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

Quantitative Post-Construction Analysis for Middle and Outer Reef Benthic Communities

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EXECUTIVE SUMMARY

The Miami Harbor Phase III Deepening Project was designed to widen and deepen the outer entrance channel to increase safe access to the Port of Miami by larger vessels, including post-Panamax class ships. To accommodate these larger vessels the outer entrance channel has been widened and deepened to 52 (±1) feet Mean Lower Low Water (MLLW) (15.6 ± 0.3 m). Avoidance and minimization of impacts to natural resources (hardbottom and seagrasses) was conducted by the U. S. Army Corps of Engineers (USACE) as the lead Federal agency through the NEPA process and a Record of Decision was signed on May 22, 2006. The project was permitted through the Florida Department of Protection (FDEP), under Permit No. 0305721-001-BI. Permit conditions provide a number of protective measures to ensure the preservation of natural resources, such as hardbottom, reef, and seagrass communities, including methods on environmental monitoring required before, during, and after dredging activities.

Great Lakes Dredge and Dock (GLDD) was responsible for implementing the required environmental monitoring program during the immediate pre-, during, and immediate post-construction time periods associated with the Miami Harbor Phase III project. Dial Cordy and Associates Inc. (DCA) was contracted by GLDD to conduct baseline, compliance and post-construction monitoring of hardbottom, reef, and seagrass habitats in the project area. Specifically, DCA was contracted to (1) conduct baseline, compliance, and post-construction surveys at hardbottom, middle and outer reef monitoring sites, and their control sites, (2) conduct baseline, compliance, and post-construction surveys at Fisherman's Channel seagrass sites, and (3) conduct baseline, compliance and post-construction surveys at Julia Tuttle Seagrass Mitigation Site (JTSMS).

This post-construction report characterizes the benthic communities within those channel-side areas of the outer reefs required to be monitored in compliance with the FDEP permit before, during and following completion of the project. The FDEP mandated monitoring study was designed to include control and channel-side sites and to compare pre- and post-construction results to detect natural variation in the resources to assist in determining the effects of the actual dredge operations on the resources surrounding the project area (SC32a). A number of parameters including benthic organism density, cover, and condition, as well as quantitative sedimentation rates were measured to test the null hypothesis (H_o):

> H_o: Benthic communities in the indirect effect (channel side) sites will remain unchanged between the pre and post-dredging surveys.

Baseline surveys established information on the population dynamics, condition and sedimentation environment of the benthic communities adjacent to the Federal Navigation Channel. These baseline results were used as a point of comparison for the post-construction survey period to document changes attributable to dredging while considering other environmental and/or anthropogenic factors that influence hardbottom resources in the area. Comparisons between baseline and post-construction benthic habitats documented changes in middle and outer reef benthic habitats. Changes in the benthic habitats were attributable to a number of factors, including natural environmental conditions and project related activities.

The most noticeable project related effects were due to sediment stress and accounted for total scleractinian colony mortality of 1.25% of all tagged colonies for all middle and outer reef monitoring sites (channel-side and control). Total scleractinian colony mortality due to sedimentation occurred at one middle reef channel-side site (R2N2-LR, 2 colonies; 8.3% of all tagged colonies at the site) and at one outer reef channel-side site (R3N1-LR, 3 colonies; 14.3% of all tagged colonies at the site). No total colony mortality associated with sedimentation occurred on the south side of the middle or outer reef sites nor at any of the north or south control sites. In addition to total coral colony mortality, sedimentation caused partial mortality of coral colonies in areas where coral colonies could not effectively remove accumulated sediment. Partial mortality due to sedimentation (PM) was recorded on 34% of all scleractinian corals at middle and outer reef sites (137 out of 400) during the compliance and/or post-construction monitoring period. The majority of corals affected by sediment-related partial mortality were at channel-side sites, although partial mortality due to sedimentation was documented at the control sites.

In addition to total colony mortality related to the effects of sediment, partial mortality of tagged scleractinian coral colonies due to sediment was documented over time (compliance through post-construction period) for tagged corals at all middle and outer reef sites (channel-side and controls). Partial mortality due to sediment occurred across channel-side and control sites at the middle and outer reefs (34%). Across the middle reef sites, R2N1-RR recorded the highest percentage of corals affected by partial mortality (93%), R2N2-LR, R2S1-RR and R2S2-LR all exhibited the next highest percentage of corals with partial mortality due to sediment (63%). The two north control sites (R2NC1-LR and R2NC2-RR) had the lowest percentage of corals affected by partial mortality due to sediment (7%). The two south control sites had 30% (R2SC1-RR) and 8% (R2SC2-LR) of corals affected by partial mortality due to sediment. At the outer reef sites, more than 70% of all tagged corals at R3N1-LR exhibited partial mortality due to sediment, while R3NC1-LR had 29% of corals affected by partial mortality. The south side of the channel at the outer reef sites exhibited less sediment-related partial mortality when compared to the north channel-side outer reef site. R3S2-LR had the lowest percentage with only 4% of corals with partial mortality due to sediment, while R3S1-CP and R3S3-SG had percentages of 42% and 36% respectively. R3SC2-LR had the lowest percentage of partial mortality (0%) among the south controls while R3SC1-CP (17%) and R3SC3-SG (13%) exhibited higher percentages.

As a result of the FDEP mandated monitoring program natural and project related effects on benthic communities were possible to discern. In the summer of 2014, a significant regional bleaching event was detected at control and channel-side sites. Shortly after the bleaching event, a white-plague disease event began to affect coral colonies (September 2014), starting at southern control sites on the middle reef. The white-plague outbreak continued to affect control and channel-side sites through 2015. White-plague disease was widespread across all middle and outer reef compliance monitoring and control sites except for R3N1-LR. White-plague accounted for 84% of the total scleractinian mortality of marked corals at the channel-side sites and 86% at the control sites. The south channel-side and control sites of the middle reef exhibited the highest coral mortality count associated with white-plague. The species most dramatically impacted include *Dichocoenia stokesi* and *Meandrina meandrites*. R2S2-LR had the highest percentage of mortality where 46% of tagged corals succumbed to the disease. R2SC2-LR had the next highest percentage of 44%, while R2S1-RR and R2SC1-RR had coral mortality associated with white-plague of 26% and 27% respectively. R2N1-RR had the highest percentage of coral mortality at the north channel-side sites with 40%. When compared to R2N2-LR, R2NC1-LR and R2NC2-RR which had relatively low mortalities of 8%, 11% and 7% respectively.

On the outer reef, the south channel-side and control sites exhibited the highest percentage of mortality associated with white-plague disease. White-plague mortality at the south channel-side sites ranged from 12% (R3S2-LR) to 26% (R3S1-CP). The south controls had higher percentages of mortality ranging from 8% (R3SC1-CP) to 40% (R3SC2-LR). R3N1-LR did not have any coral mortality associated with white-plague; however, R3NC1-LR had 25% of tagged corals exhibit mortality due to white-plague.

When considered in a regional context, white-plague mortality appeared to be greatest south of the channel, but has spread to the channel-side environment and areas north. In general terms, the middle reef sites had the highest numbers of white-plague disease-susceptible species and thus, had the highest documented mortality as compared to the nearshore hardbottom or outer reef sites.

A significant decrease in mean scleractinian coral density occurred channel-side at R2N1-RR, R2S1-RR, and R2S2-LR. R2N1-RR experienced the greatest decrease in mean density from 1.37 to 0.73 colonies/m^2. At the middle reef control sites mean coral density significantly declined at R2NC2-RR where mean density declined from 1.61 to 1.05 colonies/m^2.

A significant decrease in mean coral density occurred at R3N1-LR and R3S2-LR between baseline and post-construction surveys. Mean coral density declined from 1.03 to 0.75 colonies/m^2 at R3N1-LR and from 1.76 to 1.53 at R3S2-LR.

The causes of changes in mean coral density between baseline and post-construction cannot be determined for untagged corals. However, the majority of tagged corals at middle reef sites have died as a result of white-plague disease between baseline and post-construction surveys. At R2N1-RR, R2S1-RR, and R2NC2-RR, the only source of total colony mortality in tagged corals documented during construction or post-construction was due to white-plague disease. At R2S2-LR of the twelve tagged corals that have died during construction and post-construction monitoring one coral died from bleaching and disease and the remaining eleven died from white-plague disease.

Scleractinian size class distributions were observed to vary among location. The smaller size classes were the predominant individuals documented during baseline and post-construction surveys, with the smallest recruits (ranging in 3-5cm) observed to increase in frequency from baseline to post construction at more than half of all middle and outer reef sites; R2N1-RR, R2NC3-LR, R2S1-RR, R2SC1-RR, R3NC1-LR, R3S1-CP, R3S2-LR, R3S3-SG, AND R3SC1-CP.

The causes of changes in mean octocoral and sponge density between baseline and post-construction cannot be determined because individual colonies were not closely followed over time. Octocoral abundance declined at six out of nine middle reef sites, four of these sites were channel-side sites and two were control sites, but these changes were not statistically significant. Octocoral abundance at the outer reef declined at one channel-side site (R3N1-LR; 1.03 to 0.75 colonies/m^2), but this decline was not statistically significant. All other outer reef sites increased in octocoral density between baseline and post-construction periods. At R3NC1-LR, this increase was statistically significant.

Sponge abundance and density declined at six out of nine middle reef sites (three control sites and three channel-side sites). R2N2-LR experienced the greatest decrease in sponge density, with a statistically significant decrease of 10.3 individuals/m$^{2.}$ Northern and southern control sites also declined significantly. On outer reef sites all sites, except for R3N1-LR increased in sponge density between baseline and post-construction periods, the change at R3N1-LR was not statistically significant. Since octocorals and sponges were not closely followed over time, changes in these groups cannot be ascribed to a particular cause.

Functional group data, analyzed from video transect footage, including octocorals, scleractinians, and sponges changed little between baseline and post-construction, although groups varied over time during compliance monitoring. Due to the low cover of living functional groups, *in situ* colony counts are recommended in future project assessments for a more accurate and precise measurement of organismal change at the level of the transect and site.

Functional groups data including crustose coralline algae, turf, and bare rock (CTB) and sand varied widely throughout the compliance period as well. Increased sand was documented at all middle and outer reef channel-side sites during compliance monitoring, however, based on the post-construction video dataset analysis CTB appeared to be increasing at most middle and outer reef sites since February 2015, which would be expected as any local increases in sediment are assimilated into the benthos over time.

Sedimentation flux was calculated (daily rates) using sediments collected in traps at all reef sites. Average sedimentation rates varied depending on reef (middle or outer) and side (north or south), and grain size (greater than #230 sieve; less than #230 sieve). These rates reflected seasonal variation in sediment transport as well as proximal sources of sedimentation (i.e. location relative to active dredging equipment). In general, sedimentation rates were greater at middle reef sites when compared to outer reef sites. Sedimentation rates were greater on the north side of both the middle and outer reefs when compared to the south. Dredging activity likely elevated sedimentation rates during the project, however, winter weather also increased sedimentation rates at all sites. Sedimentation rates were lower during post-construction surveys than during baseline for both coarse and fine grained sediments. These changes in sedimentation rates may represent a seasonal difference, as baseline data were collected in the fall/winter when winds and waves re-suspended sediments (but before any dredging activity), compared with summer conditions, which were relatively calm and had lower suspended solids.

Both natural and project related impacts were observed to be important to benthic communities in the vicinity of the project area. However, the greatest impacts associated with coral mortality over time appear to be related to a catastrophic, regional-scale coral bleaching/disease outbreak that started in the fall of 2014 and continues to deleteriously affect coral populations at the time of this writing (fall 2015). The results of this study led to a rejection of the null hypothesis, as benthic communities at the middle and outer reef were changed between the pre- and post-dredging periods due to natural and project related factors.

1.0 INTRODUCTION

1.1 Study Context and Objectives

The Miami Harbor Phase III Deepening Project was designed to widen and deepen the outer entrance channel to increase safe access to the Port of Miami by larger class ships, including post-Panamax class ships. To accommodate these larger vessels, the outer entrance channel has been widened at the outer reef and deepened to 52 (±1) feet Mean Lower Low Water (MLLW) (15.6 ± 0.3 m). Avoidance and minimization of impacts to natural resources (hardbottom and seagrasses) was conducted through the NEPA process and a Record of Decision was signed on May 22, 2006. The project was permitted through the Florida Department of Protection (FDEP), under Permit No. 0305721-001-BI. Permit conditions provide a number of protective measures to ensure the preservation of natural resources, such as hardbottom, reef, and seagrass communities, including methods on environmental monitoring required before, during, and after dredging activities.

Great Lakes Dredge and Dock (GLDD) was responsible for implementing the required environmental monitoring program during the immediate pre-, during, and immediate post-construction time periods associated with the Miami Harbor Phase III project.

Dial Cordy and Associates Inc. (DCA) was contracted by GLDD to conduct baseline, compliance, and post-construction monitoring of hardbottom, reef, and seagrass habitats in the project area. Specifically, DCA was contracted to (1) conduct baseline, compliance, and post-construction surveys at hardbottom, middle and outer reef monitoring sites, and their control sites, (2) conduct baseline, compliance, and post-construction surveys at Fisherman's Channel seagrass sites, and (3) conduct baseline, compliance and post-construction surveys at Julia Tuttle Seagrass Mitigation Site (JTSMS).

This post-construction report characterizes the benthic communities within the channel-side and control site areas of the middle and outer reefs required to be monitored in compliance with the FDEP permit before, during, and following completion of the project. Since hardbottom and outer reefs reports were submitted separately during baseline, the separate presentation has been preserved for the post-construction reports. The study was designed to compare pre- and post-construction results to detect effects of dredging on adjacent benthic resources. The study also compared channel-side sites to control sites in the post-construction period. 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):

> Ho: Benthic communities in the indirect effect (channel side) sites will remain unchanged between the pre and post-dredging surveys.

1.2 Study Area

The study area is located in central Miami–Dade County, within hardbottom and reef habitats east of the Port of Miami 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 reefs 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).

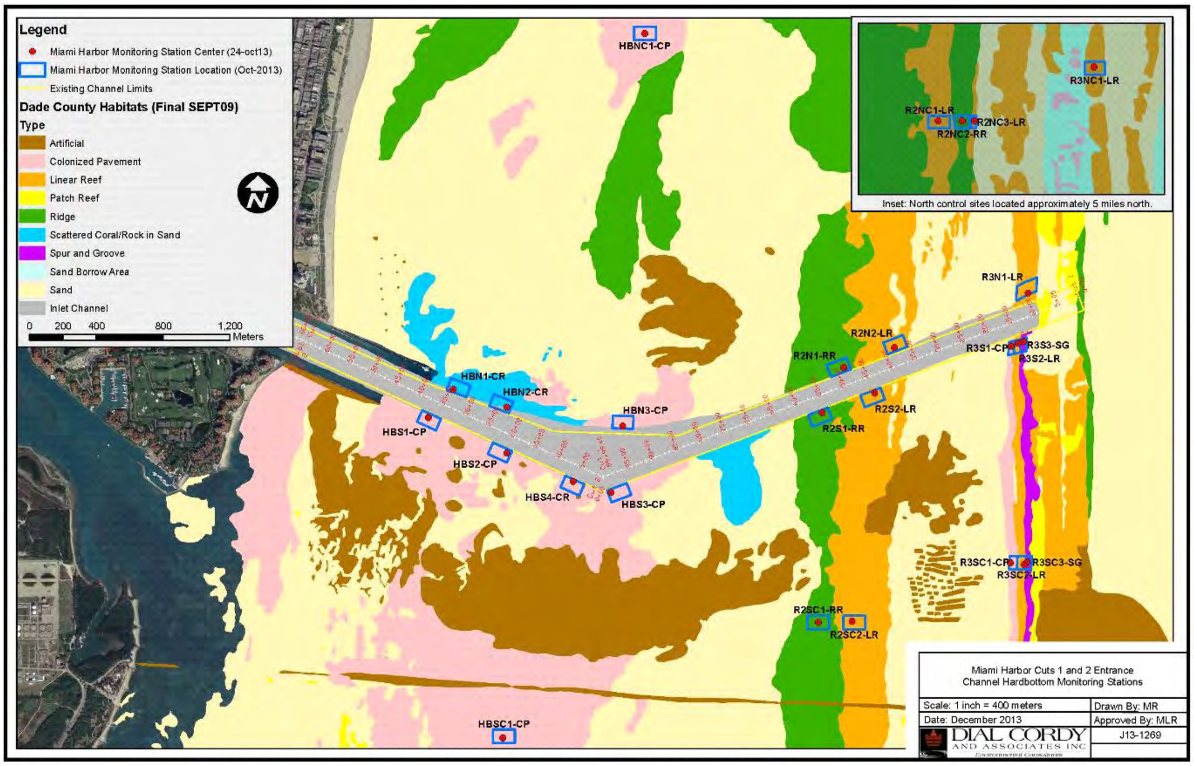

Figure 1. Miami Harbor Cuts 1 and 2 Entrance Channel hardbottom, middle, and outer reef monitoring stations. Habitat maps used were developed by Walker et al. 2008.

1.3 Previous Studies

A number of U. S. Army Corps of Engineers (USACE) studies have been conducted to support the project, starting with the Environmental Impact Statement (EIS), which was finalized by signature of the Record of Decision in 2006. Moreover, a Pilot Study was conducted in October 2009 to determine the level of effort required to adequately sample the hardbottom and reef habitats surrounding the Miami channel in order to detect a level of change in functional group cover of 5% (see Dial Cordy and Associates 2010).

Indirect-effect sites and reference sites sampled during the Pilot Study were similar to other reef areas in southeastern Florida that have been characterized by Gilliam (2007), Moyer et al. (2003), and others. In general, these areas are dominated by macroalgae (45–82% cover across sites), with lower cover of other biological groups, including corals (scleractinians and *Millepora*; 0.05–4.62% cover), sponges (0.54–6% cover), and octocorals (1 to 15% cover). The rubble, sand, and pavement group (4–71% cover) was the second most dominant cover type after macroalgae.

1.3.1 2009 Pilot Study Results

The 2009 Pilot Study documented that an analysis of variance (ANOVA) based approach would not provide sufficient statistical power to detect change at the level of 5% across groups (octocorals, macroalgae, corals, and sponges). The sample sizes required to detect a 5% change in macroalgal cover at $P = 0.05$ with a power of 0.80 ranged from 275 to 450 transects per site. Octocoral variances were also high. The sample sizes required to detect a 5% change at $P = 0.05$ with a power of 0.80 for octocorals would start at 2,200 transects per sample site. These results showed that an ANOVA approach is not practical for sampling in this variable and patchy environment. Thus, a regression based study design was recommended for quantitatively comparing before and after dredging results.

1.3.2 Quantitative Study Results 2010

Due to the low cover and sporadic occurrence of hard corals and octocorals at the 2009 Pilot Study sites, a regression-based approach on the middle and outer reefs, beginning adjacent to the channel, was conducted for the Quantitative Study Plan in 2010 (DCA 2012). For nearshore hardbottom communities west of the middle reef, a stratified random approach was conducted, based upon octocoral and scleractinian colony density within treatment and control sites identified during the Pilot Study. The report also recommended that all areas be sampled using colony counts rather than estimates of cover, due to the low cover of benthic organisms (see also Smith et al. 2011).

By following this recommended design, post-construction surveys conducted after the dredging operation would have allowed comparison with the pre-dredging data. Potential effects of the dredging operation on the middle and outer reefs would have been detectable as a significant difference between the pre- and post-dredging conditions in the relationship between distance from the channel and the magnitude of change. Effects on hardbottom sites would be detectable as significant interaction terms of ANOVA between time (before *versus* after dredging) and treatment (indirect-effect *versus* control).

1.3.3 Baseline Quantitative Study 2013

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; this was contrary to the recommended approach outlined in the 2009 Miami Harbor Pilot Study and the methods employed for the 2010 Quantitative Study (DCA 2010 and DCA 2012). The current study required a pre-dredging survey and a post-dredging survey, which are compared here to detect project effects. This document reports and compares the pre- and post-dredging survey results for middle and outer reef environments.

1.3.4 USACE Survey Results

USACE pre-bid and pre-dredge hydrographic surveys documented differences in sediment accumulation across Cuts 1 and 2 of the federal channel. The nearshore hardbottom habitat, where seven project monitoring survey sites are located, had an 18% increase in sedimentation between August 2010 and October 2013, whereas other locations in Cuts 1 and 2 had a 2-3% increase in sedimentation (personal communication Steven Conger, USACE; April 3, 2015).

1.4 Dredge Activity

General dredging activity is described here, with beginning and ending dates for dredges. For more information on adaptive management strategies used during construction, see Weekly Compliance reports. The hopper dredge Terrapin Island began dredging on November 20, 2013 adjacent to hardbottom monitoring sites. The dredge Texas and the Spider barge began chopping rock and loading dredged material to scows for the ocean dredged material disposal site (ODMDS) and Julia Tuttle seagrass mitigation site (JTSMS) disposal on December 17, 2013. Terrapin Island left the job site on December 27, 2013, but the Texas and Spider barge continued working offshore from west to east. The hopper dredge Liberty Island arrived at the Project site on May 14, 2014 and worked offshore until July 3, 2014. Dredging operations in the channel flare (easternmost portion of Cut 1) commenced on August 6, 2014. On August 24, 2014, the Texas and Spider barge moved inshore for repairs. The Texas and Spider barge dredged in Cut 2 for seventeen days before returning to Cut 1 on September 12, 2014. The Dredge Texas and Spider barge completed offshore dredging operations on December 23, 2014. The Dredge 55 operated intermittently offshore, when weather permitted until March 16, 2015. All Cut 1 and Cut 2 dredging (offshore) was accepted and therefore deemed complete, by the USACE on April 8, 2015. Dredging inshore continued until September 16, 2015. The USACE accepted the project as complete on September 17, 2015.

2.0 METHODS

2.1 Study Site Description

The middle and outer reefs baseline surveys collected information on the population dynamics, condition, and sedimentation environment of the benthic communities adjacent to the Port of Miami Phase III project area immediately before commencement of construction activities. These baseline results are used as a point of comparison for the post-construction survey to document changes attributable to dredging while considering other environmental or anthropogenic factors that influenced middle and outer reefs resources in the area. The following section describes the materials and methods used to collect post-construction data on the benthic organisms and sedimentation rates at all middle and outer sites. Raw photo, video and scanned data sheets were submitted to the USACE under separate submission in accordance with contract specification on September 2, 2015.

In 2013 site selection was conducted on a desktop computer, using ArcView™. FDEP permit site establishment polygons were imported into ArcView™. A smaller polygon, fitting within the FDEP polygon, was generated in ArcView™. The ArcView™ random point generator was used to establish a center point for the monitoring site within that smaller polygon. Site selection was conducted per FDEP Permit # 0305721-001-BI and based on habitat descriptiondescriptions by Walker et al. 2008.

In the field, HYPACK Navigational™ software was used to locate and mark the center point defined in ArcView™. Scientific divers qualitatively assessed the potential site for the appropriate habitat, reef with hard corals and octocorals. The buoy location was adjusted by divers to optimize the amount of reef and/or reef habitat in compliance with the guidance provided in the FDEP permit. Thus, transect placement was not random, instead transects were intentionally placed in areas devoid of sand where possible. This was done in order to maximize sampling reef habitat, as this was the goal of the monitoring program mandated by the FDEP permit. Three monitoring transects were established approximately 5 m apart from each other.

In the fall of 2013, during site installation, 252 scleractinians were permanently marked at middle reef sites, and 189 scleractinians were permanently marked at outer reef sites (channel-side and control, Table 1). During the two years of compliance monitoring four marked colonies were documented as missing at middle reef sites, and were never found. Two of these corals were at channel-side sites. Seven colonies disappeared at outer reef sites, and two of these corals were at channel-side sites. The cause of missing corals was presumed to be due to physical disturbance, but no obvious signs of impact were documented. The channel-side environment is active with boat traffic and has greater velocity of currents, when compared to control sites, which may explain the missing colonies. Other coral monitoring programs in southeast Florida have commonly noted tagged corals as missing (see Gilliam 2012). Analysis in the results section for post-construction has been conducted excluding these missing colonies from the total colony count.

Table 1. Number of tagged colonies during site installation at all middle and outer reef sites.

	Site	Permanently Marked Corals
Middle Reef	R2N1-RR	30
	R2N2-LR	25
	R2NC1-LR	30
	R2NC2-RR	30
	R2NC3-LR	30
	R2S1-RR	28
	R2S2-LR	24
	R2SC1-RR	30
	R2SC2-LR	25
	Total	**252**
Outer Reef	R3N1-LR	23
	R3NC1-LR	24
	R3S1-CP	19
	R3S2-LR	25
	R3S3-SG	25
	R3SC1-CP	25
	R3SC2-LR	23
	R3SC3-SG	25
	Total	**189**
	Grand Total	**441**

2.1.1 Control Sites

A total of nine control sites were established during baseline for comparison with middle and outer reef compliance (channel-side) sites. Five control sites were established for the middle reef, three in the north (9.38 km away from the channel), two sites in the linear reef (LR) habitat type, and one in the ridge reef (RR) habitat type. Two southern middle reef control sites were established in the LR and RR habitat types, 1.27 km away from the channel. Four outer reef control sites were established north and south of the channel; in the north, one representing the LR habitat type was established 9.38 km away from the channel and three southern reference sites representing colonized pavement (CP), LR, and spur and groove (SG) habitat types were 1.3 km away from the channel. The northern control sites were placed north of the Port anchorage area to avoid confounding effects due to non-project activities at the anchorage.

Middle reef channel-side sites R2N1-RR and R2N2-LR were chosen based on the presence of two habitat types in the vicinity of the channel. In the area of the northern control sites, three habitats were described for the area, one linear reef and two ridge reef areas (Figure 1). R2NC1-LR and R2NC2-RR were paired for comparison with R2N2-LR and R2N1-RR. R2NC3-LR was a redundant habitat type control site without a channel-side pair. For this reason, monitoring was not conducted at this site for the majority of the compliance period, but the site was surveyed during baseline surveys and during post-construction surveys in Week 3 and 4, in order to compare before and after project conditions. The tagged corals from R2NC3-LR are not included in the tagged coral analysis, since a complete compliance dataset was not collected.

2.1.2 Channel-side sites

A total of eight channel-side or compliance sites were established during baseline approximately 10 m from the edge of the existing channel edge on the middle reef and 10 m from the edge of the proposed reef on the outer reef. Four middle reef sites, two on the north side (R2N1-RR and R2N2-LR) and two on the south side (R2S1-RR and R2S2-LR). Outer reef channel-side sites included one site on the north side (R3N1-LR) and three on the south side (R3S1-CP, R3S2-LR, and R3S3-SG).

2.1.3 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 2). 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. 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.

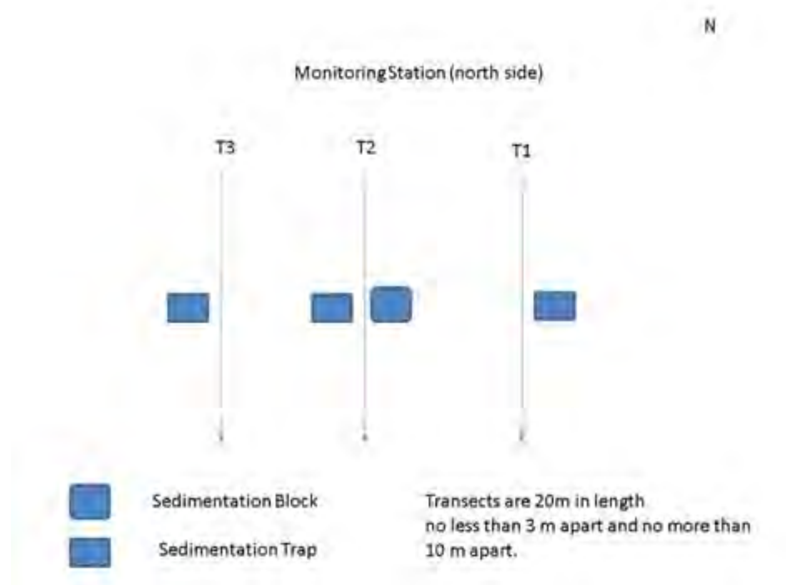

Figure 2. Middle and outer reef monitoring site layout.

2.1.4 Sedimentation Traps

Three sediment traps (Figure 3) were placed during baseline at each of the middle and outer reef monitoring sites (including control sites) to allow the comparison of net sediment trap accumulation among monitoring stations and between construction monitoring sites and reference monitoring sites. 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) (Figure 3). 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 are made and a new 28 day sediment monitoring period begins. Following completion of the post-construction monitoring program, all sediment traps and frames were removed.

Figure 3. Sediment traps installed at all offshore sites for environmental monitoring of hardbottom and reef resources in Cuts 1 and 2.

2.1.5 Sedimentation Blocks

A net sediment accumulation block was placed during baseline at each site at the 10 m mark on Transect 2 (Figure 4). This block served as the center point of the monitoring site for underwater navigational purposes. The sediment accumulation block consisted of an 8 in. x 8 in. x 8 in. concrete block attached to the bottom with hydraulic cement. The block had one side coated with antifouling paint, which was oriented as the upper surface. The antifouling paint minimized the bioaccumulation on the upper surface of the block which could interfere with sediment accumulation. The blocks were designed as an abiotic proxy for hard corals, to be used to measure an accumulation of sediment. Due to high rates of water flow associated with tidal and north to south currents, sediment blocks did not accumulate sediment during the monitoring period. Blocks were attached to exposed rock surfaces devoid of benthic fauna and no closer than 30 cm to any coral colony to assure no impact to living marine resources. Following completion of the post-construction monitoring program, all blocks were removed.

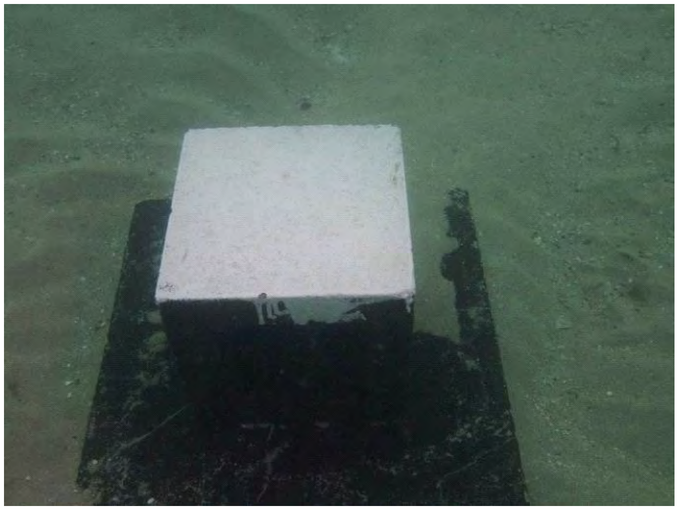

Figure 4. Sediment block used to monitor sediment accumulation at middle and outer reef sites.

2.2 Data Collection

All scientific divers were trained and qualified to conduct benthic surveys in middle and outer reef environments, as required by the FDEP permit and USACE specifications for the project. During Week 1 of baseline and post-construction surveys, all scientific divers responsible for collecting *in situ* data participated in quality assurance and quality control (QA/QC) training and exercises, with periodic follow-up throughout the monitoring period to maintain QA/QC standards over the life of the survey period. Project specific training materials were developed and included coral species identification and coral stress indicator guides. These training tools were provided to all project personnel. Previous studies have documented difficulty in differentiating coral colony species smaller than 4 cm (Edmunds et al. 1998). As a result of inter-observer variability, data on corals smaller than 3 cm were not 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).

Post-construction surveys of the middle and outer reef sites were conducted over four weeks between June 17, 2015 and July 15, 2015. Each site was surveyed approximately each week, during the four weeks of post-construction study as required by FDEP permit (Table 2). Adverse weather conditions affected the ability to conduct scientific diving on 4 of 29 days during the post-construction monitoring period. Safe diving conditions are described in EM-385 (EM-385 is the safety regulation document that guides all USACE scientific diving operations) as current speed of <1 knot and visibility >3 feet; additionally best professional judgment of wind and wave conditions is used to determine whether or not scientific dive operations may be conducted safely. Accordingly, no operations were conducted during small-craft boating advisories.

Surveys were conducted in order to ensure four distinct sampling periods were completed for each site. A sampling week was defined as a 7 day period in which each site was planned to be sampled. Due to unsafe diving conditions, sites may have been sampled four, five or six days apart or more than seven days apart (Table 2).

Post-construction sediment traps were placed at all middle reef sites on June 17, 2015 and on outer reef sites on June 20, 2015. As required by permit, sediment trap bottles were collected at

28 day intervals from baseline through the end of the post-construction monitoring. The final sediment trap samples were collected at all middle reef sites on July 15, 2015, and at all outer reef sites on July 18, 2015.

Table 2. Post-construction surveys were conducted at middle and outer reef sites between June 17, 2015 and July 15, 2015.

Site	Post-construction Survey Dates			
	Week 1	Week 2	Week 3	Week 4
R2N1-RR	06/18/2015	06/24/2015	07/06/2015	07/15/2015
R2N2-LR	06/18/2015	06/24/2015	07/06/2015	07/15/2015
R2NC1-LR	06/17/2015	06/24/2015	07/05/2015	07/13/2015
R2NC2-RR	06/17/2015	06/24/2015	07/05/2015	07/13/2015
R2NC3-LR	N/A	N/A	07/06/2015	07/13/2015
R2S1-RR	06/18/2015	06/25/2015	07/08/2015	07/15/2015
R2S2-LR	06/18/2015	06/25/2015	07/07/2015	07/15/2015
R2SC1-RR	06/18/2015	06/25/2015	07/07/2015	07/11/2015
R2SC2-LR	06/17/2015	06/24/2015	07/07/2015	07/11/2015
R3N1-LR	06/19/2015	06/25/2015	07/03/2015	07/14/2015
R3NC1-LR	06/19/2015	06/24/2015	07/05/2015	07/13/2015
R3S1-CP	06/22/2015	06/27/2015	07/02/2015	07/12/2015
R3S2-LR	06/22/2015	06/27/2015	07/02/2015	07/12/2015
R3S3-SG	06/19/2015	06/27/2015	07/03/2015	07/12/2015
R3SC1-CP	06/18/2015	06/26/2015	07/01/2015	07/11/2015
R3SC2-LR	06/19/2015	06/26/2015	07/01/2015	07/11/2015
R3SC3-SG	06/19/2015	06/26/2015	07/02/2015	07/11/2015

2.2.1 Abiotic Characteristics

General abiotic data were collected, during both baseline and post-construction survey periods, to describe the general conditions of each monitoring site. Documentation was collected on the presence of hardbottom, rock, rubble, sand, sedimentation (i.e. visibility in the water column), bare substrate, maximum water depth, and rugosity (post-construction only). Rugosity was added to the methods for post-construction at middle and outer reefs, and was not part of the original methods for the baseline survey.

2.2.2 *In Situ* Data

In situ data were collected along three 20 m x 1 m belt transects at each middle and outer reef monitoring site, each week for four weeks during the post-construction survey period (June 17 – July 15, 2015). Scientific divers placed transect tapes, marked in metric and standard along the pre-established transects, securing the tape at the beginning, mid, and end points. *In situ* post-construction data were collected using underwater data sheets and clipboards and all *in situ* data is provided in Appendix A. Scleractinian abundance and condition data were collected for each tagged colony during all four weeks of post-construction monitoring at all middle and outer reef sites and for all scleractinian species (colonies greater than 3 cm) occurring within the 20 m x 1 m belt transect. Photographs of all tagged colonies during baseline, construction, and post-construction surveys are provided in Appendix B. Landscape site photos of each compliance monitoring site during baseline and post-construction monitoring periods are provided in Appendix C. *In situ* data were collected on the abundance, condition, and maximum diameter for all scleractinian species (colonies greater than 3 cm). During Week 3, all octocoral genera occurring within the 20 m x 1 m belt transect were counted and maximum diameter was measured. Maximum diameter for erect octocorals was the maximum height, and for encrusting octocorals was the maximum diameter. Summary tables of the total numbers of scleractinian and octocorals recorded during baseline and post-construction surveys are provided in Appendix D. Additionally, abundance (counts) of sponge morphotypes and zoanthid were collected in Week 3 (Table 3, Appendix A).

Table 3. Quantitative *in situ* data collected at all middle and outer reef permanent transects during post-construction surveys, June and July 2015.

	Week 1	Week 2	Week 3	Week 4
All non-marked scleractinian species within 20m x 1m transect (colonies > 3cm)	Abundance (counts) and condition	Abundance (counts) and condition	Abundance (counts), condition, and maximum diameter	Abundance (counts), condition
Permanently marked scleractinian species	Condition	Condition	Condition and maximum diameter	Condition
Encrusting and Erect Octocorals (genera)	-	-	Abundance (counts), and maximum diameter	-
Sponge (morphotype) and Zoanthid (genera)	-	-	Abundance (counts)	-

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, polyps extended, disease, and sediment accumulation (Bruckner 2001, Dial Cordy Training PPT 2013; Table 4). Examples of corals with conditions captured during compliance monitoring and post-construction surveys are provided in Figures 5-9. Each permanently marked 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, polyp extended, disease, or other adverse condition, while a "1" would be assigned if one or more condition 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 and post-construction surveys at middle reef and outer reef sites (adapted from FRRP (Florida Reef Resilience Program) and DCA 2012). Baseline surveys are designated by a circle, while post-construction surveys are designated by a square. * designates conditions categories that were not present during baseline, but were added during compliance monitoring as needed.

Condition	Cause	Appearance	Field Code	Middle Reef Presence	Outer Reef Presence
Bleaching					
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					
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	◻	• ◻
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					
Polyps extended	Stress and feeding	Tentacles are extended on 100% of polyps on the colony.	PE	• ◻	• ◻
Fish bites	Grazing	Bites of live tissue removed.	FB	• ◻	• ◻

Condition	Cause	Appearance	Field Code	Middle Reef Presence	Outer Reef Presence
Mucus production	Sediment stress/Lunar cycle	Excessive mucus production results in a mucus film and/or sediment balled up in mucus.	M	• □	• □
Cliona delitrix	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		
Unknown condition *	Stress	Discoloration of living tissue from an unknown cause. Not related to known bleaching or disease indicators.	UC	□	□
Sedimentation indicators					
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	□	□

Condition	Cause	Appearance	Field Code	Middle Reef Presence	Outer Reef Presence
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	◻	◻
Complete Mortality Indicator					
Complete mortality *	Any	Death of the entire colony; no live tissue remaining on the skeleton.	DEAD	◻	◻

Figure 5. Photographs of bleaching conditions documented during compliance and post-construction surveys.

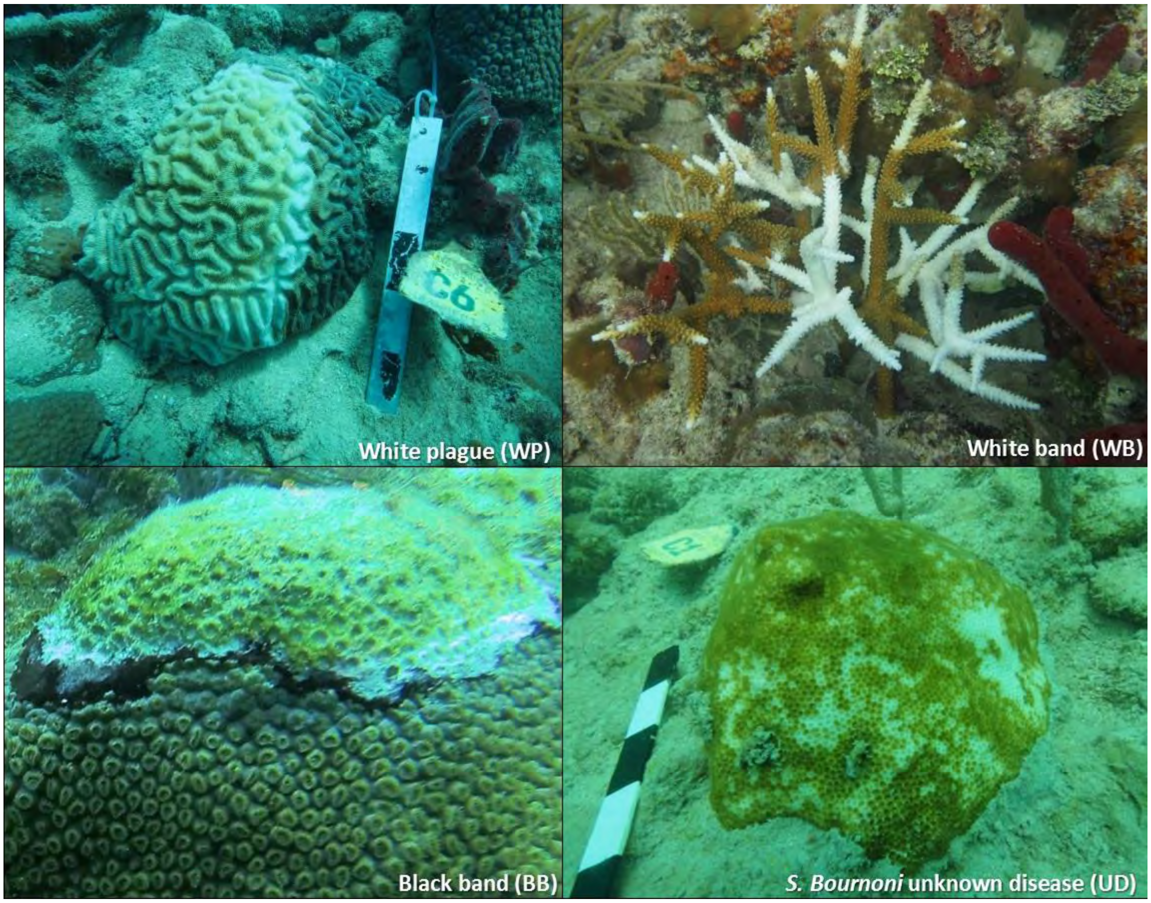

Figure 6. Photographs of disease conditions documented during baseline through post-construction surveys.

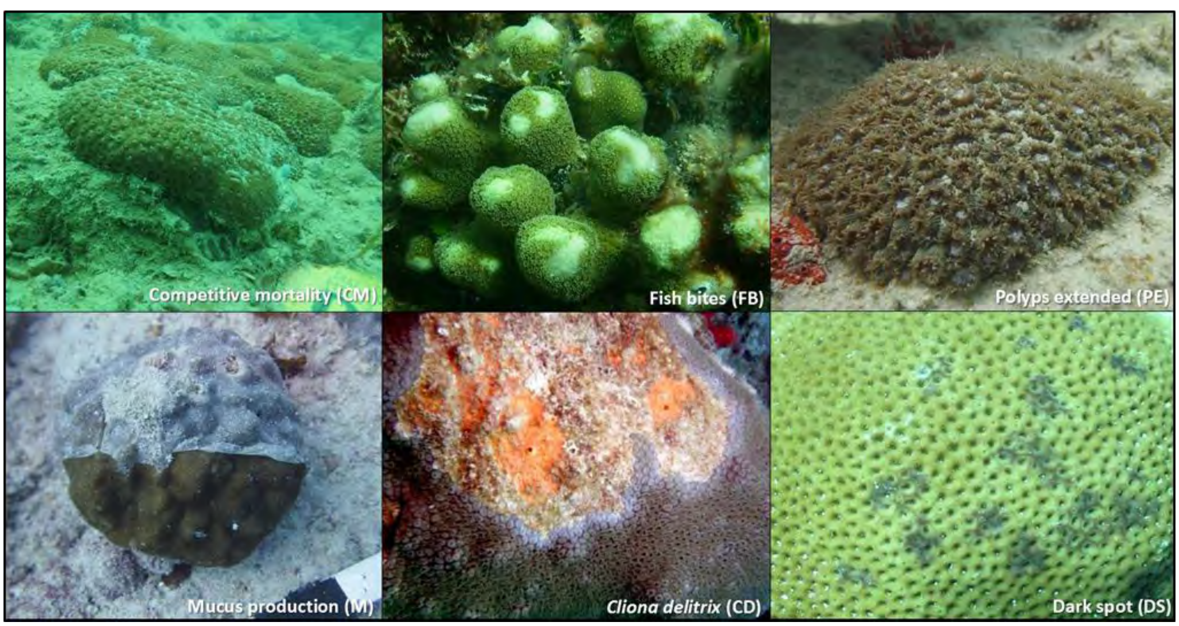

Figure 7. Photographs of stress indicators documented during compliance and post-construction surveys.

Figure 8. Photographs of stress indicators collected during compliance and post-construction surveys.

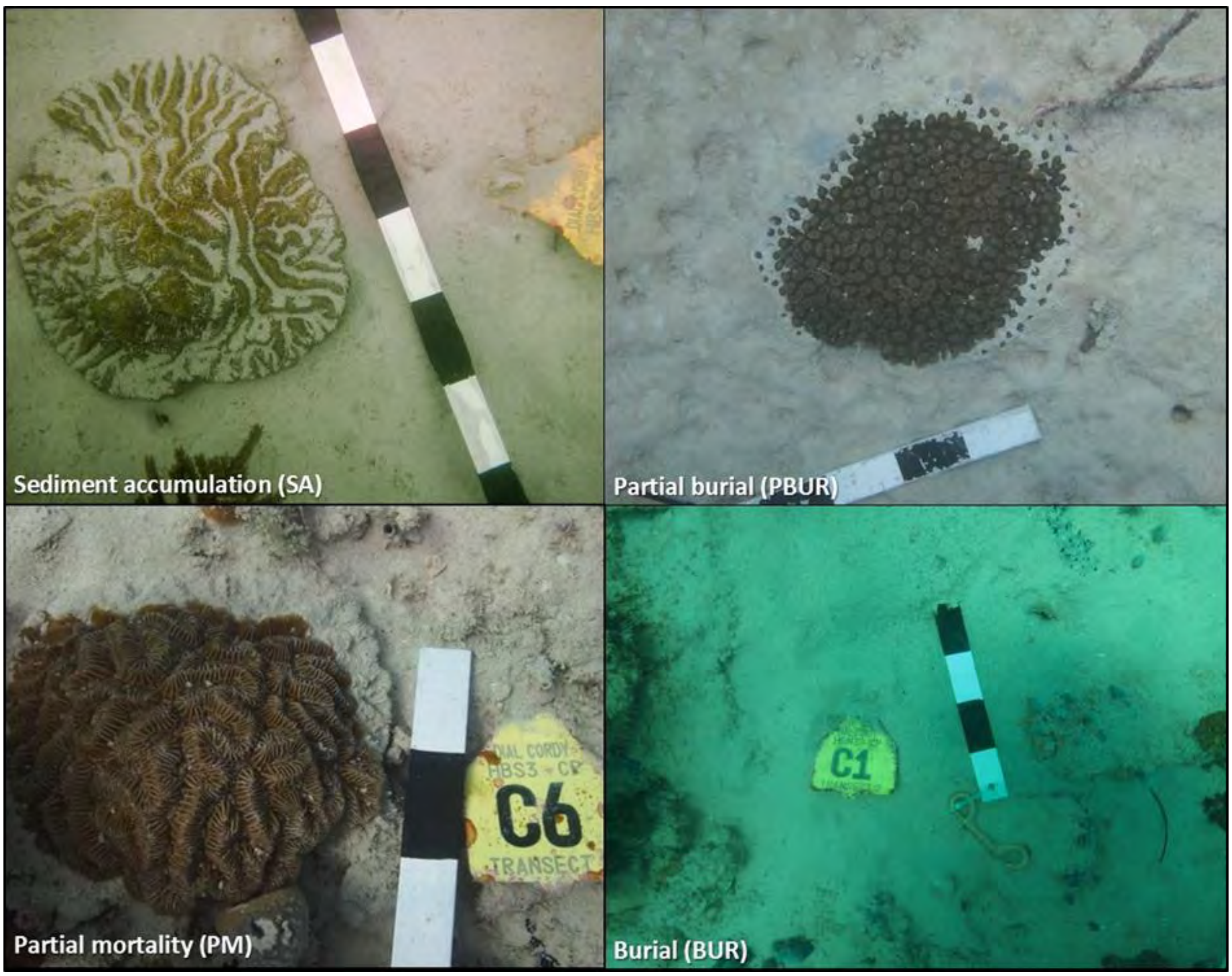

Figure 9. Photographs of sedimentation indicators documented during compliance and post-construction surveys.

2.2.4 Photo and Video

Scientific divers collected still photographs of permanently marked corals from a horizontal perspective, so that the maximum diameter of the colony was present within a single photo frame along with the permanent marker and scale bar in each of four weeks of post-construction monitoring. Photos of all tagged corals during baseline, construction and post-construction monitoring periods are provided in Appendix B. Additional photographs were collected at the center of the site, adjacent to the sediment block, 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. General site photos of all compliance monitoring sites during baseline and post-construction monitoring periods are provided in Appendix C.

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 week and each of four weeks of post-construction 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 10). The diver swam the camera along each transect at a speed of ~5 m per minute to insure 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 both the coral health and potential sedimentation stress during post-construction as well as functional group cover at both the channel-side sites and the control sites.

Figure 10. Scientific diver collecting video data of transects during baseline surveys. Photo taken October 24, 2013.

2.2.5 Sedimentation Traps

Quantitative sediment samples were collected during baseline, construction, and post-construction periods. A sediment trap at each transect held three replicate 500 mL Nalgene bottles. 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).

Post-construction monitoring sediment trap bottles were set on June 17, 2015 at all middle reef sites (except R2NC3-LR), and on June 20, 2015 at all outer reef sites. Sedimentation post-construction data were collected to understand the sediment dynamics at the monitoring sites following the completion of dredging. Sediment trap sample collection was completed for all middle reef sites on July 15, 2015, and for all outer reef sites on July 18, 2015 after 28 days. 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.

2.2.6 Sedimentation Blocks

Sediment blocks were generally located on high points at each site, above the benthos and subject to strong currents. As a result, no sediment accumulated on the blocks during baseline, compliance, or post-construction periods. Photos of the blocks were collected during monitoring surveys.

2.3 Data Analysis

2.3.1 *In Situ* Data

After *in situ* data collection, scientific divers reviewed their results and discussed issues with the on-site scientific data manager. Underwater data sheets were washed, dried and quality controlled by the Project Manager, after which post-construction data were entered into an Excel based spreadsheet program. QA/QC of data input was conducted by another scientist to insure accurate data entry for analysis.

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 E. 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 through all three to four weeks of baseline and four weeks of post-construction surveys. Only permanently marked scleractinian corals were photographed and allowed for visual record and comparison between baseline and post-construction datasets. QA/QC was conducted on permanently marked scleractinian photos for all coral conditions in the laboratory.

Coral condition data were analyzed only 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 post-construction 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 post-construction report. If an error was not noted, then no changes have been made to the baseline figure or table. All comparisons within this post-construction 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

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 from Week 3 of post-construction was analyzed for the post-construction report, as these files provided the clearest still images from the post-construction period. 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, and bare (CTB); sediment/sand (S); zoanthids (Z); hard coral (CORAL); octocoral/gorgonian (GORG); sponge (SPO); and tape, wand, shadow (TWS).

Coralline algae, turf, and bare substrate 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 post-construction 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 11 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 categories.

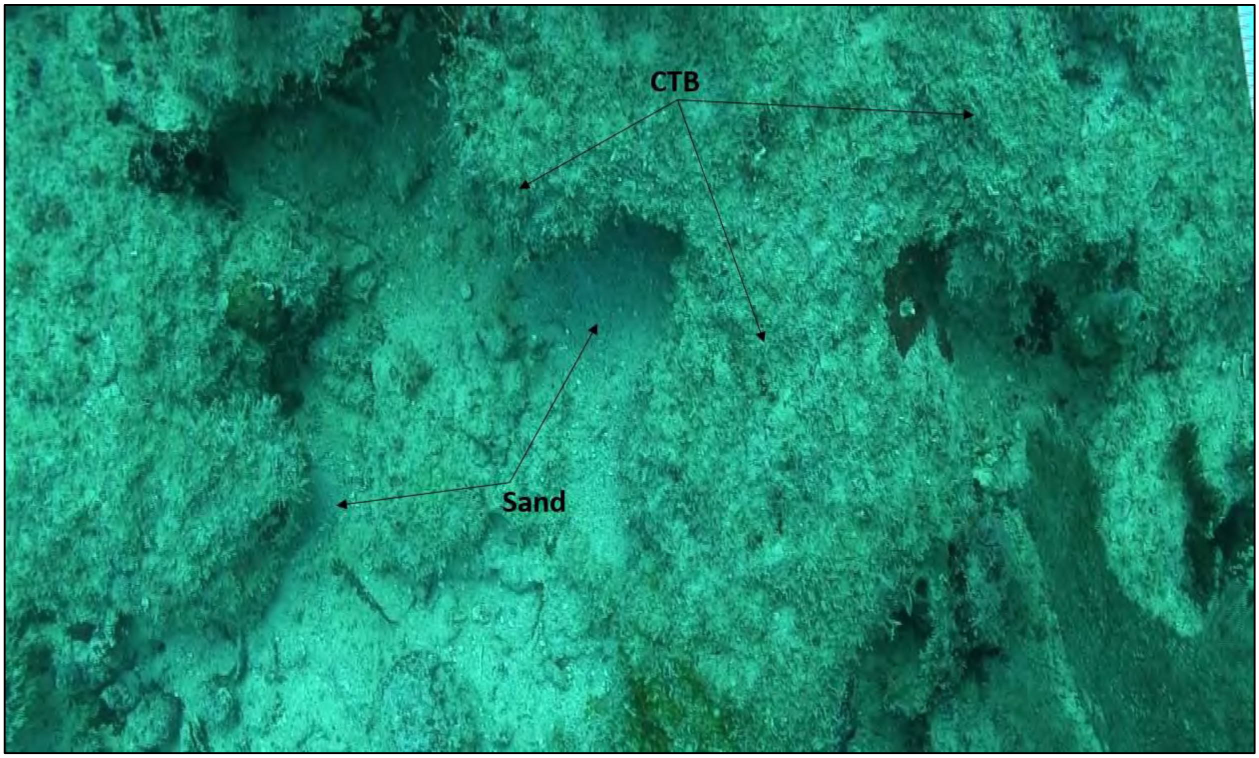

Figure 11. Still image from R3NC1-LR during baseline surveys showing the distinction between coarse-grain sand, fine-grain sand, and the CTB category.

In addition to the training of the analysts, all evaluated transects underwent QA/QC screening. For each transect that is analyzed for relative abundance of functional groups by a trained analyst, a second analyst reviewed 10% of the resulting frames. If disagreement of more than 20% exists 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.

Although no comparison between channel-side and control sites were required for the 5% change special condition (FDEP permit (SC32aiid), control site data may be used as a general point of comparison to describe regional trends. Weekly video data collected at control sites were analyzed throughout compliance monitoring when corresponding channel-side site data were collected.

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. 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

Post-construction biological monitoring results are compared with baseline monitoring results and provided below. Data collected during compliance monitoring of tagged coral colonies related to effects of sedimentation, bleaching and disease are also presented below. A thermally induced coral bleaching event during the summer of 2014 preceded a white-plague disease outbreak in the study area that directly affected coral health at control and channel-side sites, causing total mortality of many of the tagged corals associated with the project. The loss of these colonies had a direct bearing on the post-construction data set as presented below. All *in situ* post-construction monitoring data is provided in Appendix A.

3.1 Tagged Scleractinian Mortality and Conditions

A total of 400 scleractinian corals were tagged and monitored between baseline and post-construction surveys at middle and outer reef sites (Table 5) in compliance with the FDEP mandated monitoring program. Missing corals which may have been dislodged over time are not included in this count, nor are the colonies from R2NC3-LR, which was a redundant control site with no channel-side pair. Other long-term coral monitoring programs have documented dislodged or disappeared colonies over time (Gilliam 2012). Of the 400 corals surveyed, 111 died between baseline and post-construction surveys representing a total mortality rate of 27.75% over all middle and outer reef monitoring sites (Table 5). When possible, causes of coral mortality were recorded in the field and are tallied in Table 5. Patterns of mortality between channel-side and control sites were similar.

The greatest cause of mortality was attributed to white-plague disease. Following a region-wide bleaching event in summer 2014, a white-plague disease event occurred resulting in the total mortality of 94 tagged corals, representing 23.5% of the tagged and monitored corals (Table 5). Overall, white-plague disease was responsible for 84.7% of all tagged coral mortality at the middle and outer reef sites. Other coral diseases were responsible for the mortality of 7 corals (1.75% of all tagged corals), which represents 6.3% of all coral mortality (Table 5). Sediment related total mortality was recorded for 5 tagged corals (1.25% of all tagged coral), representing 4.5% of all coral mortality (Table 5). Sediment related mortality occurred at two channel-side sites, R2N2-LR and R3N1-LR. These corals were located within depressions, and were unable to shed accumulated sediment. Photographs of all tagged corals during each baseline, construction, and post-construction monitoring surveys are provided for reference in Appendix B.

Table 5. Total scleractinian mortality from baseline through post-construction as measured at each middle and outer reef monitoring site. Mortality has been broken into categories based on cause of coral mortality and include sediment, disease (white-plague not included), white-plague disease, and other or unknown causes. The white-plague disease category includes colonies photographed with definitive signs of white-plague disease and those consistent with white-plague due to the resulting mortality patterns, timing, location, and species involved. Corals showing active white-plague have also been included, but are not included in the WP mortality values. The N is all tagged colonies except missing colonies.

Survey Zone	Area	Site	Scleractinian Mortality (Baseline through Post-construction)										
			N	Sediment	Solenastrea Unknown Disease	White Band Disease	Other/ Unknown	WP Mortality	WP Active	% Sediment Mortality	% WP Mortality	Total Mortality	% of Tagged Dead
Middle Reef	North	R2N1-RR	30	0	0	0	0	12	0	0.00	40.00	12	40.00
		R2N2-LR	24	2	0	0	0	2	3	8.33	8.33	4	16.67
		R2NC1-LR	28	0	0	0	1	3	2	0.00	10.71	4	14.29
		R2NC2-RR	30	0	0	0	0	2	7	0.00	6.67	2	6.67
	South	R2S1-RR	27	0	0	0	0	7	2	0.00	25.93	7	25.93
		R2S2-LR	24	0	1	0	0	11	2	0.00	45.83	12	50.00
		R2SC1-RR	30	0	1	0	0	8	3	0.00	26.67	9	30.00
		R2SC2-LR	25	0	0	3	0	11	1	0.00	44.00	14	56.00
Outer Reef	North	R3N1-LR	21	3	0	0	0	0	0	14.29	0.00	3	14.29
		R3NC1-LR	24	0	0	0	0	6	1	0.00	25.00	6	25.00
	South	R3S1-CP	19	0	0	0	1	5	0	0.00	26.32	6	31.58
		R3S2-LR	25	0	1	0	1	3	0	0.00	12.00	5	20.00
		R3S3-SG	25	0	0	0	0	6	4	0.00	24.00	6	24.00
		R3SC1-CP	24	0	0	0	2	2	2	0.00	8.33	4	16.67
		R3SC2-LR	20	0	0	0	0	8	1	0.00	40.00	8	40.00
		R3SC3-SG	24	0	1	0	0	8	0	0.00	33.33	9	37.50
Totals			400	5	4	3	5	94	28	1.25	23.50	111	27.75

Patterns of total colony mortality were similar between channel-side and control sites. The major sources of coral mortality at middle and outer reef monitoring sites are discussed in the following sections.

3.1.1 Causes of Mortality at Channel-side Sites

From baseline surveys through post-construction surveys at all middle and outer reef channel-side sites, approximately 28% of all tagged corals died. When considering causes of coral mortality at channel-side sites, white-plague disease was responsible for the greatest amount of mortality (84%), while sediment related total colony mortality accounted for 9% of recorded scleractinian deaths, 3% of coral colonies died from *Solenastrea* Unknown disease, 2% died from unknown cause (one *Porites astreoides* colony at R3S2-LR), and 2% (one *Porites astreoides* colony) died from slope subsidence as a result of the dredging operation (Figure 12). Compliance monitoring sites were originally established approximately 10m from the planned toe of slope, inadvertently placing them within the dredge template in the area of the widener (Outer Reef only). The coral colony that died from slope subsidence was a *Solenastrea bournoni* at R3S1-CP (Figure 12). This loss was addressed in the Compliance Week 40 report, dated September 6, 2014. Engineering analysis of the dredge template determined that the loss was not due to overdredge.

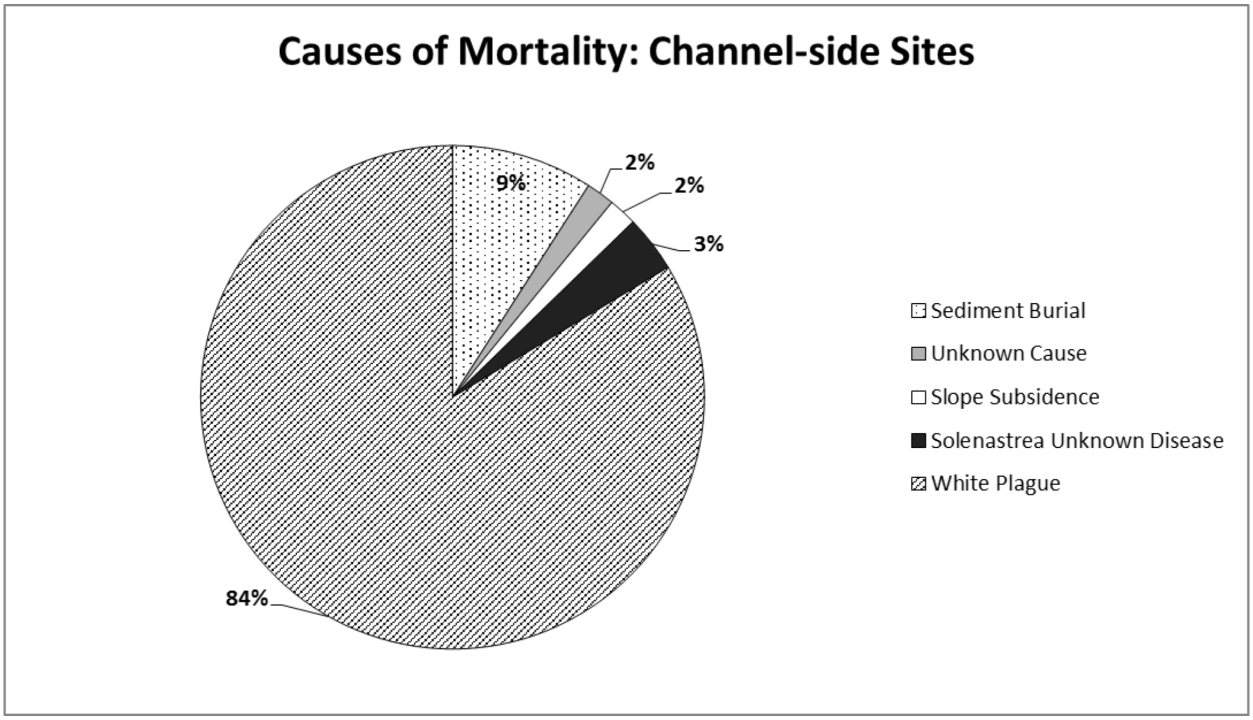

Figure 12. Percentage of causes of total scleractinian mortality across all middle and outer reef channel-side sites from baseline through post-construction surveys (tagged colonies only).

3.1.2 Causes of Mortality at Control Sites

At middle and outer reef control sites white-plague disease was the greatest cause of mortality, causing 86% of recorded scleractinian deaths at control sites (Figure 13). No complete colony mortality was caused by sediment stress at any of the control sites.

White band disease was also present at the control sites, and caused the mortality of three *A. cervicornis* colonies at R2SC2-LR. Two *A. cervicornis* colonies died during Week 29 (June 2014) of compliance monitoring, while the last one was heavily affected during that same week, but did not completely die until Week 1 of post-construction surveys (June 2015).

“Unknown cause” represented the mortality of one *P. porites* at R3SC1-CP and one *P. astreoides* colony at R2NC1-LR.

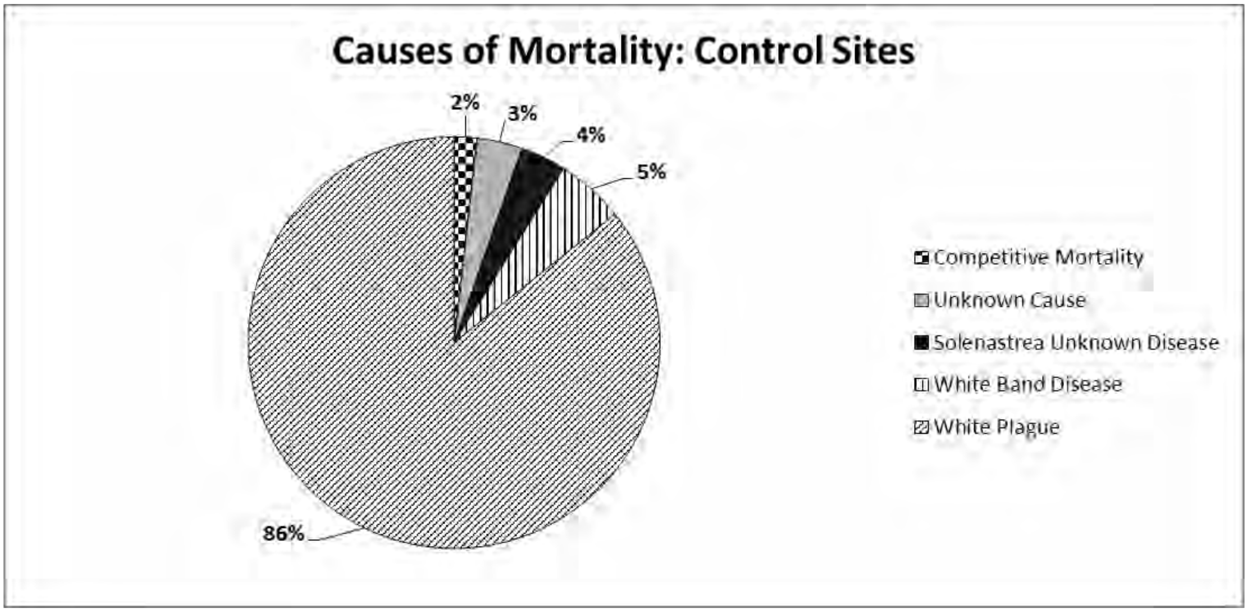

Figure 13. Percentage of causes of total scleractinian mortality across all middle and outer reef control sites from baseline through post-construction surveys (tagged colonies only).

3.1.3 White-plague Disease and Total Colony Mortality Related to Sediment

3.1.3.1 White Plague Disease

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 (Sutherland et al. 2004). The migrating disease line associated with white-plague diseases can progress rapidly, as fast as 2 cm/day, and 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).

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 middle and outer reef sites during Week 4 of post-construction surveys.

The present outbreak affected both channel-side and control sites with nearly equivalent levels of mortality. At middle and outer reef channel-side sites 23.6% of all tagged corals (46 out of 195) have died from white-plague disease whereas 23.4% of all tagged corals (48 out of 205) have died from white-plague at middle and outer reef control sites (Table 5). *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.

To date, 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) 30.5% of marked corals throughout all middle and outer sites. All middle and outer reef compliance and control sites were affected by white-plague mortality and/or active white-plague disease except R3N1-LR. Active white-plague disease was also documented at R2NC3-LR during Week 3 and 4 of post-construction.

The southern middle and outer reef channel-side and control sites were the most impacted by white-plague disease. At the southern channel-side sites, 33 out of 120 colonies (27.5%) died of white-plague disease and 8 (6.7%) were recorded with signs of active white-plague disease during post-construction. At the southern middle and outer reef control sites 37 out of 123 (30.1%) colonies died from the disease, and 7 (5.7%) showed active signs during post-construction surveys.

Despite the relatively recent occurrence of white-plague disease within compliance monitoring sites, white-plague related mortality was observed on 23.5% of all scleractinian colonies across all middle and outer reef sites since November 2014 (Table 5). In contrast, only 1.25% of all tagged corals across these sites died from sediment burial. Similar observations of white-plague related mortality have been made throughout Miami-Dade County, both near and far from the Port Miami project by William Precht of DCA from November 2014 through September 2015. A recent article highlighted the disease epidemic as well (Harvey 2015).

The white-plague disease outbreak documented above followed a period of bleaching (Summer/Fall 2014) due to thermal stress across the region. Figure 14 displays the proportion of corals surveyed that exhibited bleaching and white-plague disease during compliance monitoring. The proportion of bleached coral was highest during the summer of 2014, starting in late August 2014 through October 2014. 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. This percentage kept increasing to reach its highest documented level in March 2015, when 15% of tagged corals surveyed had white-plague disease.

Despite limited coral surveys during the summer of 2015, there are indications of a second ongoing thermal stress event affecting marked corals. Post-construction surveys took place between June and July 2015, when the sea surface temperature had again increased to 31°C. The proportions of corals with indications of thermal stress was increasing during post-construction surveys and it is possible that corals will see another episode of heavy bleaching in the late 2015 summer months as documented in 2014.

As a result of continued thermal stress and active white-plague disease it is likely that the numbers of corals killed as a result of the white-plague outbreak reported here is an underestimation of the total impact of the disease. The total impact of the white-plague disease event can only be assessed when the level of active white-plague disease has declined to the levels documented during baseline (1 coral out of 400) and the thermal stress has subsided.

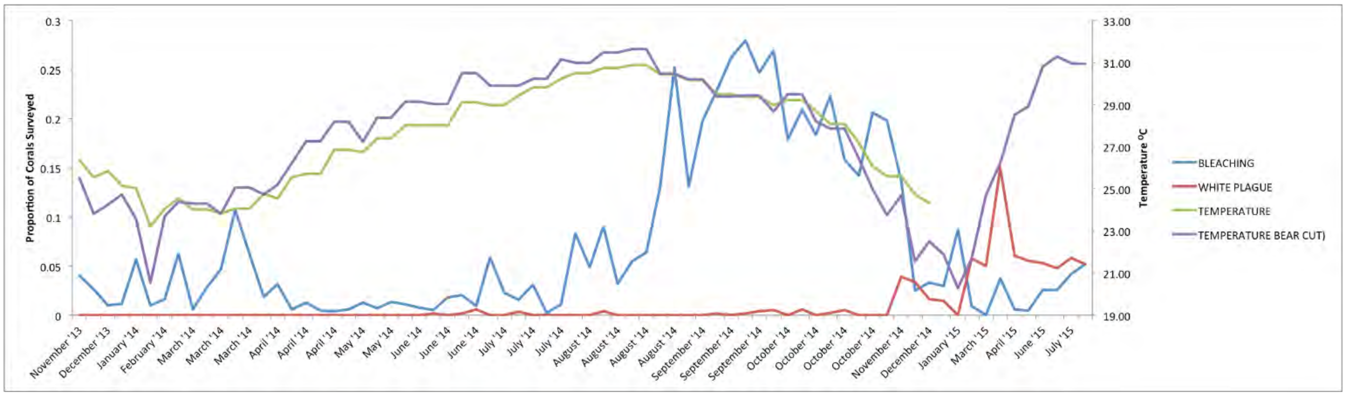

Figure 14. Proportion of corals surveyed across all compliance monitoring sites (hardbottom, middle and outer reef sites) showing signs of bleaching or white-plague disease across all monitoring weeks.

3.1.3.2 Total Colony Mortality Related to Sediment

Sediment related mortality at the channel-side sites was due to a combination of factors, including sedimentation, topography of the site, and spatial location of individual colonies in relation to topographic low areas. Two *Siderastrea siderea* colonies experienced mortality due to burial at R2N2-LR (Table 5). 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.

Three colonies experienced sediment related mortality at R3N1-LR, two *P. astreoides* and a *S. bournoni* (Table 5). While the site was relatively flat, there were several holes and a few sand channels. One of the *P. astreoides* colonies was located within a hole 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. The *S. bournoni* colony was located in a natural sand channel (25-30 cm deep), at the southern end of the site and was buried in Compliance Week 39 (August 13, 2014). The colony was identified as dead in post-construction Week 3 (July 3, 2015).

3.1.4 Unidentified Coral Disease (UD)

The coral *Solenastrea bournoni* is one of the most common corals in the waters of Miami-Dade County. It has long been thought to be one of the most eurytopic of the Atlantic reef corals, being able to sustain great variations in temperature, light, and salinity (Macintyre & Pilkey 1969). Throughout the project area, numerous colonies of *S. bournoni* showed outward signs of distress in the fall of 2013 (baseline), and continued during compliance monitoring. This unknown disease (UD) was closely monitored, and included disease-like symptoms with mottled coloration and necrotic tissues (Figure 15). Corals in the control areas as well as channel-side corals were equally affected.

Figure 15. ***S. bournoni*** **exhibiting unknown disease condition during compliance monitoring surveys. This colony was recorded as dead during post-construction surveys.**

This unknown disease was variable over time but affected *S. bournoni* throughout baseline and compliance monitoring at all middle and outer reef sites. Approximately 81% (46 out of 57) of tagged *S. bournoni* colonies at middle and outer reef sites exhibited signs of this unknown disease during baseline, compliance and/or post-construction monitoring. Of the 46 colonies documented with the unknown disease, 3 were later recorded as having white-plague disease, 1 was recorded as having died from white-plague, and 4 colonies were noted to have died from this diseases. Moreover, 2 *S. bournoni* colonies that did not have documented signs of UD during compliance were documented as having white-plague disease during post-construction surveys. Of the 11 missing tagged colonies across middle and outer reef sites, 1 *S. bournoni* recorded UD during compliance before it disappeared.

The etiology of the unknown disease affecting *S. bournoni* is unknown and further research may reveal a pathogen or group of pathogens.

3.1.5 Unknown/Other Cause of Mortality

The term "unknown cause" was used to represent the mortality of a coral colony where the cause of mortality was not documented. "Other" cause of mortality represented causes that were not identified as known disease, thermal stress, or sediment related causes. A total of five colonies were documented as dead for other/unknown reasons across all middle and outer reef sites.

Two *P. astreoides* died of unknown causes between compliance period and post-construction surveys, one colony at R2NC1-LR and one at R3S2-LR. A single *P. porites* colony died of unknown causes at R3SC1-CP. These colonies were documented as dead during Week 1 of post-construction surveys (June 2014) and had not been monitored since February 2015 (R2NC1-LR and R3S2-LR) or December 2014 (*P. porites* colony at R3SC1-CP).

At the outer reef channel-side sites two corals were documented as dead due to other causes. A single *P. astreoides* colony was documented as dead due to competitive mortality (CM) at R3SC1-CP. This colony was slowly overgrown by a sponge (*Desmapsamma anchorata*). The competitive interaction was first documented during compliance monitoring in August 2014 and the colony was documented as dead during Week 1 of post-construction surveys (June 2015). A *S. bournoni* colony was reported as dead during Week 40 (August 2014). The cause of mortality has been attributed to slope subsidence adjacent to R3S1-CP. This loss was addressed in the Compliance Week 40 report, dated September 6, 2014, engineering analysis of the dredge template determined that the loss was not due to overdredge.

3.1.6 Bleaching and Paling

In the summer of 2014, a NOAA coral watch bleaching alert was issued for the south Florida region. Regional bleaching was documented in south Florida during the summer of 2014 by a number of observers in the Florida Keys (NOAA 2014a; 2014b; NOAA 2015a), and the event was described for hard corals in the Florida Keys and Miami-Dade County. By the late summer and early fall of 2014, many of the corals off southeast Florida expelled their zooxanthellae in response to prolonged warm sea surface temperature (SST) resulting in the worst bleaching episode since 1997-1998 with corals, zoanthids, and octocorals all showing outward signs of stress (NOAA 2015b). In June 2015, NOAA released a bleaching event update, and noted that warming had begun in the Caribbean, with extensive bleaching watches and some warnings for Florida coasts (NOAA 2015a).

Bleaching and paling are primarily attributed to seasonally warm water temperatures and elevated levels of irradiance (e.g., Baker et al. 2008), but have also been documented as a stress response to cold water temperatures (Lirman et al. 2011). Corals become stressed due to temperature when the SST is 1°C warmer than the highest monthly mean temperature (Glynn and D'Croz 1990). Manzello et al. (2007) documented the bleaching threshold for the Florida reef tract as 30.5°C, above which corals would be expected to bleach. Pale or partially bleached corals were recorded at all middle reef sites during post-construction. Proportions of tagged corals showing paling ranged from 0% (R2S1-RR and R2S2-LR Week 1) to 70% at R2NC1-LR during Week 4 of post-construction surveys (Table 6). All middle reef sites showed an increase in paling corals (Figure 16), especially R2NC1-LR, R2NC2-RR, and R2SC2-LR. *S. siderea, P. astreoides,* and *S. intersepta* were the most affected species.

The increase in paling of observed corals during the post-construction survey period (June 17-July 15, 2015) was attributable to an increase in sea surface temperatures. During the post-construction survey period, water temperatures ranged from 29.8°C to 32.1°C (NOAA National Data Buoy Center 2015). From July 2015 to September 2015, sea surface temperatures remained above the maximum monthly sea surface temperature mean in Biscayne Bay (Virginia Key station), rising above the NOAA bleaching threshold during the month of September (NOAA 2015c). *S. siderea, S. intersepta*, and *S. bournoni* were the species most affected by paling throughout post-construction.

Partial bleaching also increased throughout post-construction at middle reef sites, ranging from 0-2% during Week 1 to 0% to 39% during Week 4 (R2NC1-LR). Four different tagged *P. astreoides* colonies recorded complete bleaching during Week 3 and 4 of post-construction at R2NC1-LR. High SSTs have persisted in South Florida waters through the summer and fall of 2015, and increased numbers of bleaching corals throughout the region are to be expected (NOAA 2015c, also see Harvey 2015).

Table 6. Proportion of all tagged scleractinian corals exhibiting paling (P), partial bleaching (PB), and complete bleaching (BL) across middle reef compliance sites during each of the four weeks of post-construction surveys.

Site	Week 1			Week 2			Week 3			Week 4		
	P	PB	BL	P	PB	BL	P	PB	BL	P	PB	BL
R2N1-RR	0.06	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.44	0.00	0.00
R2N2-LR	0.10	0.00	0.00	0.10	0.00	0.00	0.15	0.00	0.00	0.15	0.05	0.00
R2NC1-LR	0.13	0.04	0.00	0.29	0.13	0.00	0.50	0.21	0.03	0.70	0.39	0.02
R2NC2-RR	0.11	0.04	0.00	0.21	0.04	0.00	0.36	0.07	0.00	0.43	0.11	0.00
R2NC3-LR	N/A	N/A	N/A	N/A	N/A	N/A	0.22	0.04	0.00	0.41	0.04	0.00
R2S1-RR	0.00	0.05	0.00	0.20	0.05	0.00	0.30	0.15	0.00	0.30	0.05	0.00
R2S2-LR	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.33	0.00	0.00
R2SC1-RR	0.17	0.00	0.00	0.05	0.05	0.00	0.27	0.00	0.00	0.36	0.00	0.00
R2SC2-LR	0.27	0.18	0.00	0.36	0.09	0.00	0.64	0.09	0.00	0.55	0.09	0.00

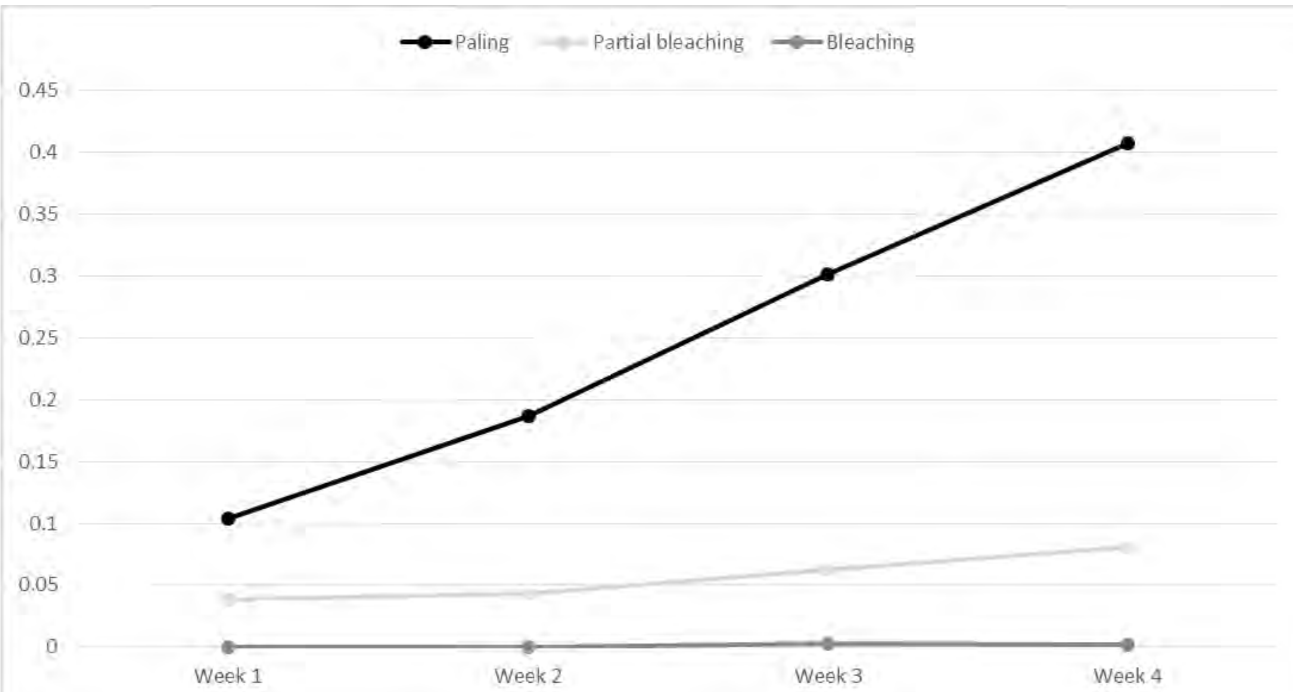

Figure 16. Mean proportion of tagged corals exhibiting paling, partial bleaching, or complete bleaching at all middle reef sites over the four weeks of post-construction assessment.

Pale or partially bleached corals were also recorded at all outer reef sites during post-construction. Corals showing paling ranged from 0% (R3S1-CP Week 1) to 38% at R3S1-LR during Week 4 of post-construction surveys (Table 7). Most outer reef sites showed an increase in paling corals from Week 1 to Week 4 of post-construction surveys (Figure 17), especially R3S1-CP (0% to 38%), R3S3-LR (0.5% to 21%), and R3SC2-LR (0.8% to 25%) (Table 7). *S. siderea, P. astreoides*, and *S. intersepta* were the most affected species.

Partial bleaching proportions remained low throughout post-construction surveys, ranging from 0-0.7% during Week 1 to 0% to 0.1% during Week 4. No tagged colonies recorded complete bleaching during post-construction surveys at outer reef sites (Table 7)

Due to the ongoing nature of the 2015 bleaching event, it is currently unknown if this thermal stress event will result in scleractinian mortality at the middle and outer reef compliance monitoring sites.

Table 7. Proportion of tagged scleractinian corals exhibiting paling (P), partial bleaching (PB), and complete bleaching (BL) across outer reef compliance sites during each of the four weeks of post-construction surveys.

Site	Week 1			Week 2			Week 3			Week 4		
	P	PB	BL	P	PB	BL	P	PB	BL	P	PB	BL
R3N1-LR	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00
R3NC1-LR	0.11	0.06	0.00	0.06	0.06	0.00	0.00	0.11	0.00	0.28	0.00	0.00
R3S1-CP	0.00	0.07	0.00	0.21	0.07	0.00	0.14	0.00	0.00	0.38	0.00	0.00
R3S2-LR	0.05	0.00	0.00	0.15	0.00	0.00	0.10	0.00	0.00	0.15	0.10	0.00
R3S3-SG	0.05	0.00	0.00	0.16	0.00	0.00	0.05	0.00	0.00	0.21	0.00	0.00
R3SC1-CP	0.05	0.00	0.00	0.20	0.00	0.00	0.20	0.05	0.00	0.15	0.00	0.00
R3SC2-LR	0.08	0.00	0.00	0.08	0.00	0.00	0.17	0.00	0.00	0.25	0.00	0.00
R3SC3-SG	0.07	0.00	0.00	0.07	0.07	0.00	0.07	0.13	0.00	0.13	0.00	0.00

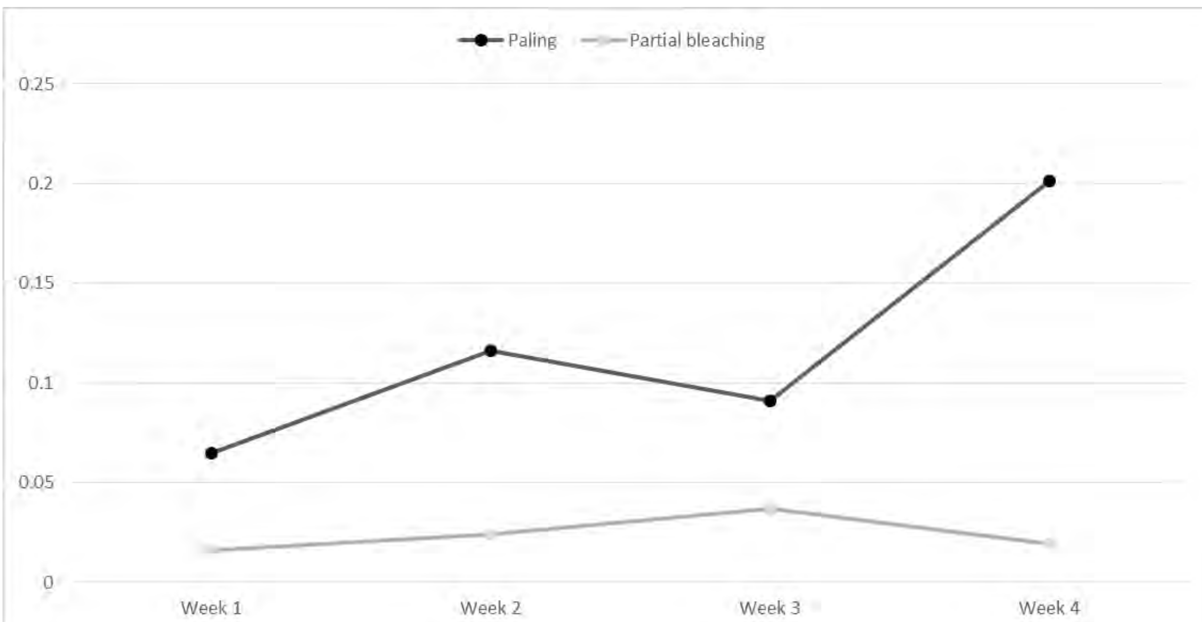

Figure 17. Mean proportion of tagged corals exhibiting paling or partial bleaching at all outer reef sites over the four weeks of post-construction assessment.

3.1.7 Sediment Stress and Partial Mortality

Sediment stress was documented as the source of mortality for 5 corals across the middle reef and outer reef monitoring sites between the baseline and post-construction surveys (Table 5). In addition, partial mortality due to sedimentation was observed during the compliance monitoring period and is quantified by site in Table 8.

Of the coral stress indicators evaluated during compliance monitoring, several were specifically targeted to evaluate the effect of sedimentation on corals. Sediment dusting (SED) was defined as a low amount, a "dusting", of sediment on top of the coral. SED was not considered a "stress" indicator and was given a condition score of zero. Sediment accumulation (SA) was an accumulation of sediment on top of the coral, between polyps, or within grooves and was qualitatively more than a dusting of sediment. Partial burial (PBUR) was the accumulation of sediment around the base of the coral, sometimes in the form of a berm, and burial (BUR) was the complete burial of the coral colony by sediment (Table 8). Recent partial mortality (PM) was the observation of dead coral skeleton where sediment had previously accumulated around a coral colony. Of these sediment stress indicators, sediment dusting, sediment accumulation, partial burial, and complete burial by sediment were generally ephemeral indicators of coral stress that could be alleviated by water movement and/or physical removal of sediment by the coral. Partial mortality (PM) however was an indicator of permanent impacts of sediment stress to coral colonies.

Scleractinian partial mortality (PM) data were collected *in situ* for all monitoring sites and by compiling partial mortality data for all sites from compliance through post-construction period. Partial mortality due to sediment was documented throughout the middle and outer reef habitats including reference sites where natural sedimentation has caused partial mortality. Rates of partial mortality due to sediment were patchy throughout the middle and outer reef habitats with the highest rates being document channel-side on the northern side of the middle reef whereas the lowest rates of channel-side partial mortality were located on the southern side of the outer reef habitat. Table 8 details the proportion of tagged corals with partial mortality due to sediment throughout the middle and outer reef habitats.

Due to the high rates of white-plague disease-related mortality documented across middle and outer reefs (DCA 2015), all sediment-related partial mortality data are presented in Table 8 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.

Partial mortality (PM) was recorded on 34% of all scleractinian corals at middle and outer reef sites (137 out of 400) during compliance and/or post-construction monitoring. Corals at R2NC3-LR are not included in these calculations, as they were only monitored during baseline and post-construction. Moreover, none of the tagged colonies at that site recorded PM during post-construction surveys.

Partial mortality occurred across channel-side sites and control sites (Table 8). Across middle reef sites, R2N1-RR recorded the highest percentage of corals affected by partial mortality (93%), while R2NC1-LR and R2NC2-RR had the lowest amount of partial mortality (7%). At outer reef sites, more than 70% of all tagged corals at R3N1-LR exhibited partial mortality, while R3SC2-LR had the lowest percentage (0%) (Table 8).

While partial mortality (PM) was an indicator of sediment stress, corals reported as having partial mortality may have experienced other non-sediment related stressors. Physical disturbances, fish bites, thermal stressors, like bleaching and paling, and various diseases were reported to affect corals that had experienced partial mortality due to sediment stress. These other stressors were reported both concurrently, when PM was recorded, and separately throughout the compliance and post-construction survey periods for individual colonies.

Compared to the respective control sites, the differences in the proportions of colonies affected by partial mortality at the channel side sites ranged from 24% (R3S3-SG) to 86% (R2N1-RR) (Table 8). Colonies at R3SC2-LR did not experience any partial mortality related to sediment stress. The difference in these proportions of partial mortality due to sediment stress at channel-side vs. controls sites suggests that the partial mortality recorded on the colonies at the channel-side sites was due to project-related and natural sedimentation.

Table 8. Sediment related partial mortality as measured during compliance and post-construction monitoring. 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". 11 coral colonies disappeared during compliance at middle and outer reef sites, and are excluded from the calculations.

Survey Zone	Area	Site	Partial Mortality Related to Sediment Stress							
			All Corals				Without Dead Corals			
			#PM	N	Prop.	SD	#PM	N	Prop.	SD
Middle Reef	North	R2N1-RR	28	30	0.93	0.25	17	18	0.94	0.24
		R2N2-LR	15	24	0.63	0.49	12	20	0.60	0.50
		R2NC1-LR	2	28	0.07	0.25	2	24	0.08	0.27
		R2NC2-RR	2	30	0.07	0.25	2	28	0.07	0.26
	South	R2S1-RR	17	27	0.63	0.49	14	20	0.70	0.47
		R2S2-LR	15	24	0.63	0.49	6	12	0.50	0.52
		R2SC1-RR	9	30	0.30	0.47	8	21	0.38	0.50
		R2SC2-LR	2	25	0.08	0.28	1	11	0.10	0.32
Outer Reef	North	R3N1-LR	15	21	0.71	0.46	14	18	0.78	0.43
		R3NC1-LR	7	24	0.29	0.46	5	18	0.28	0.46
	South	R3S1-CP	8	19	0.42	0.51	7	13	0.54	0.52
		R3S2-LR	1	25	0.04	0.20	0	20	0.00	0.00
		R3S3-SG	9	25	0.36	0.49	7	19	0.37	0.50
		R3SC1-CP	4	24	0.17	0.38	3	20	0.15	0.37
		R3SC2-LR	0	20	0.00	0.00	0	12	0.00	0.00
		R3SC3-SG	3	24	0.13	0.34	2	15	0.13	0.35
Total			137	400			100	289		

3.2 Quantitative Benthic Sampling Comparison: Scleractinians

Nine middle reef sites (R2N1-RR, R2N2-LR, R2NC1-LR, R2NC2-RR, R2NC3-LR, R2S1-RR, R2S2-LR, R2SC1-RR and R2SC2-LR) and 8 outer reef sites (R3N1-LR, R3NC1-LR, R3S1-CP, R3S2-LR, R3S3-SG, R3SC1-CP, R3SC2-LR and R3SC3-SG) were surveyed during the post-construction period, over four weeks, for comparison to baseline benthic community characteristics from June 17 to July 15, 2015.

Abiotic characteristics (e.g., substrate type and maximum water depth), colony counts of scleractinian (by species) and octocorals (by genus) were collected from all transects, as well as condition of all scleractinian corals. Maximum diameter data of all scleractinian colonies and octocorals were documented during Week 3. Additionally, counts of sponge morphotypes and zoanthids (*Palythoa*) were collected along each transect during Week 3. Photos of all permanently marked corals and video of each transect were also collected each week. Parametric and non-parametric statistics were used to analyze the abundance and density of scleractinians, octocorals, and sponges as well as the condition of corals.

3.2.1 Abiotic Characteristics

3.2.1.1 Middle Reef

All sampling was conducted in areas of middle reef habitat in 6 m to 12 m (20 feet to 40 feet) of water. Hard substrate was typically interspersed with sand pockets and rubble was present at all sites (i.e., R2N1-RR, R2N2-LR, R2NC1-LR, R2NC2-RR, R2NC3-LR, R2S1-RR, R2S2-LR, R2SC1-RR, and R2SC2-RR). The presence of abiotic features were similar between baseline and post-construction surveys at middle reef sites (Table 9).

Table 9. Abiotic characteristics for middle reef survey sites. Abiotic characteristics observed during baseline surveys are indicated by a black circle, those noted during post-construction are indicated by a square.

Abiotic Characteristics	Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-RR
Hardbottom	• □	• □	• □	• □	• □	• □	• □	• □	• □
Bare Substrate	• □	• □	• □	• □	• □	• □	• □	• □	• □
Rubble	• □	• □	• □	• □	• □	• □	• □	• □	• □
Sand	• □	• □	• □	• □	• □	• □	• □	• □	• □
Sedimentation	• □	• □	• □	• □	• □	• □	• □	• □	• □
Max Depth (ft.)	28-30	39-40	20-22	24	28-31	24-25	24-30	25-30	18-20
Rugosity (post-con only)	4.82	4.73	4.72	4.78	4.58	4.88	4.85	4.74	4.64

3.2.1.2 Outer Reef

All sampling was conducted in areas of outer reef habitat in 11 to 15 m (34 to 46 ft.) of water. Hard substrate was typically interspersed with small sand pockets (Table 10). Rubble was present at 5 of 6 southern sites (i.e., R3S1-CP, R3S2-LR, R3SC1-CP, R3SC2-LR, and R3SC3-SG) and not present north of the channel and at R3S3-SG. The presence of gross abiotic features were similar between baseline and post-construction surveys at outer reef sites (Table 10).

Table 10. Abiotic characteristics for outer reef survey sites. Abiotic characteristics observed during baseline surveys are indicated by a black circle, those noted during post-construction are indicated by a square.

Abiotic Characteristics	Site							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Hardbottom	• □	• □	• □	• □	• □	• □	• □	• □
Bare Substrate	• □	• □	• □	• □	• □	• □	• □	• □
Rubble			• □	• □		• □	• □	• □
Sand	• □	• □	• □	• □	• □	• □	• □	• □
Depth Range (ft.)	42-45	43-46	37-42	31-34	34-38	40-43	36	36-39
Rugosity (post-con only)	4.78	4.35	4.68	4.62	4.64	4.6	4.8	4.71

3.2.2 Scleractinian Occurrence

3.2.2.1 Middle Reef

During the four weeks of baseline and post-construction surveys all scleractinian corals 3 cm and larger (tagged and untagged) within the one meter belt transect (20 m) were recorded to species level and assessed for condition. Twenty seven scleractinian coral species were documented across middle reef monitoring sites during baseline surveys. Twenty scleractinian species were observed during post-construction surveys, which included one additional species that was not documented in baseline surveys (*Scolymia cubensis*). *Agaricia fragilis, Agaricia sp., Eusmilia fastigiata, Favia fragum, Madracis formosa, Madracis sp., Mycetophyllia ferox, Oculina diffusa,* and *Orbicella franksi* were documented during baseline surveys but were absent from middle reef compliance monitoring sites during post-construction (Table 11). Of the 9 species that were documented in baseline but absent in post-construction surveys, *Agaricia* sp. was represented by a single individual which was later reclassified as *A. lamarcki*. The other 8 species were represented by 2 colonies or less across middle reef sites. The differences in species presence between baseline and post-construction surveys are likely due to the presence/absence of a few representative colonies that can be influenced by changes in sample area, mortality (especially due to white-plague disease), and identification accuracy. Since untagged corals were not monitored through compliance, it is not possible to attribute a direct cause for the loss of these colonies.

During baseline *Siderastrea siderea* and *S. radians* were differentiated where possible. In some cases, colonies were identified as S. siderea/radians when the identity was unclear, usually in smaller colonies (<5 cm). Accurate differentiation of these two species is difficult when individuals are small (Edmunds et al. 1998). During compliance monitoring, all *Siderastrea* colonies were documented as *Siderastrea* species (sp.). During post-construction, *Siderastrea* colonies were identified as *Siderastrea* sp. For analysis purposes, all *Siderastrea* species have been combined.

Species that are listed as threatened under the Endangered Species Act and were recorded at middle reef sites included *Acropora cervicornis, Mycetophyllia ferox, Orbicella faveolata* and *Orbicella franksi*. *A. cervicornis* colonies were documented during both baseline and post-construction surveys at control sites only; R2SC1-RR (20 cm in baseline, 40cm in post-construction) and R2SC2-LR (25-40 cm), but only in baseline at R2NC1-LR. The colonies at R2NC1-LR were not tagged and monitored throughout compliance monitoring due to transect and site layout. Others experienced white band disease near the northern control sites and it is likely white band caused mortality of these untagged colonies (Coastal Systems International Inc. 2014). White band disease killed two tagged colonies at middle reef control site R2SC2-LR during Week 29 (June 2014). One small *M. ferox* (5-6 cm in diameter) was documented during baseline at R2N1-RR, but as it was not tagged and monitored, it is not possible to attribute a cause for loss of this colony in post-construction surveys. Two colonies of *O. faveolata* were documented and tagged at R2SC1-RR, and measured 60 cm and 50 cm respectively. In post-construction, they measured 65 cm and 60 cm, respectively. This species was documented during both baseline and post-construction surveys at R2NC3-LR as well, but these colonies were not tagged. Finally, an untagged *O. franksi* was documented only once during baseline surveys at R2NC3-LR. Summary tables of all scleractinian species surveyed during each week of baseline and post-construction surveys are provided in Appendix D.

Table 11. Scleractinian species present at each middle reef site. Scleractinian species observed during baseline surveys are indicated by a black circle, those noted during post-construction are indicated by a square.

Scleractinian species	Middle Reef Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-LR
Acropora cervicornis			•					• □	• □
Agaricia agaricites		• □	• □		• □		□		• □
Agaricia fragilis		•							
Agaricia lamarcki		□			□				□
Agaricia sp.		•							
Colpophyllia natans					• □		•		•
Dichocoenia stokesi	• □	• □	• □	• □	• □	• □	•	•	•
Diploria labyrinthiformis			• □						
Eusmilia fastigiata		•				•			
Favia fragum	•					•		•	
Madracis decactis		• □							
Madracis formosa		•							
Madracis sp.							•	•	

Scleractinian species	Middle Reef Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-LR
Meandrina meandrites	•	•	•	• □	• □	•	•	•	•
Montastrea cavernosa	• □	• □	• □	• □	• □	• □	• □	• □	• □
Mycetophyllia ferox	•								
Oculina diffusa				•	•		•		
Orbicella faveolata					• □			• □	
Orbicella franksi					•				
Porites astreoides	• □	•	• □	• □	• □	• □	• □	• □	• □
Porites	• □	• □	• □	• □	• □	• □	• □	• □	• □
Pseudodiploria strigosa	•	•		•			• □	• □	• □
Pseudodiploria clivosa	•		• □			• □	•	• □	• □
Scolymia cubensis		□							
Siderastrea radians	•	•	• □	•	•	• □		• □	• □
Siderastrea siderea	• □	• □	• □	• □	• □	• □	• □	• □	• □
Siderastrea sp.		• □	□	□	□	□	• □	• □	□
Solenastrea bournoni	• □	• □	• □	• □	• □	• □	• □	• □	
Stephanocoenia intersepta	• □	• □	• □	• □	• □	• □	• □	• □	• □

3.2.2.2 Outer Reef

Twenty-five scleractinian coral species were documented across the outer reef sites during baseline surveys. Twenty species were documented during post-construction surveys. *Pseudodiploria sp., Favia fragum, M. ferox, O. annularis,* and *Porites furcata* were observed during baseline surveys but were absent from outer reef compliance monitoring sites during post-construction (Table 12). Differences in species presence between baseline and post-construction surveys is likely due to the presence/absence of a few representative colonies that can be influenced by changes in sampling area, mortality, and identification accuracy. Of the 5 species that were documented in baseline but absent in post-construction surveys, four species (*Pseudodiploria sp., F. fragum, O. annularis,* and *P. furcata*) were only documented during a single week of the multiple week baseline survey period. This suggests that they were misidentified in the first week of baseline surveys.

Species listed as threatened under the Endangered Species Act and were recorded at outer reef sites were *M. ferox,* and *O. faveolata*. The colony of *M. ferox* at R3SC1-CP identified during baseline was a tagged colony that was later reclassified as *Mycetophyllia aliciae*. *O. faveolata* was documented at R3N1-LR (1 colony), R3S1-CP (1 colony) and R3S3-SG during baseline, but only at R3S3-SG during post-construction surveys. As the colonies at R3N1-LR and R3S1-CP were not tagged, it is not possible to attribute a cause for loss of these corals. The *O. faveolata* colony at R3S3-SG was tagged and monitored. It measured 32 cm in diameter in baseline, and 45 cm during post-construction surveys. This tagged colony is the only species across all outer reef sites that has been listed under the Endangered Species Act. Summary tables of all scleractinian species surveyed during each week of baseline and post-construction surveys are provided in Appendix D.

Table 12. Scleractinian species observed at outer reef sites during baseline surveys are indicated by a black circle, those noted during post-construction are indicated by a square.

Scleractinian species	Outer Reef Sites							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Agaricia agaricites	• □		•			□		
Agaricia lamarcki	□	□	□			• □		
Colpophyllia natans		• □		•	• □	•	•	•
Dichocoenia stokesi	• □	•	•	• □	•	•	• □	• □
Diploria labyrinthiformis				•	• □	• □		
Eusmilia fastigiata				• □		• □	• □	•
Favia fragum	•						•	•
Madracis decactis	• □	□	• □	□	• □	□		□
Meandrina meandrites	• □	•	• □	•	• □	• □	• □	• □
Montastrea cavernosa	• □	• □	• □	• □	• □	• □	• □	• □
Mycetophyllia aliciae				•		□		
Mycetophyllia ferox				•		•		
Orbicella annularis					•	•		
Orbicella faveolata	•			•	• □			

Scleractinian species	Outer Reef Sites							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Porites astreoides	• □	• □	• □	• □	• □	• □	• □	• □
Porites furcata								•
Porites porites	• □	• □	• □	•	•	• □	• □	• □
Pseudodiploria sp.							•	
Pseudodiploria strigosa	• □	•		• □	• □	□	•	• □
Scolymia cubensis		□					• □	
Siderastrea radians	•		□	□	□	□	• □	• □
Siderastrea siderea	• □	• □	• □	• □	• □	• □	• □	• □
Siderastrea sp.	•	□	• □	□	□	□	□	□
Solenastrea bournoni	• □	• □	• □	• □	• □	• □	• □	• □
Stephanocoenia intersepta	• □	• □	• □	• □	• □	• □	• □	• □

3.2.3 Scleractinian Abundance

3.2.3.1 Middle Reef

Mean scleractinian colony abundance ranged from 61.5 (R2S2-LR) to 149.5 (R2SC1-RR) colonies during baseline surveys across middle reef sites (Table 13). During post-construction surveys, R2S2-LR maintained the lowest mean scleractinian abundance with 36.8 colonies, and R2SC1-RR had the greatest number of colonies (164.3 mean colonies). With the exception of R2NC3-LR and R2SC1-RR where the mean number of corals increased, all other middle reef channel-side and control sites declined in mean number of scleractinians between baseline and post-construction surveys. The mean numbers of corals per site represent both tagged and untagged colonies. It is not possible to attribute cause of loss for untagged colonies at middle reef sites, since these were not tracked over time. However, the majority of mortality in tagged corals has been attributed to white-plague disease, white band disease, bleaching, unknown mortality, and sediment stress during construction monitoring. Coral mortality during compliance monitoring is discussed in Section 3.1.

During baseline surveys the five most abundant species at northern middle reef sites were*: Siderastrea siderea, Stephanocoenia intersepta, Montastrea cavernosa, Porites astreoides*, *and Dichocoenia stokesi* (Figure 18). During post-construction surveys the five most abundant species were: *M. cavernosa*, *P. astreoides*, *Siderastrea sp., S. bournoni,* and *S. intersepta* (Figure 19). All *Siderastrea* species were combined for post-construction graphing purposes since a number of *Siderastrea* sp. colonies were documented that could not be differentiated at the species level. The most noticeable change between surveys was a switch in the fifth most dominant coral species from *D. stokesi* during baseline surveys to *S. bournoni* during post-construction surveys. A total of 42 *D. stokesi* colonies were counted during Week 1 of baseline surveys at all northern middle reef sites representing 9.3% of all surveyed corals. During post-construction only 16 *D. stokesi* corals were documented at all northern middle reef sites during

Week 4 of post-construction monitoring, constituting just 4.1% of all surveyed corals. Although the data presented here represents all tagged and untagged colonies at all middle reef channel-side compliance monitoring sites it should be noted that 81% of all tagged middle reef *Dichocoenia stokesi* died from white-plague disease during compliance monitoring.

At the southern middle reef sites, the five most dominant species during baseline surveys were *Porites astreoides, Siderastrea siderea, Solenastrea bournoni, Stephanocoenia intersepta,* and *Porites porites,*. During post-construction surveys, *M. cavernosa* became a dominant species instead of *P. porites* (Figures 20 and 21).

A small proportion of scleractinian species made up the majority of scleractinian colonies at middle reef sites during both baseline and post-construction. The five most abundant scleractinians accounted for 76% of colonies at the northern middle reef sites and 67% of colonies documented at southern middle reef sites during baseline. The five dominant species during post-construction accounted for 82% of colonies at the northern middle reef sites and 85% of colonies at southern middle reef sites during post-construction.

Table 13. Number of scleractinian colonies and species richness during baseline and post-construction surveys at middle reef sites. Baseline values have been revised in this table.

Site	Baseline				Post-Construction			
	Number of Colonies		Number of species		Number of Colonies		Number of species	
	Mean	SE		*N*	Mean	SE		*N*
R2N1-RR	82.5	6.0	13	4	43.3	0.5	7	4
R2N2-LR	65.5	5.7	17	4	57.5	1.8	11	4
R2NC1-LR	127.5	9.1	13	4	110.8	4.0	12	4
R2NC2-RR	96.7	9.6	11	3	62.8	1.8	9	4
R2NC3-LR	103.3	16.2	14	3	106.5	4.5	13	3
R2S1-RR	56.8	1.6	12	4	44.5	1.8	10	4
R2S2-LR	61.5	2.5	14	4	36.8	1.5	9	4
R2SC1-RR	149.5	7.6	16	4	164.3	5.5	12	4
R2SC2-LR	63.0	6.9	13	4	48.0	1.6	12	4

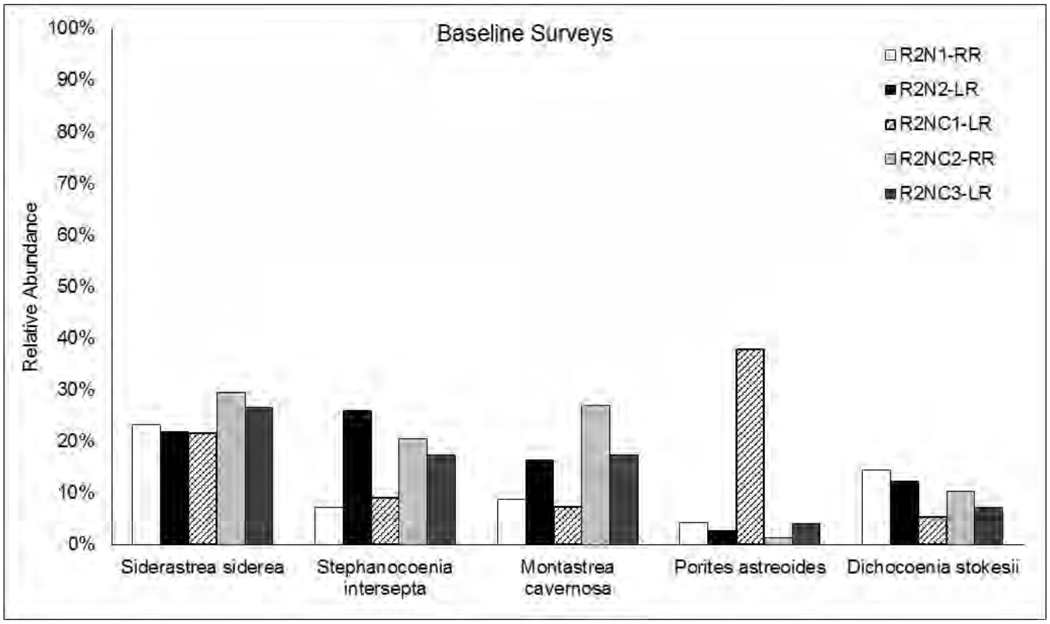

Figure 18. Relative abundance of the five dominant scleractinian corals at the northern middle reef sites during Week 1 of baseline surveys. The five species are presented above from most dominant to least dominant overall, from left to right. Baseline calculations were revised for this graph due to transcription errors.

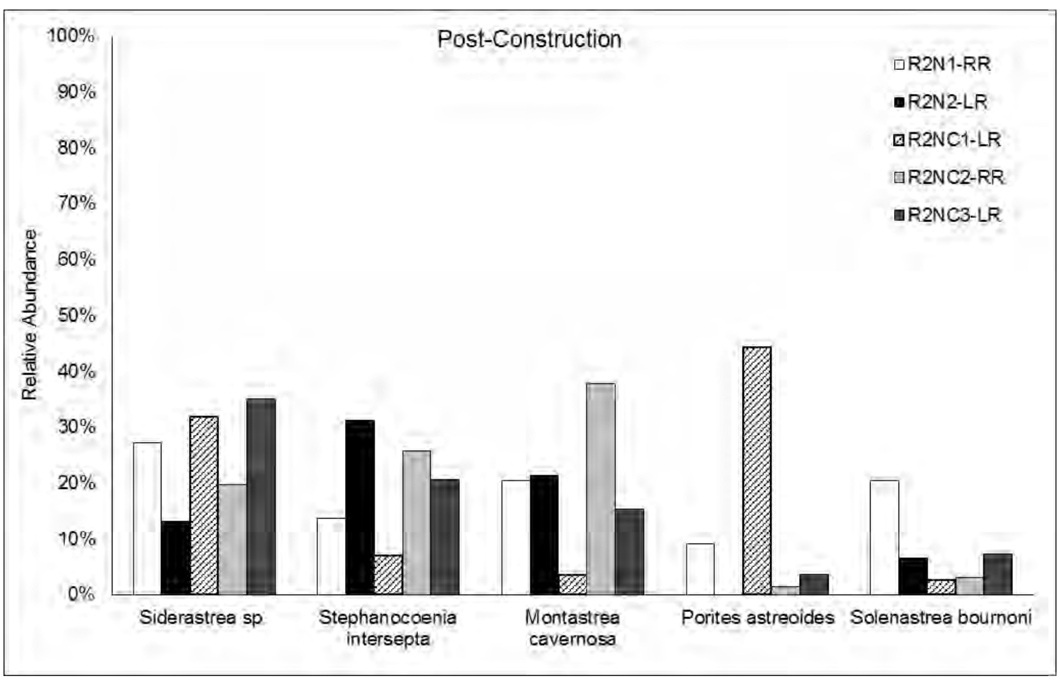

Figure 19. Relative abundance of the five dominant scleractinian corals at the northern middle reef sites during Week 3 of post-construction surveys. The five species are presented above from most dominant to least dominant overall, from left to right.

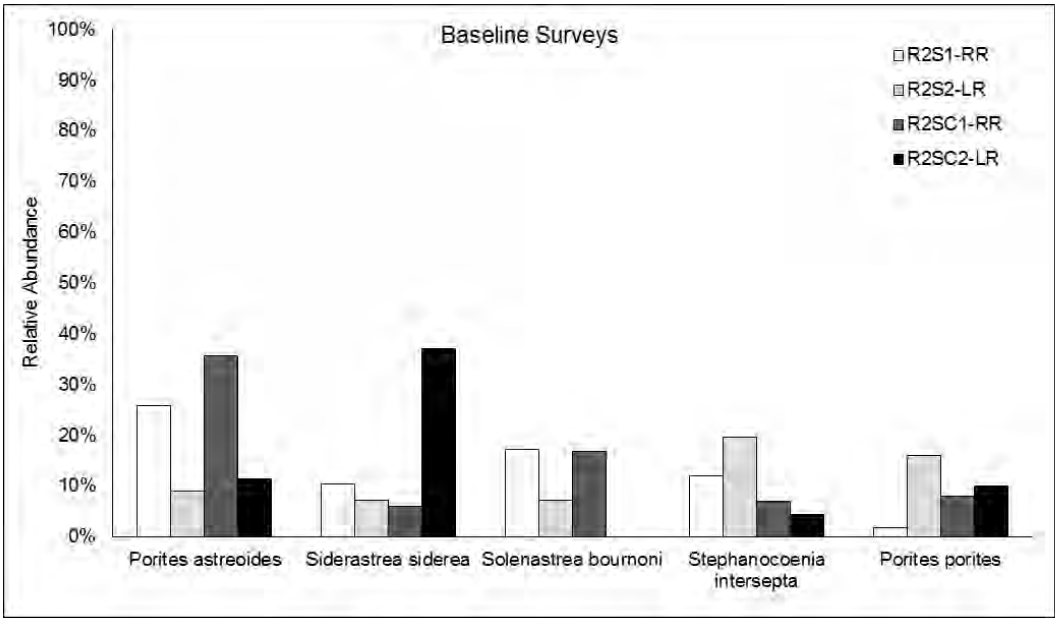

Figure 20. Relative abundance of the five dominant scleractinian corals at the southern middle reef sites during Week 1 of baseline surveys. The five species are presented above from most dominant to least dominant overall, from left to right. Baseline calculations were revised for this graph due to transcription errors.

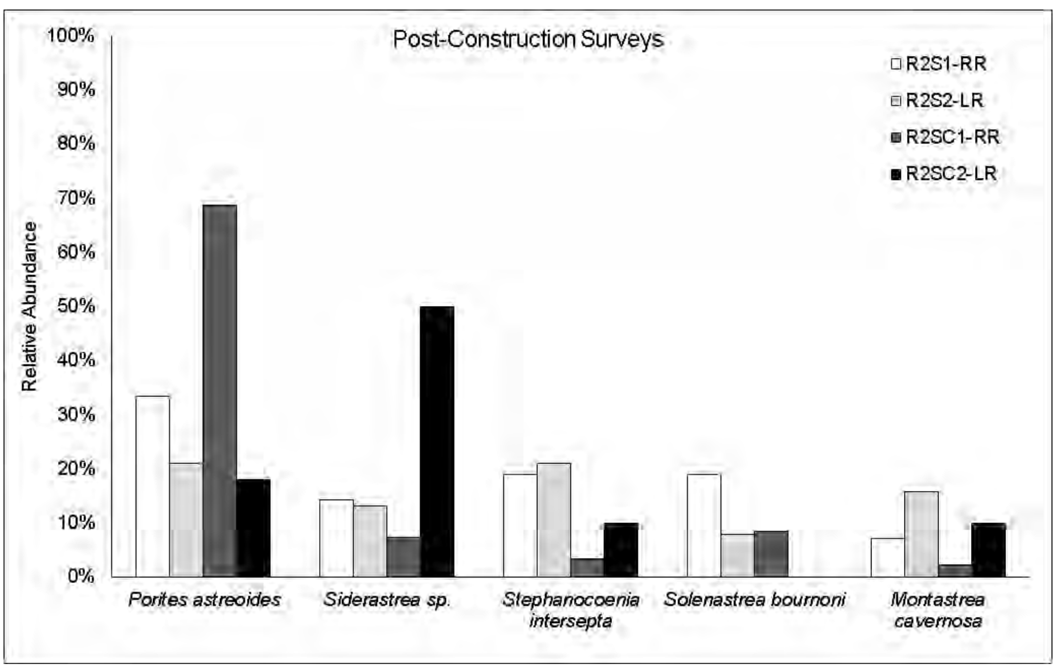

Figure 21. Relative abundance of the five dominant scleractinian corals at the southern middle reef sites during Week 3 of post-construction surveys. The five species are presented above from most dominant to least dominant overall, from left to right.

3.2.3.2 Outer Reef

Mean scleractinian colony abundance ranged from 62.0 at R3N1 to 210.0 at R3SC3 during baseline surveys across outer reef sites (Table 14). During post-construction surveys, R3N1 maintained the lowest mean scleractinian abundance with a mean of 44.8 colonies per site and R3SC3 maintained the greatest number of colonies per site with 221.8 colonies. R3NC1-LR and R3SC1-CP increased in number of scleractinians, while all other sites declined in the number of species documented. The numbers of corals per site represent both tagged and untagged colonies. As a result, it is not possible to assign causation to the loss of untagged colonies at outer reef sites. However, mortality in tagged corals has been attributed to white-plague disease, bleaching, unknown mortality, and sediment stress during construction monitoring.

During baseline and post-construction surveys the five most abundant species at northern outer reef sites were*: Porites astreoides*, *Stephanocoenia intersepta, Siderastrea siderea, Solenastrea bournoni*, *and Montastrea cavernosa* (Figure 22 and 23). At the southern sites, the five most abundant species remained the same from baseline to post-construction and were: *Porites astreoides, Siderastrea sp., Porites porites, Stephanocoenia intersepta,* and *Montastrea cavernosa* (Figure 24 and 25).

A small proportion of scleractinian species made up the majority of scleractinian colonies at outer reef sites during both baseline and post-construction (e.g., *Montastrea cavernosa*, *Porites astreoides*, *Porites porites, Siderastrea sp.,* and *Stephanocoenia intersepta*). All *Siderastrea* species were combined for post-construction graphing purposes since a number of *Siderastrea* sp. colonies were documented that were not differentiated at the species level. The five most abundant scleractinians accounted for 81% of colonies at the northern outer reef sites and 84% of colonies documented at southern outer reef sites during baseline. These five species accounted for 87% of colonies at the northern outer reef sites and 84% of colonies at southern outer reef sites during post-construction.

On the north side of the outer reef, relative abundance of the top five scleractinians species was very similar between baseline and post-construction survey periods. On the south side of the outer reef, *P. astreoides* increased in relative abundance across sites, both channel-side and controls, while the relative abundance of *Siderastrea sp.* declined.

Table 14. Number of scleractinian colonies and species richness during baseline and post-construction surveys at outer reef sites. Baseline values were revised for this table due to transcription errors.

Site	Baseline				Post-Construction			
	Number of Colonies		Number of species		Number of Colonies		Number of species	
	Mean	SE		*N*	Mean	SE		*N*
R3N1-LR	62.0	3.6	15	3	44.8	1.4	12	4
R3NC1-LR	74.0	7.0	10	2	79.0	2.7	11	4
R3S1-CP	64.0	2.5	11	3	55.3	3.7	11	4
R3S2-LR	105.7	4.1	15	3	91.3	3.2	11	4
R3S3-SG	76.0	8.0	15	3	85.5	2.6	13	4
R3SC1-CP	121.0	1.0	14	2	131.0	6.9	16	4
R3SC2-LR	141.0	11.0	15	2	170.3	8.8	12	4
R3SC3-SG	210.0	14.0	14	2	221.8	6.7	12	4

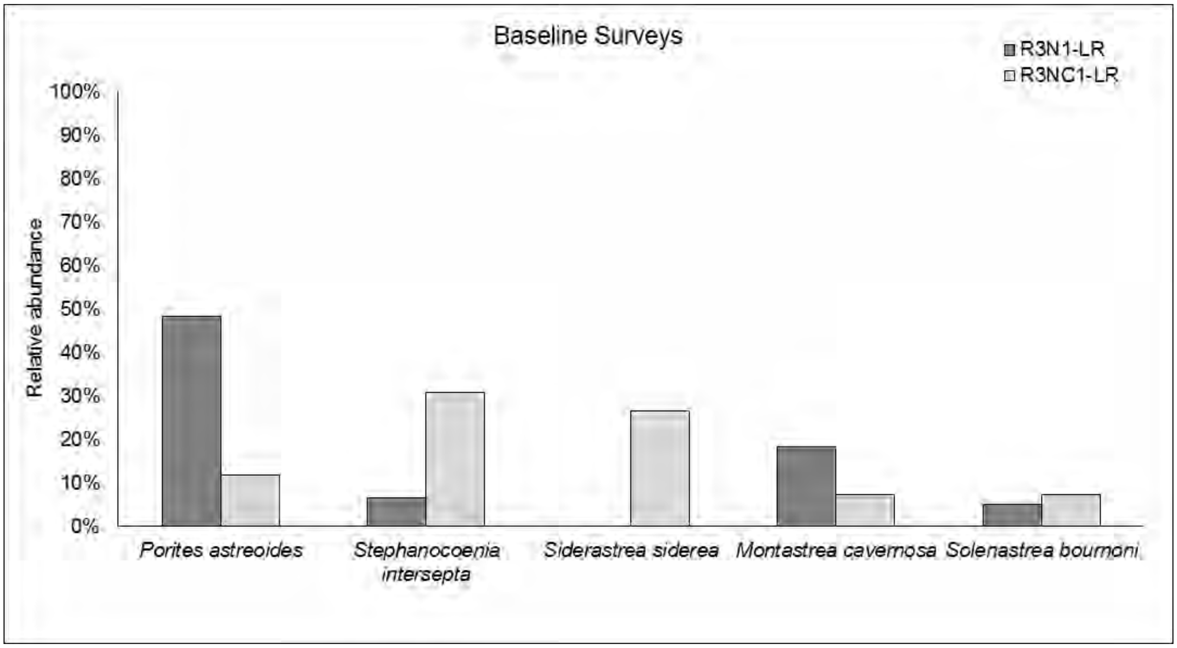

Figure 22. Relative abundance of the five dominant scleractinian corals at the northern outer reef sites during Week 1 of baseline surveys. The five species are presented above from most dominant to least dominant overall, from left to right. Baseline calculations were revised for this graph due to transcription errors.

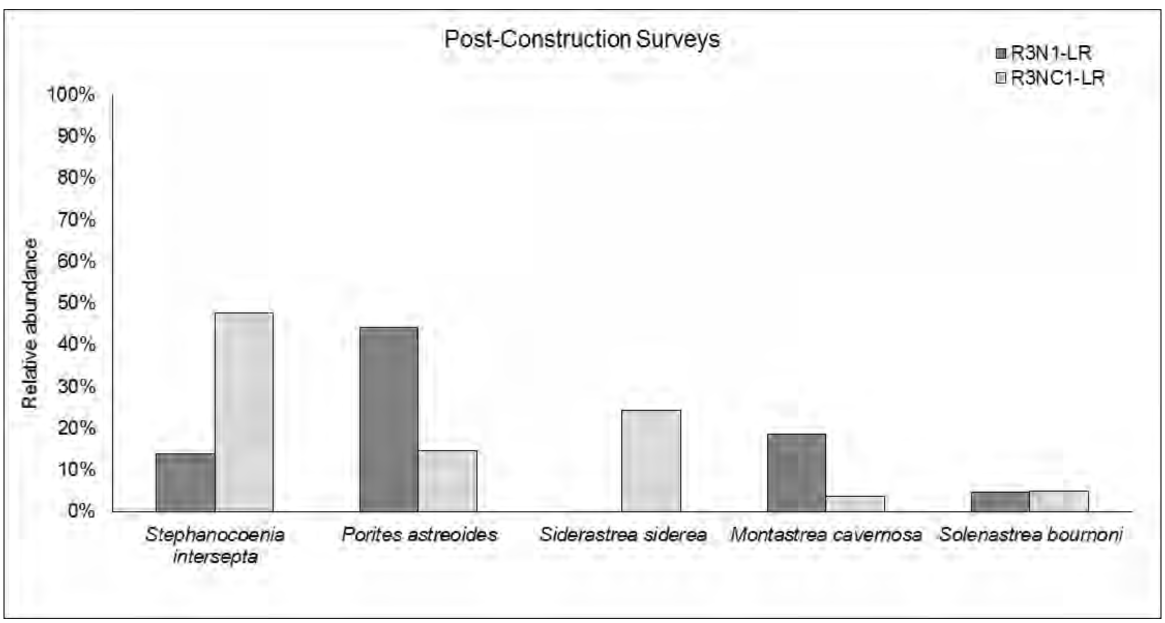

Figure 23. Relative abundance of the five dominant scleractinian corals at the northern outer reef sites during Week 3 of post-construction surveys. The five species are presented above from most dominant to least dominant overall, from left to right.

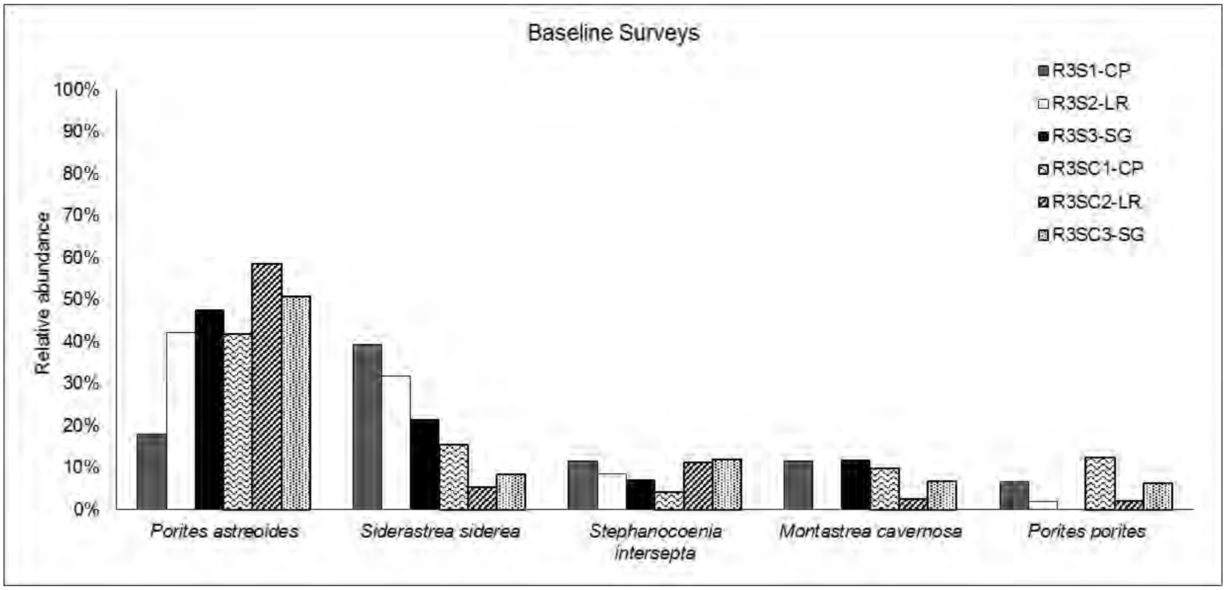

Figure 24. Relative abundance of the five dominant scleractinian corals at the southern outer reef sites during Week 1 of baseline surveys. The five species are presented above from most dominant to least dominant overall, from left to right. Baseline calculations were revised for this graph due to transcription errors.

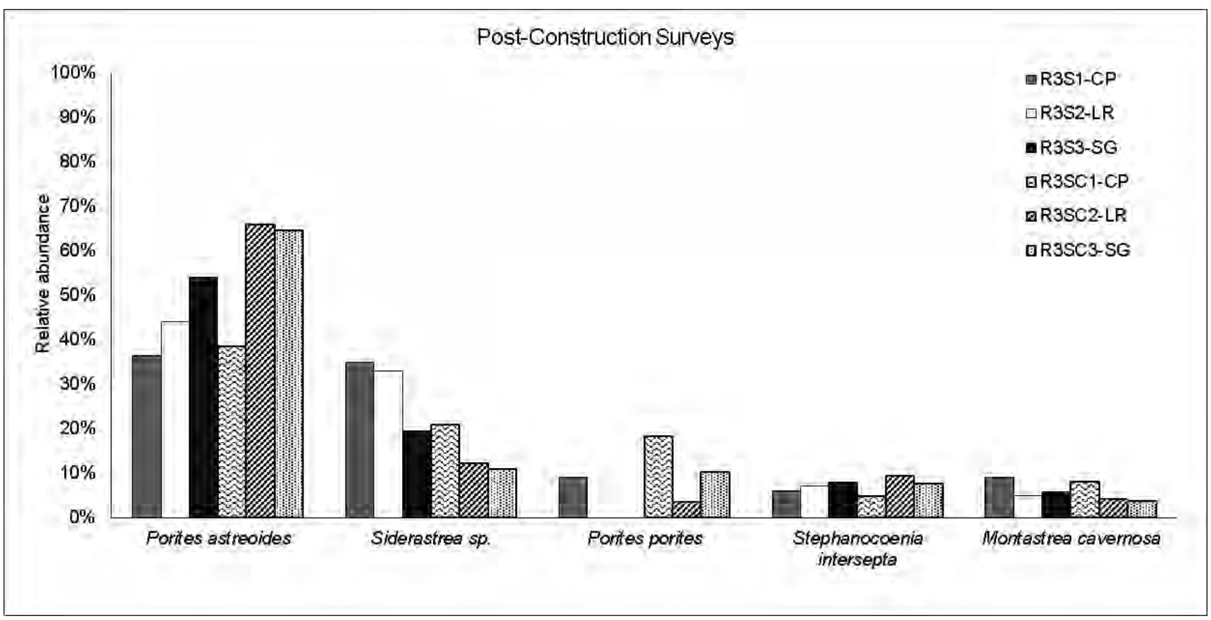

Figure 25. Relative abundance of the five dominant scleractinian corals at the southern reef sites during Week 3 of post-construction surveys. The five species are presented above from most dominant to least dominant overall, from left to right.

3.2.4 Scleractinian Density

3.2.4.1 Middle Reef

A two-way repeated measures ANOVA was used to determine if mean coral density was different among the nine middle reef sites between the baseline and post-construction assessment periods. Data were collected over four weeks for each assessment period with the exception of R2NC3-LR in which two weeks of data were collected during post-construction. Mean site densities were normally distributed (Anderson-Darling test, P>0.05), in all cases. Significant effects among the sites between the assessment periods were detected (F = 45.44, P < 0.0001; Table 15). Significant differences were detected in mean coral density between assessment periods (F = 27.73, P<0.0001), sites (F = 88.27, P<0.0001), and a significant effect was detected based on the interaction of period and site (F = 4.35, P = 0.0005) (Table 16).

Table 15. Two-way ANOVA results testing the difference in scleractinian density among and between the nine middle reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	26.38977669	1.55233981	45.44	<.0001
Error	50	1.70814815	0.03416296		
Corrected Total	67	28.09792484			

Table 16. Two-way ANOVA results testing the effects of the two time periods, baseline and post-construction (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	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	0.94747175	0.94747175	27.73	<.0001
SITE	8	24.12441754	3.01555219	88.27	<.0001
PERIOD*SITE	8	1.18766689	0.14845836	4.35	0.0005

Since there was a significant interaction between site and period, additional one-way ANOVA's were performed on each of the main factors, site, and period. During the post-construction assessment period mean coral density ranged from 0.62 colonies/m^2 (R2S2-LR) to 2.74 colonies/m^2 (R2SC1-RR, Table 17). Significant differences were detected in mean coral density between the sites during the post-construction period (F = 213.79, P < 0.001, Table 18). Mean coral density was significantly different at R2SC1-RR (mean density 2.74) from all other sites. In addition, R2NC1-LR (mean density 1.85 colonies/m^2) and R2NC3-LR (mean density 1.78 colonies/m^2) were not significantly different from each other but were significantly different than all other sites (mean densities ≤ 1.05 colonies/m^2) (Tables 17 and 18, Figure 25).

Table 17. Mean scleractinian density (with standard deviation and standard error) among nine middle reef sites across three permanent transects for baseline and post-construction assessment periods.

Site	Baseline			Post-Construction		
	Mean Density	SD	SE	Mean Density	SD	SE
R2N1-RR	1.37	0.27	0.08	0.73	0.15	0.04
R2N2-LR	1.09	0.29	0.08	0.96	0.10	0.03
R2NC1-LR	2.13	0.50	0.14	1.85	0.40	0.12
R2NC2-RR	1.61	0.27	0.08	1.05	0.14	0.04
R2NC3-LR	1.72	0.68	0.20	1.78	0.17	0.07
R2S1-RR	0.95	0.21	0.06	0.75	0.21	0.06
R2S2-LR	1.03	0.26	0.07	0.62	0.11	0.03
R2SC1-RR	2.49	0.58	0.17	2.74	0.54	0.15
R2SC2-LR	1.05	0.38	0.11	0.80	0.23	0.07

Table 18. Tukey post-hoc comparisons of mean coral density differences among middle reef sites for the post-construction assessment period.

Data type	Test statistic (p-value)	**Tukey post-hoc comparison** (sites with same letter indicated in superscript are not statistically significant)					
Non-transformed	F=213.79 (p<0.0001)	R2SC1-RR^{A}	R2NC1-LR^{B}, R2NC3-LR^{B}	R2NC2-RR^{C}			R2S2-LR^{E}
					R2N2-LR^{CD}		
						R2SC2-LR^{DE} R2S1-RR^{DE} R2N1-RR^{DE}	

Table 19. Tukey post-hoc comparisons of mean coral density differences between baseline and post-construction 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	F=42.06, p=0.0006	Baseline^{A}, Post-construction^{B}
R2N2-LR	NS	(trend) Baseline > Post-construction
R2NC1-LR	NS	(trend) Baseline > Post-construction
R2NC2-RR	F=16.17, p=0.0101	Baseline^{A}, Post-construction^{B}
R2NC3-LR	NS	(trend) Post-construction > Baseline
R2S1-RR	F=25.60, p=0.0023	Baseline^{A}, Post-construction^{B}
R2S2-LR	F=69.93, p=0.0002	Baseline^{A}, Post-construction^{B}
R2SC1-RR	NS	(trend) Post-construction > Baseline
R2SC2-LR	NS	(trend) Baseline > Post-construction

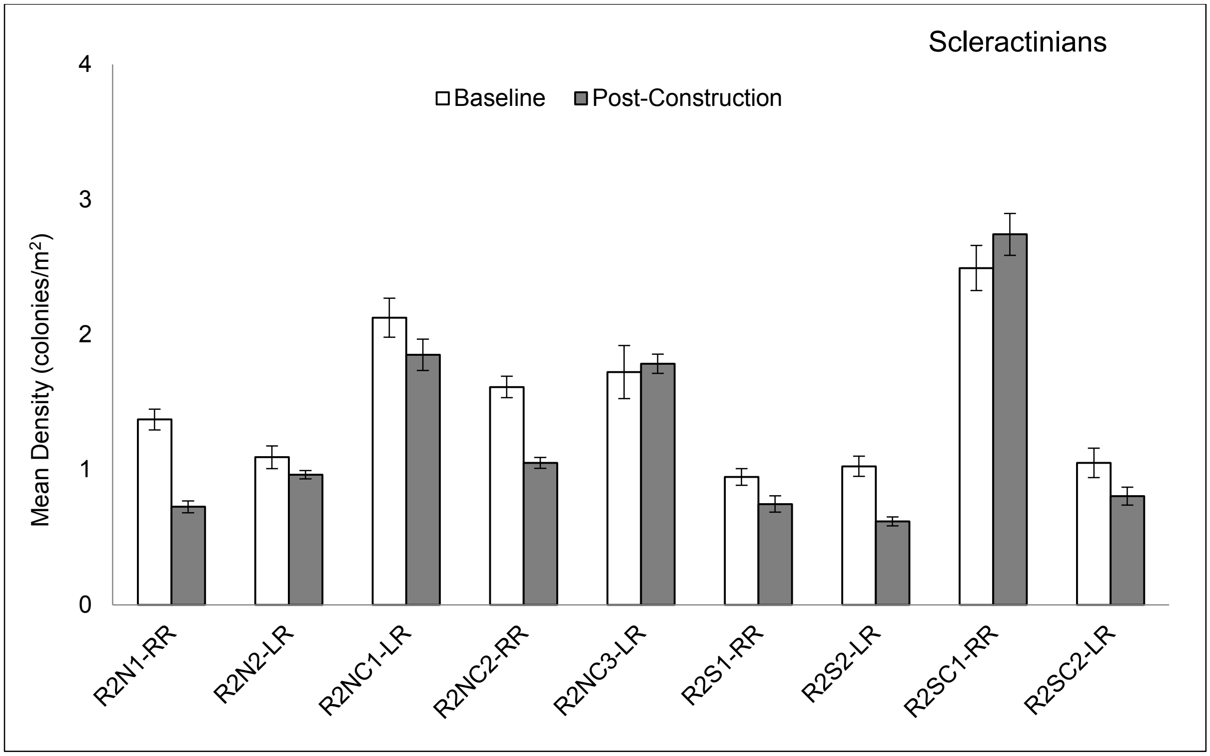

Figure 26. Mean density of scleractinian colonies at middle reef sites across all four weeks of baseline and post-construction surveys. Error bars represent the standard error for each site.

The Tukey post-hoc comparisons of mean density among individual sites between baseline and post-construction were performed on non-transformed data. Significant differences were detected at four of the nine sites. A significant decrease in mean coral density occurred channel-side at R2N1-RR, R2S1-RR, and R2S2-LR. R2N1-RR experienced the greatest decrease in mean density from 1.37 to 0.73 colonies/m^2 (Table 19, Figure 26). At the middle reef control sites mean coral density significantly declined at R2NC2-RR where mean density declined from 1.61 to 1.05 colonies/m^2 ($F = 16.17$, $P = 0.0101$, Table 19, Figure 26).

The cause of change in mean coral density between baseline and post-construction cannot be determined for untagged corals. However, between baseline and post-construction surveys, the majority of tagged corals at middle reef sites died as a result of white-plague disease (56) (Section 3.1, Table 5). At R2N1-RR, R2S1-RR, and R2NC2-RR, the only source of total colony mortality in tagged corals documented during construction or post-construction was due to white-plague disease. At R2N2-LR two coral colonies died from sedimentation stress. At R2S2-LR of the twelve tagged corals that died during construction and post-construction monitoring, one coral died from *Solenastrea* Unknown disease and the remaining eleven died from white-plague disease (Section 3.1, Table 5).

3.2.4.2 Outer Reef

A two-way repeated measures ANOVA was used to determine if mean coral density was different among the eight outer reef sites between the baseline and post-construction assessment periods. Data were collected over three weeks during baseline surveys and four weeks during post-construction. Mean site densities were normally distributed (Anderson-Darling test, $P>0.05$), in all cases. Significant effects among the sites between the assessment periods were detected (F = 86.66, P < 0.0001; Table 20). Significant differences were not detected in mean coral density between assessment periods (F = 1.15, P = 0.2903). However, significant differences were detected between sites during post-construction (F = 158.4, P<0.0001), and a significant effect was detected based on the interaction of period and site (F = 3.34, P = 0.0076) (Table 21).

Table 20. Two-way ANOVA results testing the difference in scleractinian density among and between the eight outer reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	39.98722400	2.66581493	86.66	<.0001
Error	36	1.10747685	0.03076325		
Corrected Total	51	41.09470085			

Table 21. Two-way ANOVA results testing the effects of the two time periods, baseline and post-construction (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	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	0.03543439	0.03543439	1.15	0.2903
SITE	7	34.11120241	4.87302892	158.40	<.0001
PERIOD*SITE	7	0.71896862	0.10270980	3.34	0.0076

During the post-construction assessment period mean coral density ranged from 0.75 colonies/m^2 (R3N1-LR) to 3.70 colonies/m^2 (R3SC3-SG, Table 22). Since there was a significant interaction between site and period, additional one-way ANOVA's were performed on both of the main factors, site and period. Significant differences were detected between outer reef sites during the post-construction period (F = 133.79, P < 0.0001, Table 23). Mean coral density was significantly different at each of the southern outer reef control sites, R3SC1-CP, R3SC2-LR, and R3SC3-SG, (mean density 2.19, 2.84, and 3.70 colonies/m^2 respectively) from all other outer reef sites. In addition, the lowest density coral site R3N1-LR was significantly different than all other sites except R3S1-CP (Table 23, Figure 27).

Table 22. Mean scleractinian density (with standard deviation and standard error) among eight outer reef sites across three permanent transects for baseline and post-construction assessment periods.

Site	Baseline			Post-Construction		
	Mean Density	SD	SE	Mean Density	SD	SE
R3N1-LR	1.03	0.19	0.06	0.75	0.12	0.04
R3NC1-LR	1.24	0.24	0.10	1.32	0.19	0.06
R3S1-CP	1.07	0.19	0.06	0.93	0.35	0.10
R3S2-LR	1.76	0.30	0.10	1.53	0.44	0.13
R3S3-SG	1.27	0.46	0.15	1.43	0.38	0.11
R3SC1-CP	2.01	0.44	0.18	2.19	0.53	0.15
R3SC2-LR	2.35	0.62	0.25	2.84	0.67	0.19
R3SC3-SG	3.51	0.38	0.15	3.70	0.54	0.16

Table 23. Tukey post-hoc comparisons of mean coral density differences among outer reef sites for the post-construction assessment period.

Data type	Test statistic (p-value)	**Tukey post-hoc comparison** (sites with same letter indicated in superscript are not statistically significant)					
Non-transformed	F=133.79, p<0.0001	R3SC3-SG^{A}	R3SC2-LR^{B}	R3SC1-CP^{C}	R3S2-LR^{D} R3S3-SG^{D}		R3N1-LR^{F}
					R3NC1-LR^{DE}		
						R3S1-CP^{EF}	

Table 24. Tukey post-hoc comparisons of mean coral density differences between baseline and post-construction 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=24.77, p=0.0042	Baseline^{A}, Post-construction^{B}
R3NC1-LR	NS	(trend) Post-construction > Baseline
R3S1-CP	NS	(trend) Baseline > Post-construction
R3S2-LR	F=7.18, p=0.0439	Baseline^{A}, Post-construction^{B}
R3S3-SG	NS	(trend) Post-construction > Baseline
R3SC1-CP	NS	(trend) Post-construction > Baseline
R3SC2-LR	NS	(trend) Post-construction > Baseline
R3SC3-SG	NS	(trend) Post-construction > Baseline

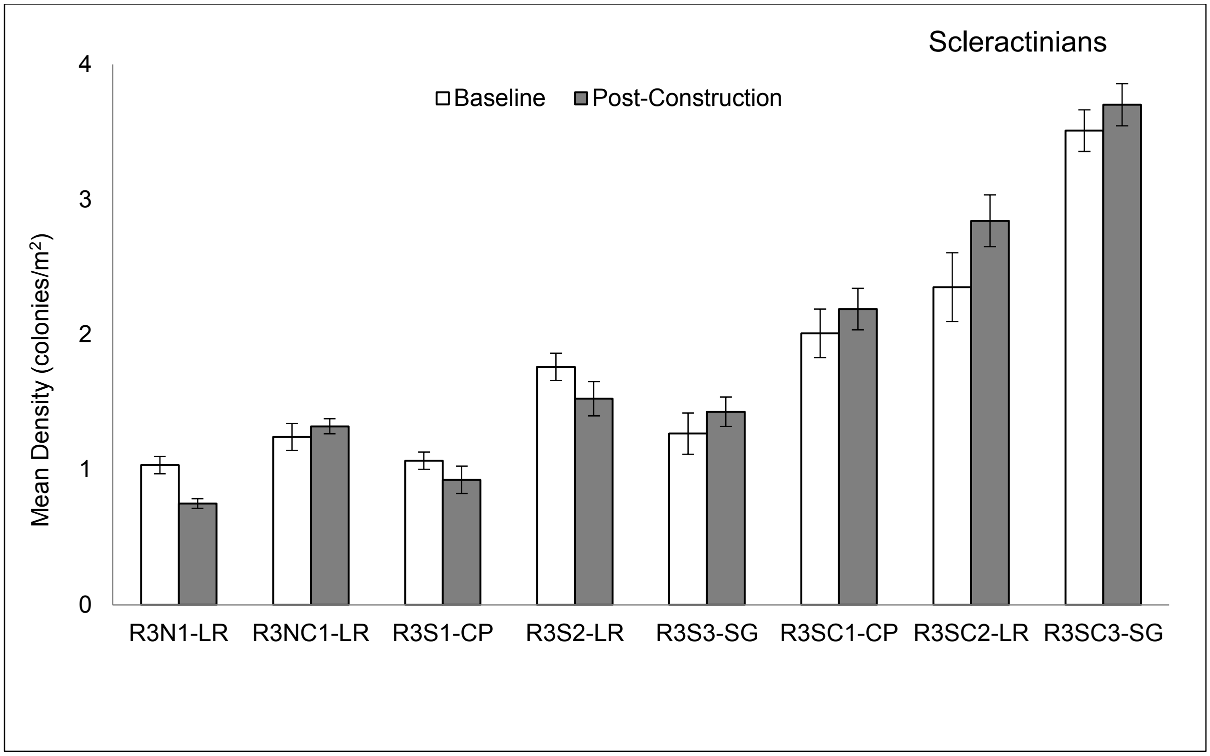

Figure 27. Mean density of scleractinian colonies at outer reef sites across all four weeks of baseline and post-construction surveys. Error bars represent the standard error for each site.

Significant differences were detected at outer reef sites between baseline and post-construction assessment periods (P < 0.001, Table 24). The Tukey post-hoc comparisons of mean density among individual sites between baseline and post-construction were performed on non-transformed data. Significant differences were detected at two of the eight sites (Table24). A significant decrease in mean coral density occurred at R3N1-LR and R3S2-LR between baseline and post-construction surveys. Mean coral density declined from 1.03 to 0.75 colonies/m^2 at R3N1-LR and from 1.76 to 1.53 at R3S2-LR (Table 24, Figure 27).

The causes of change in mean coral density between baseline and post-construction cannot be determined for untagged corals. However, the majority of tagged corals at outer reef sites died as a result of white-plague (38), other/unknown cause (4), sediment stress (3), and *Solenastrea* unknown disease (2) (Section 3.1, Table 5). At R3N1-RR, the sediment stress related mortality of three tagged corals was a result of project-related and natural sedimentation, which affected corals in topographically low areas. At R3S2-LR, one tagged coral died from bleaching and disease, one coral died from unknown causes, and three corals died from white-plague disease (Section 3.1, Table 5).

3.2.5 Scleractinian Colony Size

In general, similar patterns of scleractinian size class distributions were documented at middle and outer reef channel-side and control sites. Across all sites, the smaller size classes were the predominant individuals documented during baseline and post-construction surveys (<15 cm in maximum diameter). Summary tables of coral size class data from baseline and post-construction surveys are provided in Appendix F.

3.2.5.1 Middle Reef

Maximum diameter data were collected for all scleractinian colonies greater than 3 cm along all transects within middle reef sites in Week 1 of baseline surveys and Week 3 of post-construction surveys. Scleractinian colony size ranged from 3 cm to greater than 35 cm across 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 5 cm and 15 cm in diameter, followed by the 3-5 cm size class scleractinians (Figures 28-31) for both baseline and post-construction surveys. Different patterns were evident at individual sites. At channel-side site R2N1-RR, the smallest size classes increased 13%, while the 26-35 cm size class declined to zero. At R2N2-LR the smallest size class of corals declined by 3%, while the size class between 16 cm and 25 cm increased by 3%, between baseline and post-construction surveys. At R2N2-LR, no corals greater than 35 cm were documented in post-construction surveys, whereas one had been documented during baseline surveys. Northern control sites also showed different patterns in size class distribution, the 3-5 cm size class corals declined at R2NC1-LR and R2NC2-RR.

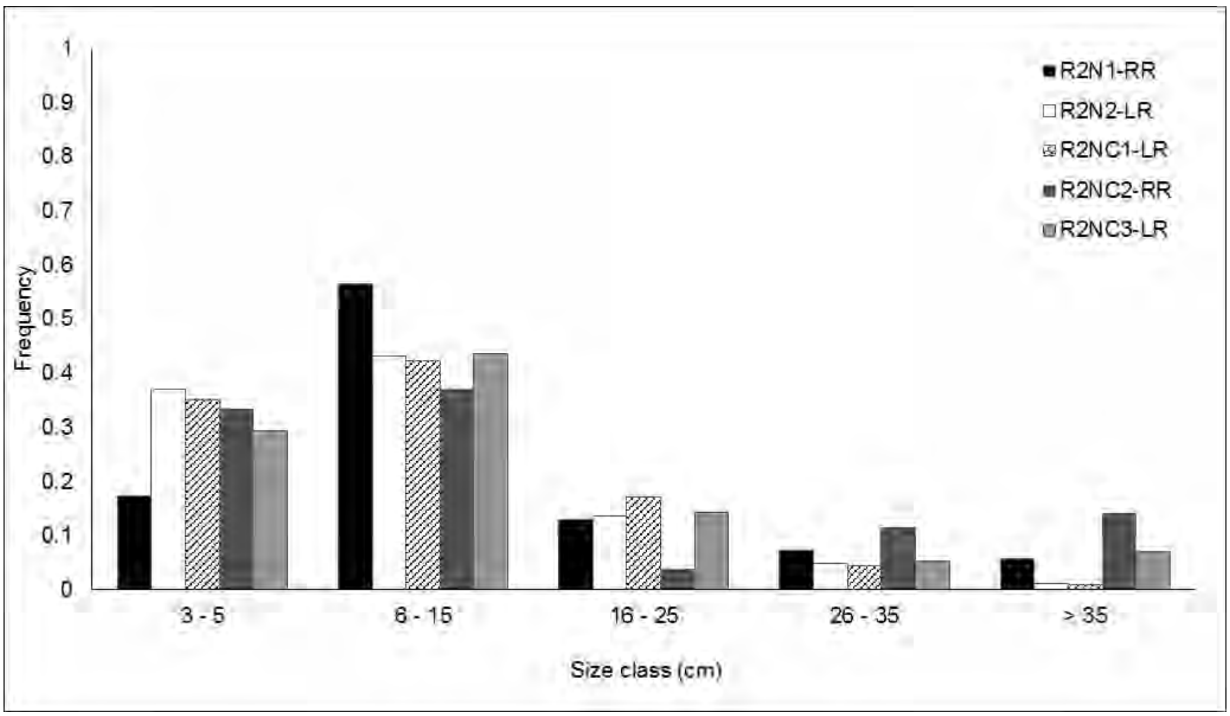

Figure 28. Proportion of scleractinian coral colonies by size class at northern middle reef sites during baseline surveys.

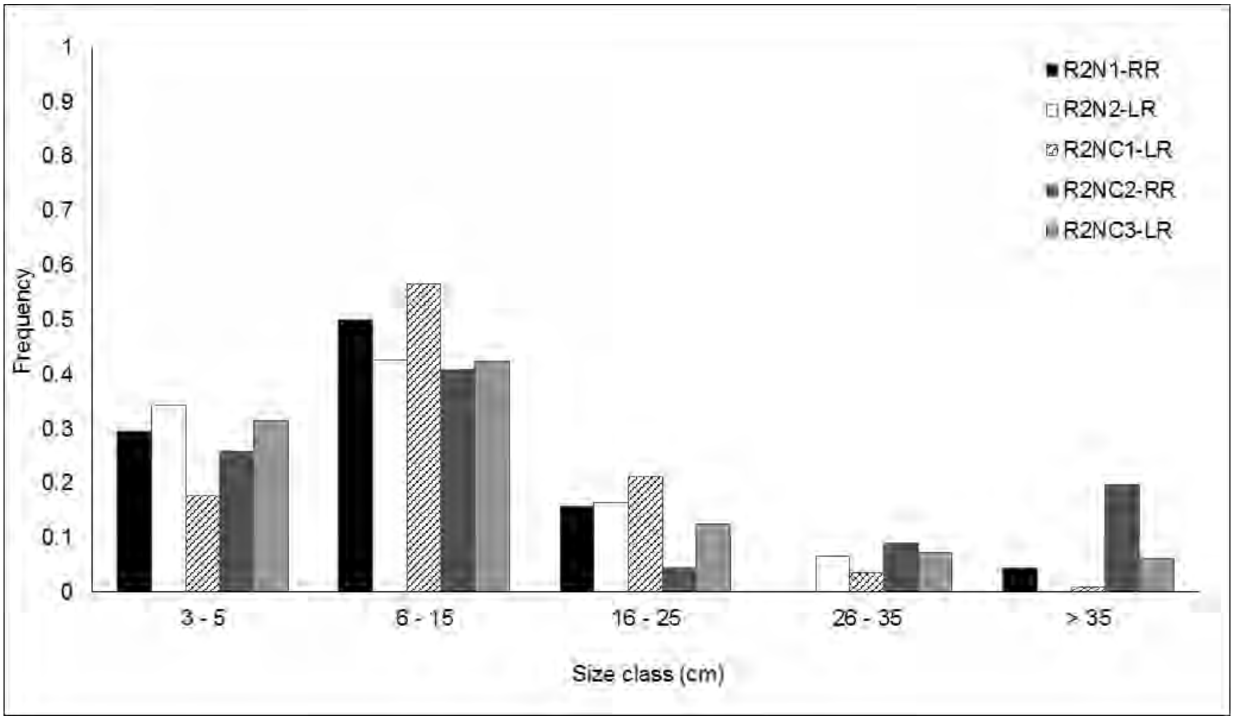

Figure 29. Proportion of scleractinian coral colonies by size class at northern middle reef sites during post-construction surveys.

At southern channel-side sites, different patterns were apparent between R2S1-LR and R2S2-RR (Figures 30 and 31). At R2S1-RR, the smallest size class of corals increased from zero in baseline, while the larger size class corals declined. At R2S2-LR corals of the smallest size class declined by 6%, while the 6-15 cm size class corals increased, but larger corals (16-25 cm and >35 cm) declined.

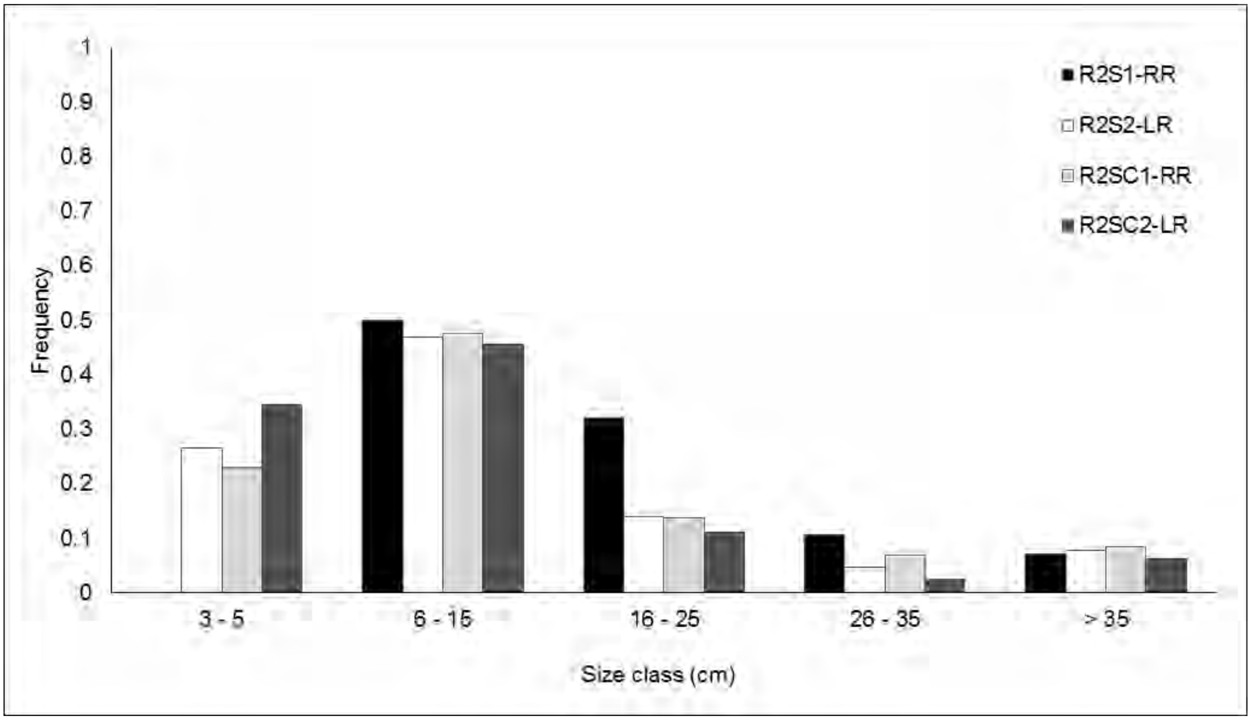

Figure 30. Proportion of scleractinian coral colonies by size class at southern middle reef sites during baseline surveys.

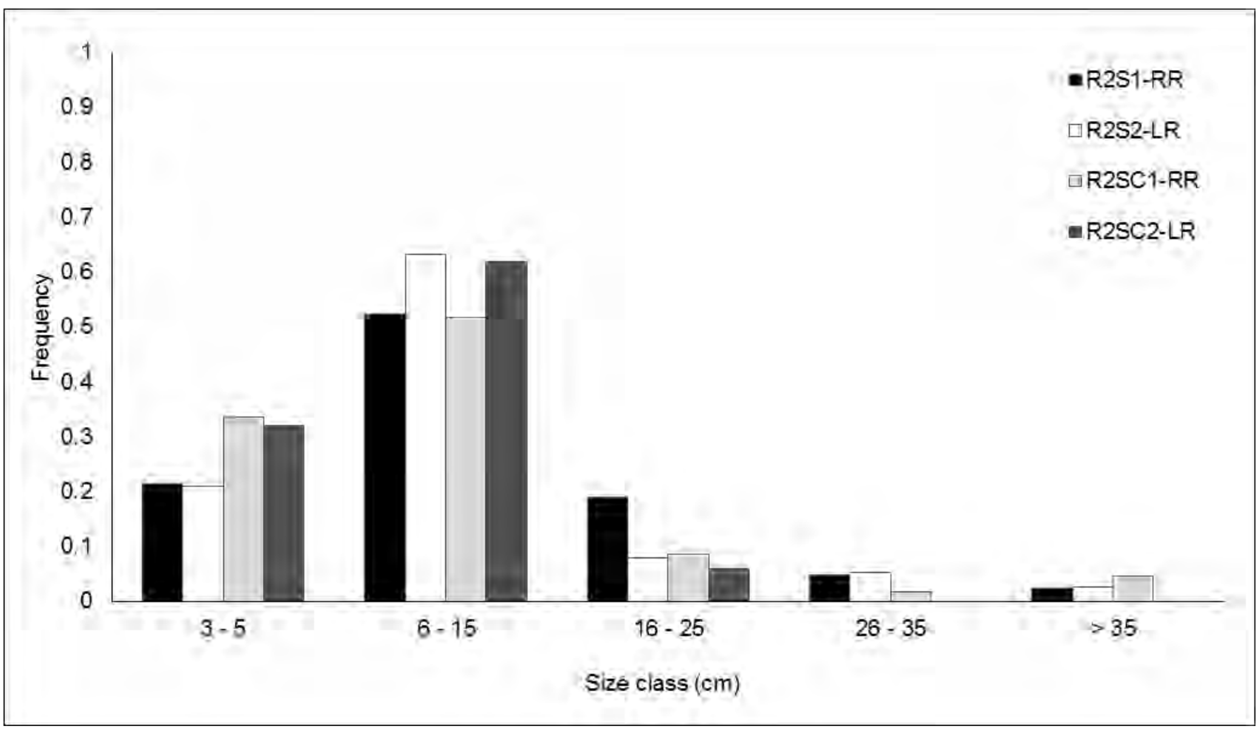

Figure 31. Proportion of scleractinian coral colonies by size class at southern middle reef sites during post-construction surveys.

3.2.5.2 Outer Reef

Maximum diameter data were collected for all scleractinian colonies greater than 3 cm along all transects within the outer reef sites during baseline in Week 1 and Week 3 during post-constructions surveys. Scleractinian corals ranged from 3 cm to more than 35 cm. Coral colony size-class data, presented as proportion of total number of colonies per site, revealed that the majority of coral colonies across the outer reef sites were between 6 cm and 15 cm in diameter for both baseline and post-construction surveys, followed by the smaller size class of 3-5 cm scleractinians (Figures 32-35).

Northern outer reef sites had similar patterns of size class distribution between baseline and post-construction surveys where corals of 15 cm and smaller were the greatest proportion of corals surveyed. A decrease of 3% was documented in the size class 3-5 cm at R3N1-LR, while this size class increased by 15% at the northern control site (R3NC1-LR).

In post-construction surveys, the smallest size class group increased at southern channel-side sites (2-8%) while the smallest size class at southern control sites declined. At channel-side sites scleractinians in the 6-15 cm size class declined in the post-construction period, except at R3S3-SG, where this group increased.

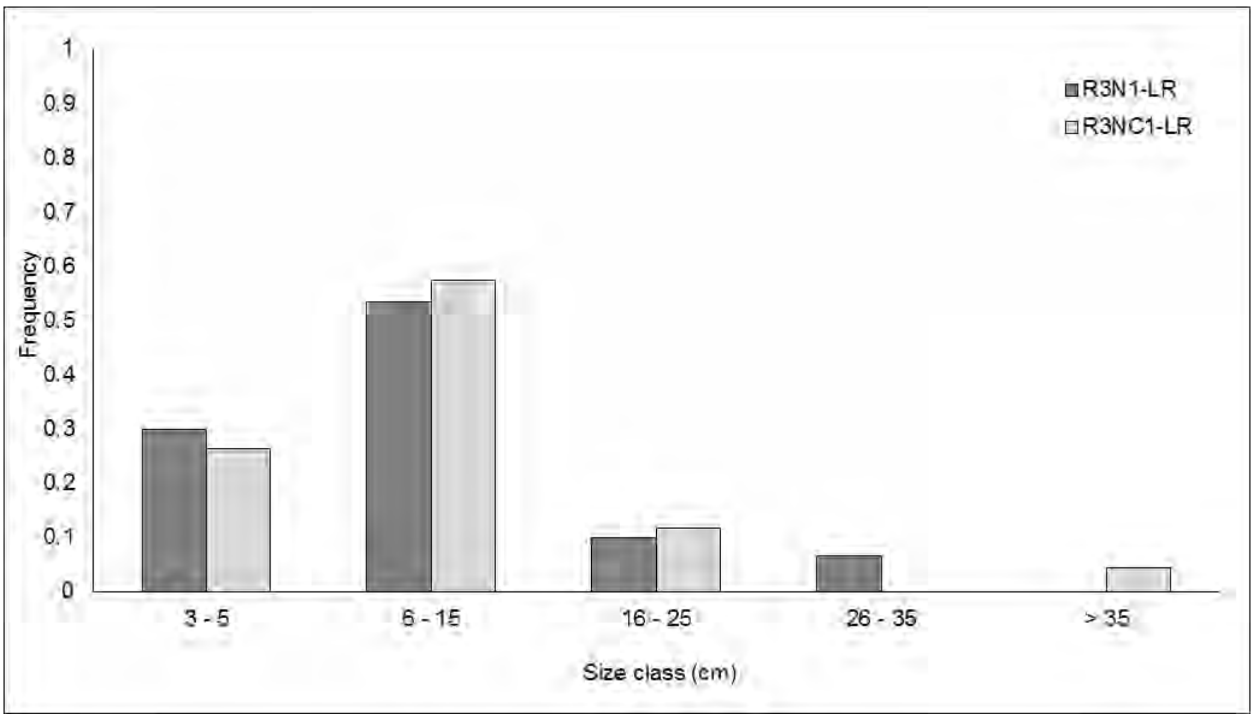

Figure 32. Proportion of scleractinian coral colonies by size class at northern outer reef sites during baseline surveys.

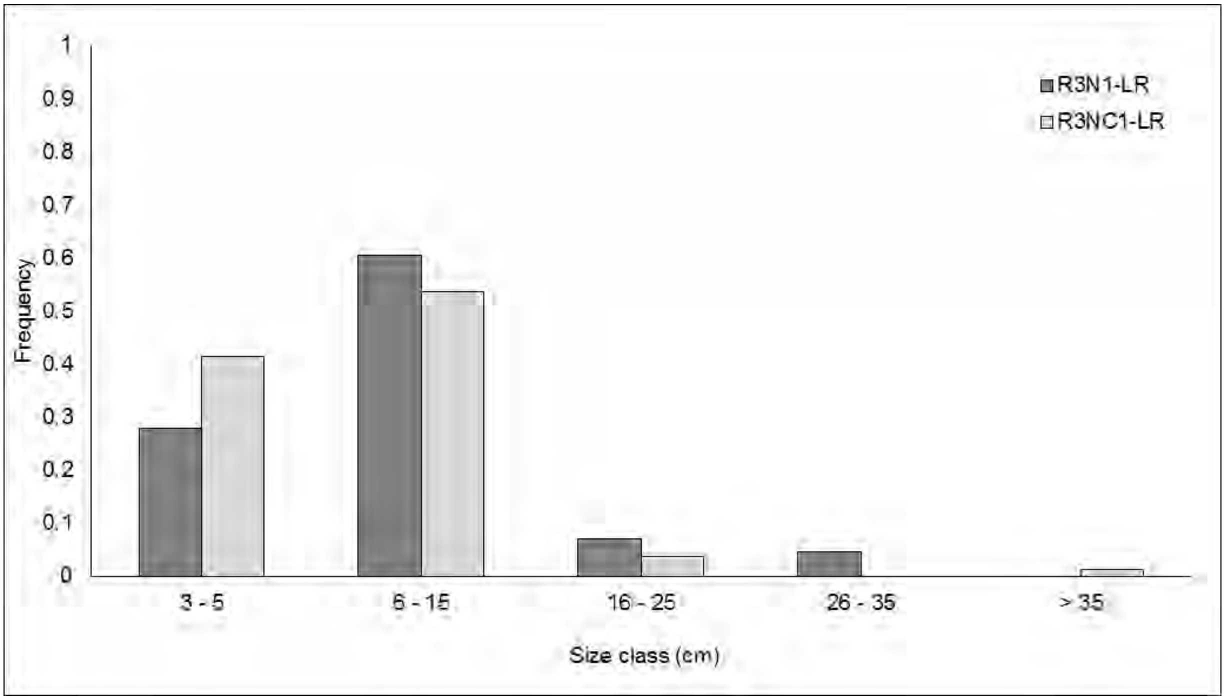

Figure 33. **Proportion of scleractinian coral colonies by size class at northern outer reef sites during post-construction surveys.**

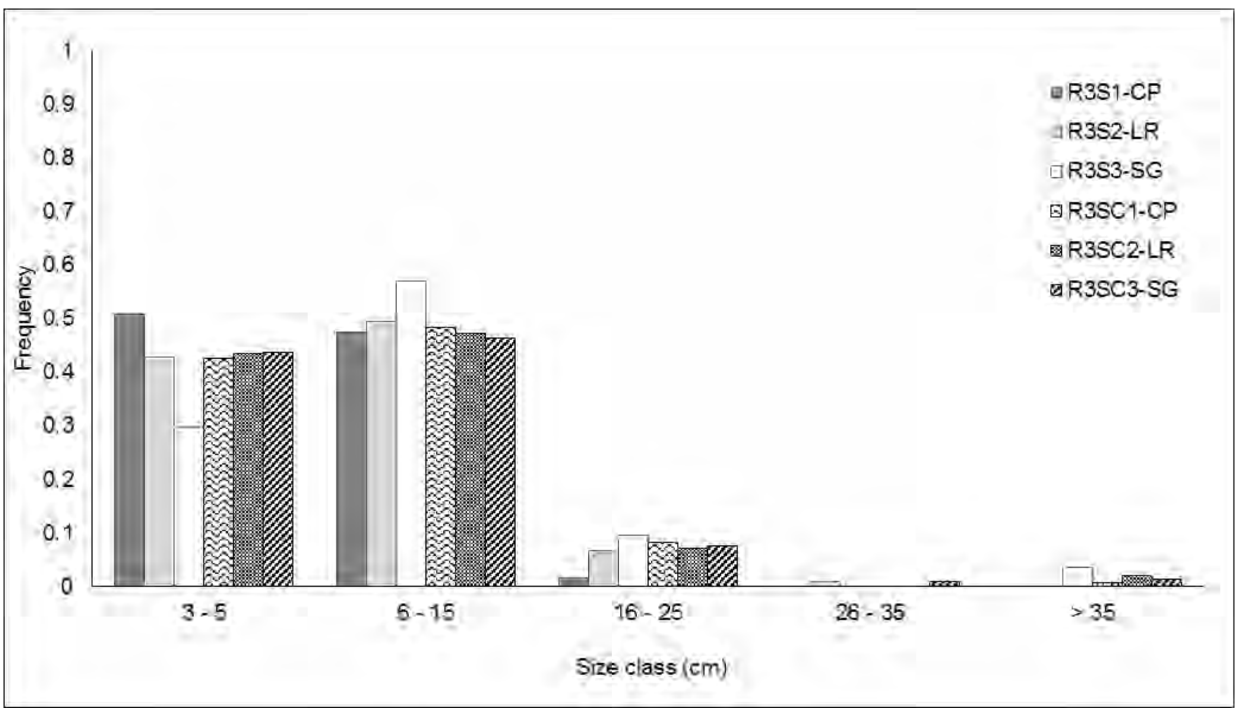

Figure 34. **Proportion of scleractinian coral colonies by size class at southern outer reef sites during baseline surveys.**

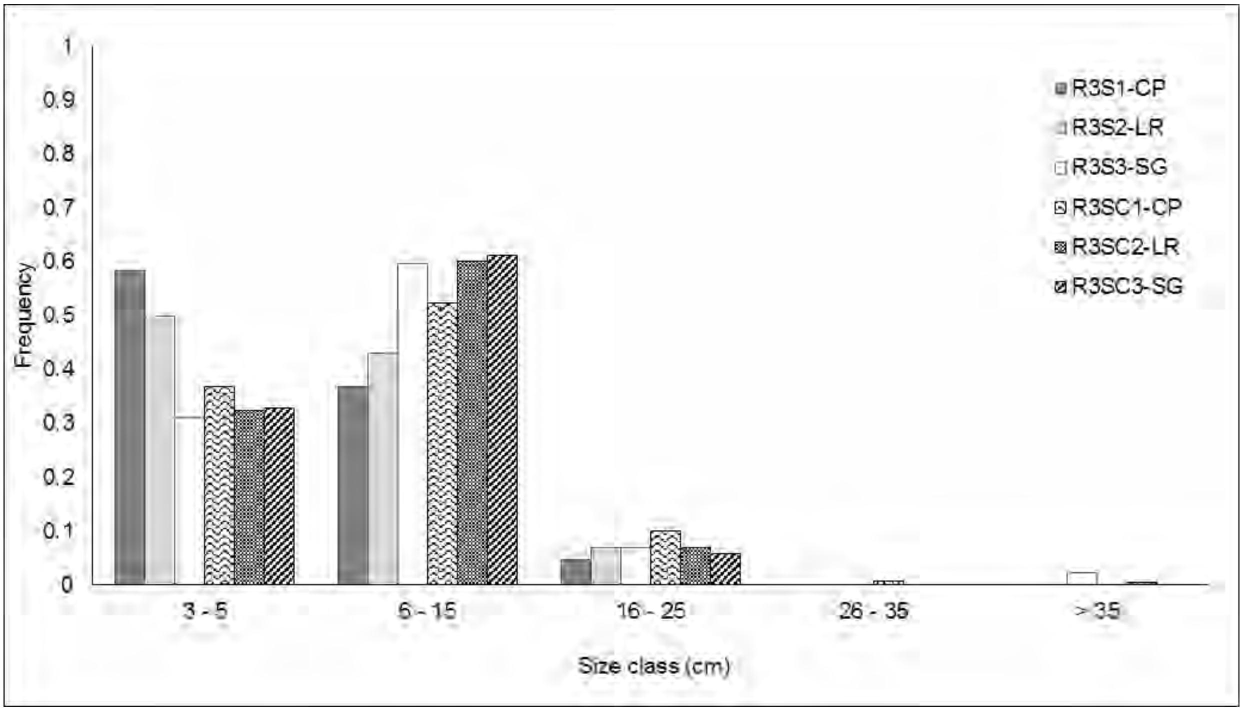

Figure 35. Proportion of scleractinian coral colonies by size class at southern outer reef sites during post-construction surveys.

3.2.6 Scleractinian Diversity and Evenness

3.2.6.1 Middle Reef

The Shannon–Wiener Diversity Index (H') was used to calculate species diversity. Diversity (H') values ranged from 1.57 to 2.22 across middle reef sites during baseline surveys and between 1.25 and 1.96 during post-construction surveys. R2SC1-RR diversity value was lowest when compared to the rest of the middle reef sites. Evenness (J') ranged from 0.26 to 0.53 during baseline surveys and between 0.24 and 0.54 during post-construction surveys across middle reef sites (Table 25).

Table 25. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for scleractinian species at middle reef sites during baseline and post-construction surveys. Baseline values were revised for this table due to transcription errors.

Scleractinians				
	Baseline		Post-Construction	
Site	H'	J'	H'	J'
R2N1-RR	2.13	0.50	1.77	0.47
R2N2-LR	2.00	0.45	1.96	0.48
R2NC1-LR	1.87	0.40	1.65	0.35
R2NC2-RR	1.70	0.39	1.64	0.39
R2NC3-LR	2.03	0.43	1.96	0.42
R2S1-RR	2.12	0.52	1.73	0.46
R2S2-LR	2.22	0.53	1.95	0.54
R2SC1-RR	1.57	0.26	1.25	0.24
R2SC2-LR	1.85	0.28	1.81	0.46

3.2.6.2 Outer Reef

The Shannon–Wiener diversity Index (H') was used to calculate species diversity. Diversity (H') values ranged from 1.57 to 1.87 across outer reef sites during baseline surveys and from 1.30 to 1.94 during post-construction. R3SC2-LR and R3SC3-SG diversity values were lowest when compared to the rest of the outer reef sites. Evenness (J') ranged from 0.32 to 0.44 across outer reef sites during baseline surveys and between 0.24 and 0.45 during post-construction surveys. Evenness was also lowest at R3SC2-LR and R3SC3-SG (Table 26).

Table 26. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for scleractinian species at outer reef sites during baseline and post-construction surveys. Baseline values were revised for this table due to transcription errors.

Scleractinians				
	Baseline		Post-Construction	
Site	H'	J'	H'	J'
R3N1-LR	1.76	0.43	1.69	0.45
R3NC1-LR	1.86	0.44	1.46	0.33
R3S1-CP	1.76	0.43	1.73	0.41
R3S2-LR	1.87	0.40	1.68	0.36
R3S3-SG	1.57	0.36	1.66	0.37
R3SC1-CP	1.83	0.38	1.94	0.39
R3SC2-LR	1.59	0.32	1.30	0.25
R3SC3-SG	1.74	0.32	1.30	0.24

3.2.7 Scleractinian Condition

3.2.7.1 Middle Reef Scleractinian Condition

Scleractinian colony-condition data were collected along all transects at the middle reef sites during baseline and post-construction surveys. Scleractinian condition data are reported from tagged scleractinian corals only. Condition categories are described in the methods (section 2.3.2) and included criteria defined in the FDEP permit. An average of 53% of scleractinians surveyed in baseline exhibited one or more stress conditions, while an average of 80% of scleractinians surveyed in post-construction showed one or more conditions, not including dead colonies.

The mean proportion of stressed corals at each site is presented in Figures 36-39 below. Spatial patterns of stress conditions were evident for sediment stress, which was elevated at channel-side sites during post-construction surveys at south and north channel-side sites on the middle reef. Coral condition, as measured by the proportion of stressed corals present in each middle reef site, was affected by sampling location. The five predominant scleractinian stress indicators were different between baseline and post-construction (Figures 36-39).These categories were chosen for comparison. “Sediment stress” included sediment accumulation, partial burial, and/or burial during baseline and post-construction surveys.

During baseline surveys, the five predominant conditions were in order of predominance: sediment stress, polyps extended, fish bites, mucus production, and unknown partial mortality (Figures 36 and 38). The unknown partial mortality (UPM) condition was observed in all weeks of baseline surveys and was described as mortality originating from the base of the colony and moving across the colony in a band-like fashion. Two diseases were also reported in the middle reef areas – white-plague disease and the unidentified disease affecting *S. bournoni*. The white-plague disease only occurred in one colony of *D. stokesi* at R2N1-LR. Winter weather conditions were shown to elevate sediment stress conditions during the baseline period (without dredging, see section 3.2.7.2). Maintenance dredging began on November 20, 2013 in the hardbottom areas (more than 750m west of the eastern middle reef sites), when R2N2-LR, R2NC2-RR and R2NC3-LR were surveyed during baseline. Interestingly, sedimentation daily rate values for middle reef sites collected before dredging (R2N1 and R2S1) were similar to sedimentation daily rate values collected while dredging was ongoing and baseline surveys were underway.

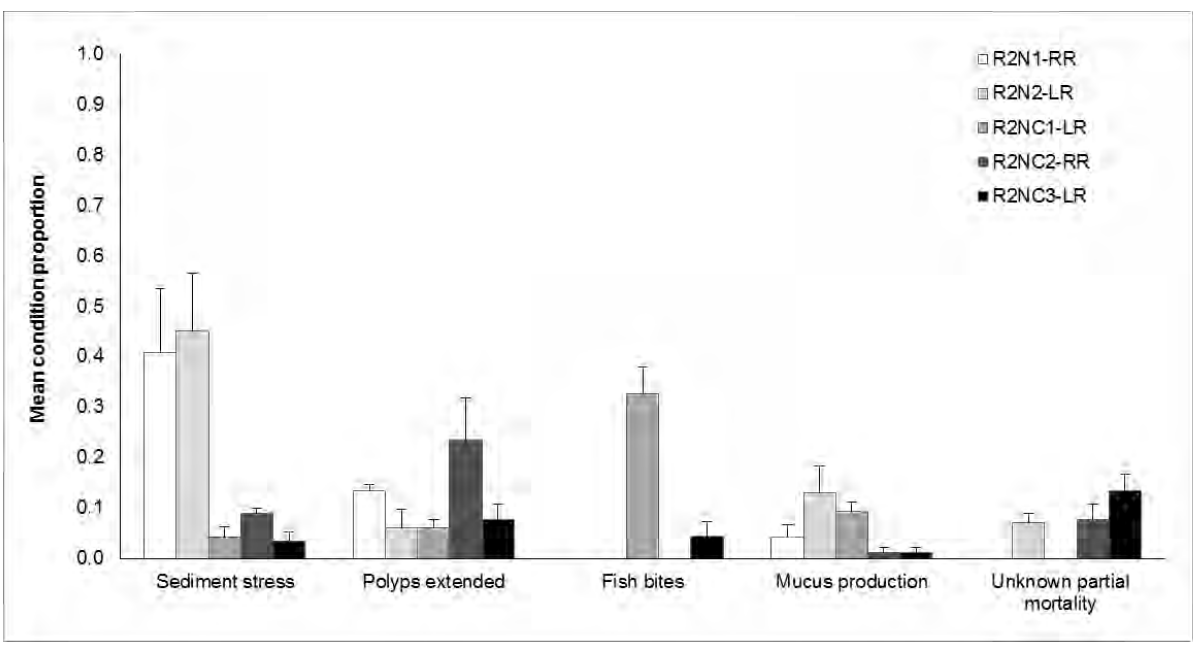

Figure 36. **Mean proportion of the five predominant scleractinian stress indicators across three (R2NC2-RR & R2NC3-LR) and four weeks (R2N1-RR, R2N2-LR, R2NC1-LR) of baseline surveys in the northern middle reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.**

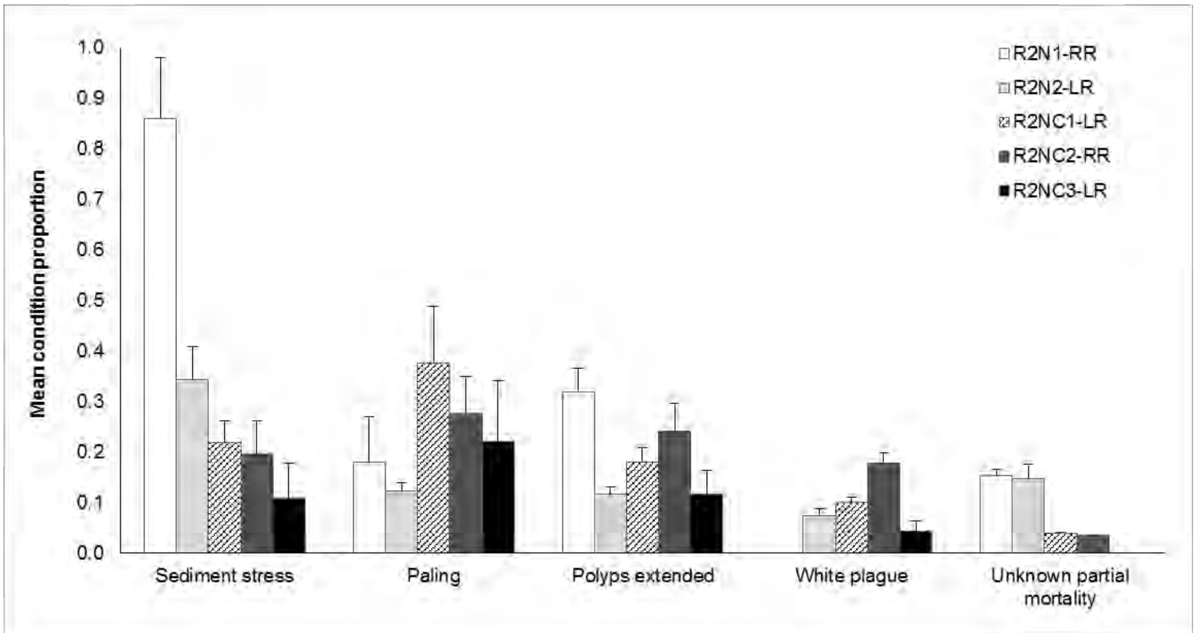

Figure 37. **Mean proportion of the five most predominant scleractinian stress indicators across all four weeks of post-construction surveys in the northern middle reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.**

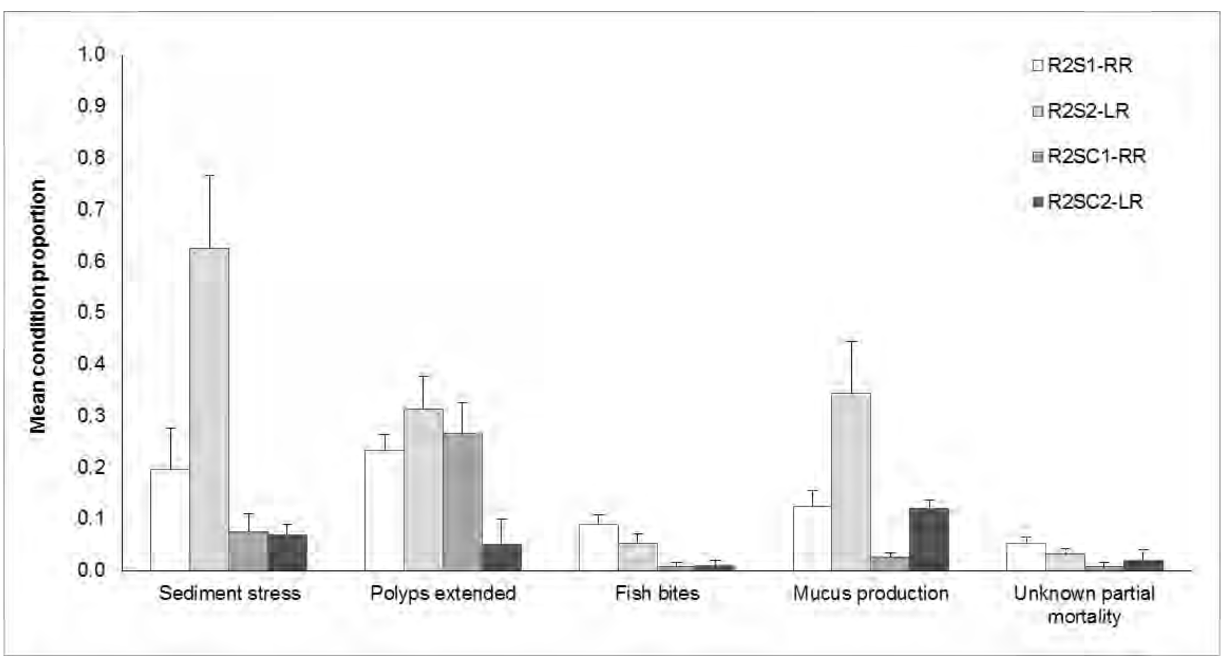

Figure 38. Mean proportion of the five most predominant scleractinian stress indicators across three (R2SC2-LR) and four weeks (R2S1-RR, R2S2-LR, R2SC1-LR) of baseline surveys in the southern middle reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.

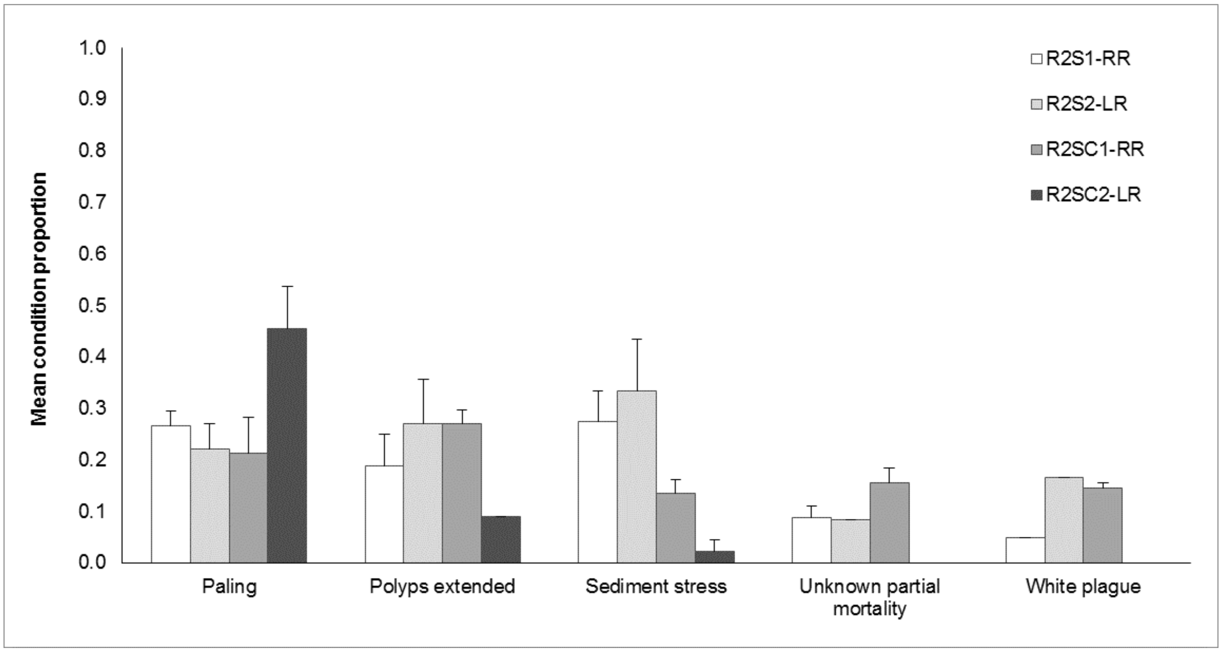

Figure 39. Mean proportion of the five most predominant scleractinian stress indicators across all four weeks of post-construction surveys at the southern middle reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.

During post-construction at the northern middle reef sites, sediment stress, paling, polyps extended, white-plague and unknown partial mortality were the five dominant scleractinian stress indicators (Figure 37). Sediment stress was highest at northern middle reef channel-side sites during baseline and post-construction surveys, although post-construction surveys documented increased sediment stress when compared to baseline values. Sediment stress at northern control sites was also elevated when compared to baseline values. Paling and white-plague disease were not present during baseline surveys, but affected all north middle reef sites in post-construction.

The five predominant stressors were the same at the southern middle reef sites, although paling was higher when compared to sediment stress in post-construction surveys (Figure 39). Sediment stress was elevated at channel-side sites when compared to control sites during baseline and post-construction surveys. Sites R2N2-LR, R2S2-LR, R2NC2-RR, R2NC3-LR, and R2SC2-LR were surveyed for two weeks of baseline where dredging occurred near hardbottom areas west of these monitoring sites, this may have increased sedimentation stress for these corals at this time. During post-construction surveys, white-plague and paling were stress indicators that were not present during baseline surveys. June and July 2015 were the hottest months on record (NOAA 2015b), and increased sea surface temperatures likely caused coral colonies to become pale during this time. Furthermore, white-plague disease was widespread across all middle reef sites causing mortality of 54 out of 218 tagged colonies, and was documented across all northern and southern sites except R2N1-RR and R2SC2-LR during post-construction surveys.

3.2.7.2 Temporal Analysis of Middle Reef Individual Condition Metrics

Baseline surveys of the middle reef sites were conducted in concurrent weeks on a per site basis. The 4 weeks of baseline for the first replicate middle reef sites (R2N1, R2S1, R2NC1 and R2SC1) began in mid-October, 2013 and were completed in mid-November, 2013 whereas baseline for the remaining five sites (R2N2, R2NC2, R2NC3, R2S2 and R2SC2) began in mid-November, 2013 and were completed in mid-December, 2013, while dredging was ongoing west of the middle reef sites.

Sites surveyed during the second baseline assessment period were documented to have suspended sediment in the water column which reduced underwater visibility for the scientific dive team. In addition to winter weather storms, dredging activity which began on November 20, 2013 west of the middle reef may have increased sedimentation during this period.

Coral condition changed significantly over the four weeks of baseline assessment for the first replicate sites of the middle reef area (R2N1-RR, R2NC1-LR, R2S1-RR and R2SC1-RR), which was likely due to the increased frequency of winter storms beginning on October 24, 2013 (Figure 40). Winter conditions, including increased turbidity and colder water temperatures may have an impact on the stress levels of corals within the study area. Only sediment stress changed significantly over the baseline study (Friedman's Tests, $\chi 2(3) = 20.406$, $p = .000$). Post-hoc pairwise tests indicated that the proportion of corals affected by sediment accumulation in Week 3 was significantly higher than in Week 1 ($P = .000$). Increased sediment mobility and associated coral stress would be expected during periods of strong wind and wave activity as documented during the baseline study period.

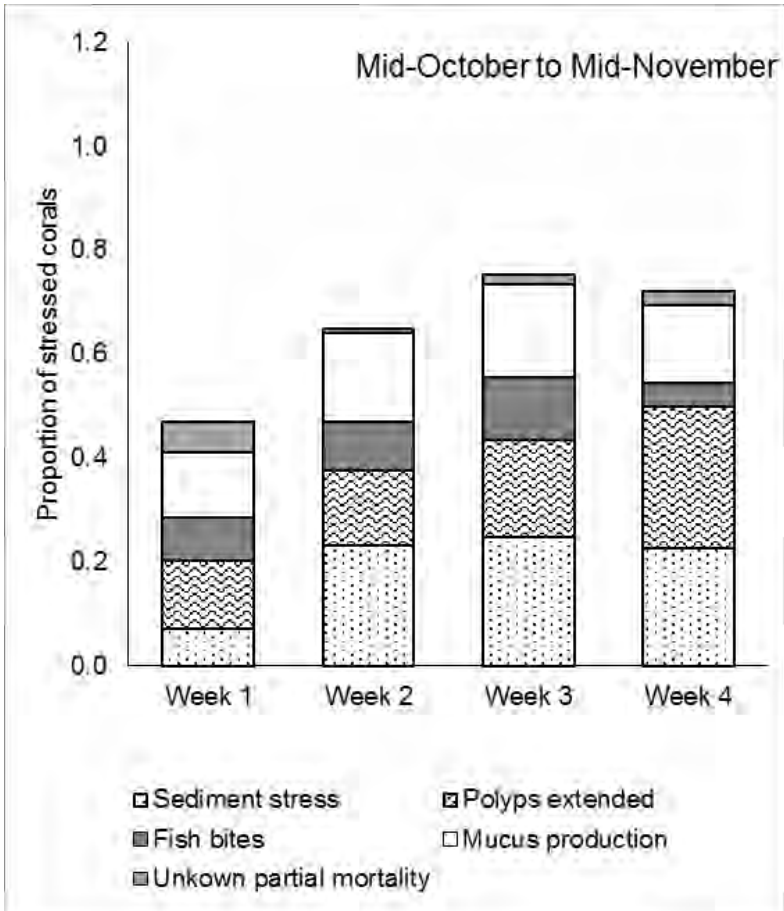

Figure 40. Weekly proportion of corals exhibiting the top five stress indicators over the four weeks of baseline assessment for sites R2N1, R2NC1, R2S1, and R2SC1. Baseline calculations were revised for this graph due to transcription errors.

For the middle reef sites that were sampled between mid-November and mid-December, 2013 (R2N2-LR, R2NC2-RR, R2NC3-LR, R2S2-LR and R2SC2-LR), four weeks of baseline data were only collected for sites R2N2-LR, R2S2-LR and R2SC2-LR. R2NC2-RR and R2NC3-LR were control sites approximately 5 miles north of the channel and weather prevented safe passage to these sites during baseline surveys in the fall/winter of 2013. Coral conditions also changed significantly over the four weeks of baseline assessment for the second replicate sites of the middle reef areas (Friedman's Test, ($\chi^2(3)$ =9.40, P = .024) (Figure 41). The observed increase was likely due to the persistence of winter storms throughout the area, as well as the increased sedimentation documented at the nearshore hardbottom sites with the commencement of dredging activities that began November 20, 2013 west of the middle reef stations.

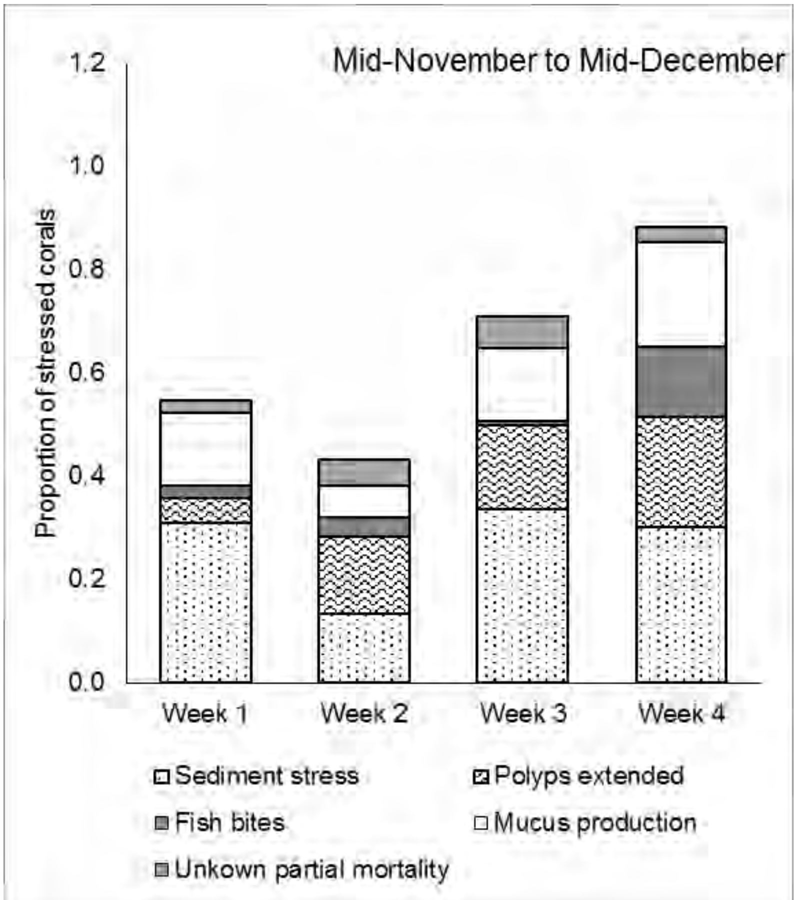

Figure 41. Weekly proportion of corals exhibiting the top five stress indicators at sites R2N2, R2S2, R2NC2, R2NC3, and R2SC2 over the four weeks of baseline assessment.

For the post-construction time period, a Friedman's test ($\chi^2(3) = 7.46$, $P = 0.0586$) indicated there was no difference in condition between weeks. A ranked ANOVA was also performed ($F = 2.83$, $P = 0.0986$) and verified this conclusion.

A ranked one-way ANOVA was conducted to test post-construction condition among sites ($F = 1.09$; $P = 0.3898$) and no statistical differences were documented.

A ranked one-way ANOVA was conducted to test differences between overall condition between all weeks of the baseline and post-construction data sets (Table 27). A Tukey's post-hoc comparison showed significant differences between baseline and post-construction overall condition for R2N1, R2NC1, and R2SC1 (Table 27).

Table 27. Tukey's post-hoc comparison for middle reef sites R2N1, R2NC1, R2S1, and R2SC1 (superscripts indicate a significant difference between survey periods, NS indicates no significant difference)

Site	Test statistic (p-value)	Tukey post-hoc comparison
R2N1-RR	F=28.05, p=0.0018	Post-construction^{A} ,Baseline^{B}
R2NC1-LR	F=15.21, p=0.0080	Post-construction^{A} ,Baseline^{B}
R2S1-RR	NS	(trend) Post-construction > Baseline
R2SC1-RR	F=29.45, p=0.0016	Post-construction^{A} ,Baseline^{B}

For sites R2N2, R2NC2, R2S2, and R2SC2 a Friedman's test ($\chi^2(3) = 4.38$, P = 0.2228) indicating there was no difference in condition between weeks. A ranked ANOVA was performed (F = 1.20, P = 0.3653) and verified this conclusion.

A ranked one-way ANOVA compared overall condition among sites for all weeks of the post-construction period and documented no significant differences for these sites, (F=0.34, p=0.7932).

Tukey's post-hoc test documented significant differences between baseline and post-construction periods for overall condition at R2N2, R2NC2, and R2SC2 (Table 28).

Table 28. Baseline and post-construction overall condition comparison using a ranked ANOVA with Tukey's post-hoc comparison (superscripts indicate a significant difference between survey periods, NS indicates no significant difference).

Site	Test statistic (p-value)	Tukey post-hoc comparison
R2N2-LR	NS	(trend) Post-construction > Baseline
R2NC2-RR	F=10.28, p=0.0238	Post-construction^{A} ,Baseline^{B}
R2S2-LR	NS	(trend) Baseline > Post-construction
R2SC2-LR	F=12.16, p=0.0130	Post-construction^{A} ,Baseline^{B}

The significant differences in overall coral conditions reported in Tables 27 and 28 are likely due to the ongoing stress of the active white-plague outbreak, and bleaching events that were occurring during post construction surveys. All sites, except R2S2-LR, either had a significant increase in the proportion of overall condition or exhibited a trend with an increase in overall conditions. R2S2-LR likely exhibited a decreasing trend in post-construction because 50% of the corals died before post-construction surveys began (Table 5). Most of the remaining corals at the site were species that were either not susceptible or less susceptible to white-plague disease.

The relative proportion of tagged corals exhibiting one of the five predominant stress indicators in a given week for post-construction is shown in Figure 42. The northern sites and southern sites had the same five dominant stressors, so all sites are grouped together in Figure 42.

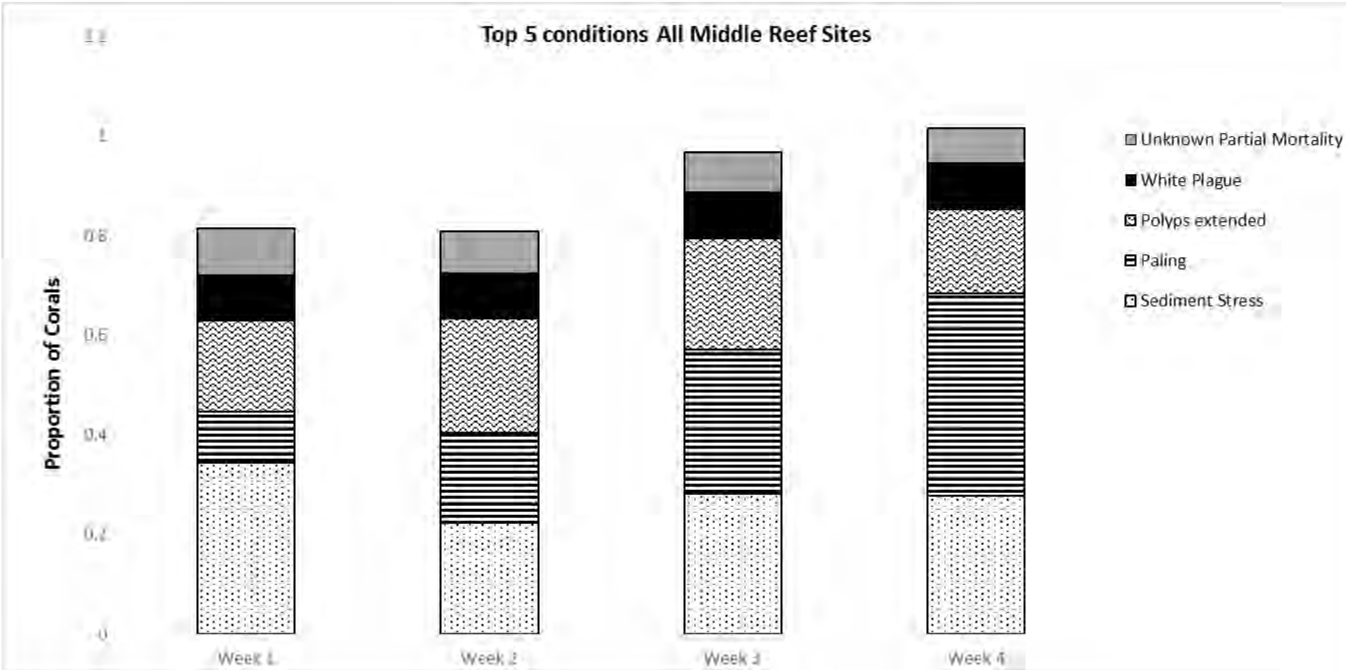

Figure 42. Weekly proportion of corals exhibiting the top five stress indicators at all middle reef sites over the four weeks of post-construction surveys.

The recent high levels of scleractinian coral mortality attributed to the white-plague disease event created a confounding factor when examining total coral stress data from compliance monitoring sites. As part of field surveys, tagged colonies which have documented total colony mortality are scored as a "1" to indicate coral stress (Table 4). Baseline condition data are presented in Table 29. As a result, sites with high coral mortality continue to have high stress values, regardless of other stressors acting on living corals (i.e. sediment stress, disease). In order to clearly present these data, mean colony condition score is presented for post-construction in two forms, first with dead colonies given a stress score of "1" (Table 30), and then with dead colonies removed from total scleractinian stress results (Table 31).

Table 29. Mean (and standard deviation) of colony condition score over four weeks of baseline data collection at all middle reef sites.

Site	Week 1		Week 2		Week 3		Week 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R2N1-RR	0.33	0.48	0.6	0.5	0.67	0.48	0.53	0.51
R2N2-LR	0.48	0.51	0.28	0.46	0.28	0.46	0.72	0.46
R2NC1-LR	0.45	0.51	0.45	0.51	0.62	0.49	0.69	0.47
R2NC2-RR	0.23	0.43	0.33	0.48	0.5	0.51	NA	NA
R2NC3-LR	0.37	0.49	0.37	0.49	0.27	0.45	NA	NA
R2S1-RR	0.46	0.51	0.68	0.48	0.71	0.46	0.61	0.5
R2S2-LR	0.75	0.44	0.79	0.41	1	0	0.92	0.28
R2SC1-RR	0.4	0.5	0.3	0.47	0.4	0.5	0.57	0.5
R2SC2-LR	0.24	0.44	0.28	0.46	0.24	0.44	0.4	0.5

Table 30. Mean (and standard deviation) of colony condition score over four weeks of post-construction data collection at all middle reef sites, including dead colonies.

Site	Week 1		Week 2		Week 3		Week 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R2N1-RR	0.97	0.18	0.87	0.35	1.00	0.00	0.90	0.31
R2N2-LR	0.75	0.44	0.67	0.48	0.71	0.46	0.79	0.41
R2NC1-LR	0.75	0.44	0.89	0.31	1.00	0.00	1.00	0.00
R2NC2-RR	0.60	0.50	0.77	0.43	0.73	0.45	0.90	0.31
R2NC3-LR	N/A	N/A	N/A	N/A	0.57	0.50	0.80	0.41
R2S1-RR	0.59	0.50	0.89	0.32	0.93	0.27	0.81	0.40
R2S2-LR	0.83	0.38	1.00	0.00	0.83	0.38	0.88	0.34
R2SC1-RR	0.80	0.41	0.77	0.43	0.93	0.25	0.87	0.35
R2SC2-LR	0.80	0.41	0.84	0.37	0.96	0.20	0.88	0.33

Table 31. Mean (and standard deviation) of colony condition score over four weeks of post-construction data collection at all middle reef sites, excluding dead colonies.

Site	Week 1		Week 2		Week 3		Week 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R2N1-RR	0.94	0.24	0.78	0.43	1.00	0.00	0.83	0.38
R2N2-LR	0.71	0.46	0.60	0.50	0.65	0.49	0.75	0.44
R2NC1-LR	0.71	0.46	0.88	0.33	1.00	0.00	1.00	0.00
R2NC2-RR	0.57	0.50	0.75	0.44	0.71	0.46	0.89	0.31
R2NC3-LR	N/A	N/A	N/A	N/A	0.52	0.51	0.78	0.42
R2S1-RR	0.45	0.51	0.85	0.37	0.90	0.31	0.75	0.44
R2S2-LR	0.67	0.49	1.00	0.00	0.67	0.49	0.75	0.45
R2SC1-RR	0.74	0.45	0.68	0.48	0.91	0.29	0.82	0.39
R2SC2-LR	0.55	0.52	0.64	0.50	0.91	0.30	0.73	0.47

3.2.7.3 Outer Reef Scleractinian Condition

Scleractinian colony-condition data were collected along all transects at the outer reef sites during post-construction surveys. Scleractinian condition data are reported from tagged scleractinian data collected during baseline and post-construction periods. Condition categories are described in the methods and included criteria defined in the FDEP permit and other stress conditions including sediment stress, bleaching, paling, diseases, fish bites, mucus production, disease, and extended polyps among others. An average of 52.3% of scleractinians surveyed in baseline exhibited one or more stress conditions, while an average of 70% of scleractinians surveyed in post-construction showed one or more conditions, not including dead colonies.

Coral condition, as measured by the proportion of stressed corals present in each outer reef site, was affected by sampling location. The five most predominant scleractinian stress indicators were different between baseline and post-construction. “Sediment stress” included sediment accumulation, partial burial, and/or burial during baseline and post-construction surveys.

During baseline surveys, the five most dominant stress conditions for both the northern and southern outer reef sites documented were sediment stress, polyps extended, fish bites, mucus production, and unknown disease (Figures 43 and 45). Poor weather and ocean conditions prevented data collection during Week 3 of baseline assessment, so no data were available for that time period. Dredging had already started near the hardbottom areas when outer reef baseline surveys were conducted, but was only conducted adjacent to hardbottom sites. Although the sedimentation was presumed to be due to weather, dredging operation cannot be excluded as a possible influence.

During post-construction, the five predominant stressors at the northern sites were polyps extended, fish bites, sediment stress, paling and unknown partial mortality (Figure 44). The unknown partial mortality (UPM) condition was observed in all weeks of post-construction surveys.

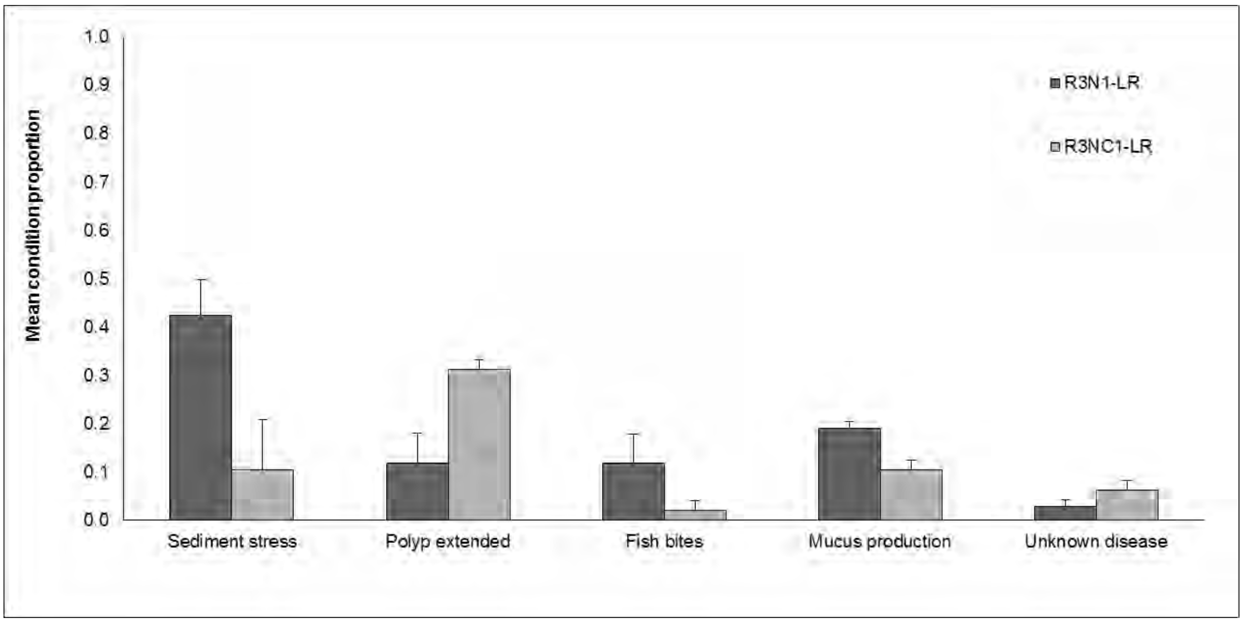

Figure 43. Mean proportion of the five most predominant scleractinian stress indicators across all three weeks of baseline surveys in the northern outer reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean. Baseline calculations were revised for this graph due to transcription errors.

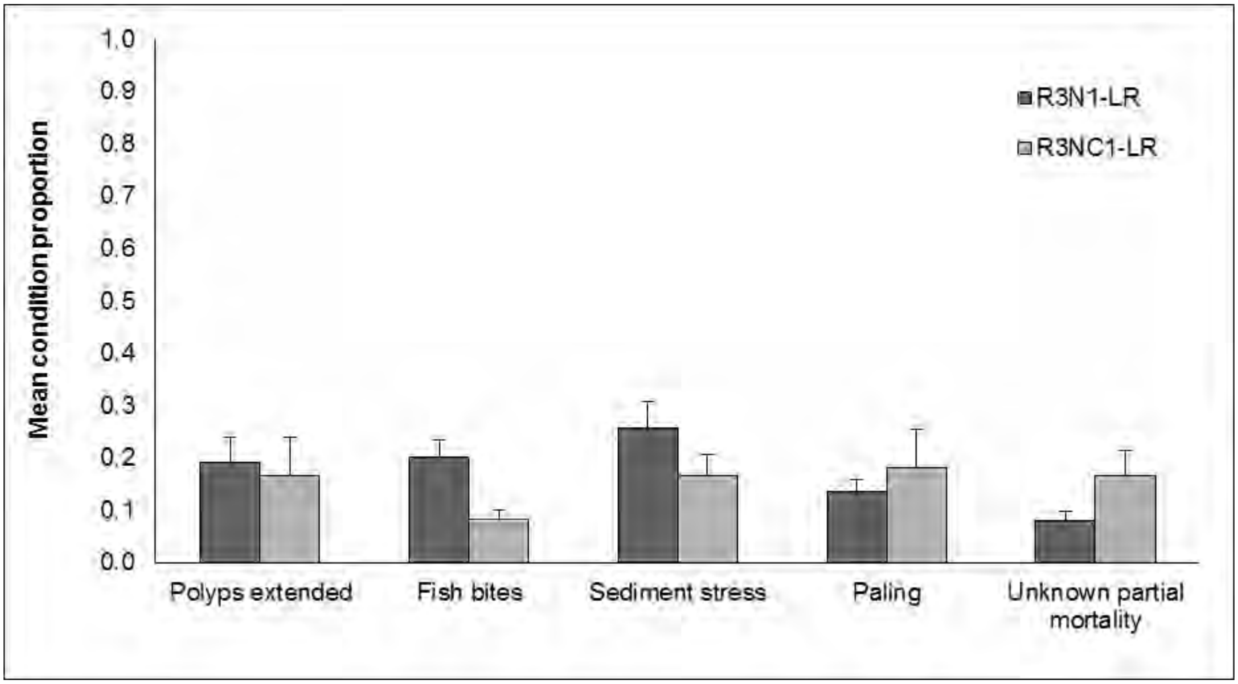

Figure 44. Mean proportion of the five most predominant scleractinian stress indicators across all four weeks of post-construction surveys in the northern outer reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.

The five dominant stressors at the southern sites remained the same as the northern sites in baseline (Figure 45), but were different in post-construction from the northern sites. During post-construction at the southern outer reef sites, the five predominant scleractinian stress indicators were sediment stress, mucus production, paling, unknown condition, and polyps extended (Figure 46). Unknown condition affected colonies of *S. intersepta, S. bournoni*, *S. siderea,* and *P. astreoides* throughout all four weeks of post-construction monitoring at all southern outer reef sites. Sediment stress decreased at all southern sites from baseline to post-construction, which may be due to the seasonal difference between baseline surveys (winter) and post-construction surveys (summer), as well as the dredging activities that had already started near the hardbottom areas when outer reef baseline surveys were ongoing.

Paling became the third most dominant stress indicator during post-construction. June and July 2015 were the hottest months on record (NOAA 2015), and increased sea surface temperatures likely caused coral colonies to become pale during this time.

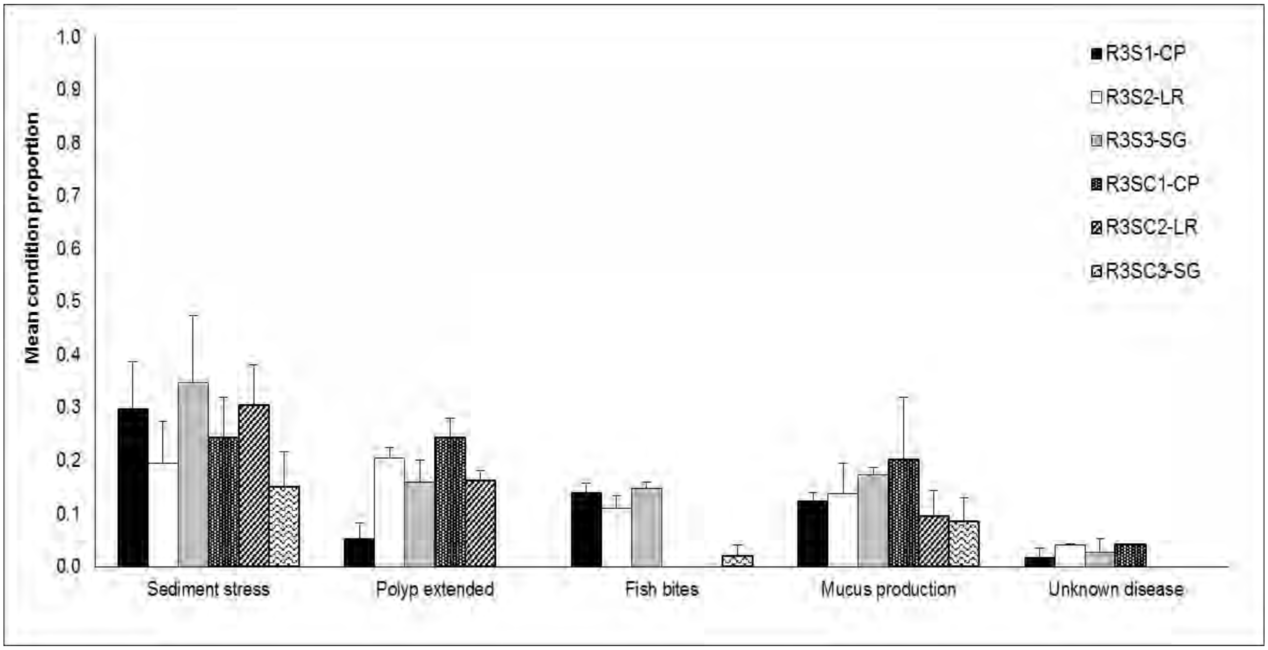

Figure 45. Mean proportion of the five most predominant scleractinian stress indicators across all three weeks of baseline surveys in the southern outer reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean. Baseline calculations were revised for this graph due to transcription errors.

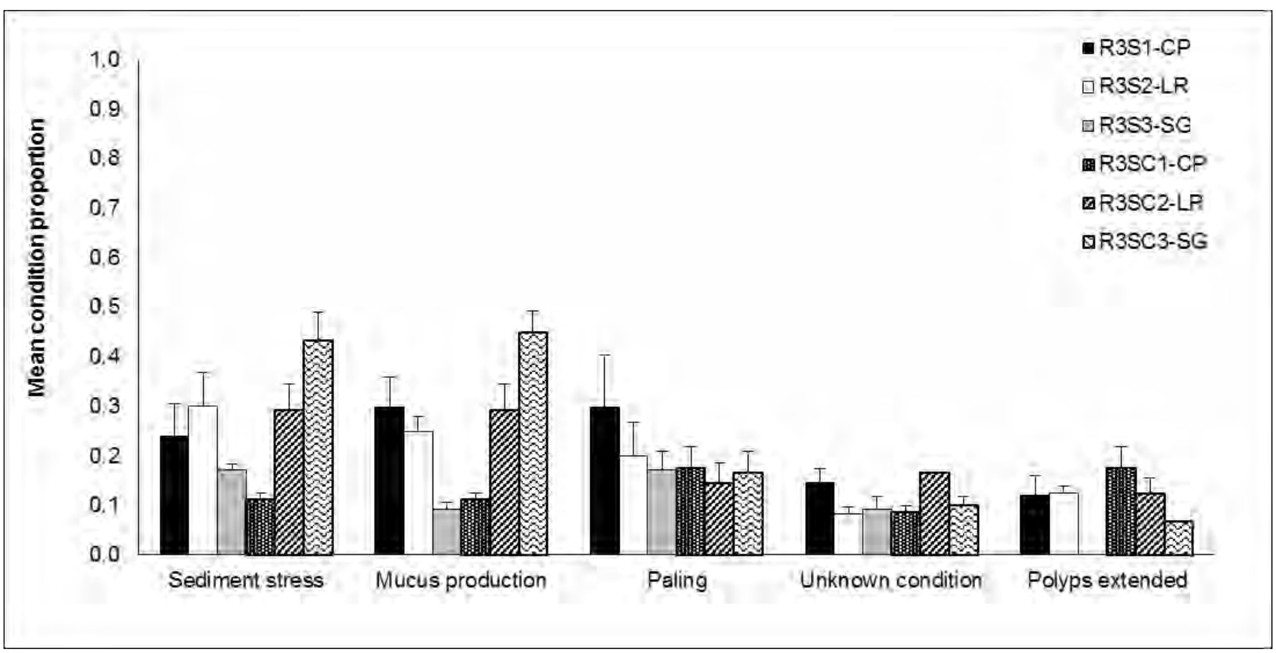

Figure 46. Mean proportion of the five most predominant scleractinian stress indicators across all four weeks of post-construction surveys in the southern outer reef sites amongst tagged coral colonies. The five stressors are presented above from most dominant to least dominant overall, from left to right. Error bars represent the standard error for each site mean.

3.2.7.4 Temporal Analysis of Outer Reef Coral Condition

The mean proportion of stressed corals at each site is presented for all three weeks of baseline sampling in Table 32, and all four weeks of post-construction in Tables 33 and 34. Baseline surveys of the outer reef sites were conducted in concurrent weeks at all outer reef sites. Weather conditions prevented data collection in Week 3 of baseline surveys at all outer reef sites and at some sites in Week 4. Week 1, 2 and 4 data were only available for sites R3N1, R3S1, R3S2, and R3S3 so the outer reef temporal analysis uses data from only these sites.

The recently high levels of scleractinian coral mortality attributed to the white-plague disease event created a confounding factor when examining total coral stress data from compliance monitoring sites. As part of field surveys, tagged colonies which have documented total colony mortality are scored as a "1" to indicate coral stress. In order to clearly present these data, mean colony condition score is presented for post-construction in two forms, first with dead colonies assigned a stress score of "1" (Table 33), and then with dead colonies removed from total scleractinian stress results (Table 34).

Table 32. Mean (and standard deviation) of colony condition score over three weeks of baseline data collection at all outer reef sites.

	Week 1		Week 2		Week 3		Week 4	
Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R3N1-LR	0.64	0.49	0.74	0.45	NA	NA	0.57	0.51
R3NC1-LR	0.63	0.49	0.56	0.51	NA	NA	NA	NA
R3S1-CP	0.58	0.51	0.47	0.51	NA	NA	0.37	0.50
R3S2-LR	0.40	0.50	0.44	0.51	NA	NA	0.52	0.51
R3S3-SG	0.52	0.51	0.64	0.49	NA	NA	0.76	0.44
R3SC1-CP	0.72	0.46	0.46	0.51	NA	NA	NA	NA
R3SC2-LR	0.48	0.51	0.41	0.50	NA	NA	NA	NA
R3SC3-SG	0.43	0.51	0.21	0.41	NA	NA	NA	NA

Table 33. Mean (and standard deviation) of colony condition score over four weeks of post-construction data collection at all outer reef sites, including dead colonies.

	Week 1		Week 2		Week 3		Week 4	
Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R3N1-LR	0.81	0.40	0.59	0.50	0.73	0.46	0.77	0.43
R3NC1-LR	0.78	0.43	0.72	0.46	0.72	0.46	0.84	0.37
R3S1-CP	0.63	0.50	0.79	0.42	0.80	0.41	0.95	0.22
R3S2-LR	0.84	0.37	0.65	0.49	0.65	0.49	0.81	0.40
R3S3-SG	0.72	0.46	0.73	0.45	0.69	0.47	0.85	0.37
R3SC1-CP	0.58	0.50	0.68	0.48	0.68	0.48	0.68	0.48
R3SC2-LR	0.80	0.41	0.76	0.44	0.81	0.40	0.90	0.30
R3SC3-SG	0.88	0.34	0.88	0.33	0.84	0.37	0.84	0.37

Table 34. Mean (and standard deviation) of colony condition score over four weeks of post-construction data collection at all outer reef sites, excluding dead colonies.

	Week 1		Week 2		Week 3		Week 4	
Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD
R3N1-LR	0.79	0.42	0.53	0.51	0.67	0.49	0.72	0.46
R3NC1-LR	0.73	0.46	0.61	0.50	0.61	0.50	0.78	0.43
R3S1-CP	0.50	0.52	0.71	0.47	0.71	0.47	0.92	0.28
R3S2-LR	0.80	0.41	0.55	0.51	0.55	0.51	0.75	0.44
R3S3-SG	0.63	0.50	0.63	0.50	0.58	0.51	0.79	0.42
R3SC1-CP	0.50	0.51	0.60	0.50	0.60	0.50	0.60	0.50
R3SC2-LR	0.67	0.49	0.58	0.51	0.67	0.49	0.83	0.39
R3SC3-SG	0.80	0.41	0.80	0.41	0.73	0.46	0.73	0.46

Sediment stress, polyps extended, fish bites, mucus production and unknown disease were the top five coral stress indicators over the three weeks of baseline assessment at all outer reef sites. The relative proportion of corals exhibiting each of these stress indicators in a given week for baseline is shown in Figure 47.

Figure 47. Weekly proportion of corals exhibiting the top five stress indicators over the three weeks of baseline assessment for outer reef sites. Baseline calculations were revised for this graph due to transcription errors.

During post-construction surveys, the top five stress indicators at the northern-side sites were sediment stress, polyps extended, fish bites, paling, and unknown partial mortality. The relative proportion of corals exhibiting each of these stress indicators in a given week is shown in Figure 48.

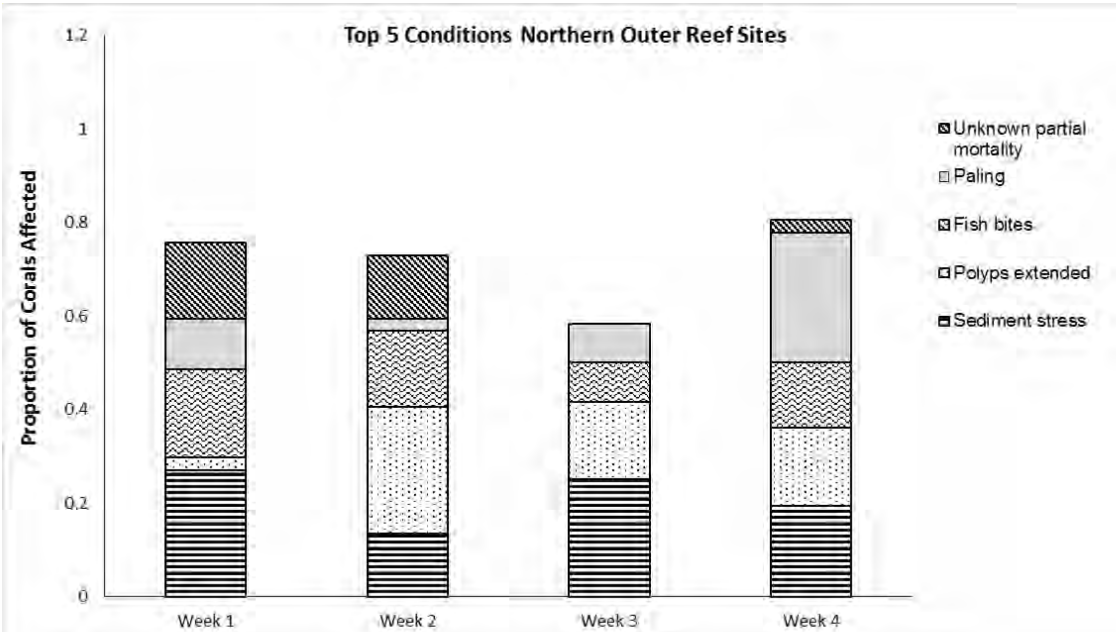

Figure 48. Weekly proportion of corals exhibiting the top five stress indicators over the four weeks of post-construction assessment for northern outer reef sites.

The southern channel-side sites exhibited different top five stress indicators from the northern side. Sediment stress, mucus production, paling, unknown condition, and polyps extended were the most recorded over the four weeks of post-construction surveys. The relative proportion of corals exhibiting each of these stress indicators in a given week is shown in Figure 49.

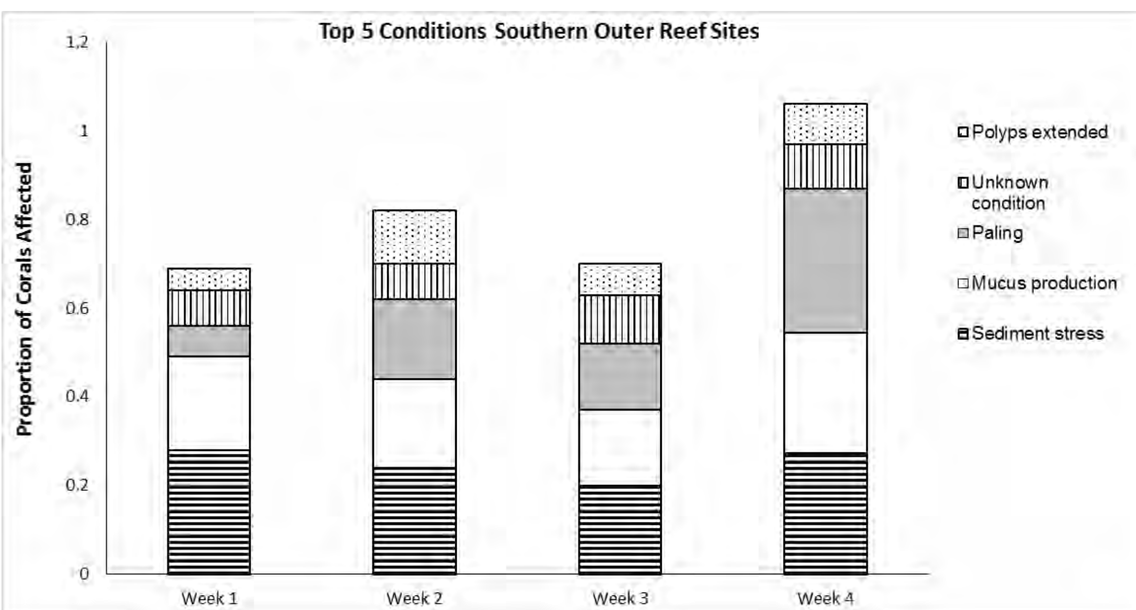

Figure 49. Weekly proportion of corals exhibiting the top five stress indicators over the four weeks of post-construction assessment for southern outer reef sites.

For the post-construction time period, a Friedman's test ($\chi^2(3) = 6.69$, $P = 0.0823$) indicated that the overall coral condition did not change significantly over the post-construction period. A ranked ANOVA was performed ($F = 2.68$, $P = 0.0735$) and confirmed this.

A ranked one-way ANOVA was conducted to test differences between overall condition between all weeks of the baseline and post-construction data sets (Table 35). A Tukey's post-hoc comparison showed significant differences between baseline and post-construction overall condition for R3SC2-LR ($F = 8.87$, $P = 0.0408$) and R3SC3-SG ($F = 103.21$, $P = 0.0005$) (Table 35).

The significant differences in overall coral conditions, at R3SC2-LR and R3SC3-SG, are likely due to the ongoing stress of the active white-plague outbreak, and bleaching events that were occurring during post construction surveys.

Table 35. Baseline and post-construction overall condition comparison using a ranked ANOVA with Tukey's post-hoc comparison (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) Post-construction > Baseline
R3NC1-LR	NS	(trend) Post-construction > Baseline
R3S1-CP	NS	(trend) Post-construction > Baseline
R3S2-LR	NS	(trend) Post-construction > Baseline
R3S3-SG	NS	(trend) Post-construction > Baseline
R3SC1-CP	NS	(trend) Post-construction > Baseline
R3SC2-LR	F=8.87, p=0.0408	Post-construction^{A}, Baseline^{B}
R3SC3-SG	F=103.21, p=0.0005	Post-construction^{A}, Baseline^{B}

3.3 Quantitative Benthic Sampling Comparison: Octocorals, Sponges and Zoanthids

3.3.1 Octocoral Occurrence

Octocoral count and size class data were collected during baseline surveys in Week 1 and during post-construction surveys in Week 3. Octocoral data are presented for middle and outer reef sites below. Summary tables of octocoral counts for each week of baseline and post-construction surveys are provided in Appendix D.

3.3.1.1 Middle Reef

Middle reef sites included six to ten octocoral genera. R2N1-RR and R2S2-LR had the highest number of genera (10 genera) during baseline, whereas R2N2-LR had the fewest number of genera (6). During post-construction surveys, R2NC2-RR and R2S2-LR both had the highest number of genera (10), while R2S2-LR remained the lowest (Table 36).

Genera presence differences between baseline and post-construction surveys are likely due to the presence/absence of rare genera that can be influenced by changes in sample area, mortality, and identification accuracy. Only *Pterogorgia* was observed during baseline surveys but was absent from middle reef compliance monitoring sites during post-construction (i.e. R2N1-RR).

Table 36. Octocoral genera present at each middle reef site. Baseline surveys are indicated by a black dot and post-construction surveys are indicated by a square.

Octocoral genera	Middle Reef Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-LR
Briareum	• □	• □	• □	• □	• □		• □	□	• □
Erythropodium	• □	• □	• □	• □	• □		• □	□	• □
Eunicea	• □	• □	• □	• □	• □	• □	• □	• □	• □
Gorgonia	• □	• □	• □	• □	• □	• □	• □	• □	• □
Muricea	• □	• □	• □	• □	• □	• □	• □	• □	• □
Plexaura	• □	□	• □	• □	• □	• □	• □	• □	• □
Plexaurella	• □			• □	• □	• □	• □	• □	
Pseudoplexaura	• □		• □	• □	• □	• □	• □	• □	• □
Pseudopterogorgia	• □	• □	• □	• □	• □	• □	• □	• □	• □
Pterogorgia	•			□		• □	• □		• □

3.3.1.2 Outer Reef

Outer reef sites included four to seven octocoral genera during baseline, and five to nine during post-construction. R3NC1-LR, R3S3-SG, R3SC1-CP, R3SC2-LR and R3SC3-SG all had the highest number of genera during baseline surveys (7), while R3N1-LR and R3S1-CP had the lowest (4). During post-construction, R3SC3-SG recorded the highest number of octocoral genera (9), while R3N1-LR and R3S1-CP continued to have the lowest number (5) (Table 37).

Differences in genera presence between baseline and post-construction surveys are likely due to the presence/absence of rare genera that can be influenced by changes in sample area, mortality, and identification accuracy. A single *Gorgonia ventilata* was observed during baseline surveys at R3S1-CP, but was absent from outer reef compliance monitoring sites during post-construction. A small number of *Gorgonia* at R3N1-LR, *Plexaura* at R3S1-CP, *Plexaurella* at R3NC1-LR and R3S1-CP, *Pseudoplexaura* at R3SC3-SG and *Pterogorgia* at R3S2-LR, R3SC2-LR, and R3SC3-SG were only documented in post-construction surveys.

Table 37. Octocoral genera present at each outer reef site. Baseline surveys are indicated by a black circle and post-construction surveys are indicated by a square.

Octocoral genera	Outer Reef Sites							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Erythropodium		• □		• □	• □	• □	• □	• □
Eunicea	• □	• □	• □	• □	• □	• □	• □	• □
Gorgonia	□	• □	•	• □	• □	• □	• □	• □
Muricea	• □	• □		□	• □	• □	• □	• □
Plexaura	• □	• □	□	• □	• □	• □	• □	• □
Plexaurella		□	□			• □		• □
Pseudoplexaura		• □	• □	• □	• □	□	• □	□
Pseudopterogorgia	• □	• □	• □	• □	• □	• □	• □	• □
Pterogorgia				□			□	□

3.3.2 Octocoral Abundance and Density

3.3.2.1 Middle Reef

Patterns of octocoral genera relative abundance varied across sites, but *Eunicea*, *Gorgonia*, and *Pseudopterogorgia* were dominant across all middle reef sites during baseline and post-construction surveys. R2NC2-RR had the greatest number of colonies (1500 in baseline and 913 in post-construction), and R2N2-LR had the least number of octocorals (111 in baseline and 103 in post-construction), as well as the fewest genera with 6 identified during baseline and 7 documented in post-construction surveys (Figures 51-54, Table 38).

The nearly 40% decline in octocoral abundance at R2NC2-RR was likely due to lobster fishing activities. During the course of site visits to most of the control sites, divers noted a number of long-line lobster traps. Many of the lines ran across monitoring sites. During lobster season, these lines were retrieved and re-deployed on a regular basis. As a result, many dislodged corals and octocorals were noted and photographed and numerous severed sponges (especially *Xestospongia muta*) were documented. In extreme circumstances, the lines denuded all but the smallest colonies and holdfasts (see Figure 50). In light of no other major physical disturbances in these areas during the duration of the project, it is likely that the losses of colonies within our control stations were due to repeated disturbances caused by long-line lobster trap fishing practices.

Figure 50. Lobster long-line traps were documented to sheer and topple benthic organisms at control sites. These effects may explain documented declines between baseline and post-construction periods for octocorals and sponges at control sites.

Table 38. Number of octocoral colonies and generic richness of octocoral colonies at middle reef sites during baseline and post-construction surveys. Colonies were counted during Week 1 in baseline surveys and Week 3 in post-construction surveys. Baseline values were revised for this table due to transcription errors.

Site	Baseline		Post-Construction	
	Number of Colonies	Number of Genera	Number of Colonies	Number of genera
R2N1-RR	696	10	597	9
R2N2-LR	111	6	103	7
R2NC1-LR	439	8	371	8
R2NC2-RR	1500	9	913	10
R2NC3-LR	713	9	951	9
R2S1-RR	156	8	148	8
R2S2-LR	571	10	520	10
R2SC1-RR	425	8	629	9
R2SC2-LR	682	9	727	9

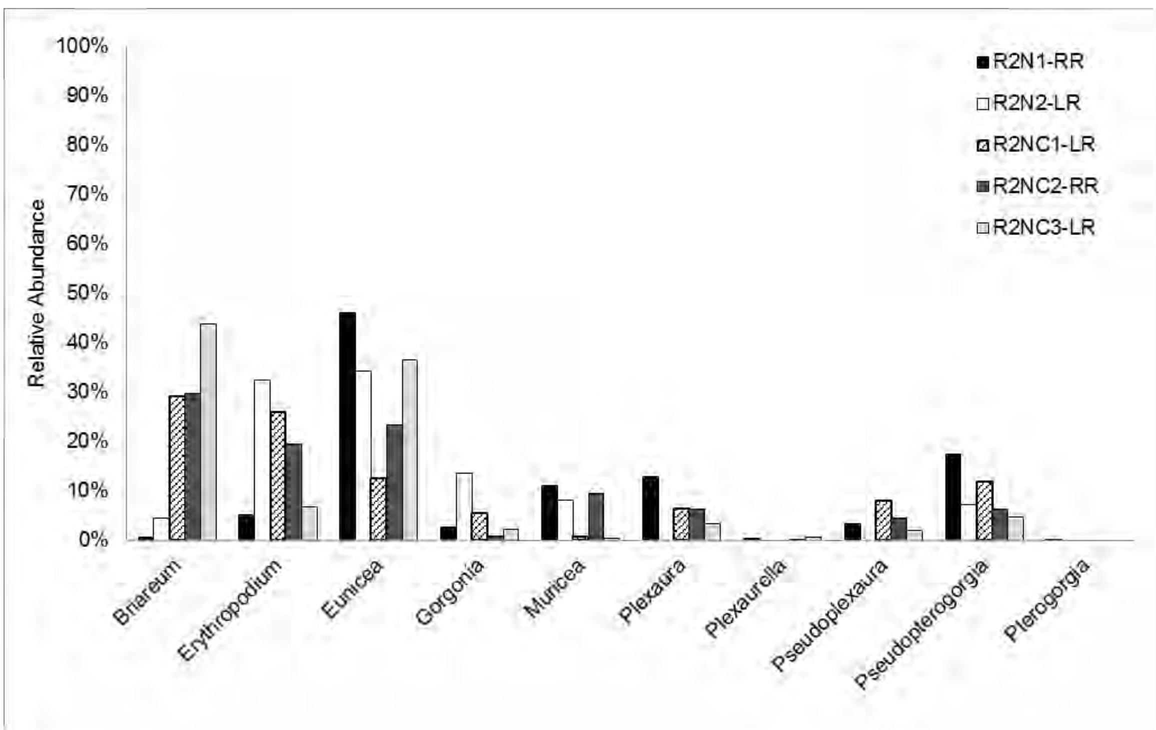

Figure 51. Relative abundance of octocorals at northern middle reef sites during baseline surveys.

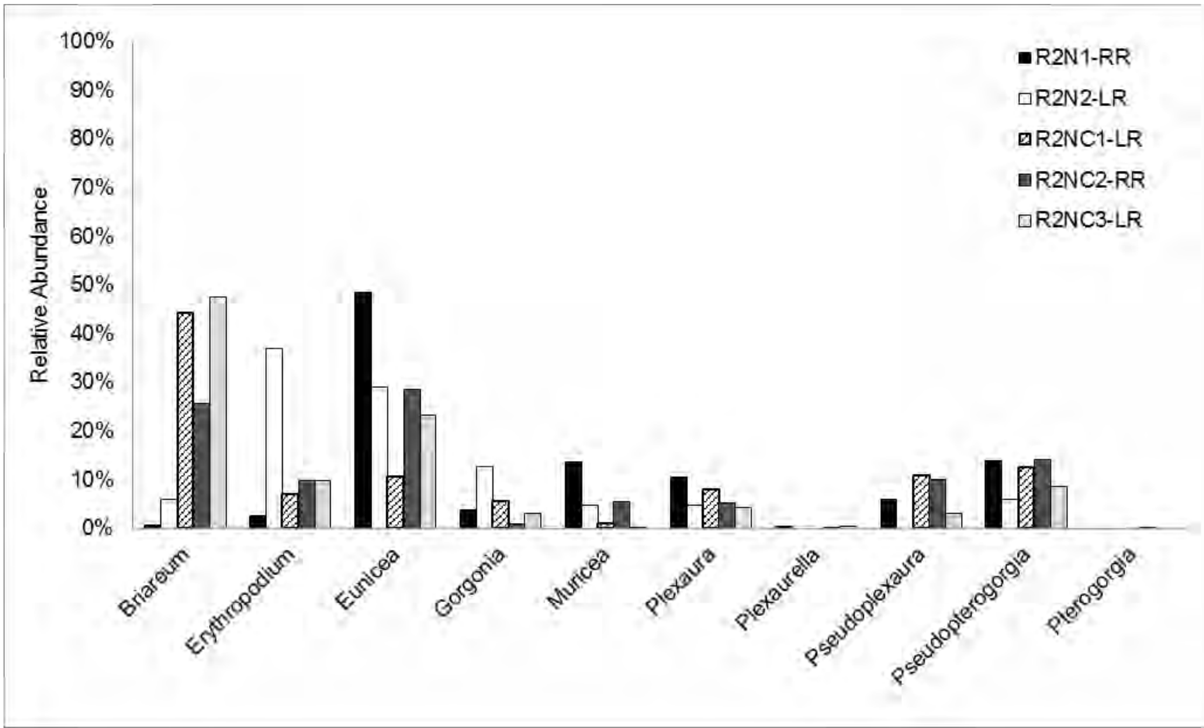

Figure 52. Relative abundance of octocorals at northern middle reef sites during post-construction surveys.

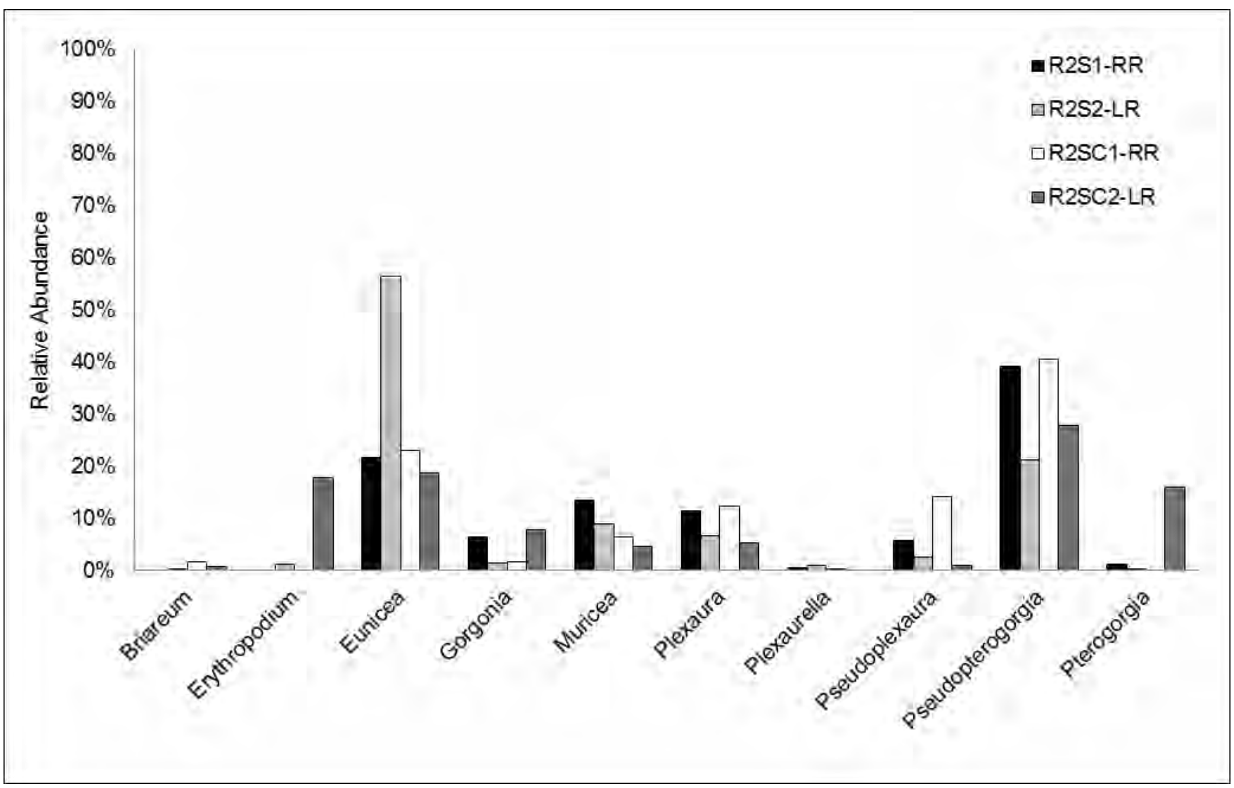

Figure 53. Relative abundance of octocorals at southern middle reef sites during baseline surveys. Baseline values were revised for this graph due to transcription errors.

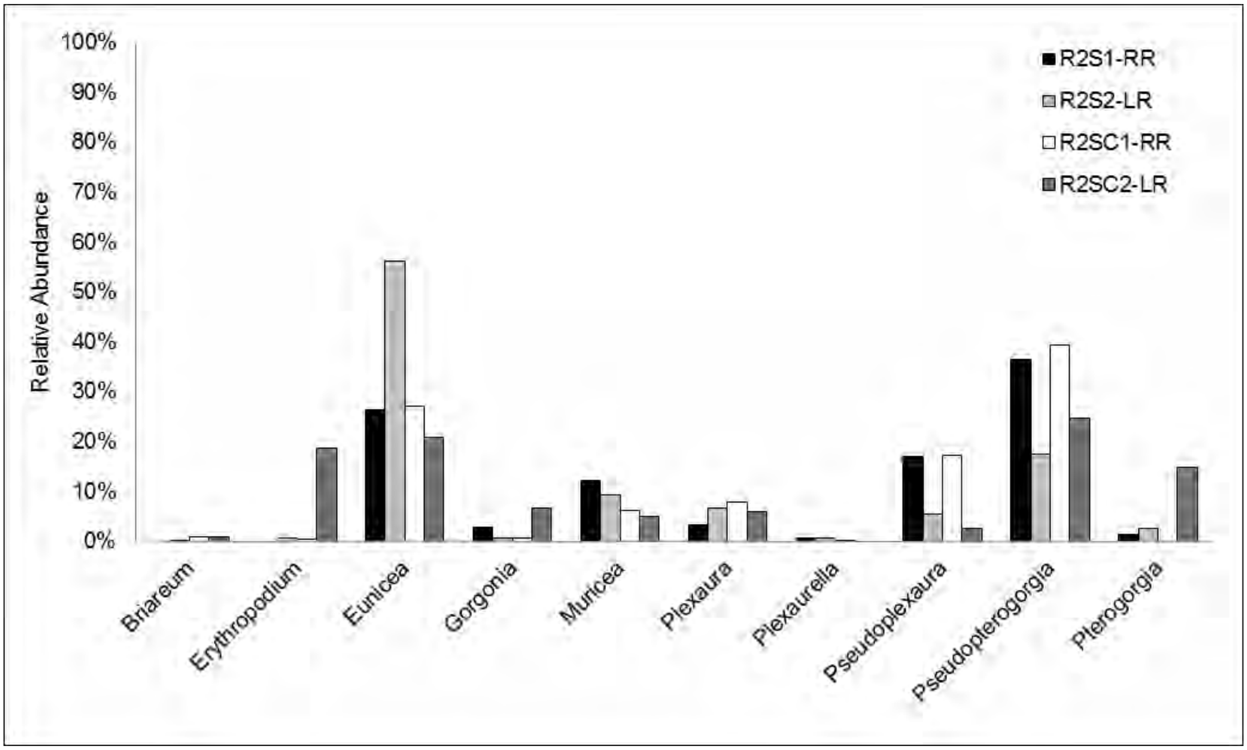

Figure 54. Relative abundance of octocorals at southern middle reef sites during post-construction surveys.

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 post-construction assessment periods. Data were collected one time during both baseline and post-construction surveys. Mean site densities were normally distributed (Anderson-Darling test, $P > 0.05$), in all cases. Significant effects among the sites between the assessment periods were detected ($F = 8.35$, $P < 0.0001$; Table 39). No significant effects between the assessment periods were detected ($F = 0.43$, $P = 0.5179$; Table 40). Significant effects were detected between sites ($F = 15.77$, $P < 0.001$), and no significant effect was detected based on the interaction between period and site ($F = 1.93$, $P = 0.0848$) (Table 40).

Table 39. Two-way repeated measures ANOVA results testing the difference in octocoral density among and between the nine middle reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	1719.977037	101.175120	8.35	<.0001
Error	36	436.005000	12.111250		
Corrected Total	53	2155.982037			

Table 40. Two-way repeated measures ANOVA results testing the effects of the two assessment periods (baseline and post-construction), the effects of octocoral locations, and the interaction between the two effects on the mean density of octocorals among the nine middle reef survey sites.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	5.164630	5.164630	0.43	0.5179
SITE	8	1527.473704	190.934213	15.77	<.0001
PERIOD*SITE	8	187.338704	23.417338	1.93	0.0848

For the post-construction assessment period mean octocoral density ranged from 1.72 colonies/m^2 (R2N2-LR) to 15.85 colonies/m^2 (R2NC3-LR) (Table 41). Significant differences were detected between the sites during the post-construction period ($F = 15.77$, $P < 0.001$, Table 40) and Tukey post-hoc comparisons were performed to determine significant differences. Middle reef sites with the highest octocoral densities (R2NC2-RR, mean density 15.22 colonies/m^{2,} and R2NC3-LR, mean density 15.85 colonies/m^2) were not significantly different from one another but R2NC2-RR was significantly different from all other middle reef sites (Table 42). Similarly, the middle reef site with the lowest octocoral density (R2N2-LR) was not significantly different from other low density sites (R2S1-RR and R2NC1-LR) but was significantly different from all other middle reef sites (Table 42, Figure 55). The relationships and significance tests among middle reef sites in terms of mean octocoral densities are depicted in Table 42.

Table 41. Mean octocoral density (with standard deviation and standard error) among nine middle reef sites across three permanent transects.

Site	Baseline			Post-Construction		
	Mean Density	SD	SE	Mean Density	SD	SE
R2N1-RR	11.60	1.88	1.09	9.95	0.72	0.42
R2N2-LR	1.83	1.03	0.59	1.72	0.98	0.57
R2NC1-LR	7.32	1.58	0.91	6.18	0.79	0.46
R2NC2-RR	25.00	9.42	5.44	15.22	0.86	0.50
R2NC3-LR	11.88	5.86	3.39	15.85	2.68	1.54
R2S1-RR	2.60	0.71	0.41	2.47	0.40	0.23
R2S2-LR	9.52	6.13	3.54	8.67	5.66	3.27
R2SC1-RR	7.08	0.37	0.21	10.48	1.35	0.78
R2SC2-LR	11.37	2.29	1.32	12.12	0.58	0.34

Table 42. Tukey post-hoc comparisons of mean octocoral density differences at the nine middle reef sites for the post-construction assessment period.

Data type	Test statistic (p-value)	**Tukey post-hoc comparison** (sites with same letter indicated in superscript are not statistically significant)			
Non-transformed	F=15.77, p<0.0001	R2NC2-RR^{A}	R2SC2-LR^{BC} R2N1-RR^{BC}		R2N2-LR^{E}
				R2S1-RR^{DE}	
		R2NC3-LR^{AB}	R2NC1-RR^{CDE}		
			R2S2-LR^{BCD}, R2SC1-RR^{BCD}		

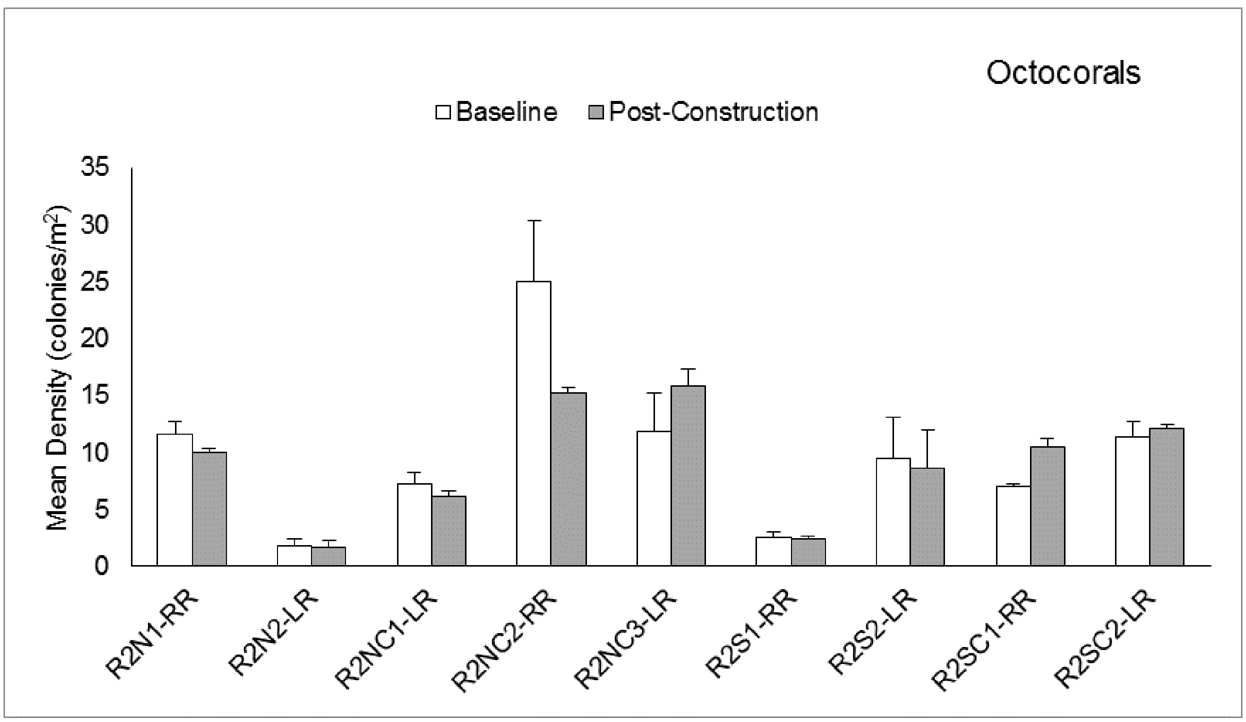

Figure 55. Mean density of octocoral colonies at middle reef sites, documented in Week 1 of baseline and Week 3 of post-construction surveys. Error bars represent the standard error.

3.3.2.2 Outer Reef

Patterns of octocoral genera relative abundance varied across sites, but *Eunicea*, *Gorgonia*, and *Pseudopterogorgia* were the dominant octocoral genera across all outer reef sites during baseline and post-construction surveys. R3SC3-SG had the greatest number of colonies (474 in baseline and 513 during post-construction), R3S1-CP had the least number of octocorals (84 in baseline and 91 during post-construction), and R3N1-LR had the fewest genera (4 in baseline and 5 during post-construction) (Figures 56-59 and Table 43).

The biggest change in octocoral diversity between baseline and post-construction surveys was that a small number of *Pterogorgia* colonies were identified at R3S2-LR, R3SC2-LR, and R3SC3-SG during post-construction (Figure 58 and 59).

Table 43. Number of octocoral colonies and generic richness at outer reef sites. Data collected during baseline and post-construction surveys.

Site	Baseline		Post-Construction	
	Number of Colonies	Number of Genera	Number of Colonies	Number of genera
R3N1-LR	119	4	103	5
R3NC1-LR	354	7	569	8
R3S1-CP	84	4	91	5
R3S2-LR	160	6	196	8
R3S3-SG	183	7	203	7
R3SC1-CP	220	7	278	8
R3SC2-LR	279	7	341	8
R3SC3-SG	474	7	513	9

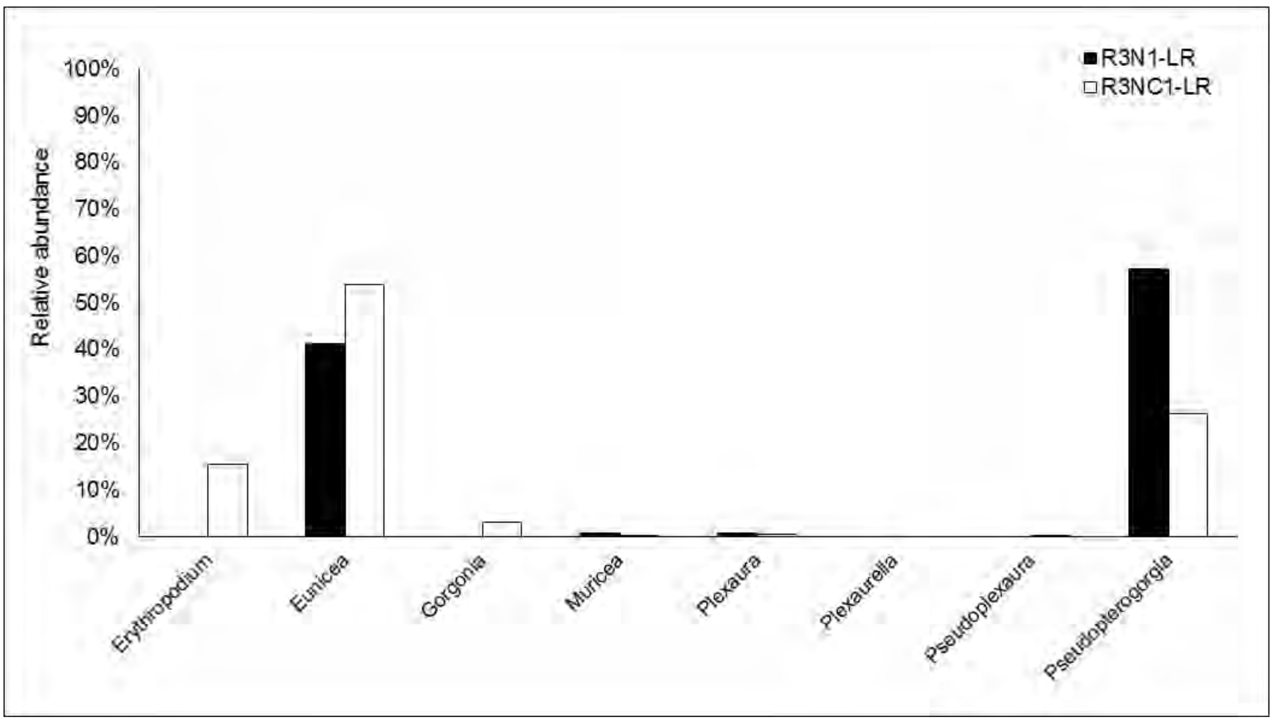

Figure 56. Relative abundance of octocorals at northern outer reef sites during baseline surveys.

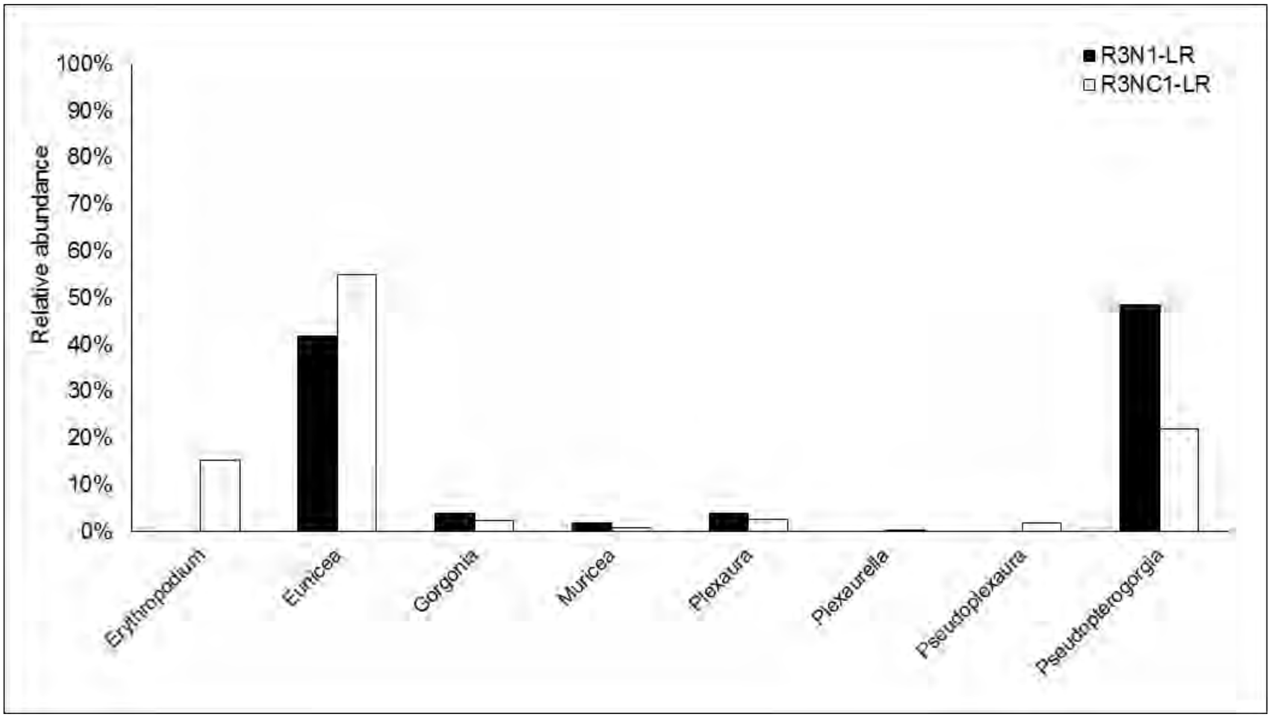

Figure 57. Relative abundance of octocorals at northern outer reef sites during post-construction surveys.

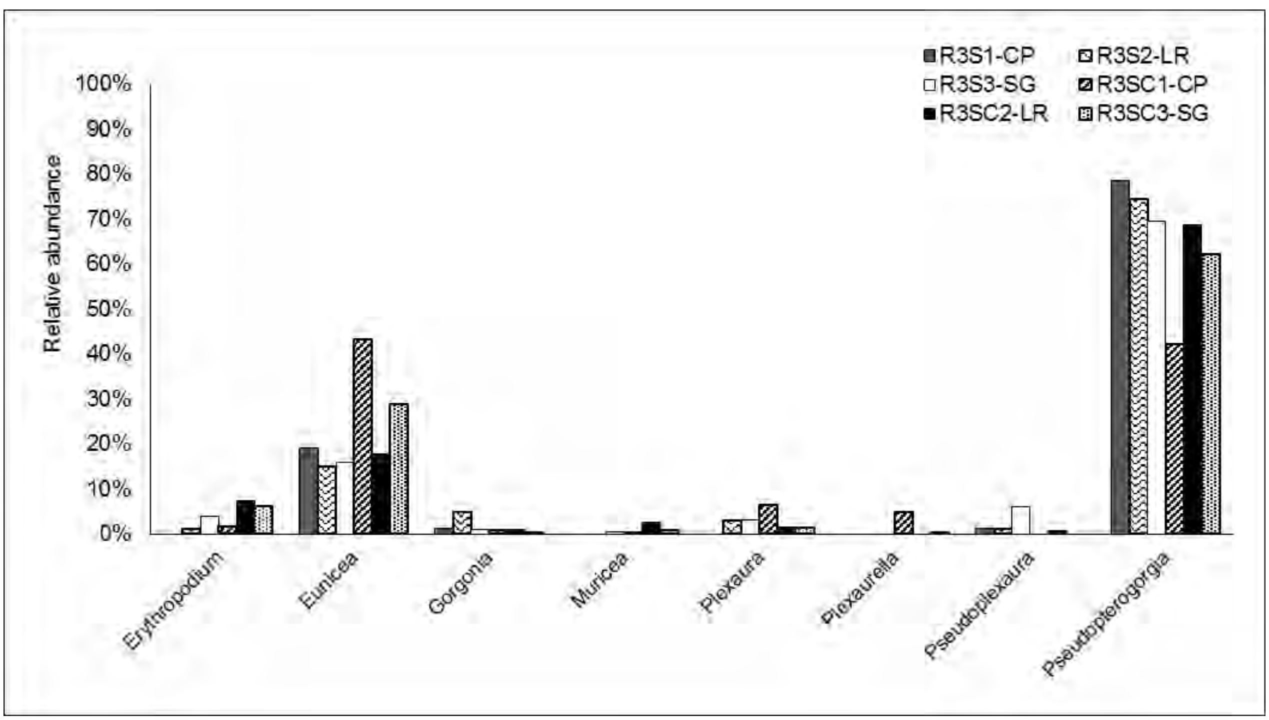

Figure 58. Relative abundance of octocorals at southern outer reef sites during baseline surveys. Baseline values were revised for this graph due to transcription errors.

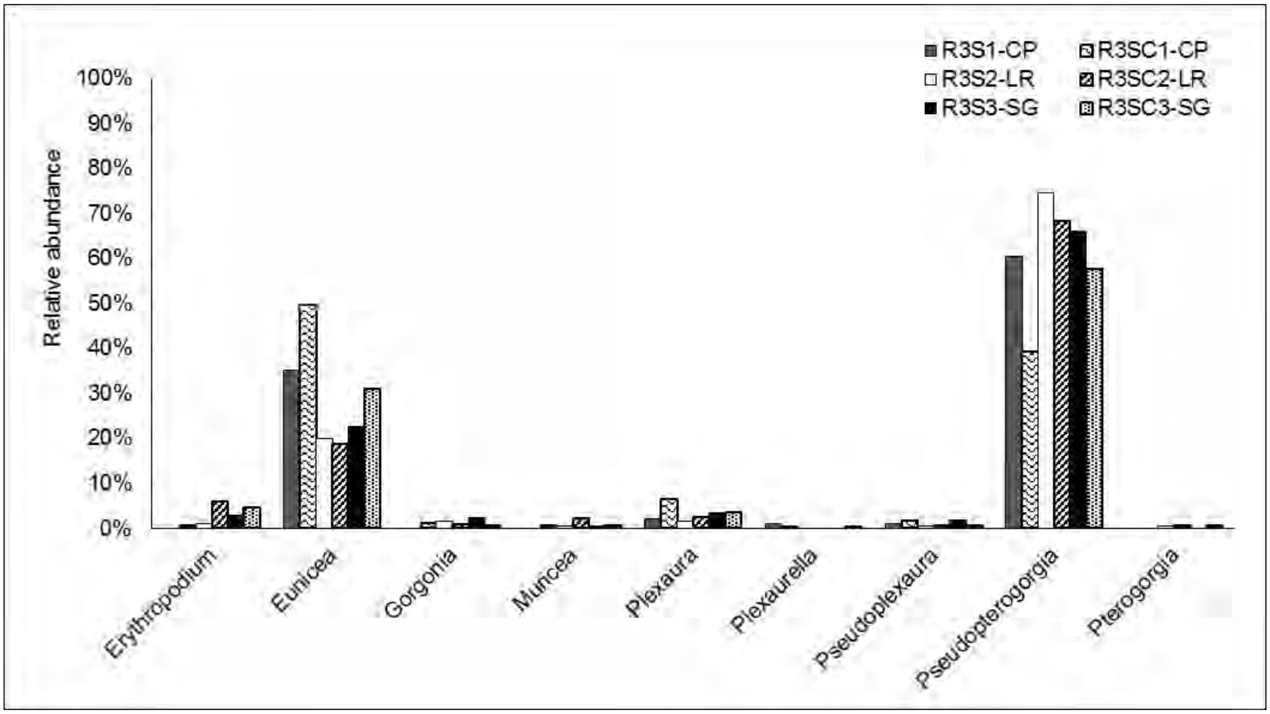

Figure 59. Relative abundance of octocorals at southern outer reef sites during post-construction surveys.

A two-way repeated measures ANOVA was used to determine if mean octocoral density was different among the eight outer reef sites between the baseline and post-construction assessment periods. Data were collected one time for both the baseline and post-construction assessment periods. Mean site densities were normally distributed (Anderson-Darling test, P > 0.05), in all cases. Significant effects among the sites between the assessment periods were detected (F = 25.11, P < 0.0001; Table 44). Significant effects were also detected based on the period of observation (F = 11.91, P = 0.0016), between sites (F = 49.44, P < 0.001), and in the interaction between period and site (F = 2.67, P = 0.0269) (Table 45).

Table 44. Two-way ANOVA results testing the difference in octocoral density among and between the eight outer reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	291.9216146	19.4614410	25.11	<.0001
Error	32	24.7966667	0.7748958		
Corrected Total	47	316.7182812			

Table 45. Two-way repeated measures ANOVA results testing the effects of the two assessment periods (baseline and post-construction), the effects of coral locations, and the interaction between the two effects on the mean density of octocorals among the eight outer reef survey sites.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	9.2313021	9.2313021	11.91	0.0016
SITE	7	268.1903646	38.3129092	49.44	<.0001
PERIOD*SITE	7	14.4999479	2.0714211	2.67	0.0269

Since there was a significant interaction between site and period, additional one-way ANOVA's were performed on both of the main factors, site, and period. For the post-construction assessment period mean octocoral density ranged from 1.52 colonies/m^2 (R3S1-LR) to 9.48 colonies/m^2 (R3NC1-LR) (Table 46). Significant differences were detected between the sites during the post-construction period ($F = 30.86$, $P < 0.001$, Table 47). Tukey post-hoc comparisons were performed to determine significant differences of mean octocoral density between outer reef sites during the post construction assessment. Outer reef sites with the highest octocoral densities (R3NC1-LR and R3SC3-SG) were not significantly different from one another but were significantly different from all other outer reef sites (Table 47). Similarly, the outer reef sites with the lowest octocoral densities (R3N1-LR and R3S1-CP) were not significantly different from each other but were significantly different from all outer reef control sites and R3S3-SG (Table 47, Figure 60). The relationships and significance tests among outer reef sites in terms of mean octocoral densities are depicted in Table 46.

Table 46. Mean octocoral density (with standard deviation and standard error) among eight outer reef sites across three permanent transects.

	Baseline			Post-Construction		
Site	**Mean Density**	**SD**	**SE**	**Mean Density**	**SD**	**SE**
R3N1-LR	1.98	0.25	0.15	1.72	0.38	0.22
R3NC1-LR	5.90	0.65	0.38	9.48	1.40	0.81
R3S1-CP	1.40	0.09	0.05	1.52	0.54	0.31
R3S2-LR	2.67	0.57	0.33	3.27	0.90	0.52
R3S3-SG	3.05	0.80	0.46	3.38	0.81	0.47
R3SC1-CP	3.67	1.03	0.59	4.63	1.02	0.59
R3SC2-LR	4.65	1.26	0.73	5.68	1.09	0.63
R3SC3-SG	7.90	1.21	0.70	8.55	0.85	0.49

Table 47. Tukey post-hoc comparisons of mean octocoral density differences at the eight outer reef sites for the post-construction assessment period.

<table>
<tr><th>Data type</th><th>Test statistic (p-value)</th><th colspan="4">Tukey post-hoc comparison (sites with same letter indicated in superscript are not statistically significant)</th></tr>
<tr><td rowspan="2">Non-transformed</td><td rowspan="2">F=30.86, p<0.0001</td><td>R3NC1-LR^{A}
R3SC3-SG^{A}</td><td>R3SC2-LR^{B}
R3SC1-CP^{B}</td><td></td><td>R3N1-LR^{C}
R3S1-CP^{C}</td></tr>
<tr><td></td><td colspan="3">R3S3-SG^{BC}, R3S2-LR^{BC}</td></tr>
</table>

Table 48. Tukey post-hoc comparisons of mean octocoral coral density differences between baseline and post-construction 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
R3NC1-LR	F=16.04, p=0.0161	Post-construction^A, Baseline^B
R3SC3-SG	NS	(trend) Post-construction > Baseline
R3SC2-LR	NS	(trend) Post-construction > Baseline
R3SC1-CP	NS	(trend) Post-construction > Baseline
R3S3-SG	NS	(trend) Post-construction > Baseline
R3S2-LR	NS	(trend) Post-construction > Baseline
R3N1-LR	NS	(trend) Baseline > Post-construction
R3S1-CP	NS	(trend) Post-construction > Baseline

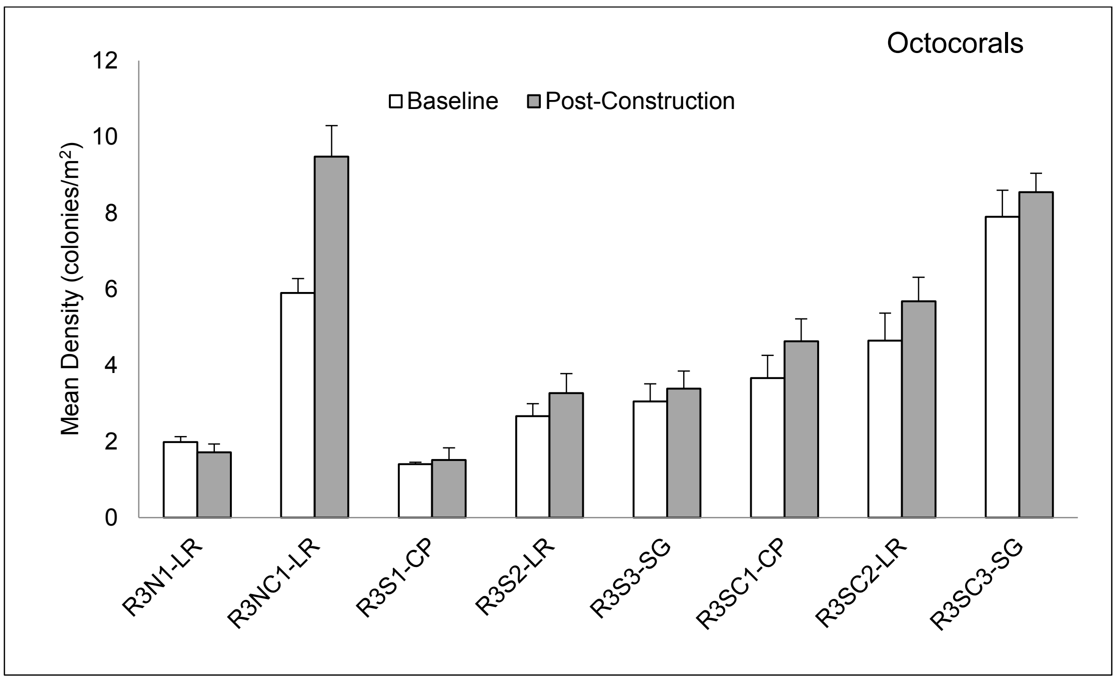

Figure 60. Mean density of octocoral colonies at middle reef sites, documented in Week 1 of baseline and Week 3 of post-construction surveys. Error bars represent the standard error.

The Tukey post-hoc comparisons of mean octocoral density among individual sites between baseline and post-construction were performed on non-transformed data. Mean octocoral density was higher during post-construction surveys at all sites except R3N1-LR (Table 46). Significant differences between assessment periods were only detected at R3NC1-LR. Mean octocoral density increased at R3NC1-LR from 5.90 to 9.48 colonies/m^2 (Table 46, Figure 60).

Octocoral density ranged from 1.98 to 7.90 colonies per m^2 across all outer reef sites during baseline, and from 1.52 to 9.48 colonies/m^2 during post-construction (Table 46). Across all sites during post-construction, mean octocoral density was lowest for R3S1-CP (1.52 colonies/m^2) and highest at R3NC1-LR (9.48 colonies/m^2) (Figure 60; Table 46).

3.3.3 Octocoral Colony Size

3.3.3.1 Middle Reef

Maximum diameter data were collected for all octocorals along all transects at middle reef sites in Week 1 during baseline monitoring period and in Week 3 of the post-construction monitoring period. Summary tables for octocoral size distribution data for baseline and post-construction monitoring periods are provided in Appendix F. Maximum diameter was defined as the maximum linear extent of a colony (cm), height for erect or branching varieties, or diameter for encrusting varieties. Size class distribution varied by site, but generally octocorals from 6-35 cm were the predominant size octocorals across middle reef channel-side and control sites. (Figures 61 – 64, corresponding tables included in Appendix F).

On northern middle reef channel-side sites between baseline and post-construction monitoring periods, the smallest octocorals (<5 cm) declined by 7% (R2N1-RR) and 12% (R2N2-LR). Octocorals in the size class 6 cm to 20 cm also declined at northern channel-side sites on the middle reef. Small size class ocotocorals (< 5 cm) declined between 1% and 28% at northern middle reef control sites. The smallest size class of octocorals also declined at southern middle reef channel side sites between 4% and 8% (Figure 61 and 62). The smallest octocorals (<5 cm) declined by approximately 2% at southern control sites on the middle reef.

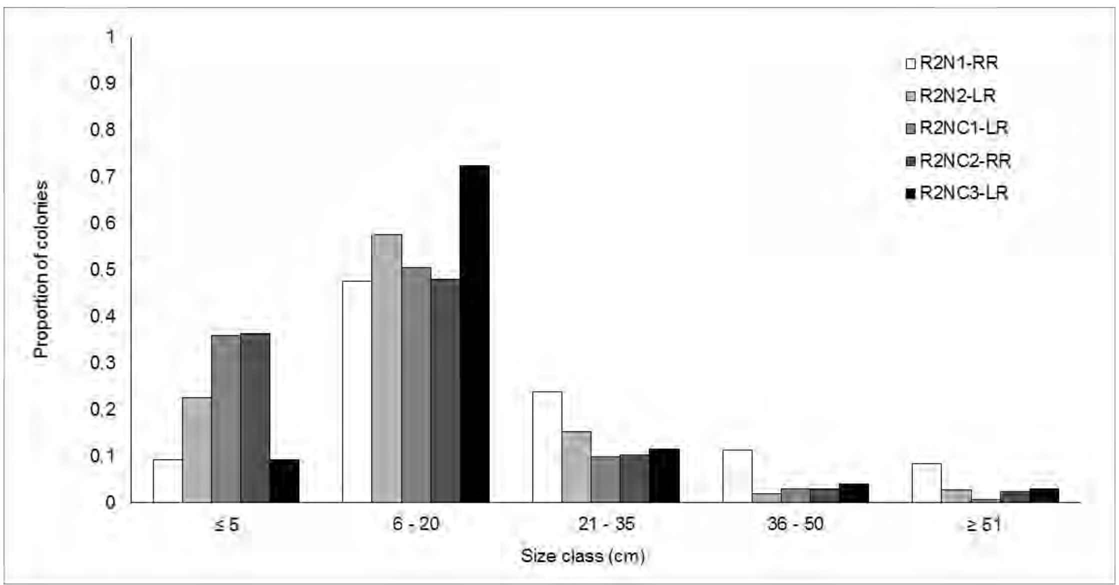

Figure 61. Proportion of octocoral colonies by size class for northern middle reef sites during baseline surveys.

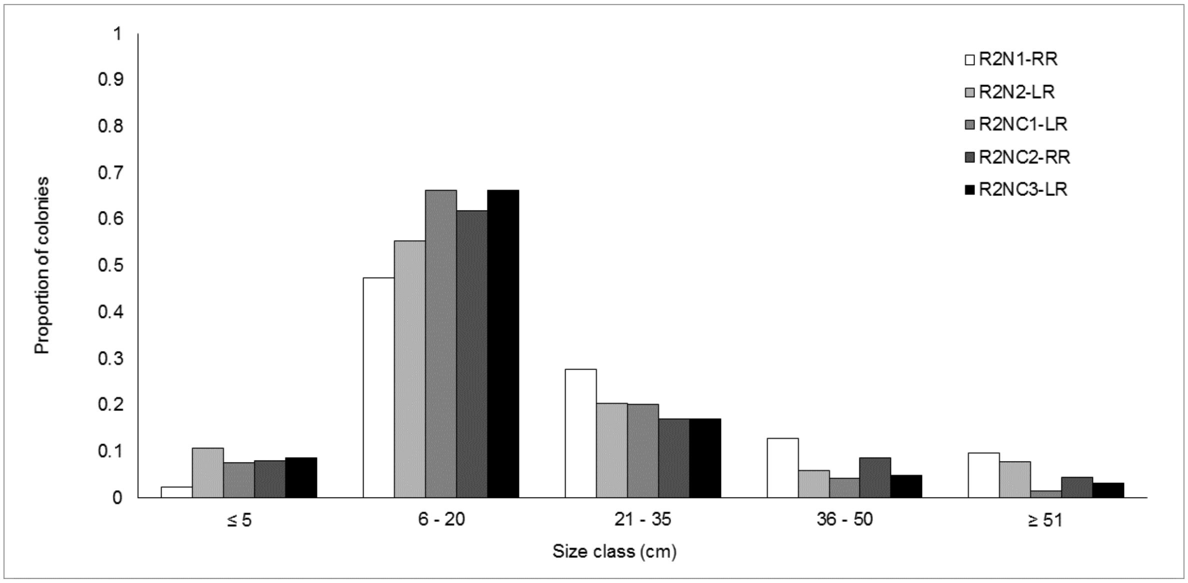

Figure 62. Proportion of octocoral colonies by size class for northern middle reef sites during post-construction surveys.

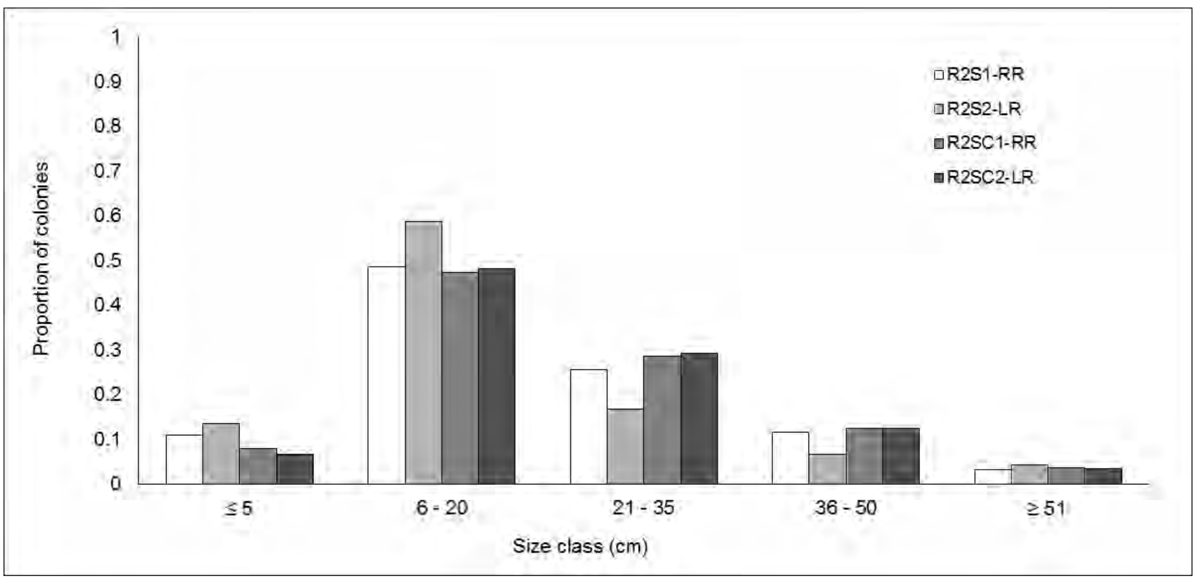

Figure 63. Proportion of octocoral colonies by size class for southern middle reef sites during baseline surveys.

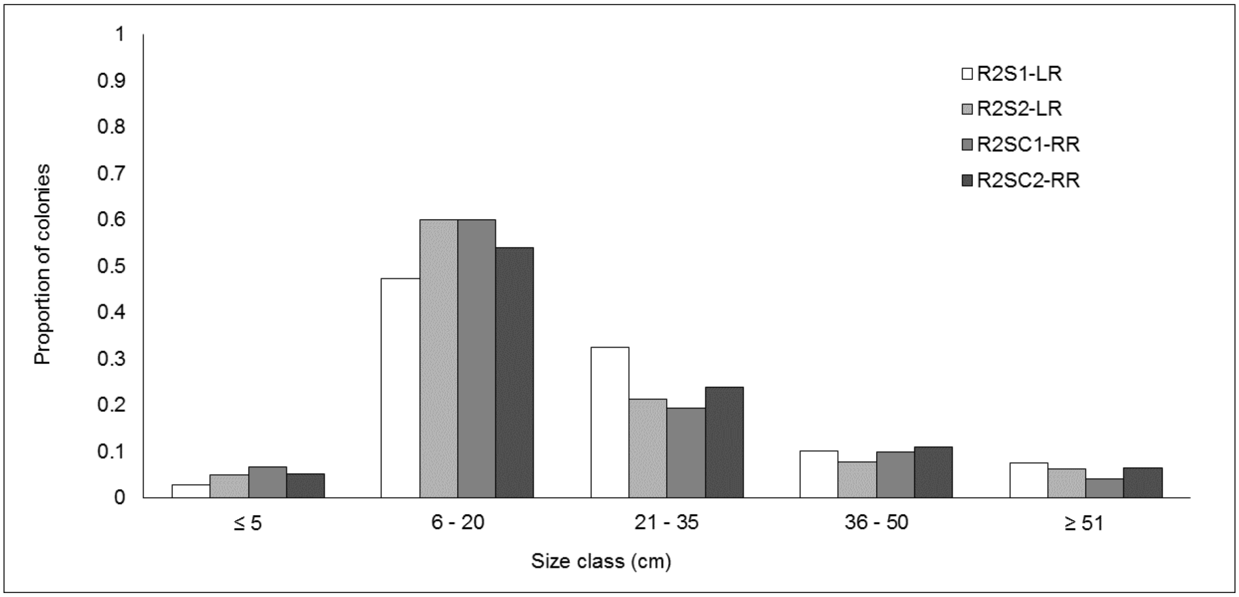

Figure 64. Proportion of octocoral colonies by size class for southern middle reef sites during post-construction surveys.

3.3.3.2 Outer Reef

Maximum diameter data were collected for all octocorals along all transects within the outer reef sites during Week 1 of baseline surveys and Week 3 of post-construction surveys. Maximum diameter was defined as the maximum linear extent of a colony (cm), height for erect or branching varieties, and diameter for encrusting varieties. Summary tables for all octocoral size distribution data are provided in Appendix F. Octocoral size-class data revealed that the majority of colonies across the outer reef sites were 6 cm to 35 cm in maximum diameter (Figures 65 - 68).

At R3N1-LR, octocorals documented less than 20 cm in maximum diameter declined by 11% (<5 cm) or 6% (6-20 cm). At R3NC1-LR small size classes increased, while the larger size classes declined. At southern channel-side sites the smallest size class categories declined across all three sites (2-3%). At southern control sites, the pattern was mixed, but generally the smallest size class of octocorals declined (2-19%).

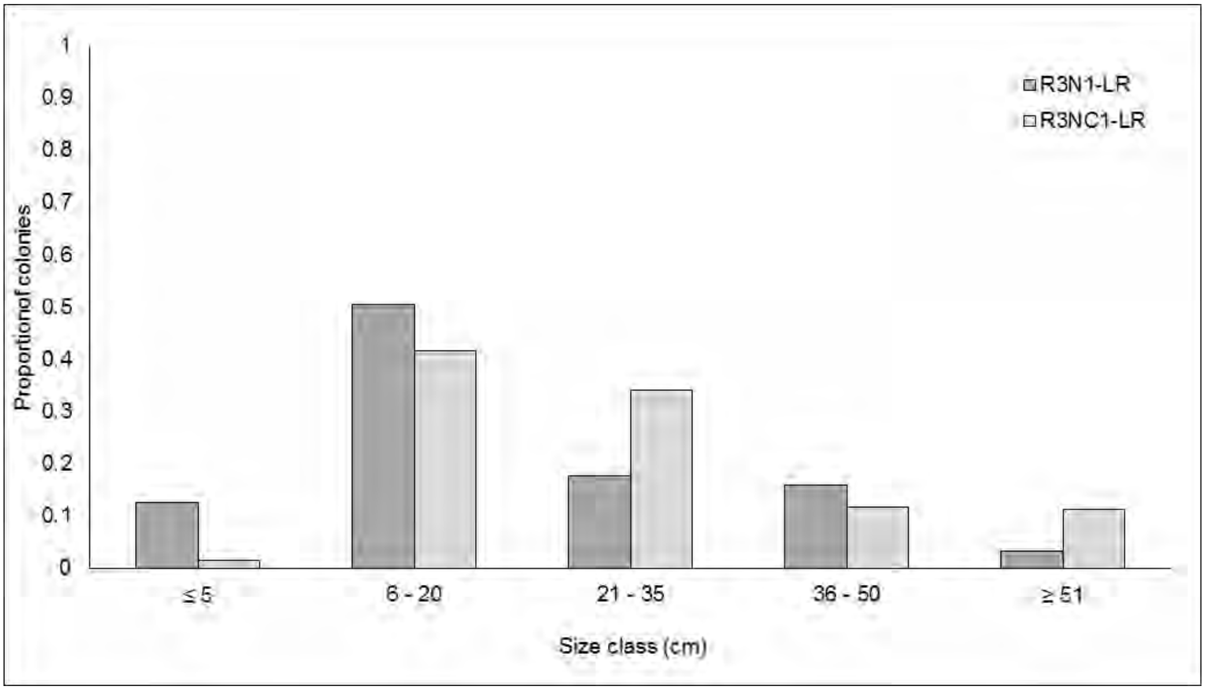

Figure 65. **Proportion of octocoral colonies by size class for northern outer reef sites during baseline surveys.**

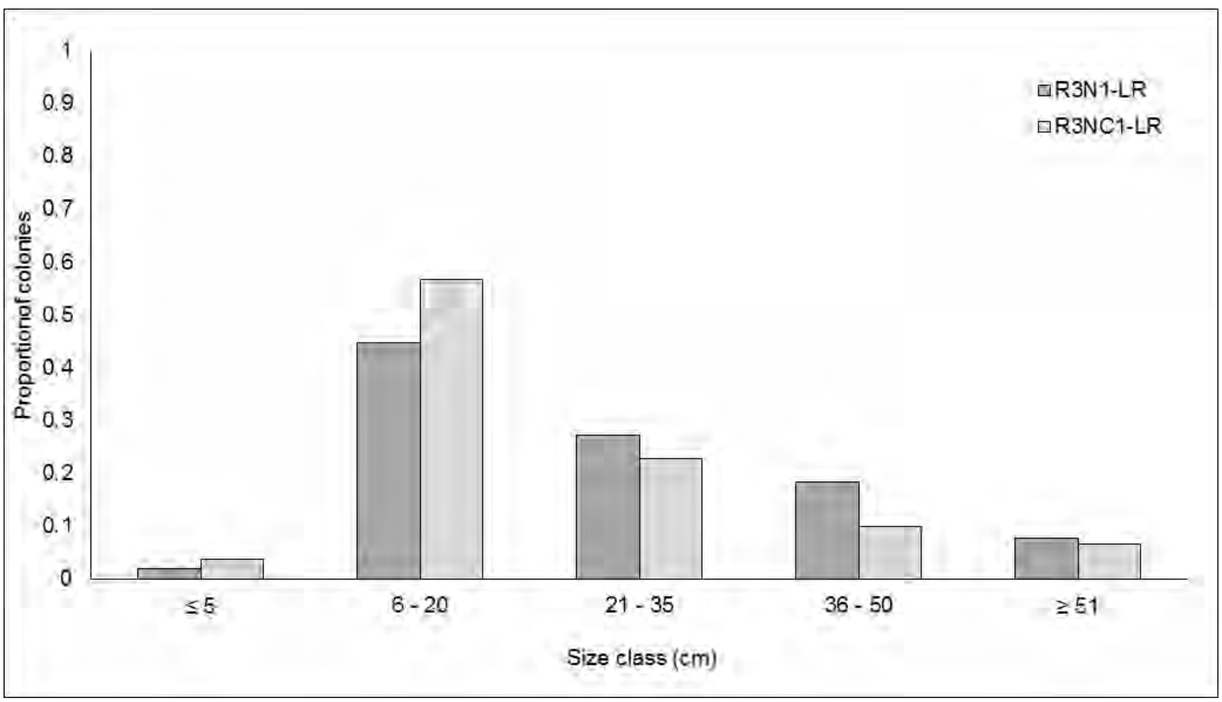

Figure 66. **Proportion of octocoral colonies by size class for northern outer reef sites during post-construction surveys.**

The southern outer reef sites all saw either no change or an increase in the proportion of octocoral colonies larger than 51 cm between baseline and post-construction. Moreover, R3S2-LR, R3S3-SG, R3SC2-LR, and R3SC3-SG decreased in the proportion of octocoral colonies equal or smaller than 5 cm.

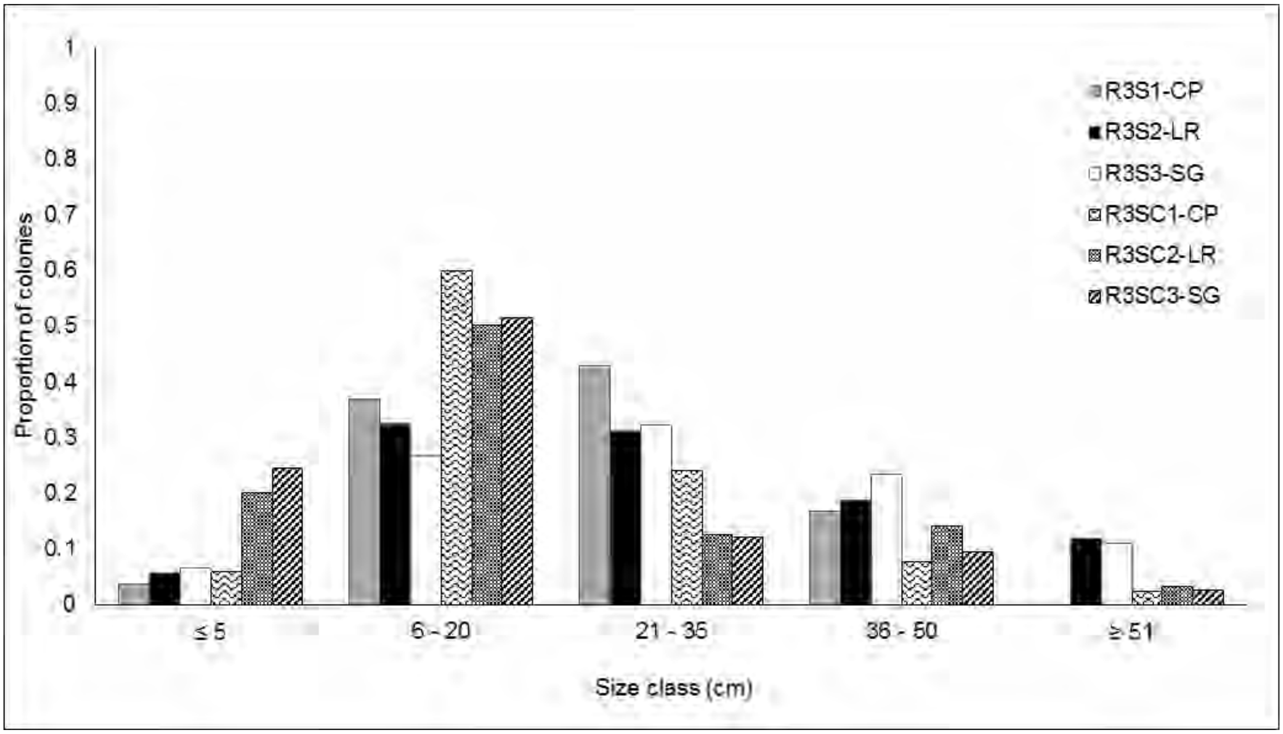

Figure 67. Proportion of octocoral colonies by size class for southern outer reef sites during baseline surveys.

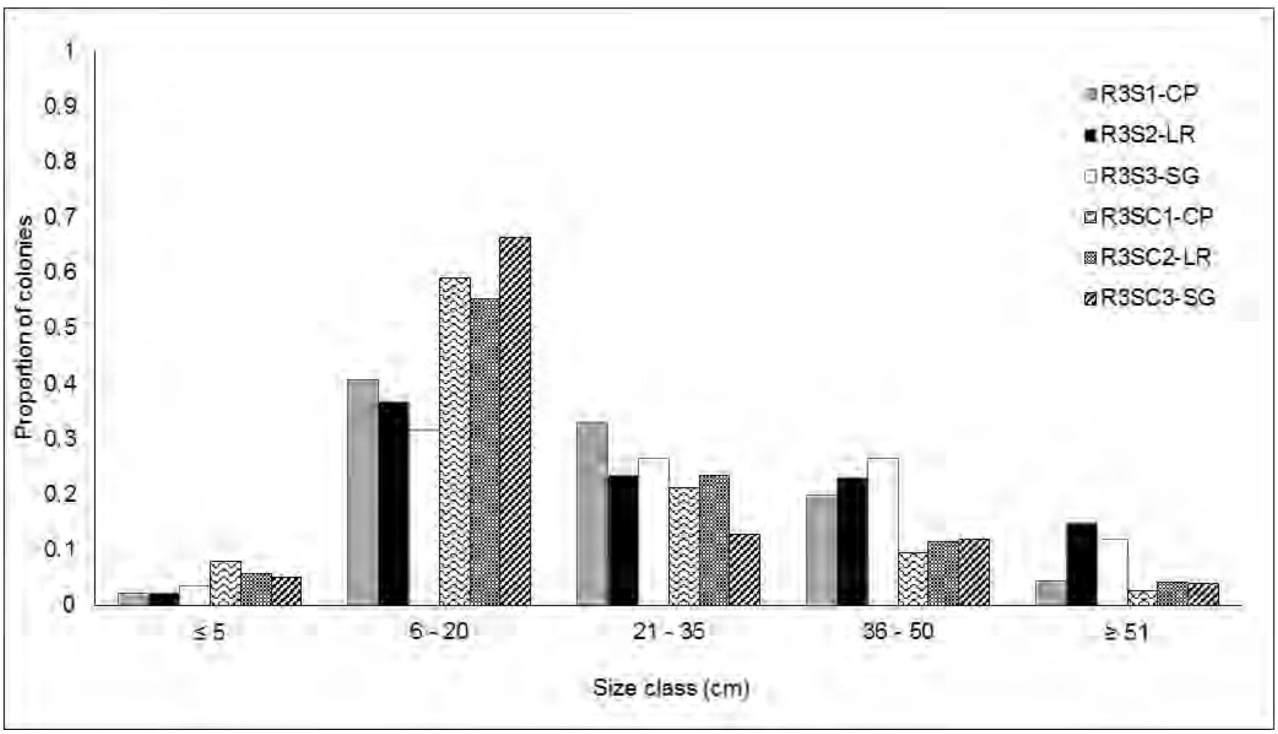

Figure 68. Proportion of octocoral colonies by size class for southern outer reef sites during post-construction surveys.

3.3.4 Octocoral Diversity

3.3.4.1 Middle Reef

Octocoral generic diversity (H') ranged from 1.34 to 1.85 across middle reef sites during baseline and between 1.40 and 1.90 during post-construction surveys. Diversity was highest at R2SC2-LR during both survey periods and was lowest at R2S2-LR. Evenness (J') ranged from 0.21 to 0.33 during baseline surveys across middle reef sites and from 0.22 to 0.35 during post-construction surveys. Evenness was highest at R2N2-LR during both survey periods and lowest for both R2S2-RR and R2NC3-LR (Table 49).

Table 49. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for octocoral genera at middle reef sites for baseline and post-construction surveys.

Octocorals				
	Baseline		Post-Construction	
Site	H'	J'	H'	J'
R2N1-RR	1.60	0.24	1.57	0.25
R2N2-LR	1.54	0.33	1.61	0.35
R2NC1-LR	1.79	0.29	1.70	0.29
R2NC2-RR	1.78	0.24	1.81	0.27
R2NC3-LR	1.38	0.21	1.51	0.22
R2S1-RR	1.65	0.33	1.58	0.32
R2S2-LR	1.34	0.21	1.40	0.22
R2SC1-RR	1.57	0.26	1.50	0.23
R2SC2-LR	1.85	0.28	1.90	0.29

3.3.4.2 Outer Reef

Octocoral genera diversity (H') ranged from 0.61 to 1.19 across outer reef sites during baseline surveys and between 0.80 and 1.25 during post-construction. Diversity was highest at R3SC1-CP (H'=1.19) during baseline surveys and at R3NC1-LR (H'=1.25) during post-construction. Diversity was lowest at R3S1-CP during baseline surveys (H'=0.61) and at R3S2-LR during post-construction (H'=0.80). Evenness (J') ranged from 0.13 to 0.22 during baseline surveys across outer reef sites and between 0.15 and 0.23 during post-construction. Evenness was lowest for R3SC3-SG during baseline and R3S2-LR during post-construction surveys (Table 50).

Table 50. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for octocoral genera at outer reef sites for baseline and post-construction surveys. – Baseline values were revised in this table due to transcription errors.

Octocorals				
	Baseline		Post-Construction	
Site	H'	J'	H'	J'
R3N1-LR	0.77	0.16	1.04	0.23
R3NC1-LR	1.14	0.19	1.25	0.20
R3S1-CP	0.61	0.14	0.85	0.19
R3S2-LR	0.87	0.17	0.80	0.15
R3S3-SG	1.03	0.20	1.03	0.19
R3SC1-CP	1.19	0.22	1.10	0.20
R3SC2-LR	0.70	0.13	1.03	0.18
R3SC3-SG	0.95	0.15	1.10	0.18

3.3.5 Sponge Presence and Density

Sponge morphotype count data were collected in Week 1 of baseline and in Week 3 of post-construction surveys. Results are discussed below for middle and outer reef sites.

3.3.5.1 Middle Reef

Sponge morphotypes were widespread across middle reef sites, ranging from 5 to 8 morphotypes present at any given site during baseline, and from 7 to 8 during post-construction (Table 51). *Xestospongia* was only documented at 4 of 9 sites during baseline (i.e., R2N2-LR, R2NC1-LR, R2NC3-LR, and R2SC2-LR), but was recorded during post-construction at all sites except R2NC2-RR and R2S2-LR. No *Cliona delitrix* was found at R2SC1-RR during baseline, but was documented at that site during post-construction surveys. A "lumpy" category was added during post-construction surveys for the sponge colonies that did not conform to any previously defined category.

Sponge density ranked second amongst functional group categories (e.g., scleractinian, octocoral, sponge, zoanthid) and ranged from 2.82 (R2SC1-RR) to 21.8 (R2N2-LR) individuals/m^2 during baseline. In post-construction, sponge density ranged from 3.45 (R2NC2-RR) to 11.45 (R2N2-LR) individuals/m^2 (Table 54; Figure 69).

Table 51. Sponge morphotype presence at middle reef sites during baseline and post-construction surveys. Baseline presence is denoted by a black circle and post-construction is indicated by a square.

Sponge type	Middle Reef Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-LR
Ball	• □	• □	•	• □	• □	• □	• □	• □	• □
Cliona	•	• □	• □	• □	• □	•	• □	□	• □
Encrusting	• □	• □	• □	• □	• □	• □	• □	• □	• □
Finger	• □	• □	• □	• □	• □	• □	• □	• □	• □
Tube	• □	• □	• □	• □	• □	• □	• □	• □	• □
Vase	• □	• □	• □	• □	• □	• □	• □	• □	• □
Xestospongia	□	• □	• □		• □	□		□	• □
Lumpy	□	□	□	□	□	□	□	□	□

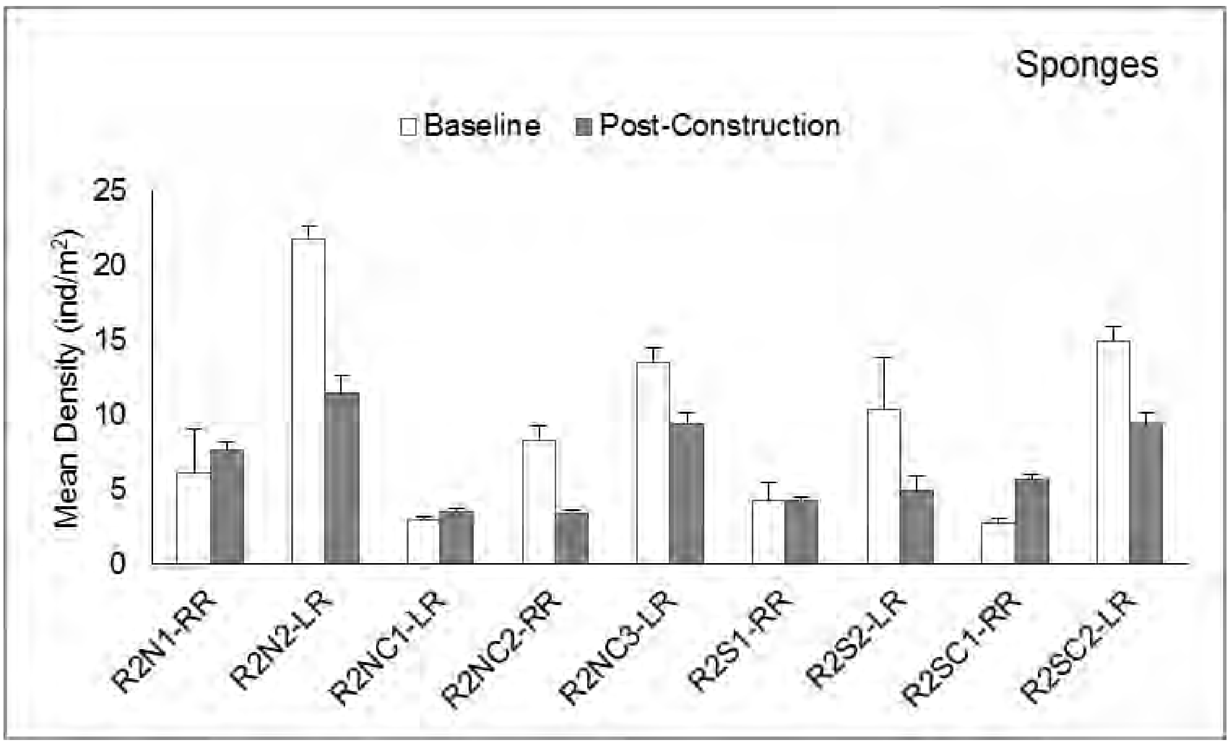

Figure 69. Sponge density values for middle reef sites during baseline and post-construction surveys. Error bars represent the standard error of the mean.

A two way ANOVA was used to determine if mean sponge density was different among the nine middle reef sites between the baseline and post-construction assessment periods. Mean site densities were normally distributed in all cases (Anderson-Darling test, $P > 0.05$). Significant effects among the sites between the assessment periods were detected ($F = 14.92$, $P < 0.0001$; Table 52). Significant differences were detected in mean sponge density between assessment periods ($F = 21.29$, $P < 0.0001$), sites ($F = 23.64$, $P < 0.001$), and a significant effect was detected based on the interaction of period and site ($F = 5.41$, $P = 0.002$) (Table 53). A Bonferroni adjustment was used to create a pairwise comparison of the interaction effect.

Table 52. Two-way ANOVA results testing the difference in sponge density among and between the nine middle reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	1281.245370	75.367375	14.92	<.0001
Error	36	181.806667	5.050185		
Corrected Total	53	1463.052037			

Table 53. Two-way ANOVA results testing the effects of the two assessment periods (baseline and post-construction), the effects of sponge locations, and the interaction between the two effects on sponge density among the nine middle reef survey areas.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	107.5266667	107.5266667	21.29	<.0001
SITE	8	955.0387037	119.3798380	23.64	<.0001
PERIOD*SITE	8	218.6800000	27.3350000	5.41	0.0002

Additional Tukey post-hoc comparisons were performed on the non-transformed data to determine significant differences of mean sponge density between sites during the post-construction period and among individual sites between the baseline and post-construction assessment periods. During the post-construction assessment period mean sponge density ranged from 3.45 individuals/m^2 (R2NC2-RR) to 11.45 individuals/m^2 (R2N2-LR) (Table 54). Significant differences were detected between the sites during post construction period ($F = 18.53$, $P < 0.0001$, Table 55). The relationships and significance among middle reef sites in terms of mean sponge densities are depicted in Table 55.

Table 54. Mean sponge density (with standard deviation and standard error) among nine middle reef sites across three permanent transects.

	Baseline			Post-Construction		
Site	Mean Density	SD	SE	Mean Density	SD	SE
R2N1-RR	6.13	5.11	2.95	7.60	1.06	0.61
R2N2-LR	21.75	1.63	0.94	11.45	2.00	1.16
R2NC1-LR	3.00	0.30	0.17	3.57	0.34	0.20
R2NC2-RR	8.27	1.68	0.97	3.45	0.36	0.21
R2NC3-LR	13.52	1.69	0.97	9.38	1.30	0.75
R2S1-RR	4.30	2.13	1.23	4.27	0.50	0.29
R2S2-LR	10.42	6.01	3.47	4.90	1.69	0.98
R2SC1-RR	2.82	0.56	0.32	5.67	0.63	0.37
R2SC2-LR	14.88	1.73	1.00	9.40	1.37	0.79

Table 55. Tukey post-hoc comparisons of mean sponge density differences between middle reef sites for the post-construction assessment period.

<table>
<tr><th>Test statistic (p-value)</th><th colspan="5">Tukey post-hoc comparison (sites with same letter indicated in superscript are not statistically significant)</th></tr>
<tr><td rowspan="2">F=18.53 (p<0.0001)</td><td>R2N2-LR^{A}</td><td></td><td>R2N1-RR^{BC}</td><td></td><td>R2NC1-LR^{D}
R2NC2-RR^{D}</td></tr>
<tr><td colspan="3">R2SC2-LR^{AB}
R2NC3-LR^{AB}</td><td colspan="2">R2SC1-RR^{CD} R2S2-LR^{CD}
R2S1-RR^{CD}</td></tr>
</table>

The post-hoc comparison of mean density among individual sites between baseline and post-construction indicated that five of the nine sites had significant differences of mean sponge density. A significant increase in mean density occurred at R2SC1-RR, where mean density more than doubled from 2.82 to 5.67 individuals/m^2 (F = 34.24, P=0.0043, Tables 54 & 56, Figure 69). Significant decreases were detected at R2N2-LR (F = 47.75, P = 0.0023), R2NC2-RR (F = 23.71, P = 0.0082), R2NC3-LR (F = 11.33, P = 0.0282), R2SC1-RR (F = 34.24, P=0.0043) and R2SC2-LR (F = 18.44, P = 0.0127) (Table 56). R2N2-LR experienced the greatest decrease in sponge density, with a decrease of 10.3 individuals/m^2 (Tables 54 & 56, Figure 69).

Table 56. Tukey post-hoc comparisons of mean sponge density differences between baseline and post-construction 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) Post-construct > Baseline
R2N2-LR	F=47.75 (p=0.0023)	Baseline^{A}, Post-construction^{B}
R2NC1-LR	NS	(trend) Post-construct > Baseline
R2NC2-RR	F=23.71 (p=0.0082)	Baseline^{A}, Post-construction^{B}
R2NC3-LR	F=11.33 (P=0.0282)	Baseline^{A}, Post-construction^{B}
R2S1-RR	NS	(trend) Baseline > Post-construct
R2S2-LR	NS	(trend) Baseline > Post-construct
R2SC1-RR	F=34.24 (p=0.0043)	Post-construction^{A}, Baseline^{B}
R2SC2-LR	F=18.44 (P=0.0127)	Baseline^{A}, Post-construction^{B}

3.2.5.2 Outer Reef

Sponge morphotypes were widespread across outer reef sites and present at all sites with the exception of *Cliona*, which only occurred in 7 of 8 sites during post-construction, and was not present at R3NC1-LR (Table 57). Sponge density ranked second behind octocorals as the most dominant functional group category and ranged from 2.62 (R3S1-CP) to 8.18 (R3N1-LR) individuals per m^2. A “lumpy” category was added during post-construction surveys for the sponge colonies that could not be identified as any of the other types.

Sponge density ranked second amongst functional group categories (e.g., scleractinian, octocoral, sponge, zoanthid) and ranged from 2.62 (R3S1-CP) to 8.18 (R3N1-LR) individuals/m^2 during baseline. In post-construction, sponge density ranged from 4.92 (R3S1-CP) to 13.42 (R3NC1-LR) individuals/m^2 (Figure 70). Sponge density increased at all sites during post-construction except R3N1-LR.

Table 57. Sponge morphotype presence at outer reef sites during baseline and post-construction surveys. Baseline presence is denoted by a black circle and post-construction is indicated by a square.

Sponge type	Outer Reef Sites							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Ball	• □	• □	• □	• □	• □	• □	• □	• □
Cliona	• □	•	• □	• □	• □	• □	□	□
Encrusting	• □	• □	• □	• □	• □	• □	• □	• □
Finger	• □	• □	• □	• □	• □	• □	• □	• □
Tube	• □	• □	• □	• □	• □	• □	• □	• □
Vase	• □	• □	• □	• □	• □	• □	• □	• □
Xestospongia	• □	• □	• □	• □	• □	• □	• □	• □
Lumpy	□	□	□	□	□	□	□	□

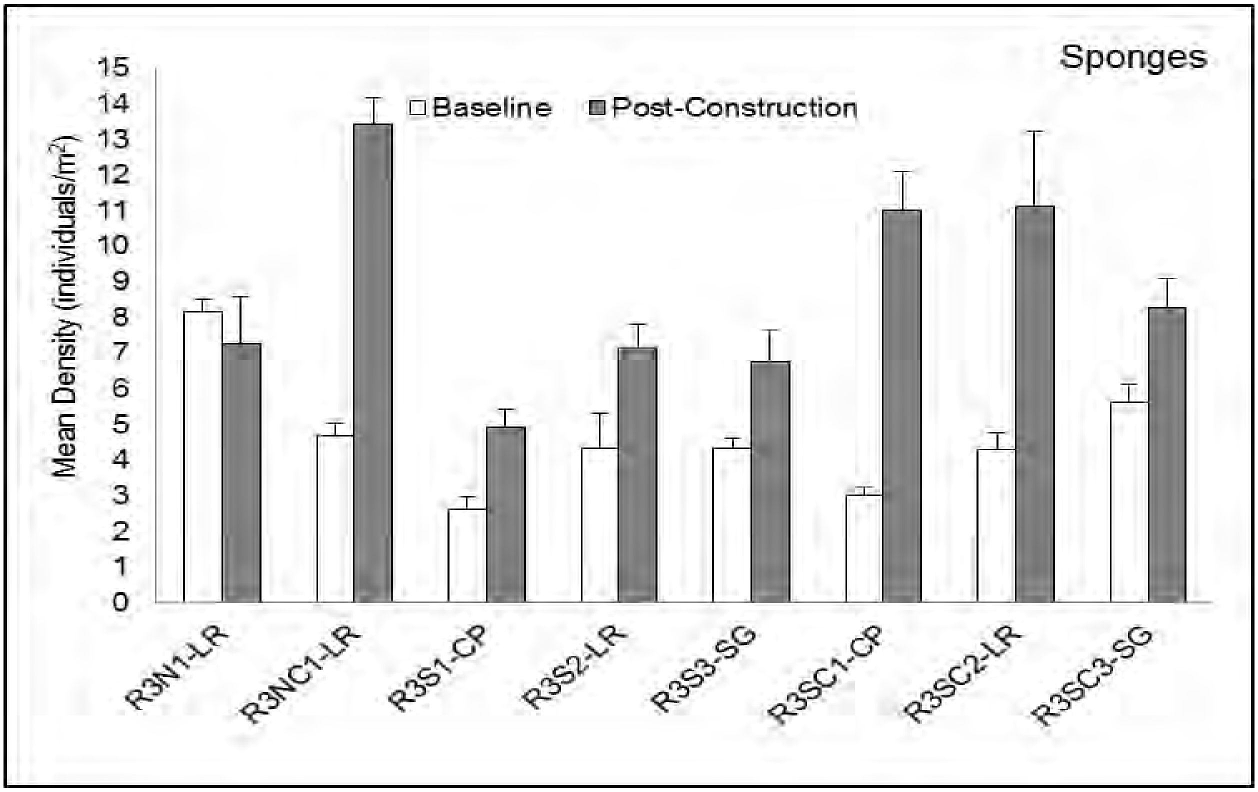

Figure 70. Sponge density values for outer reef sites during baseline collected in Week 1 and during Week 3 in post-construction surveys. Error bars represent the standard error of the mean.

A two way ANOVA was used to determine if mean sponge density was different among the eight outer reef sites between the baseline and post-construction assessment periods. Mean site densities were normally distributed in all cases (Anderson-Darling test, $P > 0.05$). Significant effects among the sites between the assessment periods were detected ($P < 0.0001$; Table 58). Significant differences were detected in mean sponge densitybased on the effects of the survey periods (F = 88.04, P < 0.001), the effect of the sites (F = 6.96, P < 0.001) and the interaction of period and site (F = 7.42, P < 0.0001) (Table 59). A Bonferroni adjustment was used to create a pairwise comparison of the interaction effect.

Table 58. Two-way ANOVA results testing the difference in sponge density among and between the eight outer reef sites between the two assessment periods.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	431.9178646	28.7945243	12.58	<.0001
Error	32	73.2483333	2.2890104		
Corrected Total	47	505.1661979			

Table 59. Two-way ANOVA results testing the effects of the two assessment periods (baseline and post-construction), the effects of sponge locations, and the interaction between the two effects on sponge density among the eight outer reef survey areas.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PERIOD	1	201.5150521	201.5150521	88.04	<.0001
SITE	7	111.5066146	15.9295164	6.96	<.0001
PERIOD*SITE	7	118.8961979	16.9851711	7.42	<.0001

Additional Tukey post-hoc comparisons were performed on the non-transformed data to determine significant differences of mean sponge density between outer reef sites during the post-construction period and among individual sites between the baseline and post-construction assessment periods. During the post-construction assessment period mean sponge density ranged from 4.92 individuals/m^2 (R3S1-CP) to 13.42 individuals/m^2 (R3NC1-LR) (Table 60). Significant differences were detected between the sites during post construction period (F = 6.27, P < 0.0001, Table 61). The relationships and significance test among outer reef sites in terms of mean sponge densities are depicted in Table 61.

Table 60. Mean sponge density (with standard deviation and standard error) among nine middle reef sites across three permanent transects.

	Baseline			Post-Construction		
Site	**Mean Density**	**SD**	**SE**	**Mean Density**	**SD**	**SE**
R3N1-LR	8.18	0.55	0.32	7.25	2.30	1.33
R3NC1-LR	4.68	0.65	0.38	13.42	1.33	0.77
R3S1-CP	2.62	0.63	0.36	4.92	0.93	0.54
R3S2-LR	4.33	1.70	0.98	7.15	1.13	0.65
R3S3-SG	4.35	0.46	0.26	6.77	1.57	0.90
R3SC1-CP	3.00	0.44	0.26	11.00	1.91	1.10
R3SC2-LR	4.32	0.81	0.47	11.13	3.65	2.11
R3SC3-SG	5.63	0.89	0.52	8.27	1.46	0.84

Table 61. Tukey post-hoc comparisons of mean sponge density differences between outer reef sites for the post-construction assessment period.

Test statistic (p-value)	**Tukey post-hoc comparison** (sites with same letter indicated in superscript are not statistically significant)		
F=6.27, p=0.0012	R3NC1-LR^{A}		R3S1-CP^{C}
	R3SC2-LR^{AB} R3SC1-CP^{AB}		R3N1-LR^{BC}, R3S2-LR^{BC}, R3S3-SG^{BC}
	R3SC3-SG^{ABC}		

The post-hoc comparison of mean density among individual sites between baseline and post-construction indicated four of the eight sites had significant differences of mean sponge density. The four sites: R3NC1-LR (P = 0.0005), R3S1-CP (P = 0.0238), R3SC1-CP (P = 0.0012), and R3SC2-LR (P = 0.0343) all had significant increases in mean sponge density (Table 62, Figure 70). R3S1-CP experienced the smallest increase of 2.3 individuals/m^2, and R3NC1-LR had the greatest increase in density with 8.73 individuals/m^2 more than the baseline assessment period. Only R3N1-LR exhibited a decline in sponge density from the baseline assessment period (Table 60, Figure 70).

Table 62. Tukey post-hoc comparisons of mean sponge density differences between baseline and post-construction 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 > Post-construct
R3NC1-LR	F=104.52 (p=0.0005)	Post-construction^{A}, Baseline^{B}
R3S1-CP	F=12.60 (p=0.0238)	Post-construction^{A}, Baseline^{B}
R3S2-LR	NS	(trend) Post-construct > Baseline
R3S3-SG	NS	(trend) Post-construct > Baseline
R3SC1-CP	F=50.16 (p=0.0012)	Post-construction^{A}, Baseline^{B}
R3SC2-LR	F=9.96 (0.0343)	Post-construction^{A}, Baseline^{B}
R3SC3-SG	NS	(trend) Post-construct > Baseline

3.3.6 Zoanthid Presence & Density

3.3.6.1 Middle Reef

The zoanthid *Palythoa caribaeorum* was the only occurring zoanthid and was widespread in high densities across middle reef sites. No zoanthids were reported at R2S1-RR and R2SC1-RR (Table 63, Figure 71) during baseline, but were reported at all sites during post-construction. R2SC2-LR was documented with exceptionally high *Palythoa* densities, which averaged 3.75 individuals/m^2 across the monitoring station transects during baseline and 4.38 individuals/m^2 during post-construction. The rest of the middle reef sites ranged from 0.27 (R2S1-RR) to 1.25 (R2NC1-LR).

Table 63. Zoanthid presence at middle reef sites during baseline and post-construction surveys. Baseline presence is indicated by a black circle, post-construction presence is denoted by a square.

Zoanthid genera	Middle Reef Sites								
	R2N1-RR	R2N2-LR	R2NC1-LR	R2NC2-RR	R2NC3-LR	R2S1-RR	R2S2-LR	R2SC1-RR	R2SC2-LR
Palythoa	• □	• □	• □	• □	• □	□	• □	□	• □

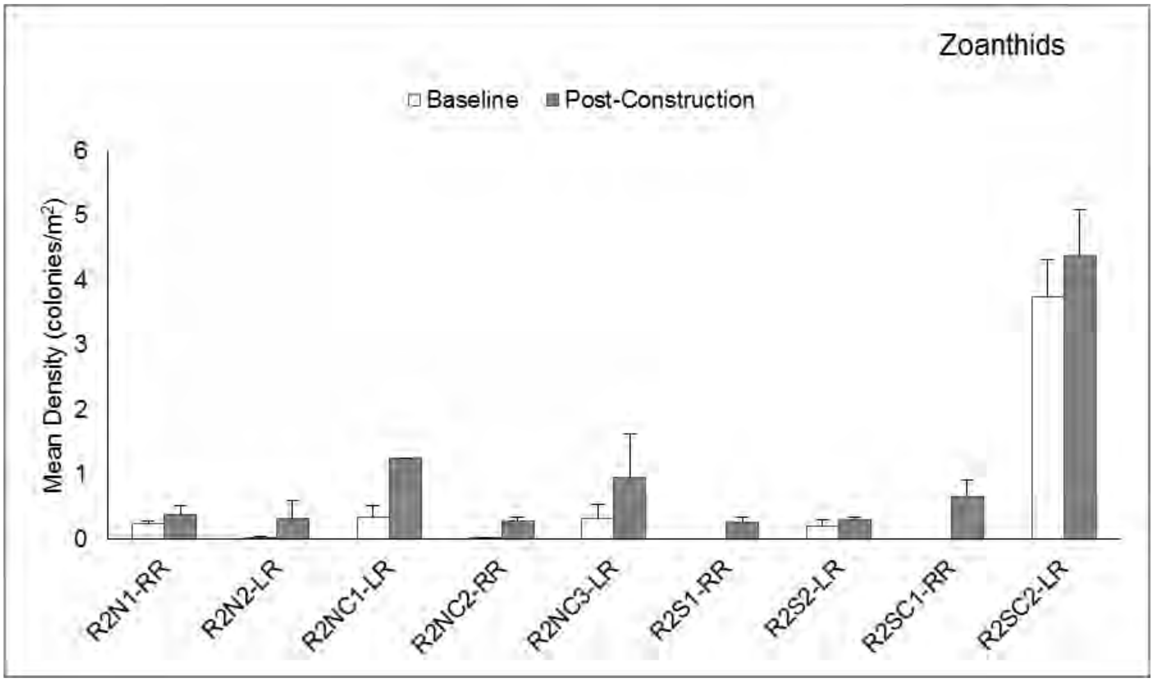

Figure 71. Zoanthid density values for middle reef sites during baseline and post-construction surveys. Error bars represent the standard error of the mean.

3.3.6.2 Outer Reef

Palythoa was present at all outer reef sites during both baseline and post-construction. During baseline, density was low and ranged from 0.02 (R3SC1-CP and R3S1-CP) to 0.47 (R3SC2-LR) individuals/m^2 (Table 64, Figure 72). In post-construction, density ranged from 0.02 (R31-CP) to 1.23 (R3SC2-LR).

Table 64. Zoanthid presence at outer reef sites during baseline and post-construction surveys. Baseline presence is indicated by a black circle, post-construction presence is denoted by a square.

Zoanthid genera	Outer Reef Sites							
	R3N1-LR	R3NC1-LR	R3S1-CP	R3S2-LR	R3S3-SG	R3SC1-CP	R3SC2-LR	R3SC3-SG
Palythoa	• □	• □	• □	• □	• □	• □	• □	• □

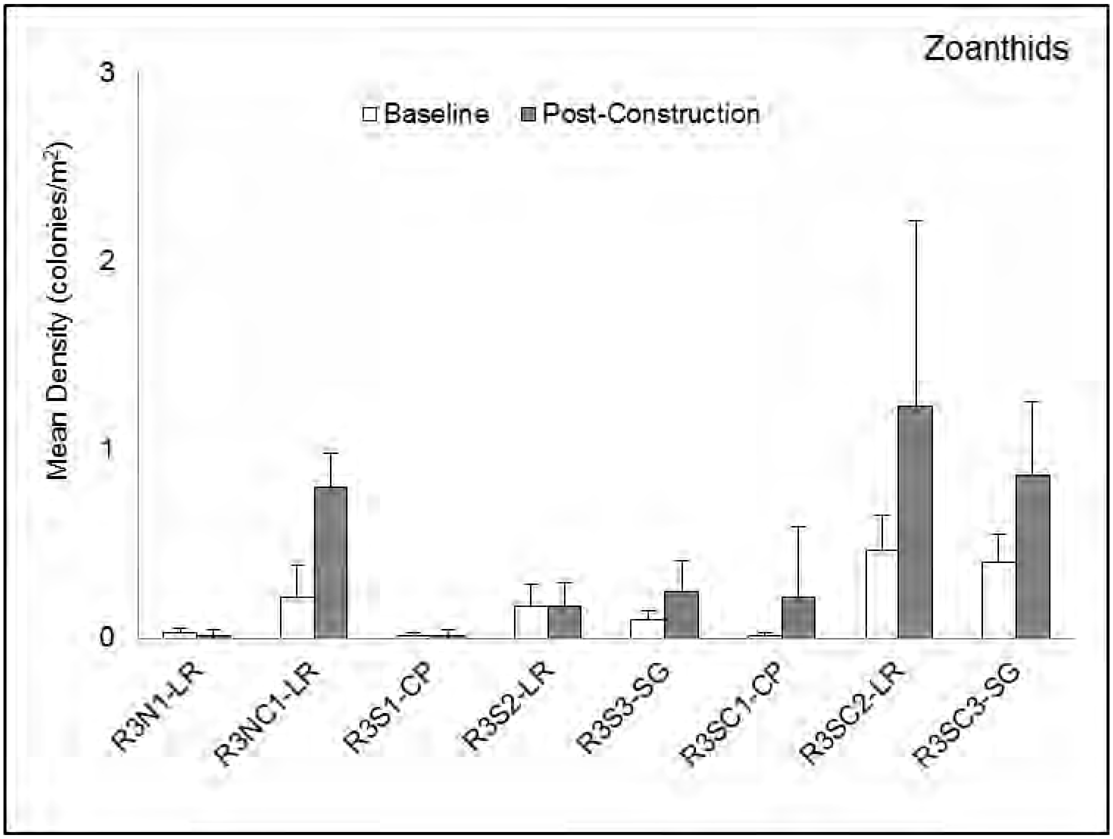

Figure 72. Zoanthid density values for outer reef sites during baseline and post-construction surveys. Error bars represent the standard error of the mean.

3.4 Functional Group Percent Cover

3.4.1 Middle Reef

3.4.1.1 Baseline and Post-construction Comparison

Functional group percent cover was highly variable across monitoring sites in the middle reef from baseline through post-construction. Baseline videos from R2NC3-LR and R2SC1-RR were re-analyzed following additional QA/QC examinations. These new results are presented below in Figures 73 and 75.

During baseline the benthic composition of the northern sites consisted mostly of crustose coralline algae, turf, and/or bare substrate (CTB) (Figure 73). In addition to CTB, octocorals accounted for a large percentage of the benthic cover at R2N1-RR and R2NC2-LR. Zoanthids accounted for a larger amount of cover at R2NC1-LR and R2NC3-LR. Sandy substrate was a major feature at R2N2-LR, R2NC1-LR, and R2NC3-LR, due to large sand patches within these sites. R2NC2-RR exhibited the highest percentage of coral cover for the northern survey sites (Figure 73). During post-construction surveys, sand increased and became the dominant functional group at R2N1-RR (49.2%), while CTB remained the primary functional group at the rest of the northern sites (Figure 74). Similar to baseline, octocorals were highest in cover at R2N1-RR and R2NC2-RR (16.9% and 16.2% respectively), and R2NC2-RR had the highest percentage of coral cover (2.9%).

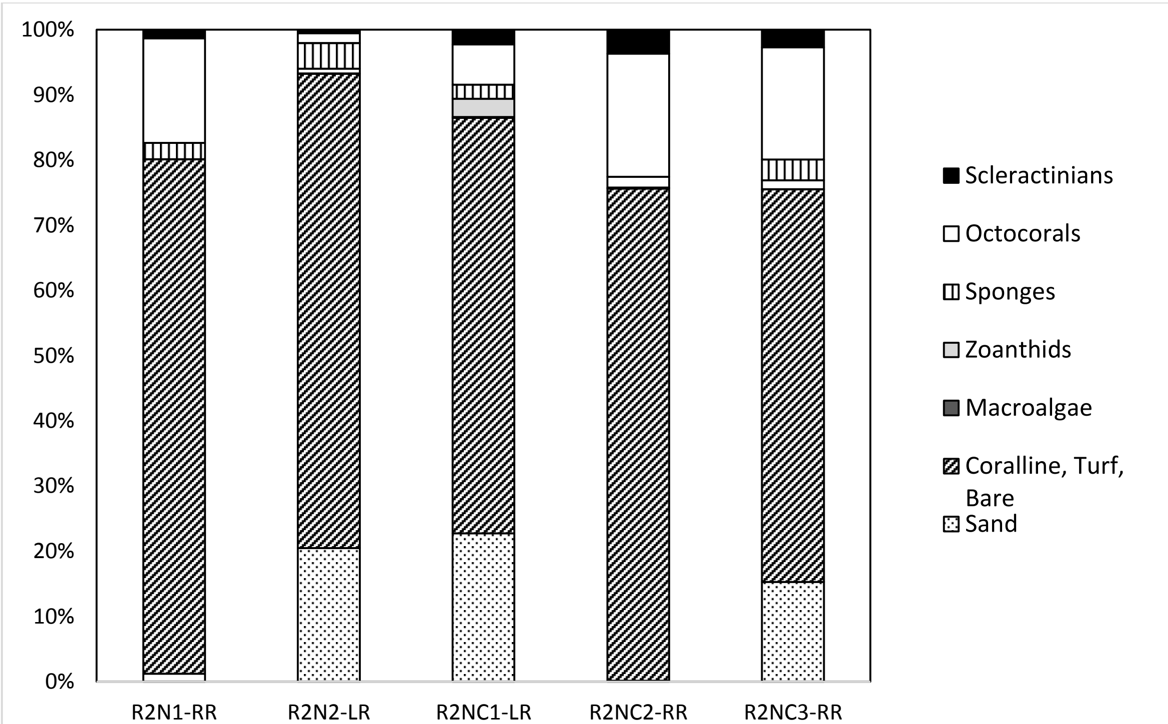

Figure 73. Functional group percent cover for northern middle reef survey sites during baseline surveys. Baseline values have been revised following QA/QC in this graph, specifically R2NC3-LR was reanalyzed.

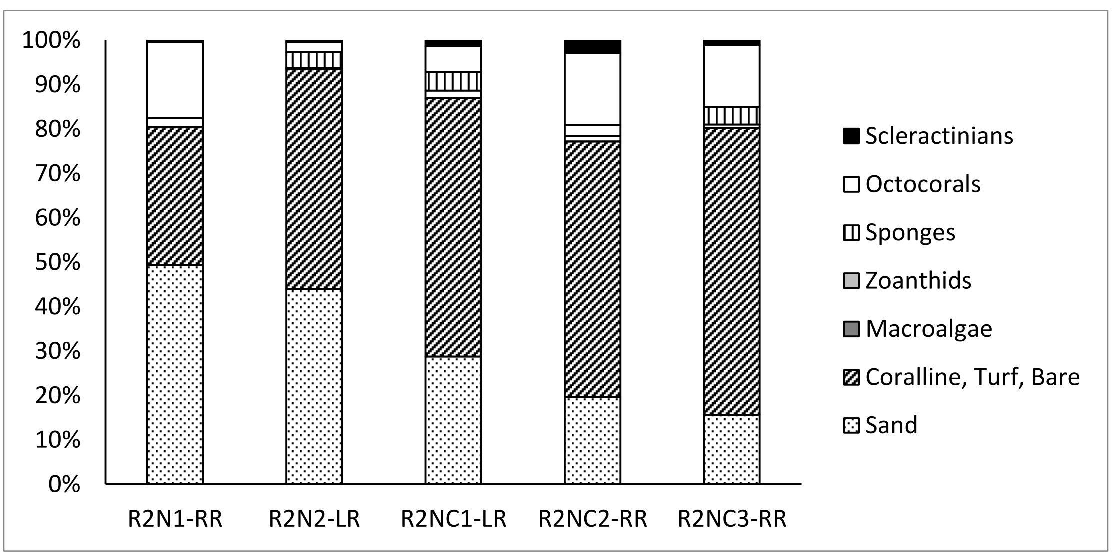

Figure 74. Functional group percent cover for northern middle reef survey sites during post-construction surveys.

CTB was also the primary functional group at southern middle reef sites during baseline, R2S1-RR (90.2%) and R2S2-LR (81.2%) (Figure 75). R2SC1-RR had the highest percent cover of sand (21.8%) and scleractinians (3.5%). Octocorals were most dominant at R2SC2-LR (21.8%) and R2S2-LR (12.1%). During post-construction, sand percent cover increased at all sites, and became predominant at R2S1-RR (57.2%) and R2S2-LR (46.3%) (Figure 76). CTB remained the dominant group at the control sites during post-construction. Octocorals were the highest at R2SC2-LR (20.9%) and R2SC1-RR (10.8%), and R2SC1-RR also had the highest scleractinian cover (1.3%). Post-construction functional group percent cover data is provided in Appendix G.

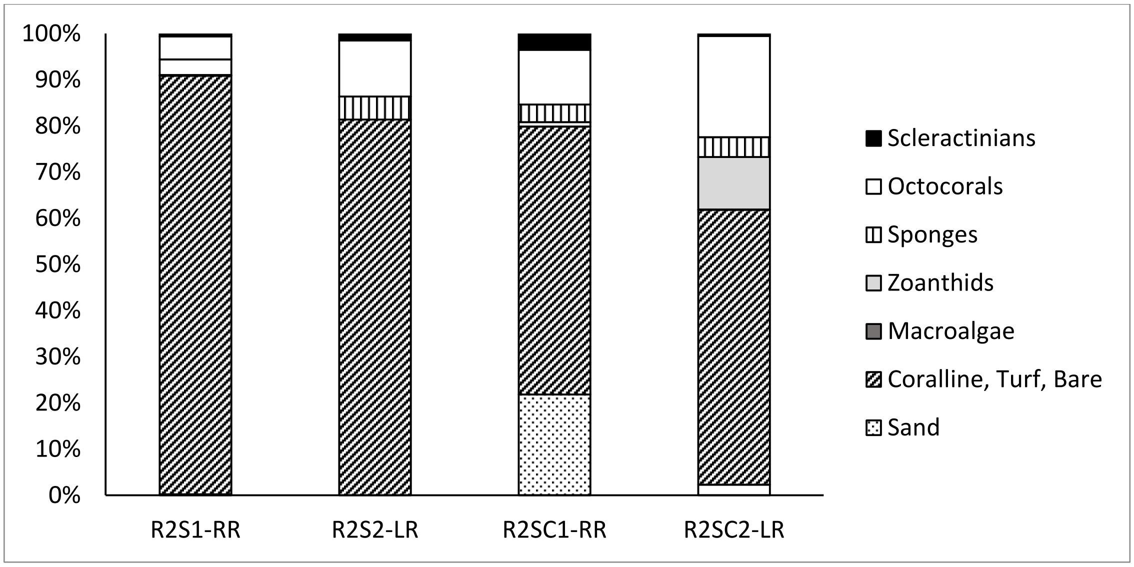

Figure 75. Functional group percent cover for southern middle reef survey sites during baseline surveys. Baseline values have been revised following QA/QC in this graph, specifically R2SC1-RR was reanalyzed.

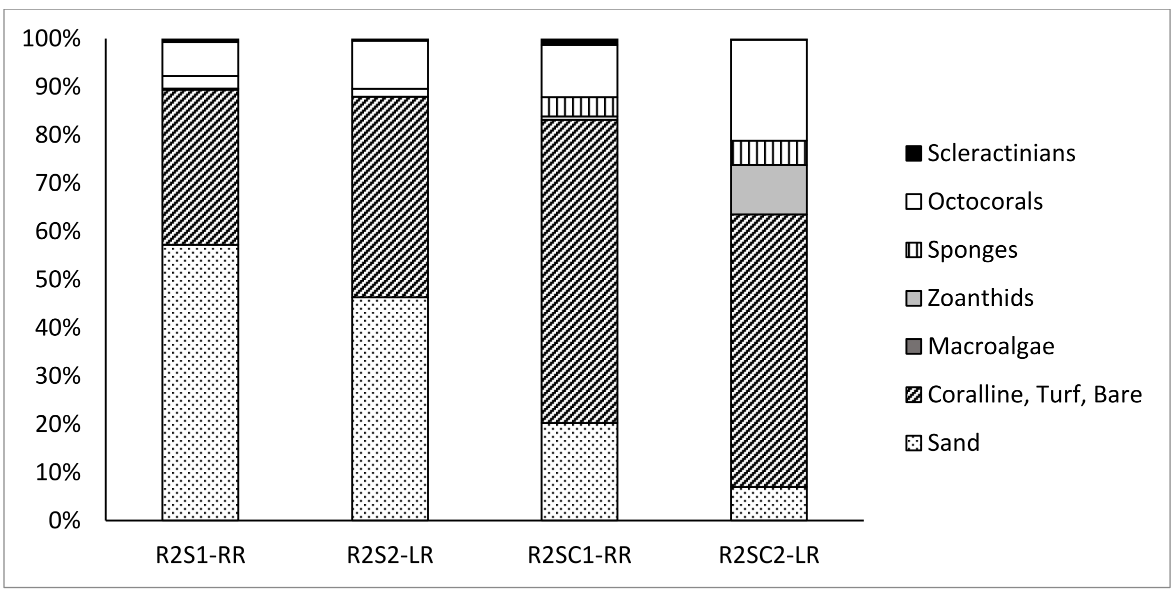

Figure 76. Functional group percent cover for southern middle reef survey sites during post-construction surveys.

3.4.1.2 CTB vs. Sand

Two functional groups – sand and CTB (crustose turf and bare) were used as proxies to record levels of sediment at channel-side and control sites from baseline through post-construction. Data were collected following the same sampling protocols used for hardbottom sampling. High variability was documented in CTB (crustose turf and bare) and sand cover. Throughout compliance monitoring at middle reef sites, the relative proportion of CTB and sand at each site varied as a function of weather conditions (winter v. summer), dominant current patterns and spatial relationship to the dredging operation (Figures 77-84).

Northern middle reef channel-side site baseline CTB values were 75.6% at R2N2-LR and 78.3% at R2N1-RR. The control sites had 62.8%, at R2NC1-LR, and 75.5%, at R2NC2-RR, respectively to the corresponding channel sites for the baseline assessment period. After the baseline period, CTB values decreased at the channel side sites and R2NC1-LR. However, R2NC2-RR experienced an initial increase of approximately 12%, before declining by approximately 27%. The lowest CTB levels were observed in compliance week 44 (Sept. 2014). R2N1-RR had a CTB value of less than 4%, which represented an approximately 75% decrease and R2N2-LR had a value less than 14%, approximately a 59% decrease from initial baseline calculations. The corresponding control sites did not experience similar decreases. CTB levels decreased by approximately 8% at R2NC2-RR, and increased approximately 6% at R2NC1-LR. CTB values were increasing in the final video analysis, which was post-construction surveys, at all sites, ranging between 15% and 22% (Figures 77-80).

Southern middle reef channel-side site baseline CTB values were 81.2% at R2S2-LR and 90.2% at R2S1-RR. The control sites documented 59.5%, at R2SC2-LR, and 58.0%, R2SC1-RR, respectively for the baseline assessment period. Similar to the northern sites, the two southern channel-side sites and R2SC1-RR experienced a decline in CTB cover after the baseline assessment period. R2SC2-LR experienced slightly less than a 5% increase before declining by 14% the following week. The lowest CTB value was observed at R2S2-RR during compliance week 33 (June 2014). The observed value was less than 3%, with an overall decrease of approximately 79% from the baseline assessment. The corresponding control site R2SC2-LR experienced a 17% decrease from baseline over the same time period. R2S1-RR had the greatest decrease of approximately 83%, which was observed in compliance week 69/70 (March 2015). R2SC1-RR CTB value decreased by approximately 8% from baseline over the same period. Similar to the northern sites, all CTB values were increasing in post construction analysis ranging between 12% and 32% (Figures 81-84). All functional group percent cover data from baseline through post-construction monitoring are provided in Appendix H.

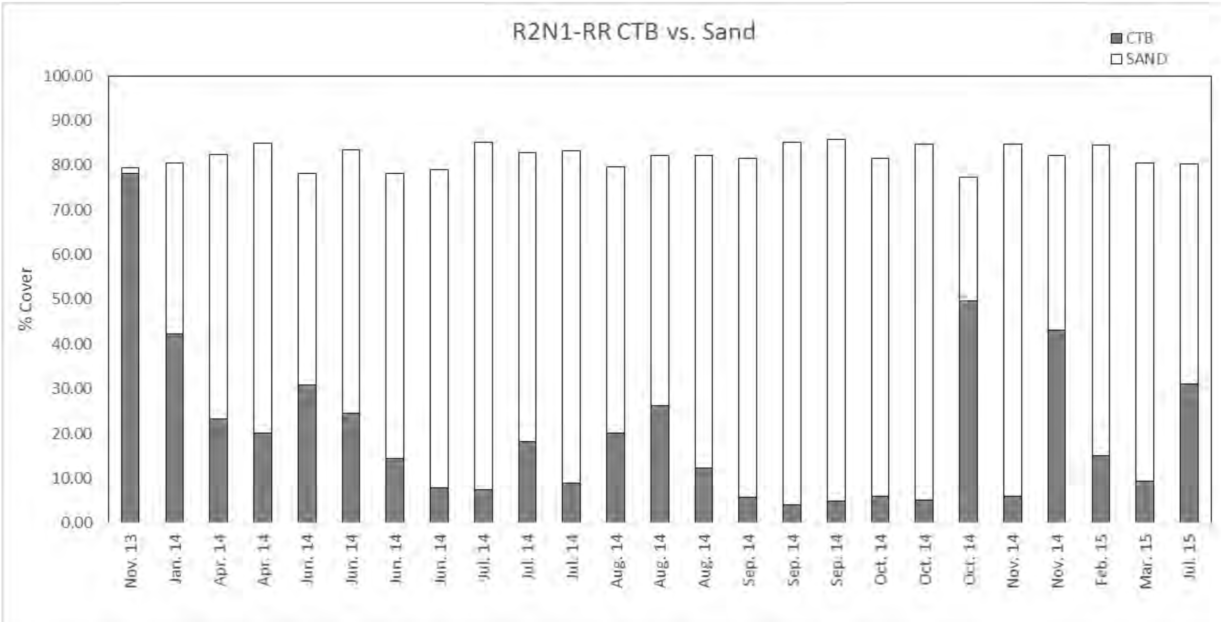

Figure 77. R2N1-RR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

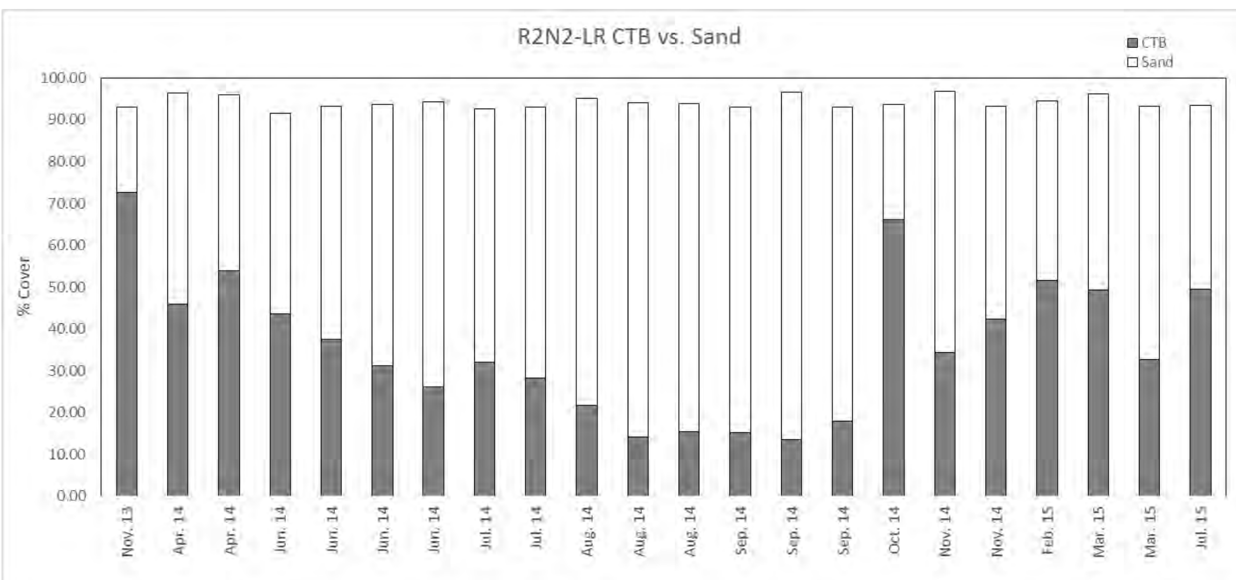

Figure 78. R2N2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

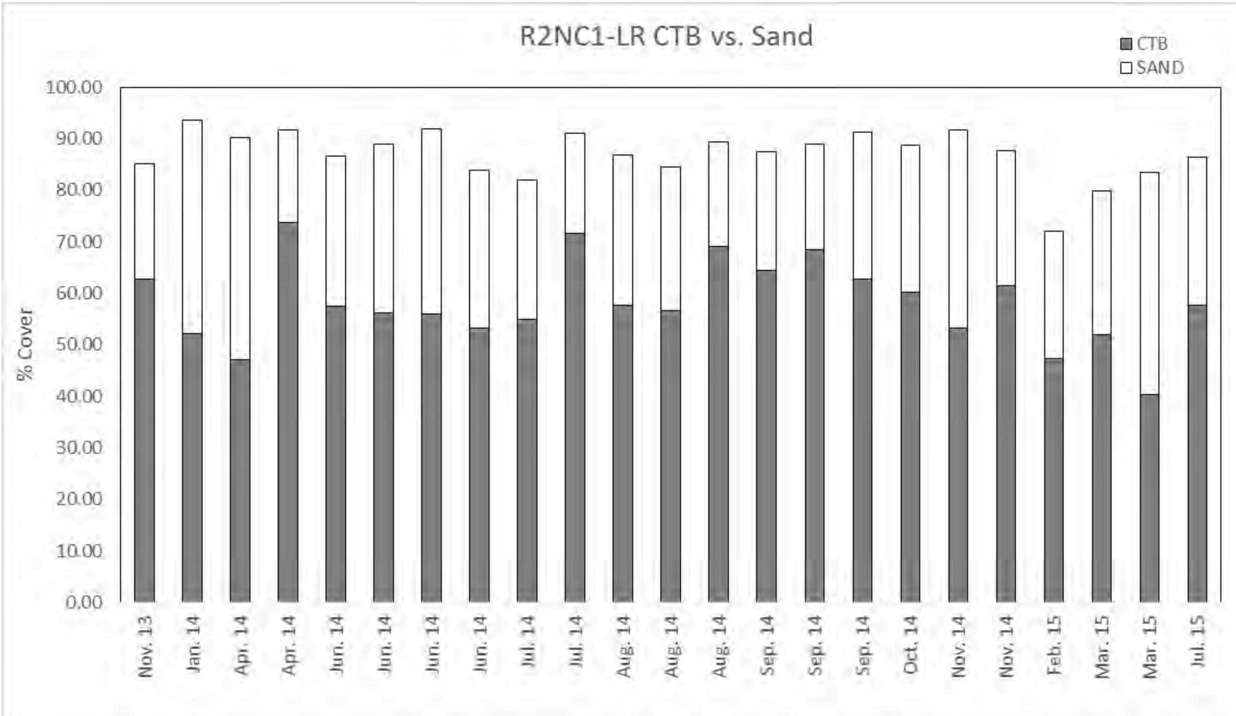

Figure 79. **R2NC1-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

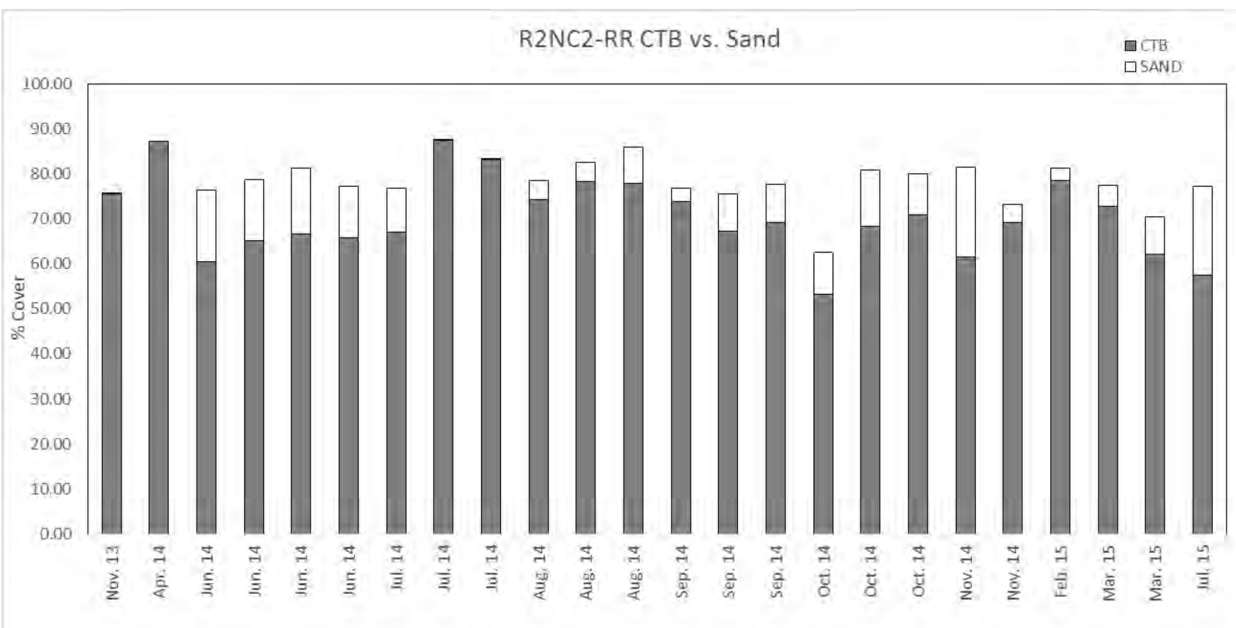

Figure 80. **R2NC2-RR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

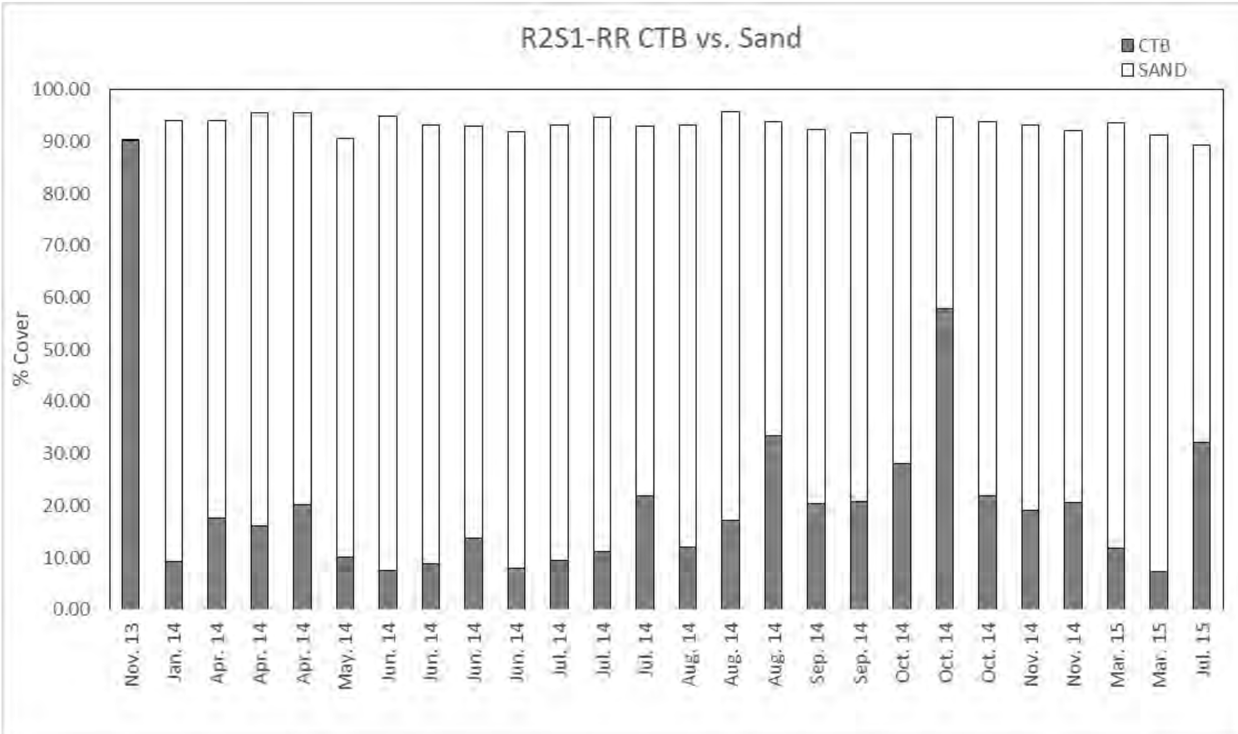

Figure 81. **R2S1-RR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

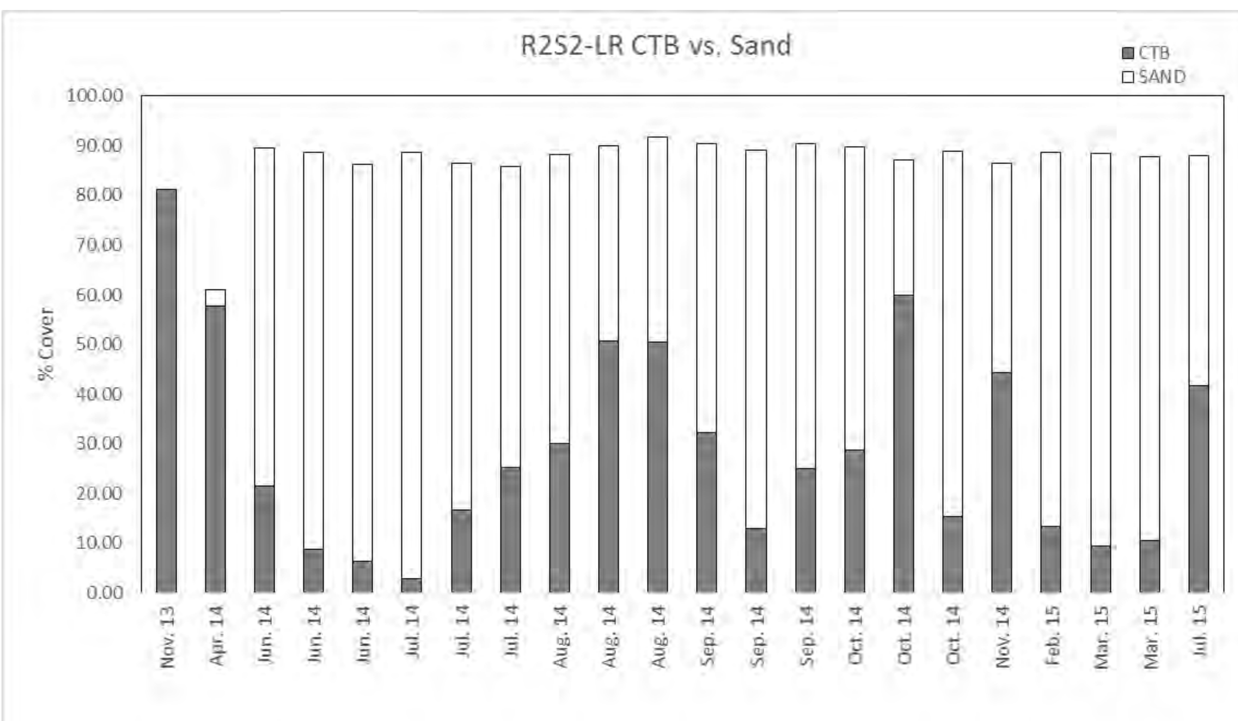

Figure 82. **R2S2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

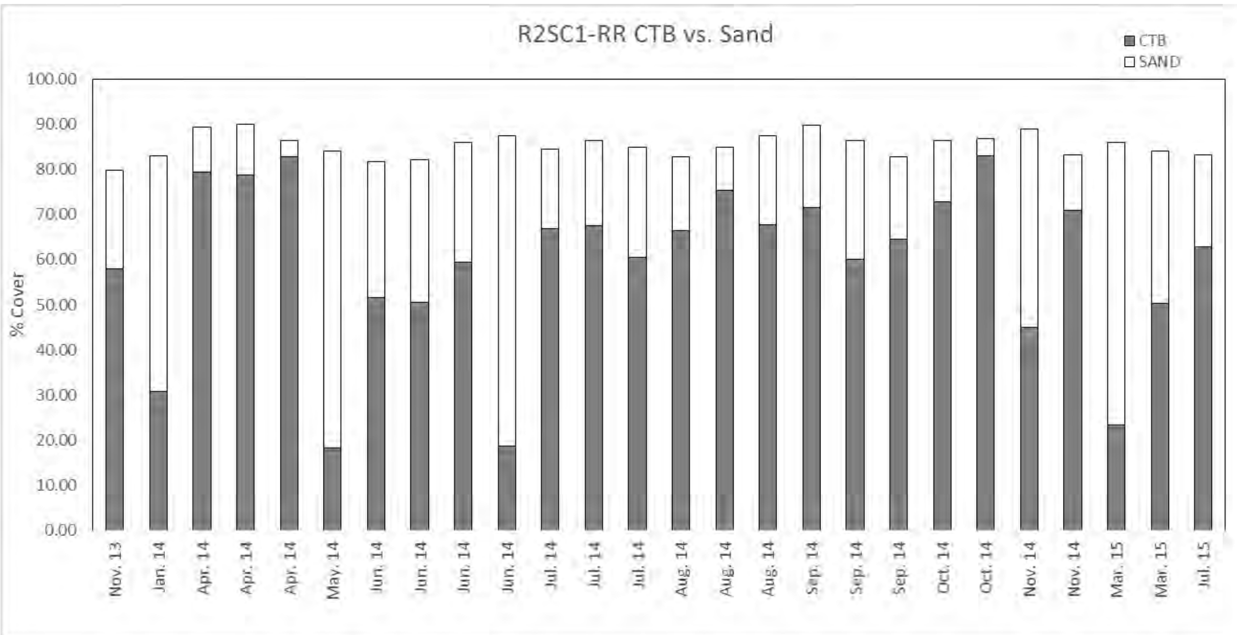

Figure 83. **R2SC1-RR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

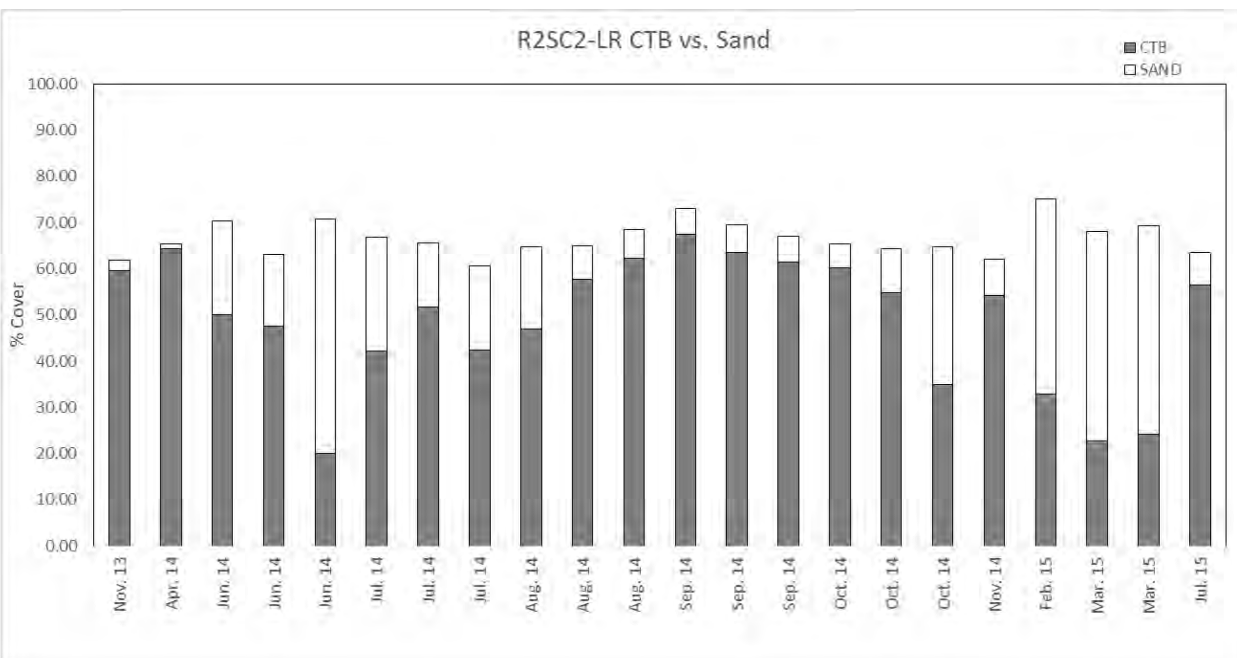

Figure 84. **R2SC2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

3.4.2 Outer Reef

3.4.2.1 Baseline and Post-construction Comparison

Functional group percent cover was highly variable across monitoring sites in the outer reef area from baseline through post-construction. Baseline videos from R3S1-CP and R3SC1-CP were re-analyzed following additional QA/QC examinations. These new results are presented below in Figure 87. Throughout compliance monitoring, the relative proportions of CTB and sand at each site varied greatly as a function of seasonal variations and presumably dredge positioning, it should be noted that sites were only surveyed when a dredge was within 750 m of a site in compliance with the FDEP permit conditions.

During baseline, CTB was the most dominant at both northern sites (Figure 85). R3N1-LR had 72.5% CTB cover, while R3NC1-LR had 65.3%. Octocorals were the highest at R3NC1-LR (16.4%), and scleractinian cover was very similar at both sites (0.66% at R3N1-LR and 0.69% at R3NC1-LR). This distribution of CTB and sand remained the same during post-construction (Figure 86). CTB was equal at both sites (71%), while sand was the highest at R3N1-LR (17.6%). Octocorals remained the highest at R3NC1-LR (13.1%), and again scleractinian cover was very similar at both sites (0.54% at R3N1-LR, and 0.58% at R3NC1-LR). Nevertheless, the distribution of CTB versus sand was highly variable throughout compliance monitoring, specifically at R3N1-LR (Figure 89).

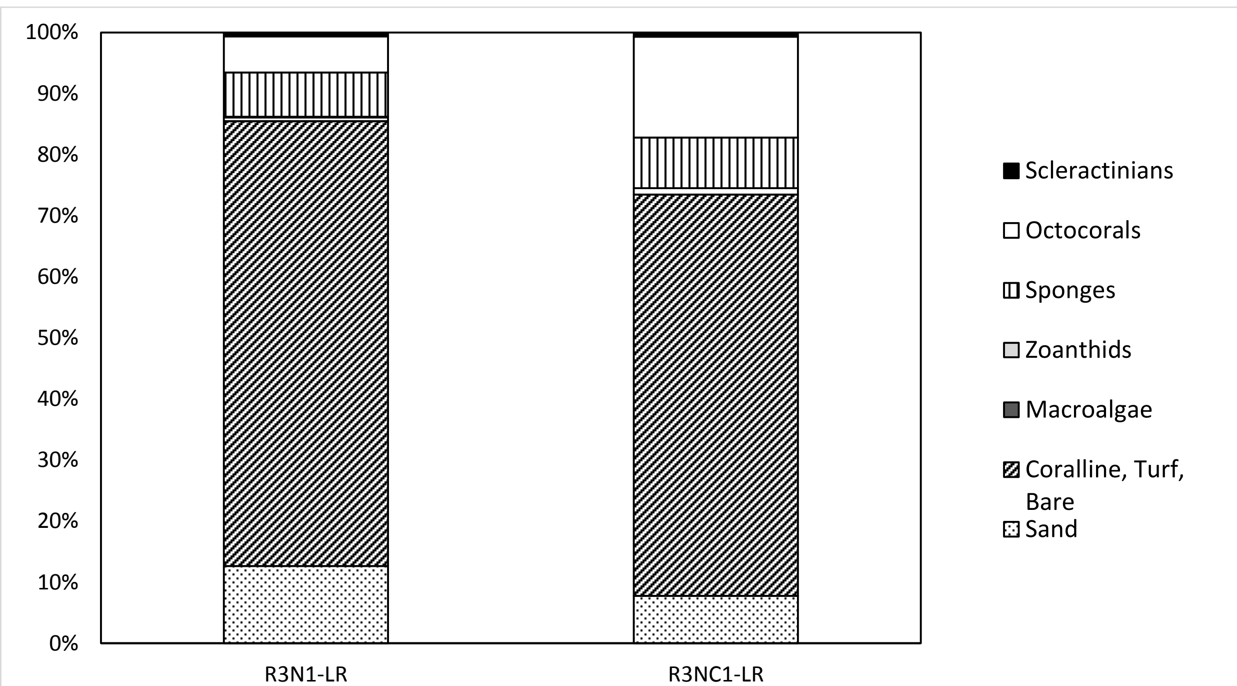

Figure 85. Functional group percent cover for northern outer reef survey sites during baseline surveys. This baseline graph has been revised.

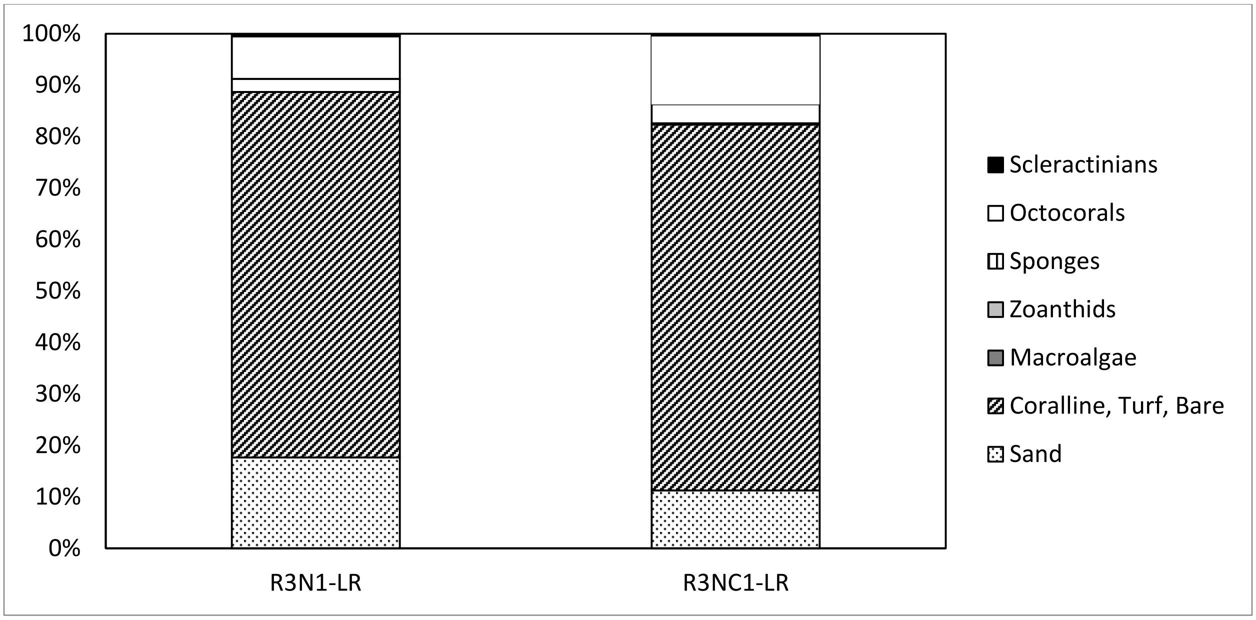

Figure 86. Functional group percent cover for northern outer reef survey sites during post-construction surveys.

During baseline, the benthic composition of southern outer reef sites consisted mostly of crustose coralline algae, turf, and/or bare substrate (CTB). CTB cover ranged from 63.3% (R3S1-CP) to 81.7% at R3S3-SG (Figure 87). Sand was highest at R3S1-CP (28.8%), and lowest at R3SC3-SG (0.6%). In addition to CTB, gorgonians and sponges accounted for a large percentage of the benthic cover, ranging from 5.5% to 13.1% across southern outer reef sites. Coral cover was low across southern outer reef sites, ranging from 0.15 (R3S1-CP) to 1.32% at R3S3-SG (Figure 87). In post-construction, CTB remained the most dominant feature across southern outer reef sites, ranging from 62.7% (R3S1-CP) to 73.6% at R3S2-LR (Figure 88). Sand did increase in post-construction, with R3S1-CP exhibiting the highest sand percent cover (32.2%). Scleractinian cover remained low across all sites, ranging from 0.2% (R3S1-CP) to 1.1% (R3SC1-LR). Octocorals cover was highest at R3S3-SG (16.3%). All post-construction functional group percent cover data is provided in Appendix G.

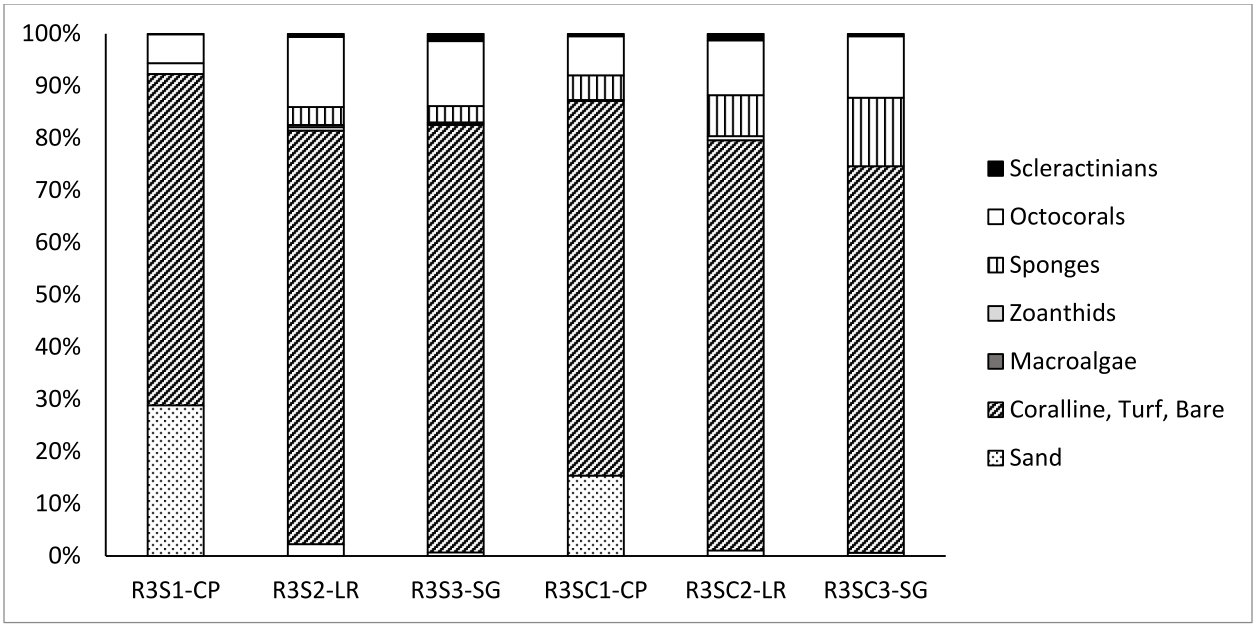

Figure 87. Functional group percent cover for southern outer reef survey sites during baseline surveys. This baseline graph has been revised, specifically R3S1-CP and R3SC1-CP were reanalyzed.

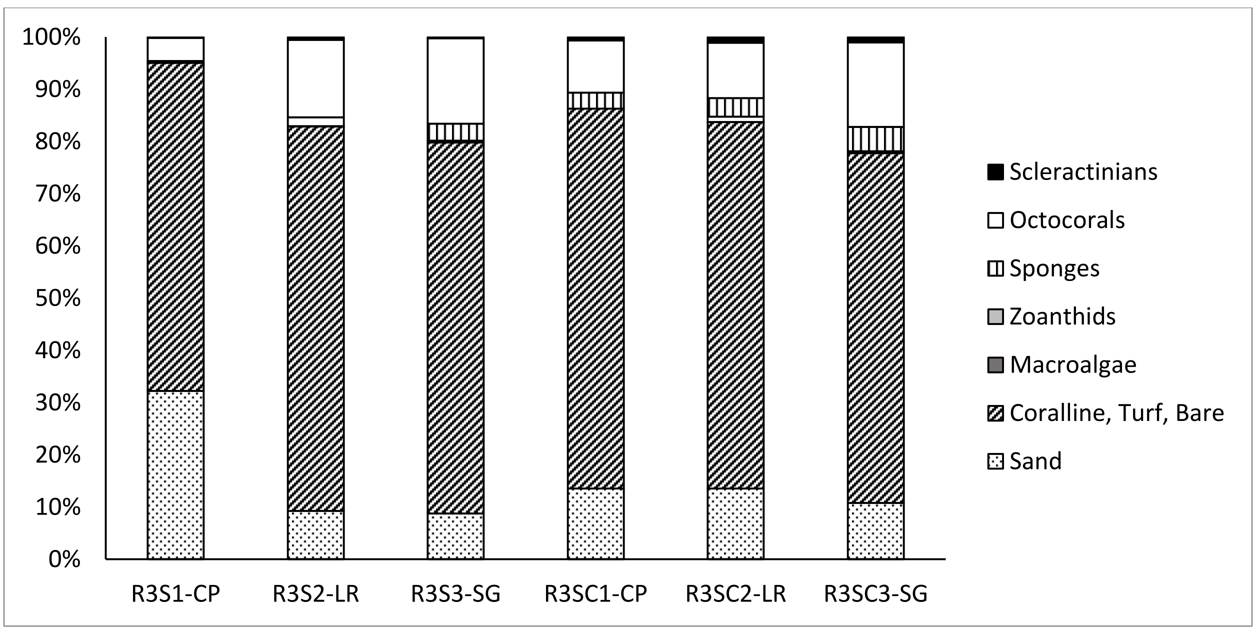

Figure 88. Functional group percent cover for southern outer reef survey sites during post-construction surveys.

3.4.2.2 CTB vs Sand

The northern outer reef channel side site, R3N1-LR, CTB value was 72.56% during the baseline assessment period. The corresponding control site, R3NC1-LR, had a value of 65.4% (Figures 89-90). After the baseline period, CTB values declined for both sites, while sand increased. The lowest CTB value of 6.3% at R3N1-LR was observed during compliance week 39 (August 2014). This value represented a decrease of 66% compared to baseline values, while R3NC1-LR exhibited an increase of approximately 1.5% during the same period. During the post-construction assessment period R3N1-LR experienced a 41% increase from the final compliance week, while R3NC1-LR CTB values decreased by approximately 2% (Figures 89-90).

The southern outer reef channel-side sites baseline CTB values ranged from 63.3%, at R3S1-CP, to 81.7%, at R3S3-SG (Figures 91-93). The control sites ranged from 71.7%, at R3SC1-CP, to 78.0%, at R3SC2-LR. After the baseline period, changes in CTB varied across all sites. Half of the sites experienced increases in CTB cover during the first survey after baseline: R3S2-LR (+7.5%), R3SC1-CP (+2.5%), and R3SC3-SG (+5.5%). The other sites all experienced a decrease in CTB cover: R3S1-CP (-32%), R3S3-SG (-56%), and R3SC2-LR (-4%). The site with the greatest decrease in CTB cover during compliance monitoring was R3S3-SG. A 68% decline from baseline was observed during the final week of compliance monitoring (February 2015). R3SC3-SG experienced a 21% decline during the same assessment period. R3S2-LR experienced a 62% decline during compliance week 57 (December 2014), while the corresponding control R3SC2-LR experienced a 56% decline in CTB coverage. R3S1-CP declined the most during compliance week 50 (October 2014), CTB coverage declined by approximately 44%. CTB coverage declined at R3SC1-CP by approximately 33%.

During the post-construction assessment period, all sites had documented increases in CTB levels. CTB cover increased at channel-side sites as follows: R3S2-LR +26.2%, R3S1-CP +37.6%, and R3S3-SG +57.8% (Figures 91-93). The control sites also all experienced increases in CTB cover as follows: R3SC2-LR +14.7%, R3SC3-SG +15.0%, and R3SC1-CP +51.2% (Figures 94-96). All functional groups percent cover data from baseline through post-construction surveys is provided in Appendix H.

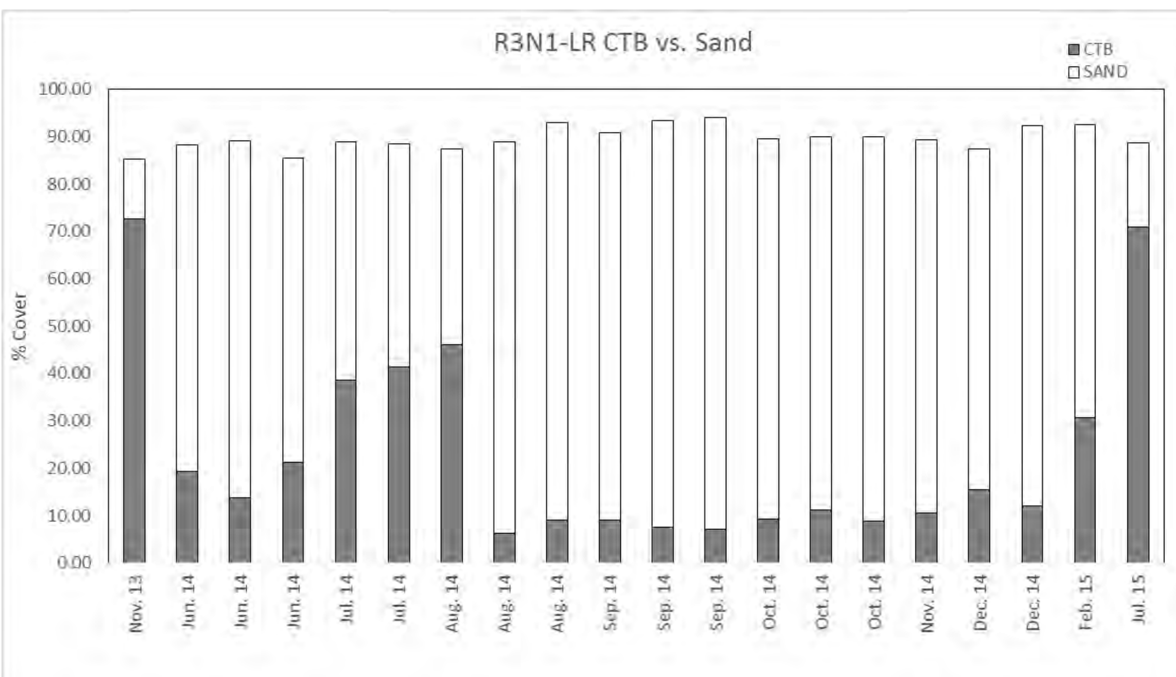

Figure 89. R3N1-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

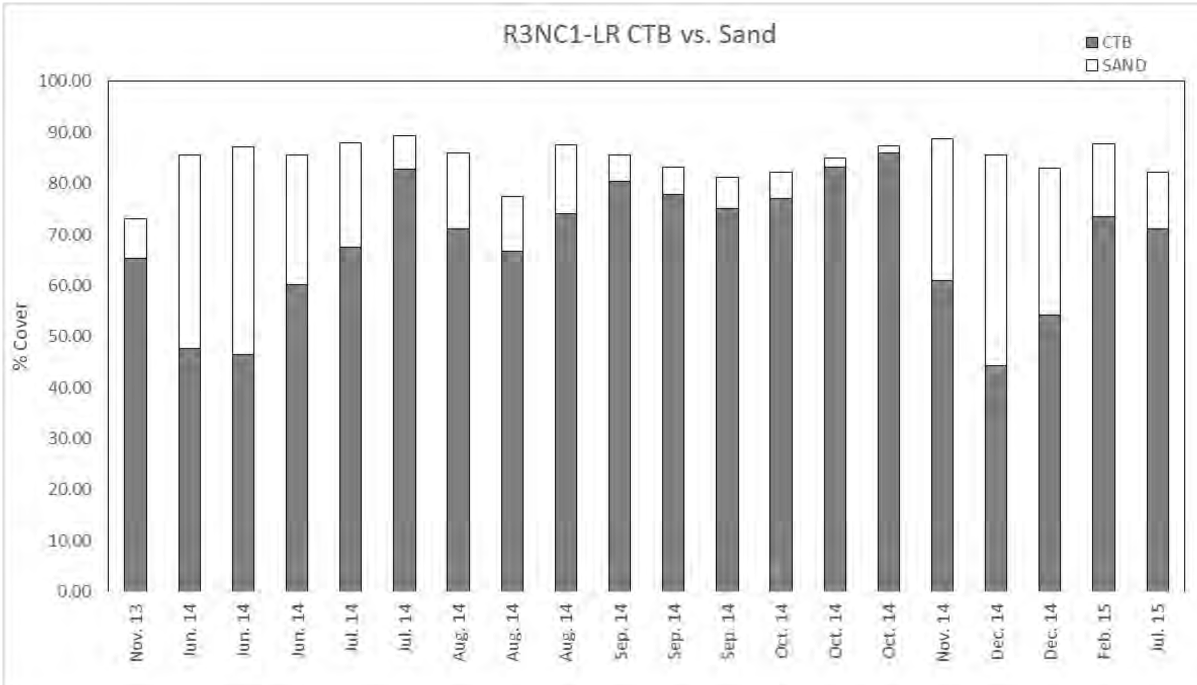

Figure 90. **R3NC1-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

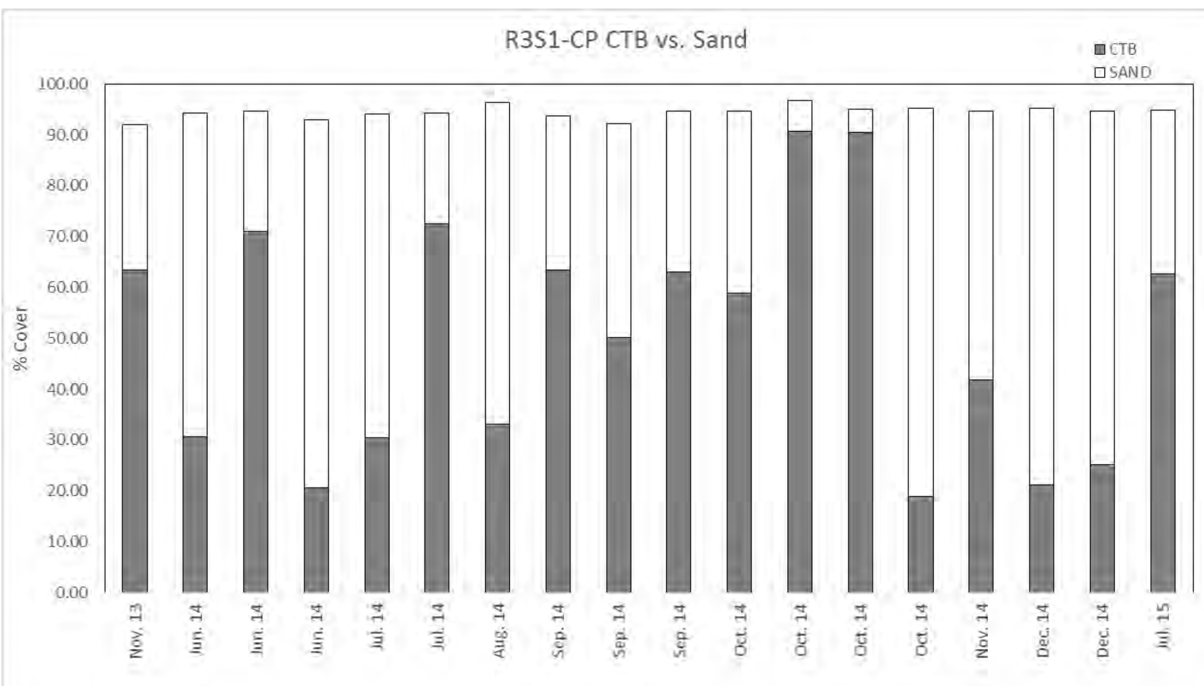

Figure 91. **R3S1-CP CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.**

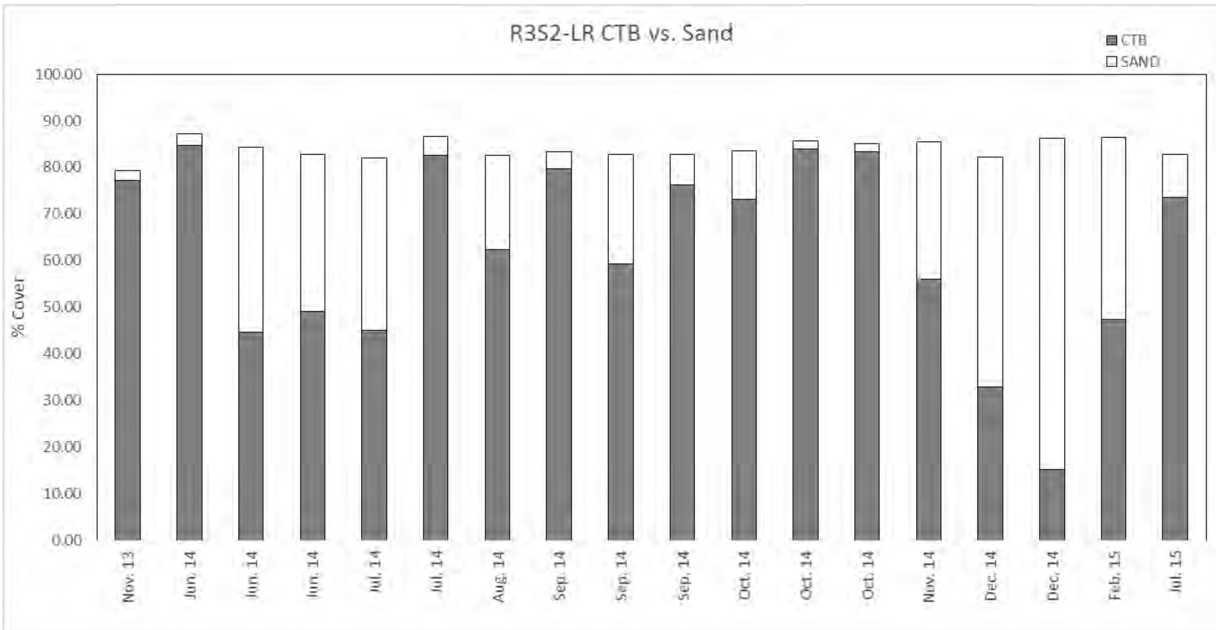

Figure 92. R3S2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

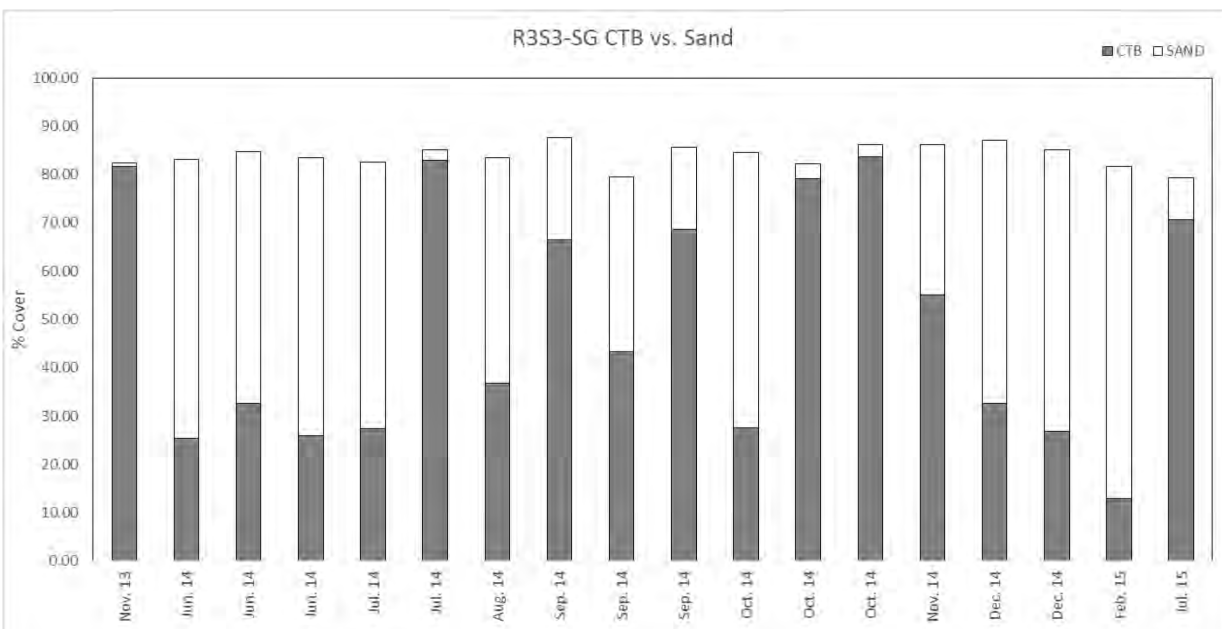

Figure 93. R3S3-SG CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

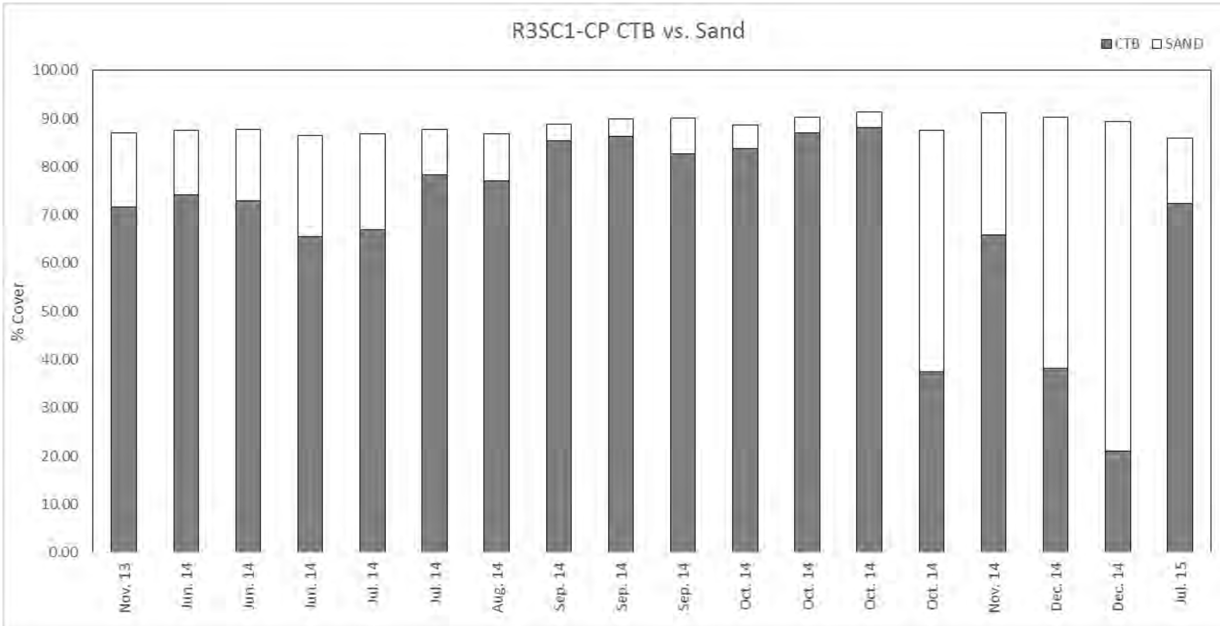

Figure 94. R3SC1-CP CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

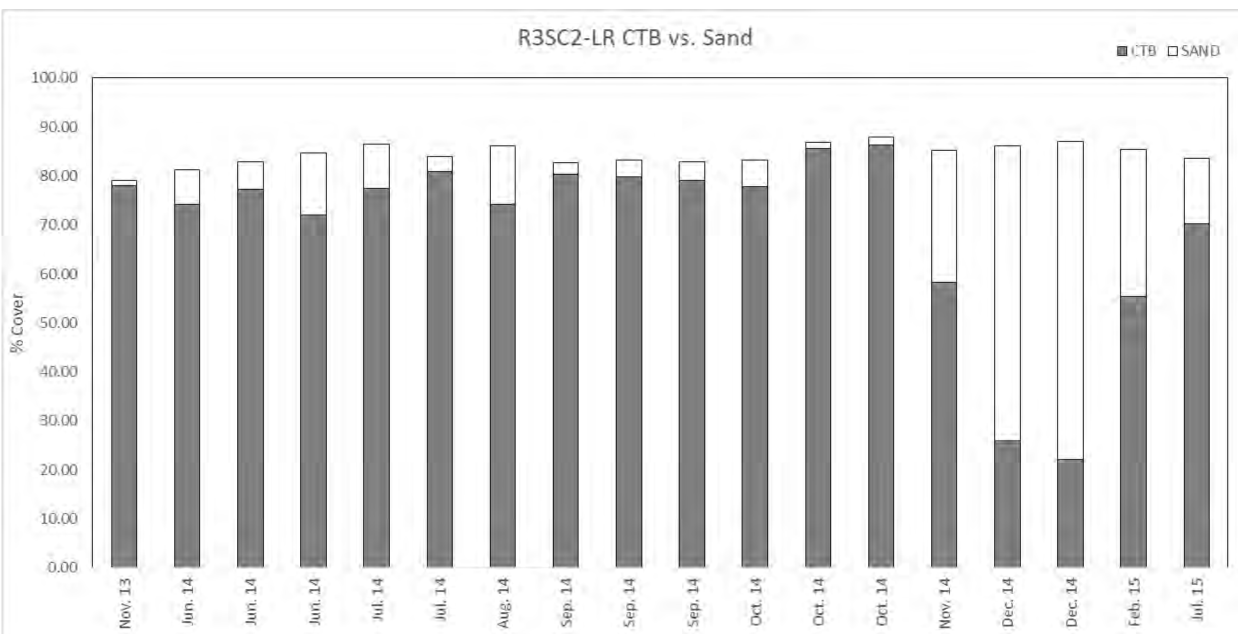

Figure 95. R3SC2-LR CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

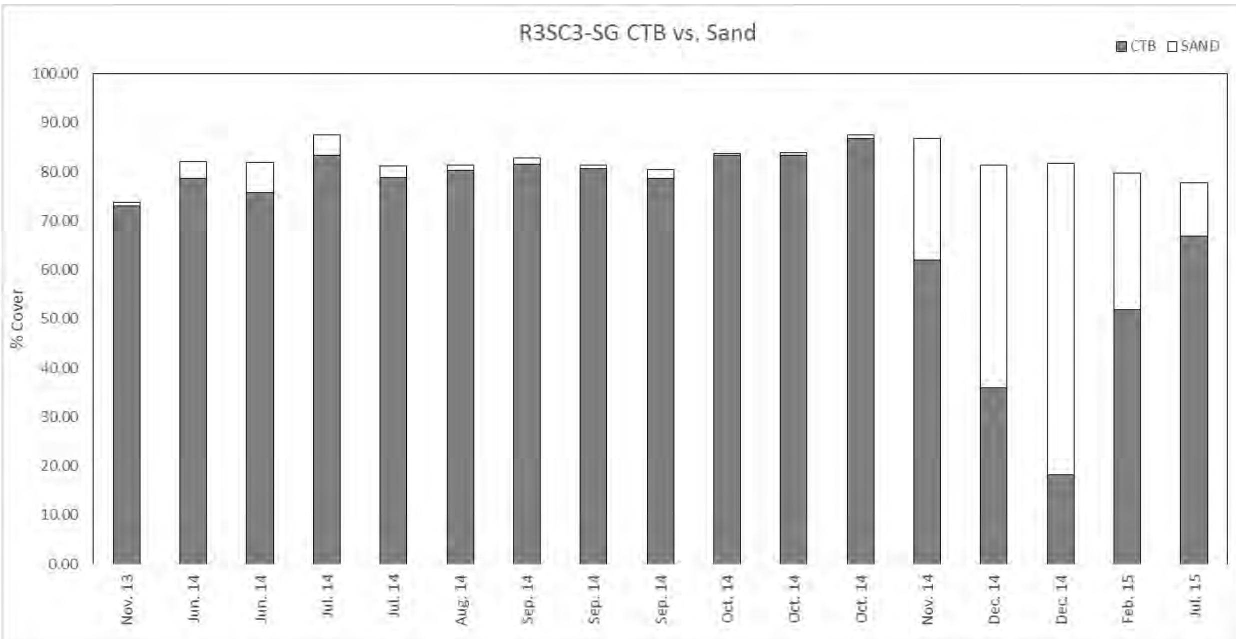

Figure 96. R3S3-SG CTB (crustose, turf, and bare) and sand data analysis based on video transect analysis. First column of the figure represents baseline analysis, and last column on the figure represents post-construction analysis.

3.5 Quantitative Sedimentation Accumulation Rates

Sedimentation data were collected from the sediment traps at middle reef sites (N = 24) and outer reef sites (N = 24) at each transect at the end of the post-construction survey period (28 days after installation). Three replicates were combined to create a single sample per transect, for a total of three samples per site. A daily sedimentation rate was calculated for each site as an average of the three samples for a single site. Samples were separated into two fractions in the lab, a coarser grain fraction (≥ #230 sieve) and a finer fraction (< #230 sieve). All quantitative sedimentation data from baseline through post-construction surveys is provided in Appendix I.

3.5.1 Middle Reef

Sedimentation samples were collected from the sediment traps at each transect at the end of the baseline survey period or when weather conditions permitted safe scientific dive operations (24 to 89 days after sediment bottles were placed on site). Sites R2N1, R2S1, R2NC1, and R2SC1 were placed and collected before the commencement of dredging, while the other middle reef site sediment bottles were collected after construction activities began near the hardbottom areas. 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 limitations on safe boating and diving conditions. Coarse-grain sedimentation rates (g/day) were highest at north channel-side site R2N1-RR (1.81 g/day) and lowest at R2NC3-LR (0.05 g/day) during baseline. Fine-grain sedimentation rates ranged from 0.19 g/day (R2NC3-LR) to 0.71 g/day (R2N2-LR). Consequently, it is not possible to exclude dredging from influencing sedimentation rates in addition to winter weather conditions. However, baseline sedimentation rates for R2N1-RR, R2S1-RR (before dredging) and R2N2-LR and R2S2-LR (after dredging) were very similar, which suggests dredging may not have affected daily sedimentation rates for the eastern sites in a measurable way.

During post-construction surveys, the sedimentation rates of both coarse-grain and fine-grain sediments were lower. Coarse-grain sedimentation rates were highest at R2N1-RR (0.11 g/day), and lowest at all four control sites (0 g/day) (Figure 97). Fine-grain sedimentation rates were highest at R2N2-LR (0.14 g/day), and lowest at R2SC1-RR (0.03 g/day) (Figure 98). During post-construction, sedimentation rates were lower for both coarse and fine grained sediments at both north and south sites when compared to baseline results, which is likely a seasonal effect (baseline performed in fall/winter v. post-construction performed in summer) and the absence of dredge activity for R2N2-LR, R2S2-LR, R2SC2-LR, and R2NC2-RR. Sedimentation bottles were not collected from R2NC3 during compliance or post-construction because the site was a redundant habitat site with no paired channel side site for comparison.

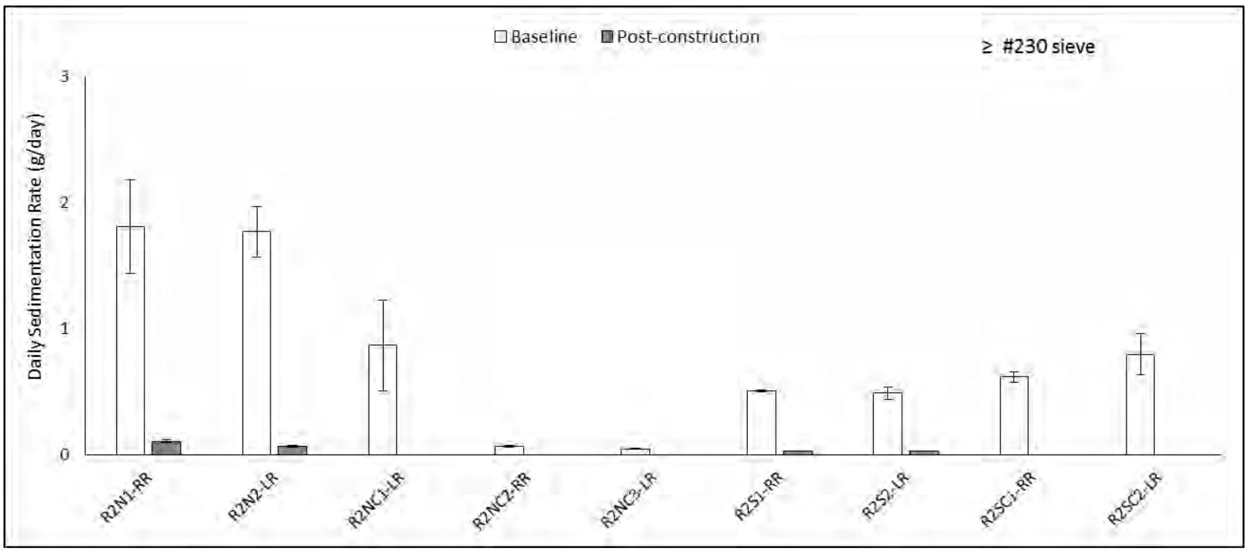

Figure 97. Daily sedimentation rates at middle reef sites for coarse-grain sediment (≥ #230 sieve) during baseline and post-construction surveys. Error bars represent the standard error. No bottles were installed at R2NC3-LR for post-construction.

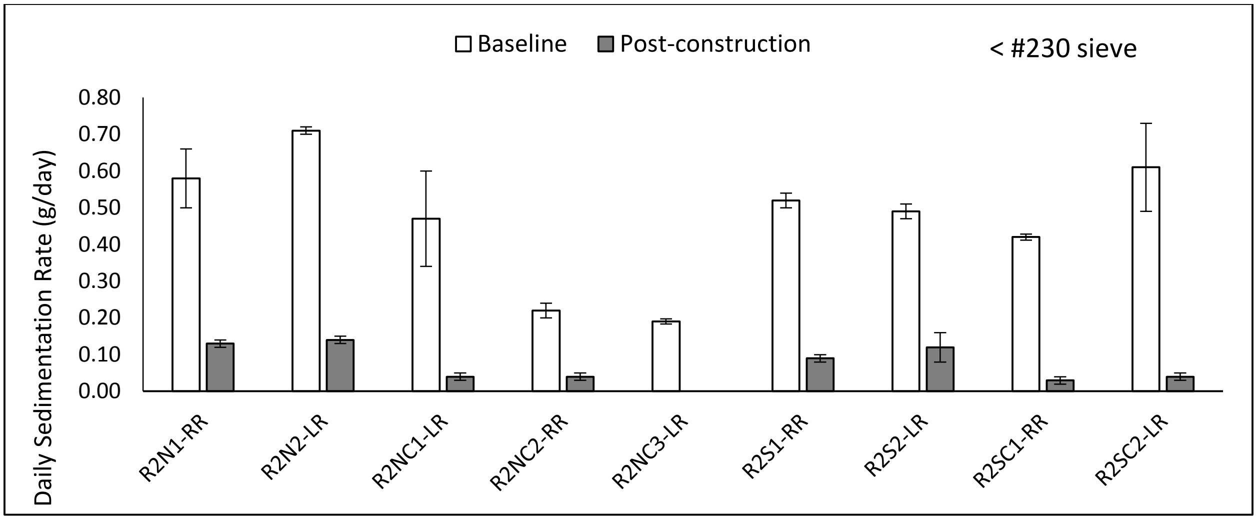

Figure 98. Daily sedimentation rates at middle reef sites for fine-grain sediment (< #230 sieve) during baseline and post-construction surveys. Error bars represent the standard error. No bottles were installed at R2NC3-LR for post-construction.

Average daily sedimentation rates for the project were tabulated and presented here for each site, from baseline through post-construction. Dredges Texas, Terrapin Island and Liberty Island conducted dredging operations offshore from November 2013 to December 2014 (Table 65). The clamshell Dredge 55 dredged by itself intermittently offshore (spot clean-ups), between January and March 16, 2015. The USACE accepted offshore dredging on April 8, 2015. Vertical lines represent the start of dredging and the last day of dredging offshore for the hopper dredge Terrapin Island, Dredge Texas and hopper dredge Liberty Island (Figures 99 – 102).

Between baseline and post-construction 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 (Figures 99 - 102). Sedimentation rates for coarse grain sediment were elevated in December 2014 and March 2015 at northern channel-side sites, and in May, June and December 2014, and January 2015 for fine grain sediments. Dredging activities and winter weather conditions in the middle reef area from November to late December 2014 contributed to the increase in mean daily sedimentation rates at the two northern channel-side sites during this time period. Sedimentation rates decreased in January, but increased again in March 2015. In February 2015, sediment samples were not collectable due to winter weather conditions that persisted until March 15, 2015. Channel-side sites sedimentation rates declined from March 2015 and as of July 2015, were very similar to control sites values.

Table 65. Dredge commencement and completion dates are presented for each dredge offshore. Maintenance periods where dredges may not have been working 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	11/20/2013	12/27/2013
Liberty Island	Hopper	5/14/2014	7/3/2014
55	Clamshell	4/5/2014	03/16/2015

Sedimentation rates at southern channel-side sites were not as elevated as the northern sites, and the trends at channel-side sites closely matches the trends at the control sites. Rates of coarse-grain sediments increased at all sites (channel-side and controls) in January and

December 2014, and were all again slightly higher in March 2015. Fine-grain sedimentation rates were elevated in January, May and December 2014, and March 2015. Similarly, to the coarse grain sedimentation patterns, the channel-side sites and controls sites followed the same trend during every collection period. The spike in December 2014 may be explained by the nearby dredging activities, but the mean sedimentation rate also increased at the two southern control sites, which also suggests that natural sand movement, as well as winter weather patterns played a role in in this southern area.

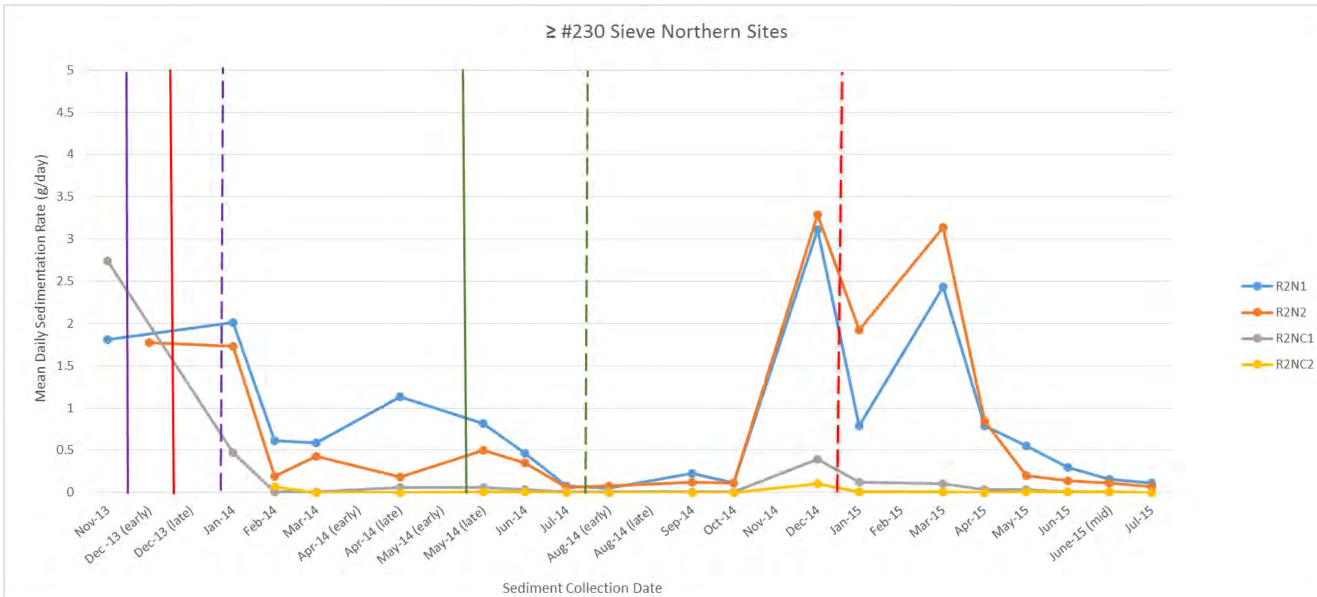

Figure 99. Daily sedimentation rates at northern middle reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R2N2 and R2NC2 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

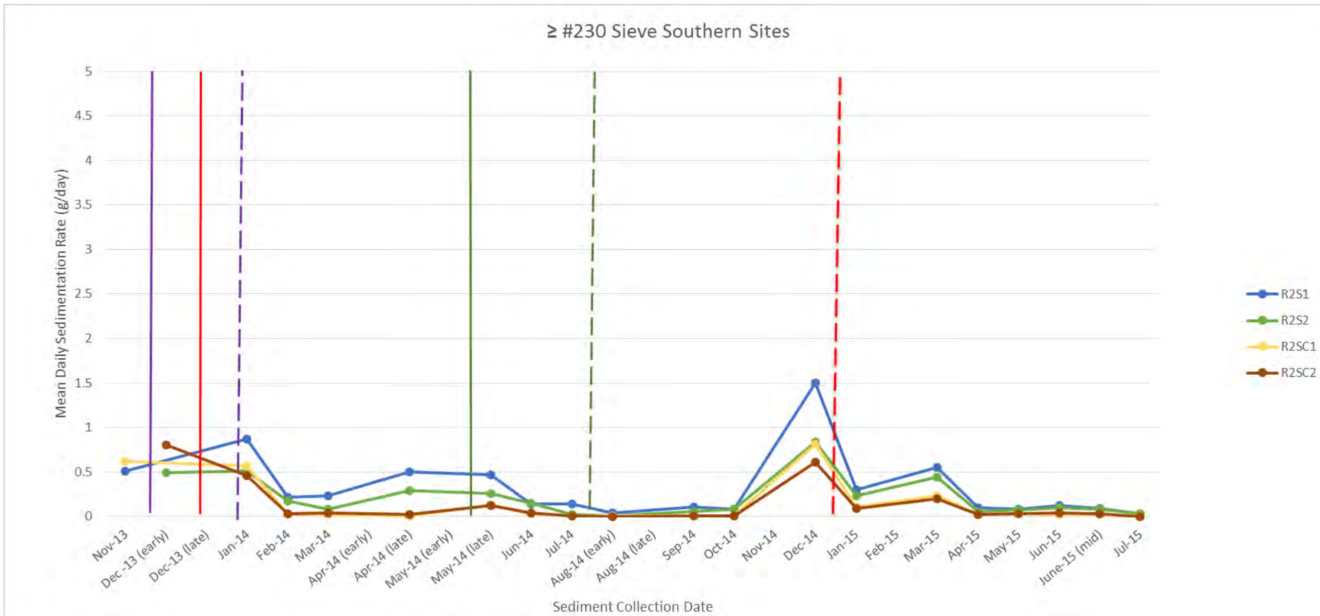

Figure 100. Daily sedimentation rates at southern middle reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R2S2 and R2SC2 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

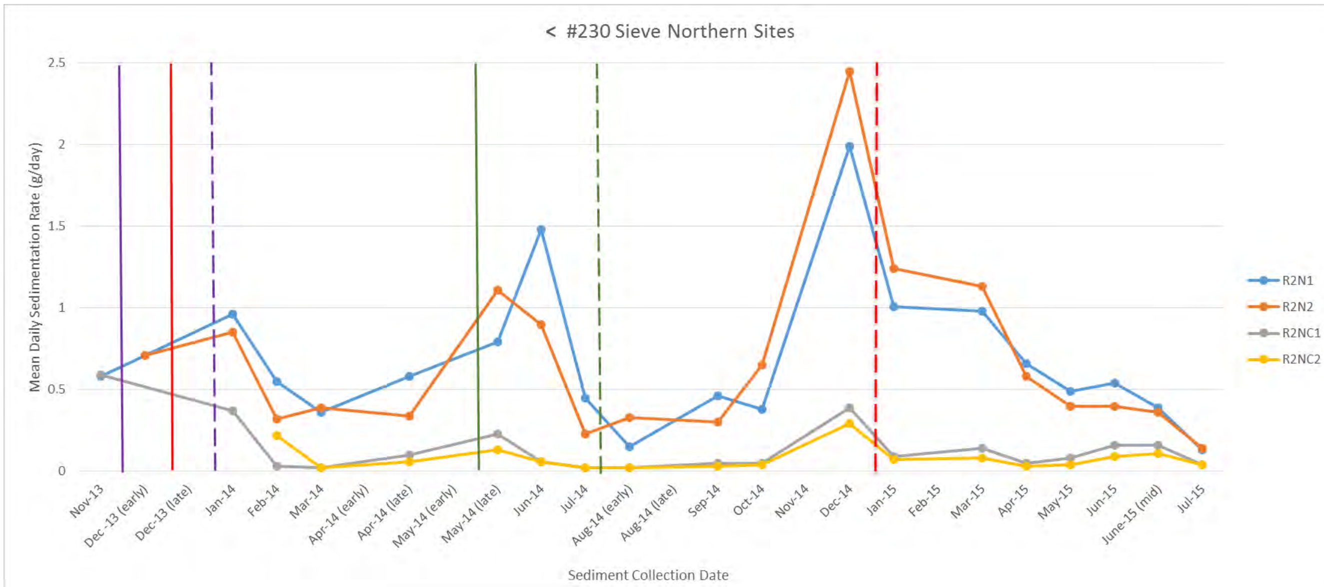

Figure 101. Daily sedimentation rates at northern middle reef sites for fine-grain sediment (< #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R2N2 and R2NC2 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

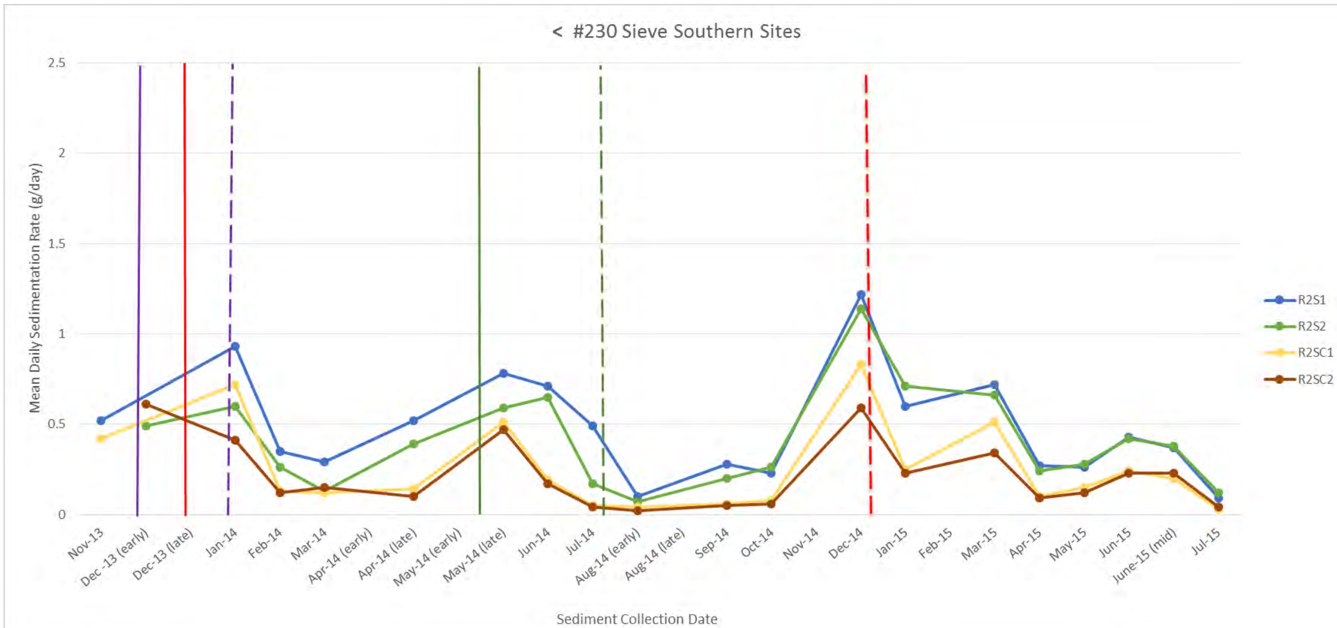

Figure 102. Daily sedimentation rates at southern middle reef sites for fine-grain sediment (< #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R2S2 and R2SC2 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

3.5.2 Outer Reef

Sediment samples were collected from the sediment traps at each transect at the end of the baseline survey period or when weather conditions permitted safe scientific dive operations (26 to 75 days after sediment bottles were placed on site). Coarse-grain sedimentation rates (g/day) were highest at R3N1-LR (0.09 g/day) and lowest at R3S2-LR and R3S3-SG (0.04 g/day) during baseline. Fine grain sedimentation rates ranged from 0.07 g/day (R3NC1-LR and R3S3-SG) to 0.17 g/day (R3SC1-CP).

Dredging had already started near hardbottom sites when baseline surveys commenced at outer reef sites, and when sediment bottles were placed and collected. While the sedimentation rates were not as high as at middle reef sites during baseline, it is likely that the dredge activities contributed to the sedimentation rates seen at outer reefs at that time. Nevertheless, sedimentation rates were high at all three south control sites for both coarse and fine-grain sediments, so it is also likely that different hydrodynamics and transportation may affect outer reef sites when compared to middle reef sites.

During post-construction surveys, the sedimentation rates of both coarse-grain and fine-grain sediments were lower. Coarse-grain sedimentation rates were highest at R3N1-LR (0.08 g/day), and lowest at R3NC1-LR (0 g/day) (Figure 103). Fine-grain sedimentation rates ranged from

0.02 g/day to 0.05g/day (Figure 104). During post-construction, 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-CP which interestingly had similar coarse grain sedimentation rates in baseline and post-construction survey periods.

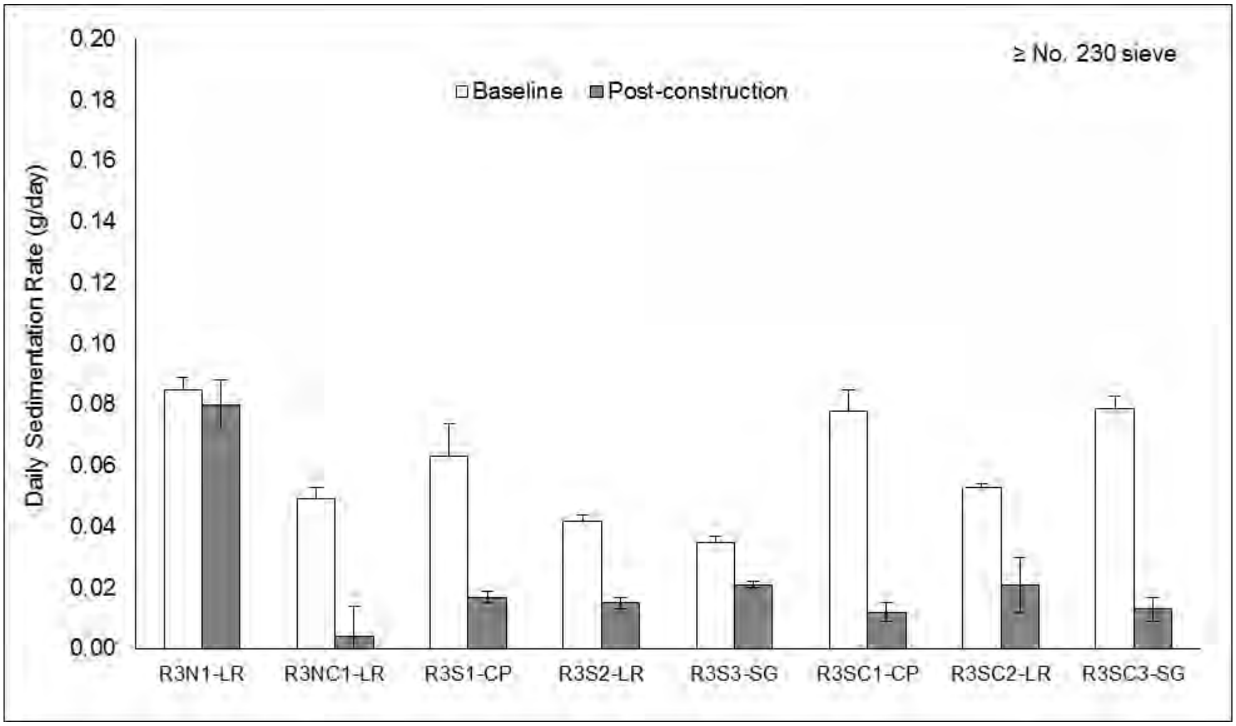

Figure 103. Daily sedimentation rates at outer reef sites for coarse-grain sediment (≥ #230 sieve) during baseline and post-construction surveys. Error bars represent the standard error.

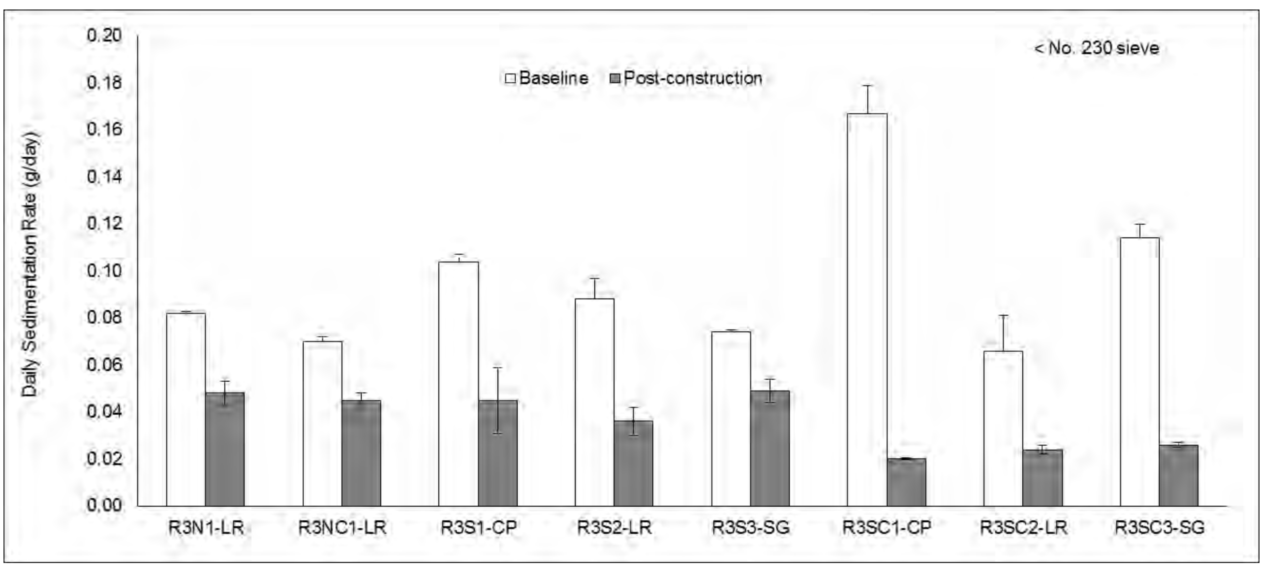

Figure 104. Daily sedimentation rates at outer reef sites for fine-grain sediment (< #230 sieve) during baseline and post-construction surveys. Error bars represent the standard error.

Average sedimentation daily rates for the project were tabulated and presented here for each site, from baseline through post-construction. Dredges Texas, Terrapin Island and Liberty Island conducted dredging operations offshore from November 2013 to December 2014 (Table 65). The clamshell Dredge 55 worked intermittently offshore between January and March 16, 2015. Vertical lines represent the start of dredging and the last days of dredging offshore for the Dredge Texas, Terrapin Island, and Liberty Island (Figures 105-108).

Between baseline and post-construction, 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 (Figures 105-108). Sedimentation rates for coarse grain sediment were elevated in August 2014 at the northern channel-side site, in August and December 2014, and in March 2015 for fine grain sediments. Dredging activities in the outer reef area during the summer of 2014 likely caused the spike of mean daily sedimentation rate at the northern channel-side site. Sedimentation rates decreased following the repositioning of the dredges in inside areas, and mean daily rates at channel-side sites have virtually matched the rates of the northern control sites since April 2015.

Sedimentation rates at southern channel-side sites were not as elevated as the northern sites, and the trends at channel-side sites closely matches the trends at the control sites. Rates of coarse-grain sediments did not exhibit any drastic increases throughout compliance monitoring, and mean daily sedimentation rates remained between 0 and 0.2 g/day. Fine-grain sedimentation rates were elevated during the winter months, from October 2014 through March 2015. Similarly, to the middle reef southern sites, the channel-side sites and controls sites followed the same trend during every collection period. It is possible that different natural sand movement and hydrodynamic patterns are in play at the southern outer reef sites. Table 14 shows the start and stop dates of dredges working on the project. The clamshell Dredge 55 is not displayed, but only worked offshore in early 2015 doing spot clean-ups. All offshore dredging was completed by March 16, 2015. The completion of dredging offshore was accepted by the USACE on April 8, 2015.

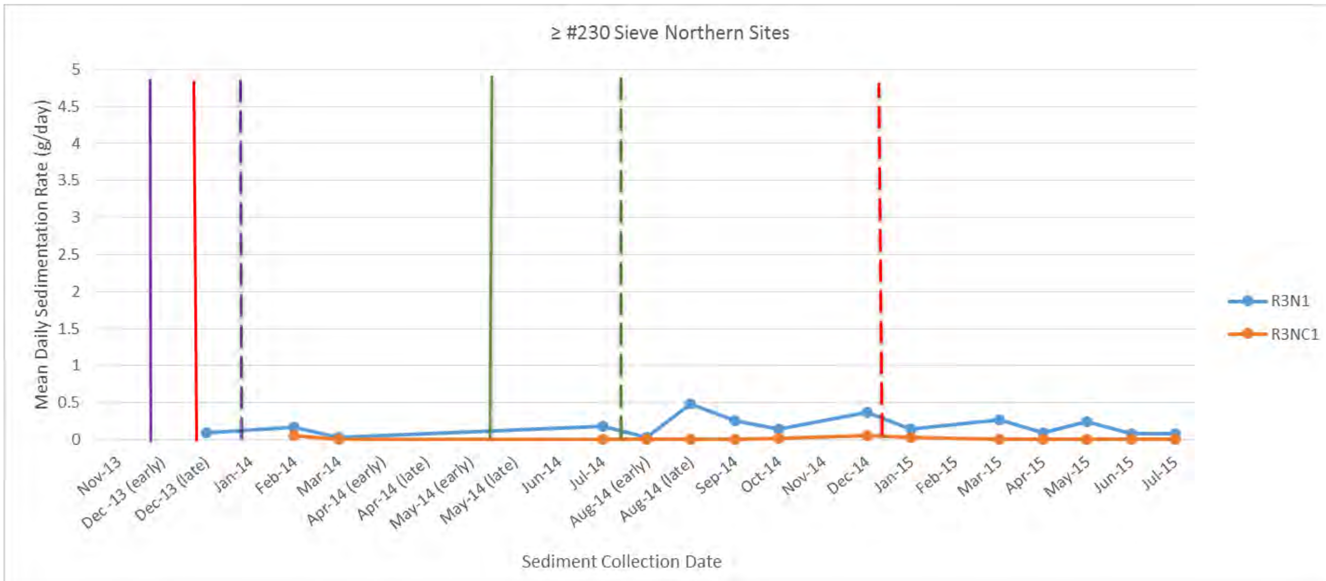

Figure 105. Daily sedimentation rates at northern outer reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R3N1 and R3NC1 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

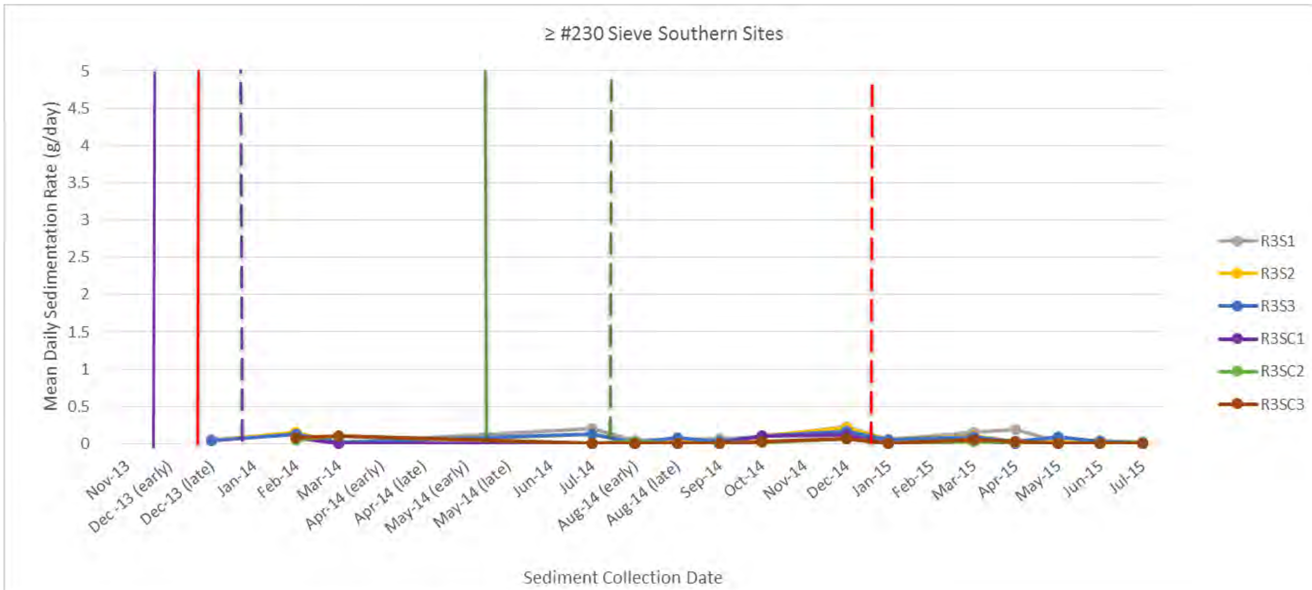

Figure 106. Daily sedimentation rates at southern outer reef sites for coarse-grain sediment (≥ #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from all southern outer reef due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

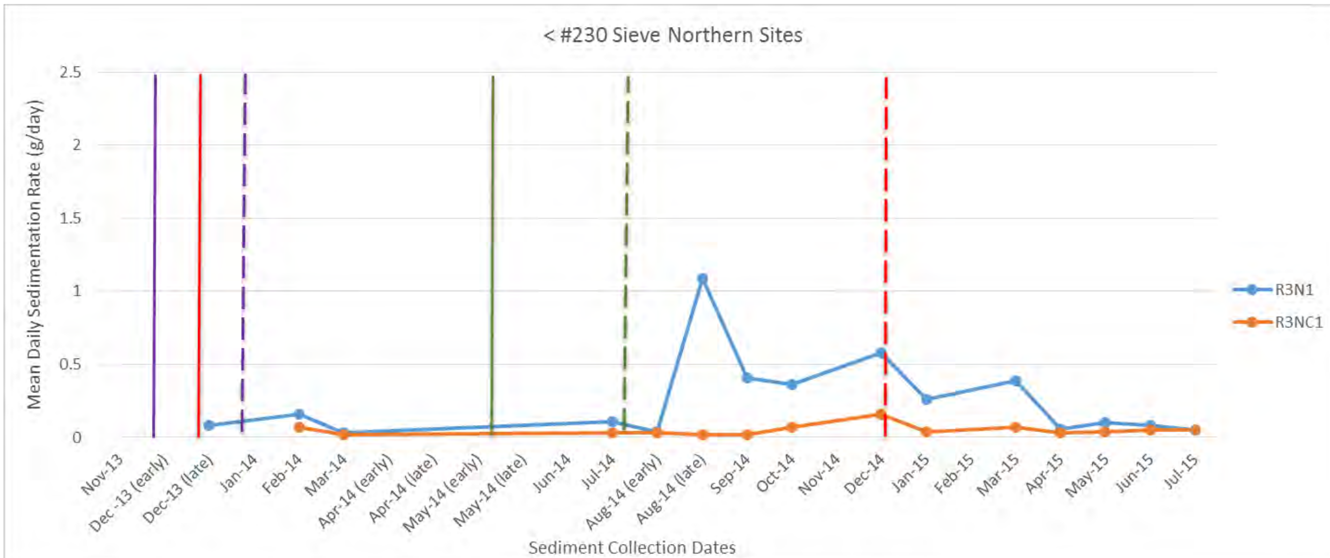

Figure 107. Daily sedimentation rates at northern outer reef sites for fine-grain sediment (< #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from R3N1 and R3NC1 due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

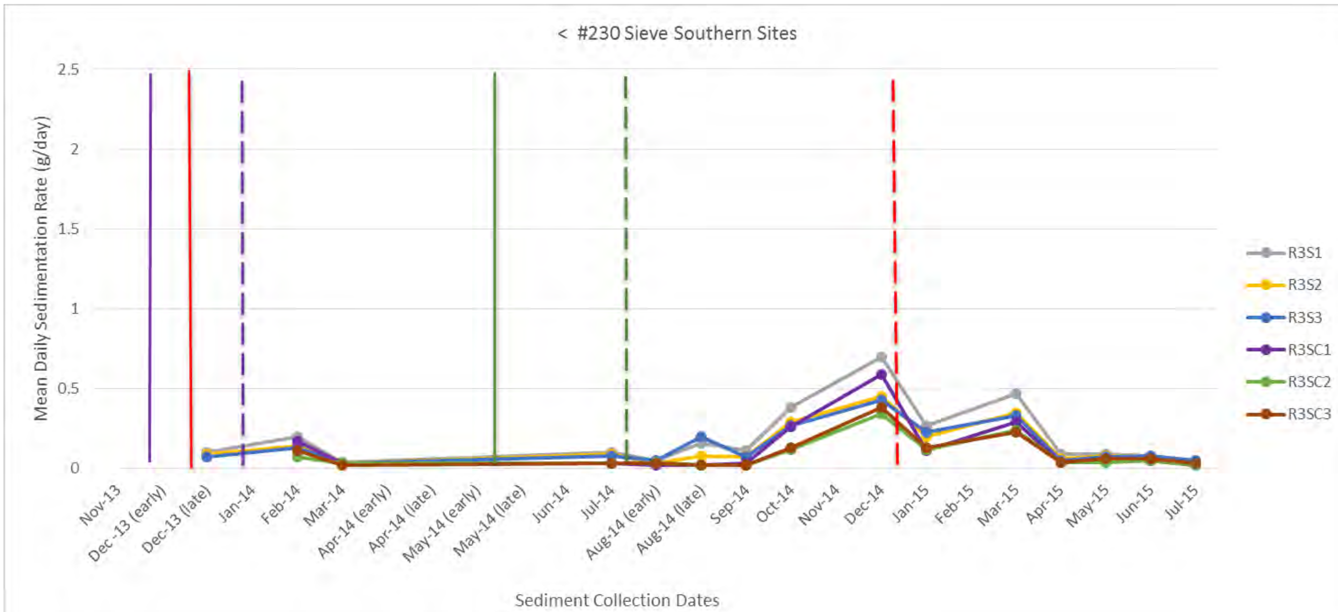

Figure 108. Daily sedimentation rates at southern outer reef sites for fine-grain sediment (< #230 sieve) from baseline through post-construction surveys. The solid purple line on November 20, 2013 represents the first day of dredging by the hopper dredge Terrapin Island. The solid red line represents the first day of 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). Sediment samples were not collected, until after the commencement of dredge operations, from all southern outer reef due to environmental conditions that created unsafe diving conditions as well as hazardous conditions that prevented safe passage to the sites.

4.0 SUMMARY

Baseline surveys established information on the population dynamics, condition and sedimentation environment of the benthic communities adjacent to the Federal Navigation Channel. These baseline results were used as a point of comparison for the post-construction survey period to document changes attributable to dredging while considering other environmental or anthropogenic factors that influence middle and outer reef resources in the area. Comparisons between baseline and post-construction benthic habitats documented changes in middle and outer reef benthic habitats. Changes in the benthic habitats were attributable to a number of factors, including both natural environmental perturbations and project related activities.

The greatest project related effects documented at the end of post-construction surveys at FDEP monitoring sites in the middle and outer reef habitat were the mortality of 5 tagged coral colonies at channel-side sites, or 1.25% of tagged colonies across all middle and outer reef sites. Total scleractinian colony mortality due to sedimentation occurred at one middle reef channel-side site (R2N2-LR, 2 colonies; 8.3% of all tagged colonies) and at one outer reef channel-side site (R3N1-LR, 3 colonies; 14.3% of all tagged colonies). No total colony mortality associated with sedimentation occurred on the south side of the middle or outer reef sites nor at any of the north or south control sites. However, partial mortality due to sediment (PM) was recorded on 34% of all scleractinian corals at middle and outer reef sites (137 out of 400) during compliance and/or post-construction monitoring. The majority of corals affected by sediment-related partial mortality were at channel-side sites, although some partial mortality did occur at control sites. Across the middle reef sites, R2N1-RR recorded the highest percentage of corals affected by partial mortality due to sediment (93%), R2N2-LR, R2S1-RR and R2S2-LR all exhibited the next highest percentage of corals with sediment-related partial mortality (63%). The two north control sites (R2NC1-LR and R2NC2-RR) had the lowest percentage of corals affected by sediment-related partial mortality (7%). The two south control sites had 30% (R2SC1-RR) and 8% (R2SC2-LR) of corals affected by sediment-related partial mortality. At the outer reef sites, more than 70% of all tagged corals at R3N1-LR exhibited partial mortality due to sediment, while R3NC1-LR had 29% of corals affected by sediment-related partial mortality. The south side of the channel at the outer reef sites exhibited less sediment-related partial mortality when compared to the north channel-side outer reef site. R3S2-LR had the lowest percentage with only 4% of corals with partial mortality due to sediment, while R3S1-CP and R3S3-SG had percentages of 42% and 36% respectively. R3SC2-LR had the lowest percentage of partial mortality due to sediment (0%) among the south controls while R3SC1-CP (17%) and R3SC3-SG (13%) exhibited higher percentages.

As a result of the FDEP mandated monitoring program natural and project related effects on benthic communities were discerned. In the summer of 2014, a significant regional bleaching event was detected at control and channel-side sites. Shortly after the bleaching event, a white-plague disease event began to affect coral colonies (September 2014), starting at southern control sites on the middle reef. The white-plague outbreak continued to affect control and channel-side sites through 2015. These regional influences had a much greater effect on scleractinians within channel-side and control sites, when compared to the project-related impacts. White-plague disease was widespread across all middle and outer reef compliance monitoring and control sites except for R3N1-LR. White-plague accounted for 84% of the total scleractinian mortality at the channel-side sites and 86% at the control sites. The south channel-side and control sites of the middle reef exhibited the highest coral mortality count associated with white-plague. R2S2-LR had the highest percentage of mortality where 46% of tagged corals succumbed to the disease. R2SC2-LR had the next highest percentage of 44% while R2S1-RR and R2SC1-RR had coral mortality associated with white-plague of 26% and 27% respectively. R2N1-RR had the highest percentage of coral mortality at the north channel-side sites with 40%. When compared to R2N2-LR, R2NC1-LR, and R2NC2-RR which had relatively low mortalities of 8%, 11% and 7% respectively.

The south channel-side and control sites of the outer reef exhibited the highest percentage of mortality associated with white-plague. White-plague mortality at the south channel-side sites ranged from 12% (R3S2-LR) to 26% (R3S1-CP). The south controls had higher percentages of mortality ranging from 8% (R3SC1-CP) to 40% (R3SC2-LR). R3N1-LR did not have any documented coral mortality associated with white-plague; however, R3NC1-LR had 25% of tagged corals exhibit mortality due to white-plague. When considered in a regional context, white-plague mortality appeared to be greatest south of the channel, but has spread to channel-side environment and areas north. In general terms, the middle reef sites (Reef 2) had the highest numbers of white-plague disease-susceptible species and thus, had the highest mortality (as compared to the nearshore hardbottom or outer reef sites).

A significant decrease in mean scleractinian coral density occurred channel-side at R2N1-RR, R2S1-RR, and R2S2-LR. R2N1-RR experienced the greatest decrease in mean density from 1.37 to 0.73 colonies/m^2. At the middle reef control sites mean coral density significantly declined at R2NC2-RR where mean density declined from 1.61 to 1.05 colonies/m^2 (P = 0.0289).

The causes of changes in mean coral density between baseline and post-construction cannot be determined for untagged corals. However, the majority of tagged corals at middle reef sites have died as a result of white-plague disease between baseline and post-construction surveys. At R2N1-RR, R2S1-RR, and R2NC2-RR, the only source of total colony mortality in tagged corals documented during construction or post-construction was due to white-plague disease. At R2S2-LR of the twelve tagged corals that have died during construction and post-construction monitoring one coral died from bleaching and disease and the remaining eleven died from documented white-plague disease.

Octocoral abundance declined at six out of nine middle reef sites, four of these sites were channel-side sites, and two were control sites. 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 post-construction assessment periods. Mean density was not significantly different when assessed for period and site interaction. During the post-construction period, as in the baseline period, sites were significantly different from each other. Octocoral abundance at the outer reef declined at one channel-side site (R3N1-LR; 1.03 to 0.75 colonies/m^2), but this decline was not statistically significant. All other outer reef sites increased in octocoral density between baseline and post-construction periods, at R3NC1-LR, this increase was statistically significant. In order to better understand effects on octocorals or any other benthic organism of interest, individuals must be tagged and followed through time in order to separate project related and regional impacts.

Sponge abundance and density declined at six out of nine middle reef sites. A two-way repeated measures ANOVA indicated that five of the nine sites had significant differences of mean sponge density. A significant increase in mean density occurred at R2SC1-RR, where mean density more than doubled from 2.82 to 5.67 individuals/m^2. Significant decreases were detected at R2N2-LR, R2NC2-RR, R2NC3-LR, R2SC1-RR and R2SC2-LR. R2N2-LR experienced the greatest decrease in sponge density, with a decrease of 10.3 individuals/$m^{2.}$ On the outer reef, all sites, except for R3N1-LR, increased in sponge density between baseline and post-construction periods. The post-hoc comparison of mean density among individual sites between baseline and post-construction indicated four of the eight sites had significant differences of mean sponge density. The four sites: R3NC1-LR, R3S1-CP, R3SC1-CP, and R3SC2-LR all had significant increases in mean sponge density (Figure 70). R3S1-CP experienced the smallest increase of 2.3 individuals/m^2, and R3NC1-LR had the greatest increase in density with 8.73 individuals/m^2 more than the baseline assessment period. Only R3N1-LR exhibited a decline in sponge density from the baseline assessment period, but this change was not significantly different. In order to better understand effects on sponges or any other benthic organism of interest, individuals must be tagged and followed through time in order to separate project related and regional impacts.

Functional group data, analyzed from video transect footage, including octocorals, scleractinians, and sponges changed little between baseline and post-construction, although groups varied over time during compliance monitoring. Due to the low cover of living functional groups, *in situ* colony counts are recommended for a more accurate and precise measurement of organismal change at the level of the transect and site, in the future. Functional groups data including CTB and sand varied widely throughout the compliance period as well. Increased sand was documented during construction monitoring, however, based on the post-construction video dataset analysis CTB appeared to be increasing at most middle and outer reef sites since

February 2015, which would be expected as any local increases in sediment are assimilated into the benthos over time

Sedimentation flux was calculated (daily rates) using sediments collected in traps at all reef sites, in compliance with the FDEP permit. Average sedimentation rates varied depending on reef (middle or outer)), side (north or south),) of the channel, and grain size (greater than #230 sieve; less than #230 sieve). These rates reflected seasonal variation in sediment transport as well as proximal sources of sedimentation (i.e. location relative to active dredging equipment). In general, sedimentation rates were greater at middle reef sites when compared to outer reef sites. Sedimentation rates were greater on the north side of both the middle and outer reefs. Dredging activity likely elevated sedimentation rates during the project, however, winter weather also increased sedimentation rates at both channel-side and control sites. Sedimentation rates were lower during post-construction surveys than during baseline for both coarse and fine grained sediments. These changes in sedimentation rates may represent a seasonal difference, as baseline data were collected in the fall/winter when winds and waves re-suspended sediments, compared with summer conditions, which were relatively calm and had lower suspended solids.

Because of a number of factors, benthic communities changed over time at the middle and outer reef sites (both channel-side and controls). As such, the monitoring program and collected data were unable to validate the null hypothesis for the benthic communities at these sites. Both natural and project related impacts were observed to be important, however, the greatest impacts associated with coral mortality over time appear to be related to a catastrophic, regional-scale coral bleaching/disease outbreak that started in the fall of 2014 and continues to deleteriously affect coral populations at the time of this writing (fall 2015).

Recommendations

Consider regression based study design to document project effects over a greater spatial extent rather than monitoring at only project-adjacent and control sites. This would provide a more complete understanding of project related effects throughout the monitoring time period.

For diver safety consider locating project adjacent sites no closer than 30m to project related activities.

Provide more detailed baseline information for a greater area than 150m away from the project location, so that project related effects can be measured.

Consider repeated measures to look at all representatives of community (i.e. corals, octocorals, and sponges) to differentiate project and regional effects.

Continuous weekly monitoring of resources from baseline through post-construction would provide information on how organism stress abates when construction is not present. In addition, continual monitoring would decrease the number of individuals assigned mortality of unknown cause.

Integration of real-time aerial (satellite) imagery of sediment plumes, in-water turbidity monitoring of these plumes, and *in-situ* sediment deposition monitoring (concentrations of TSS) on the benthic community associated with dredging operations, during construction. This will allow for concentrating field efforts to determine if certain areas are being unduly impacted by sediment fallout above levels that may be considered stressful to the benthic communities in the project area. Real-time adaptive management would be seamless with these data available to both the project team and regulators.

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