post-Construction report on hardbottom.FDEP Final Order #0305721-001-BI. 2012. PortMiami Phase III Federal Channel Expansion Project. 47pp. Florida Department of Environmental Protection, Tallahassee, FL. 94 pages.

DCA (Dial Cordy and Associates Inc.) 2015b. Post-Construction report on middle and outer reef. FDEP Final Order #0305721-001-BI. 2012. PortMiami Phase III Federal Channel Expansion Project. 137pp. Florida Department of Environmental Protection, Tallahassee, FL.

DCA (Dial Cordy and Associates Inc.) 2015c. Impact Assessment report on hardbottom reef FDEP Final Order #0305721-001-BI. 2012. PortMiami Phase III Federal Channel Expansion Project. 47pp. Florida Department of Environmental Protection, Tallahassee, FL.

DCA (Dial Cordy and Associates Inc.) 2015d. Impact Assessment report on middle and outer Reef. FDEP Final Order #0305721-001-BI. 2012. PortMiami Phase III Federal Channel Expansion Project. 137pp. Florida Department of Environmental Protection, Tallahassee, FL.

Florida Reef Resilience Program (FRRP) 2015. Disturbance Response Monitoring Quick Look Report: Summer 2015. http://frrp.org/wp-content/uploads/2015/12/2015-Summer-DRM-Quick-Look-Report_vs2.pdf

Florida Reef Resilience Program (FRRP) 2016. Disturbance Response Monitoring Quick Look Report: Summer 2016. http://frrp.org/wp-content/uploads/2016/11/2016-Summer-DRM-Quick-Look-Report.pdf

Gilliam, D.S. 2007. Southeast Florida Coral Reef Evaluation and Monitoring Project 2006 Year 4 Final Report. Prepared for Florida Fish and Wildlife Conservation Commission, Fish & Wildlife Research Institute, Florida Department of Environmental Protection. Pp. 31.

Hayes, N.K., Walton, C.J., Brinkhuis, V., Ruzika, R., and Gilliam, D.S. 2017. SECREMP Southeast Florida Coral Reef Evaluation and Monitoring Project. FDEP-CRCP 2017 Research and Academic Learning Exchange.

https://www.youtube.com/watch?v=3Aj_VIOhJQo&list=PLraw0H6njzME6cabdw1vRg7Ct0QMlhLoh&index=2

Humann, P. and Deloach, N. 2002. Reef Coral Identification: Florida, Caribbean, Bahamas (Reef Set, Vol. 3). New World Publishing. Jacksonville, Florida.

Kohler, K.E. and Gill, S.M. 2006. Coral point count with excel extensions (CPCe): A visual basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32 pp. 1259-1269.

Manzello, D.P. 2015. Rapid recent warming of coral reefs in the Florida Keys. Scientific Reports 5 16762, doi: 10.1038/srep16762

Marszalek, D.S. 1981. Impact of dredging on a subtropical reef community, southeast Florida, U.S.A. Proceedings 4th International Coral Reef Symposium, Manilla. 1 147-153.

Miller, J., Muller, E., Rogers, C., Waara, R., Atkinson, A., Whelan, K.R.T., Patterson, M. and Witcher, B.E. 2009. Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands. Coral Reefs 28(4) 925-937.

Miller, M. W., Karazsia, J., Groves, C. E., Griffin, S., Moore, T., Wilber, P., & Gregg, K. (2016). Detecting sedimentation impacts to coral reefs resulting from dredging the PortMiami, Florida USA. *PeerJ*, *4*, e2711. http://doi.org/10.7717/peerj.2711

Miller, M., and Precht, W. 2013. Climate Change Impacts on South Florida Coral Reefs. http://www.ces.fau.edu/files/projects/climate_change/ecology_february_2013/10_Miller.pdf

Moyer, R.P., Riegl, B.M., Banks, K. and Dodge, R.E. 2003. Spatial patterns and ecology of benthic communities on a high-latitude South Florida (Broward County, USA) reef system. Coral Reefs 22(4) 447-464.

NOAA. 2014a. Coral Reef Watch Bleaching Alert, Florida. http://coralreefwatch.noaa.gov/satellite/regions/florida.php

NOAA. 2014b. 2014 surprisingly rough on coral reefs, and El Niño looms in 2015. https://www.climate.gov/news-features/featured-images/2014-surprisingly-rough-coral-reefs-and-el-ni%C3%B1o-looms-2015

NOAA. 2015a. Coral Reef Watch: Global Bleaching Update http://coralreefwatch.noaa.gov/satellite/analyses_guidance/global_bleaching_update_20150602.php

NOAA. 2015b. Coral Reef Watch -- 2014 annual summaries of thermal conditions related to coral bleaching for U.S. National Coral Reef Monitoring Program (NCRMP) jurisdictions. http://coralreefwatch.noaa.gov/satellite/analyses_guidance/2014_annual_summaries_thermal_stress_conditions_NCRMP.pdf

NOAA. 2015c. NOAA declares third ever global coral bleaching event. http://www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coral-bleaching-event.html

NOAA 2016. Coral Reef Watch Virtual Stations. https://coralreefwatch.noaa.gov/satellite/vs/docs/list_vs_group_latlon_201103.php

Precht, W.F., Gintert, B.E., Robbart, M.L., Fura, R., and van Woesik, R. 2016. Unprecedented disease-related coral mortality in southeastern Florida. Scientific Reports 6 31374; doi. 10.1038/srep31374

Richardson, L.L., Goldberg, W.M., Carlton, R.G. and Halas, J.C. 1998. Coral disease outbreak in the Florida Keys: Plague Type II. Rev. Biol. Trop. 46(5) 187-198.

Somerfield, P.J., Jaap, W.C., Clarke, K.R., Callahan, M., Hackett, K., Porter, J.,and Yanev, G. 2008. Changes in coral reef communities among the Florida Keys, 1996–2003. Coral Reefs 27(4) 951-965.

Storlazzi, C.D., Field, M.E., Bothner, M.H. 2011. The use (and misuse) of sediment traps in coral reef environments, theory, observations, and suggested protocols. Coral Reefs 30 pp. 23-38.

Sutherland, K.P., Porter, J.W. andC. Torres. 2004. Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals. Mar. Ecol. Prog. Ser. 266 pp. 273-302.

Vargas-Angel, B., Peters, E.C., Kramarsky-Winter, E., Gilliam, D. and Dodge, R.E. 2007. Cellular Reactions to Sedimentation and Temperature Stress in the Caribbean Coral *Montastraeacavernosa*. Journal of Invertebrate Pathology 95 pp. 140-145.

Walker, B.K., B. Riegl, and R.E. Dodge. 2008. Mapping coral reef habitats in southeast Florida using a combined technique approach. Journal of Coastal Research 24**:** 1138-1150.

Walker, B.K. 2012. Spatial analyses of benthic habitats to define coral reef ecosystem regions and potential biogeographic boundaries along a latitudinal gradient. PloS one 7(1) e30466.

Weil, E., Urreiztieta, I. and Garzon-Ferreira, J. 2002. Geographic variability in the incidence of coral and octocoral diseases in the wider Caribbean. Proc 9th Int. Coral Reef Symp. Bali: 2, pp. 1231-1237.

Due to their size, the Appendices are in separate files.

APPENDIX A

LANDSCAPE SITE PHOTOS BASELINE-IMPACT ASSESSMENT

Due to their size, the Appendices are in separate files.

APPENDIX B

LIGHTROOM PHOTOS OF TAGGED CORALS BASELINE THROUGH IMPACT ASSESSMENT

Due to their size, the Appendices are in separate files.

APPENDIX C

STATISTICAL RESULTS

Due to their size, the Appendices are in separate files.

APPENDIX D

SEDIMENTATION ACCUMULATION DATA

Due to their size, the Appendices are in separate files.

APPENDIX E

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