Benthic Community Reconnaissance Survey

Port Everglades Navigation Improvements Project

FINAL REPORT

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Prepared for:
David Miller and Associates
130 Park Street SE, Suite 350
Vienna, VA 22180

and

Broward County
Port Everglades Department
1850 Eller Drive
Fort Lauderdale, FL 33316

and

Jacksonville District
US Army Corps of Engineers
701 San Marco Blvd.
Jacksonville, FL 32207

Prepared by:
Dial Cordy and Associates Inc.
1011 Ives Dairy Road, Suite 210
Miami, FL 33179

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1.0 INTRODUCTION

On July 26th, 2016 an Interagency Working Group (IWG) was created to evaluate and minimize potential environmental impacts from the Port Everglades Navigation and Improvements Project (PENIP). The IWG includes representatives from the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), NMFS, Florida Department of Environmental Protection (FDEP), Florida Fish and Wildlife Conservation Commission (FWC), Broward County Environmental Protection and Growth Management Department (EPGMD), and Port Everglades. On March 27, 2017, the IWG approved the *Reconnaissance Survey Protocol Port Everglades Navigation Improvements Project* (Appendix A). This plan provided the agreed upon study objectives and survey methods.

On June 13, 2017, Dial Cordy and Associates (DCA) was contracted by David Miller and Associates (DMA), under contract with the Broward County Port Everglades Department, to implement the *Reconnaissance Survey Protocol Port Everglades Navigation Improvements Project* (Appendix A) and prepare this report. Following site visits by IWG members, an addendum was submitted and adopted on September 20, 2017 that amended the final survey protocol (Appendix A). The following report details the results of the reconnaissance survey.

1.1 Survey Objectives

The objective of the survey was to obtain information on benthic natural communities for continued project planning and Florida Department of Environmental Protection (FDEP) state permitting, for the area surrounding the existing Port Everglades entrance channel. The main focus was the area in and within 150 m (492.13 ft) of the proposed limits of the entrance channel. This 150 m (492.13 ft) area is also known as the “mixing zone” and is the area identified by the Army Corps of Engineers (USACE), through the National Environmental Policy Act (NEPA) process, to be the area of potential direct (area of deepening and widening of the channel) and indirect impact (area surrounding the channel expansion out to 150 m (492.13 ft)) predicted to occur due to the deepening and widening of the Outer Entrance Channel (OEC) (USACE 2015).

The survey findings will be used in determining the following:

a) Amount of compensatory mitigation required to offset impacts
    i) Uniform Mitigation Assessment Method ((UMAM)(62-345, Florida Administrative Code (F.A.C.)))
    ii) Current condition of resources (373.414(1)(a)(7), and 373.414(18), Florida Statute (F.S.))
b) Mitigation Plan (373.414, F.S.)
    i) Establish a reference dataset to set success criteria
    ii) Determine appropriate enhancement activities (e.g., nurseries and out-planting).
c) Impact Minimization (FDEP Environmental Resource Permit (ERP) Applicant’s Handbook, Vol. 1, 10.2.1)
    i) Distribution and abundance of benthic organisms (not limited to corals)
    ii) Relocation of benthic organisms out of the predicted impact area
d) Provide data inside and outside of the 150 m (492.13 ft) mixing zone to characterize habitats for Essential Fish Habitat (EFH) consultation with National Marine Fisheries Service (NMFS) and supplemental NEPA determinations.

e) Document any seagrasses present along transects.
f) Inform the design of future surveys, including pre-construction, construction, and post-construction.

1.2 Spatial Extent of Reconnaissance Survey

The spatial extent of the survey area included the 150 m (492.13 ft) indirect impact area (mixing zone) north, and south, of the proposed channel. The USACE agreed in the final Environmental Impact Statement (EIS) to provide up-front mitigation for the areas to be newly dredged and for the mixing zone area. This area covers potential dredge and dredge support vessel anchoring areas outside of the dredge footprint. Additional survey areas outside of the mixing zone were also added to the March, 2017 reconnaissance protocol within the Endangered Species Act (ESA) study area boundary as requested by NMFS for EFH consultation purposes (referred to as the EFH zone), and for additional information regarding habitats further from the channel for the supplemental NEPA effort. To assist in characterizing this larger area, 25 additional transects were added to the survey protocol for a total of 195 sites (Figure 1). The number of sites surveyed in each of the specific reef tracts, habitats, and their location north/south of the channel are provided in Table 1. In accordance with the IWG, the benthic communities to the south of the channel were previously characterized (see NSU 2011) and were therefore not included in the current sampling effort. Descriptions of the surveyed habitats are provided in Section 3.1.

For the resources within the proposed channel expansion footprint (direct impact areas and downslope areas) that were not surveyed due to concerns regarding diver safety, data collected within the adjacent habitat type was used to estimate current condition. Data collected from the northern side of the channel was used to estimate current condition of the outer reef direct impact area (IWG 2017).

1.3 Reconnaissance Survey Assessment Areas

Survey areas were determined by habitat type, using the Walker and Klug 2014 data set, based on direction from the IWG. Within the mixing zone there were eight (8) habitat types north and nine (9) habitat types south of the channel that were surveyed. Habitat types on the north side included: artificial (AR), colonized pavement (CP) shallow; linear reef (LR) inner, linear reef middle, colonized pavement deep, linear reef outer, spur and groove (SG), and aggregated patch reef (PR) deep. Habitat types on the south side included: ridge reef (RR) shallow, colonized pavement shallow, artificial, linear reef inner, linear reef middle, colonized pavement deep, linear reef outer, spur and groove, and aggregated patch reef deep. The eastern most habitat type, outer ridge deep, was not surveyed (IWG 2017). Descriptions of all surveyed habitats, including representative photos are provided in Section 3.1.

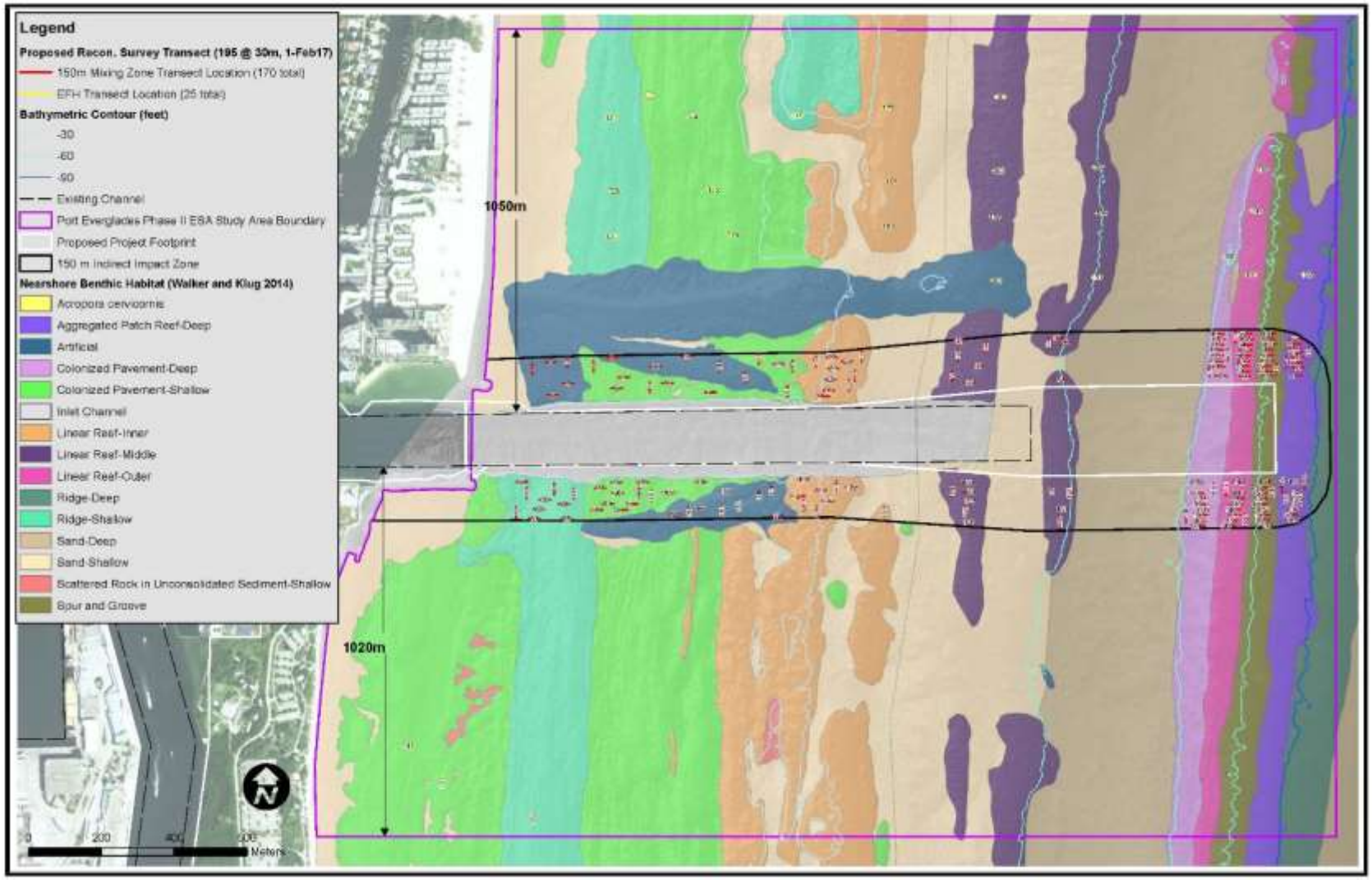

Figure 1. Reconnaissance Survey Transect Locations

Table 1. Number of sites surveyed per reef type, habitat, and side of channel.

Reef	Habitat	Area	Side of Channel	Total Sites
Hardbottom & Inner	Artificial (AR)	150-m Mixing Zone	North	10
			South	9
		EFH	North	0
			South	0
	Colonized Pavement (CP)	150-m Mixing Zone	North	10
			South	12
		EFH	North	3
			South	2
	Linear Reef (LR)	150-m Mixing Zone	North	10
			South	9
		EFH	North	3
			South	0
	Ridge Reef (RR)	150-m Mixing Zone	North	0
			South	10
		EFH	North	4
			South	1
	Nearshore Hardbottom and Inner Reef Total			**83**
Middle	Artificial (AR)	150-m Mixing Zone	North	0
			South	0
		EFH	North	1
			South	0
	Linear Reef (LR)	150-m Mixing Zone	North	10
			South	10
		EFH	North	6
			South	0
	Middle Reef Total			**27**
Outer	Aggregated Patch Reef (PR)	150-m Mixing Zone	North	10
			South	10
		EFH	North	1
			South	0
	Colonized Pavement (CP)	150-m Mixing Zone	North	10
			South	10
		EFH	North	1
			South	0
	Linear Reef (LR)	150-m Mixing Zone	North	10
			South	10
		EFH	North	3
			South	0
	Spur and Groove (SG)	150-m Mixing Zone	North	10
			South	10
		EFH	North	0
			South	0
	Outer Reef Total			**85**

2.0 METHODS

2.1 Reconnaissance Surveys (DCA 2017 Recon Survey)

This survey implemented the project-specific methodology and site locations approved by the IWG in the *Reconnaissance Survey Protocol Port Everglades Navigation Improvements Project* (Appendix A) at 170 transects located within the mixing zone (Table 2), and 25 EFH transects (Table 3) as defined in the protocol (IWG 2017). Transects were randomly stratified in each habitat type within a buffered area. In ArcView GIS a 10 m (32.80 ft) buffer area was established for each habitat type, so no transect would be closer to a habitat boundary than 10 m (32.80 ft), including a transition from reef to sand. Also, a 10 m (32.80 ft) boundary was applied to transects, so no transects touched or overlapped one another. An additional 25 transects were placed outside of the mixing zone to provide additional information for EFH consultation (Table 3). As a result, a total of 195 transects were surveyed under this protocol. Based upon bathymetry data, the 195 proposed transects were in depths from 3.35 - 26.21 m (11-86 ft). There were 65 transects in 3.35 - 8.84 m (11-29 ft), 85 transects in 9.14 - 17.98 m (30-59 ft), and 45 transects in 18.23 - 26.21 m) (60-86 ft). The same methods were used for all 195 transects. The results for all transects are included in this report. GPS coordinates for all transect origins and ends are provided in Appendix B.

Table 2. Port Everglades reconnaissance survey sampling design for transects within 150-m mixing zone.

	Port Everglades Reconnaissance Survey Plan
Number of transects	170
Number of quadrats per transect	7
Area per quadrat (m^2)	0.5
Area sampled in quadrats per transect (m^2)	3.5
Area sampled in belt per transect (m^2)	30
Total area sampled in quads (m^2)	595
Total area sampled in belt (m^2)	5,100
Acres of reef within mixing zone	130.6
Reef (m^2) area within mixing zone*	528,644.9
% of area sampled with quads	0.11
% of area sampled with belt	0.96

*** For the deep ridge habitat type, data from Dodge et al. (2001) was reviewed and synthesized into the report.**

Table 3. Port Everglades reconnaissance survey sampling design that was used to characterize the reef habitats more distant from the channel.

	Port Everglades Reconnaissance Survey Plan - EFH
Number of transects	25
Number of quadrats per transect	7
Area per quadrat (m^2)	0.5
Area sampled in quadrats per transect (m^2)	3.5
Area sampled in belt per transect (m^2)	30
Total area sampled in quads (m^2)	87.5
Total area sampled in belt (m^2)	750
Acres of reef within 1050x1020 m	695.5
Reef (m^2) area within 1050x1020 m*	2,814,783
% of area sampled with quads	0.003
% of area sampled with belt	0.027

*** For the deep ridge habitat type, data from Dodge et al. (2001) was reviewed and synthesized into the report.**

2.2 Transect Data Collection

Transects were oriented either north-to-south or west-to-east, unless extensive sand patches were located along these headings, in which case transects were oriented along a heading that maximized hardbottom habitat, per the *Addendum to the Port Everglades Navigation Improvements Project Reconnaissance Survey Protocol* (Appendix A). At each site, HYPACK navigational software was used to establish two anchors with attached surface buoys at the start and end coordinates of each transect. Divers equipped with compasses used these anchors as reference points when establishing the transect. The transect tape was laid out and oriented along a 90º or 180º heading, unless substantial sand was encountered. If sand was encountered, divers would re-orient the transect to avoid the sand patch, and the revised heading of the transect was recorded. The following data was collected along each transect line (Figure 2):

1. Downward-facing digital video was collected with the camera held 50 cm (19.69 in) above the bottom along the right side of the transect. No analysis of the video was required under the survey protocol. It should be noted that small organisms (<3 cm) (<.39 in) from this height may not be identifiable to species. Video was acquired at a rate of 5 m (16.40 ft) per minute to provide video that may be analyzed using Point Count, at a later date. A camera without distortion (i.e., without a fish-eye lens) was used to collect video.

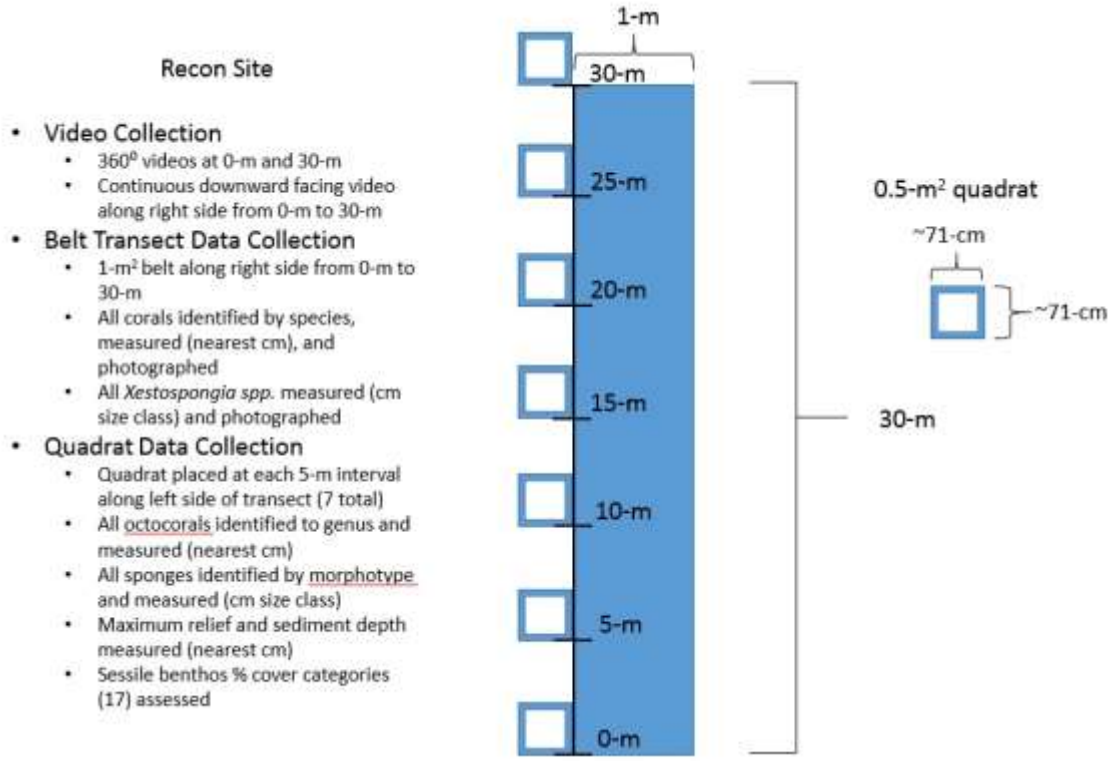

Figure 2. Diagram of 30 m reconnaissance transect area.

2. Panoramic (360º) video was collected at the start and end of each transect. Each video was taken at an angle of approximately 45º with respect to the horizon in order to assess sediment and substrate type. The downward facing and panoramic video from each site is available for viewing on the Benthic data viewer - http://bcgis.maps.arcgis.com/apps/View/index.html?appid=15d44b2af45945b5b61b777fd5361b76http://bcgis.maps.arcgis.com/apps/View/index.html?appid=15d44b2af45945b5b61b777fd5361b76

3. Representative photographs of each site were collected. Physical features, including sand patches and substrate type along the transect, were noted and photographed. Soft substrate categories included coarse sand, fine sand (mud-like), and mixed (coarse and fine) sand. Soft substrates were characterized visually and tactilely.

4. Belt transect data were collected within a 1 m (3.28 ft) wide belt along the right side of the transect (30-m^2). Belt transect data included:
   i. Coral identification by species, maximum dimension (cm), and count. Each coral was photographed with a scale bar.
   ii. *Xestospongia muta* count by size class (0-10 cm, 10.1–25 cm, 25.1–50 cm, >50 cm). (0-3.94 in, 3.98-9.84 in, 9.88-19.69 in, >19.69 in). Each sponge was photographed with a scale bar.
   iii. Habitat transitions were noted by divers.

5. Quadrat data were collected along the left side of the transect within seven (7) 0.5 m^2 (5.38 sf) quadrats (located at every 5 m (16.4 ft) interval starting at 0 m (0 ft)) for a total area of 3.5 m^2 (37.67 sf) per transect. Data collected within each quadrat included:

i. Percent cover by functional groups (simplified Benthic Ecological Assessment for Marginal Reefs) (BEAMR)) (Makowski et al. 2009). See Table 4 for list of functional groups.
ii. Octocoral identification by genus, maximum dimension (cm), and count.
iii. Sponge identification by morphology (*i.e.* encrusting, branching, tube/vase, massive/amorphous, and ball) and count by size class (0–10 cm, 10.1–25 cm, 25.1–50 cm, >50 cm) (0-3.94 in, 3.98-9.84 in, 9.88-19.69 in, >19.69 in).
iv. Maximum relief (cm) and maximum sediment depth (cm).
v. Planar photograph (*i.e.* birds-eye view) was taken of each quadrat.

Data sheet templates for the quadrat data and belt transect data are provided in Appendix C.

Table 4. Functional group data collected within reconnaissance survey quadrats as stipulated by FDEP.

Functional Groups to be Used (N=17):
Fine Sediment (mud-like)
Sandy Sediment (coarse)
Mixed Sediment (fine and sandy)
Bare Substratum
Seagrasses
Macroalgae (by family: red, brown, green)
Turf Algae
Turf Algae with Sediment
Crustose Coralline Algae (CCA)
Cyanobacteria
Sponges
Corals
Octocorals
Zoanthids
Hydrocorals
Sessile Worms
Other Invertebrates
-Anemones
-Bivalves
-Barnacles
-Bryozoans
-Tunicates

Prior to the start of data collection, scientific divers responsible for data collection conducted quality assurance and quality control (QA/QC) procedures to ensure minimal variability between data collectors for both belt and quadrat data. For the functional group data, QA/QC procedures were conducted to ensure a maximum deviation of 10% between data collectors. During the course of QA/QC, an additional functional group category (turf algae with sediment) was added. Data collectors decided this was a necessary category due to the presence of a high prevalence of turf algae laden with sediment at the majority of sites. Representative photographs of each functional group are shown in Figure 3. Sediment types were determined by previous guidelines set by FDEP which stipulated fine and sandy (coarse) sediment types must consist solely of that sediment type; any amount of fine or sandy sediment mixed in with an opposing type would be classified as mixed (Pers. comm. FDEP). Qualitative characterization of sediment types in the field has inherent difficulties due to the spectrum of grain sizes and the inter-observer variability between data collectors. Standardization of field methods for sediment characterization should be further examined.

On each transect, habitat transitions and substrate characterizations were noted by the belt transect data collector. Substrate characteristics and habitat transitions were determined and classified as either “hardbottom” or “sand” habitat types. Since hardbottom habitat includes a continuum of habitat (Kosmynin et al. 2016) from emergent hardbottom to rubble to sand veneer hardbottom with hardbottom organisms, any notes pertaining to rocks, rubble, boulders and/or hardbottom were categorized as “hardbottom.” Transect sections were only classified as “sand” when the recorded data was written as “sand” alone (i.e. sand, sand channel). Site videos and photos were also used to verify written observations. Percentages of sand and hardbottom were calculated for each transect and are provided in Appendix D.

2.3 Data Entry and QA/QC

Following the completion of each reconnaissance site, datasheets were QA/QC reviewed on the boat by qualified biologists that met IWG standards for scientific divers (IWG 2017). QA/QC procedures were completed to ensure all relevant fields on all datasheets were completed. Additionally, the QA/QC personnel would check that the functional group percent values for each quadrat summed to 100%. In the event that the functional group percent cover did not sum to 100%, QA/QC personnel would consult with the data collector and a correction would be made. QA/QC personnel initialed all datasheets once on-boat QA/QC procedures were complete.

Datasheets and secure digital (SD) cards containing photograph and video data were transported back to the DCA office where they were filed. Data were entered by transect into a master spreadsheet. Coral datasheets were compared to photos of the corals in the lab to ensure accuracy. Entered data was QA/QC reviewed by a second observer to minimize transcription errors. In the event that functional group percent cover values did not sum to 100%, and was not caught during the on-boat review process, the data collector would be contacted and provided with the functional group percent cover values and the photo of the corresponding quadrat in order to provide a correction. All emails regarding this correspondence were filed as part of the administrative record.

Following completion of data entry and data QA/QC, summary statistics were calculated for all reconnaissance data.

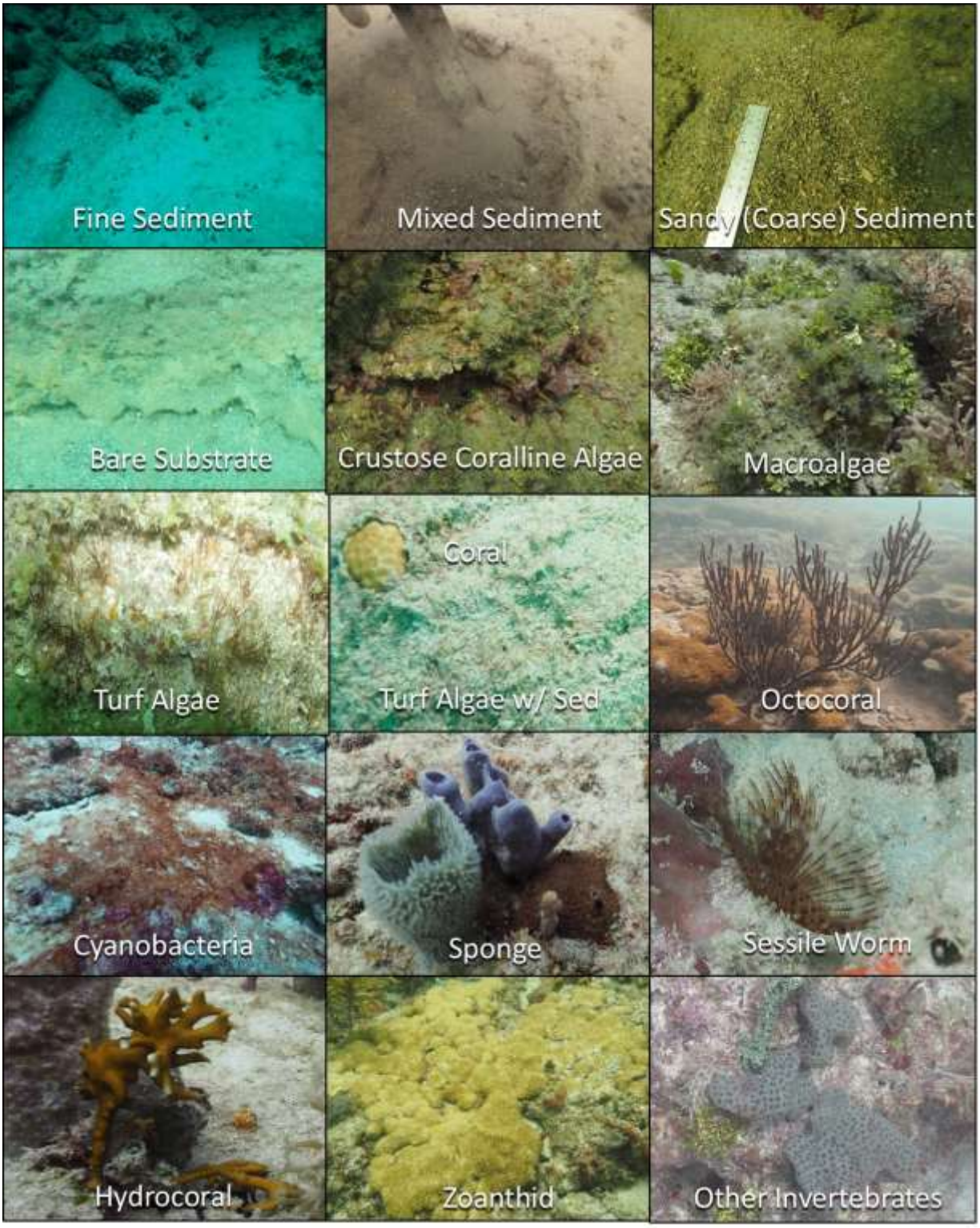

Figure 3. Representative photographs of reconnaissance functional groups. Note: seagrass was not observed at any reconnaissance sites so it is not shown here.

2.4 Addendum to Reconnaissance Survey Protocol

Following an *in-situ* review of surveys by the IWG, an addendum to the final survey protocol was submitted/adopted on September 20, 2017. During site visits conducted on July 18-19, 2017, IWG members observed some reconnaissance transects contained extensive sand features that were not previously identified at the time of site selection. Transect locations had originally been established using the best information available at the time the survey protocol was approved by the IWG in March 2017 (*i.e.* a regional map of benthic habitats with a minimum mapping unit of 0.10 hectare (ha) (0.25 ac) produced by Walker and Klug, 2014) (Figure 4). The current transect locations were overlaid on the NOAA, National Ocean Service, Bathymetric Attributed Grid (BAG) as well as the Walker and Klug (2014) (accuracy ~0.10 ha (0.25 ac)) maps modified with the groundtruthed draft (as of August 8, 2017) side scan sonar interpretation (accuracy ~0.1 acre) of benthic habitats (sand vs hardbottom) (Figure 5), which was produced by DCA. Due to revised habitat boundaries and previously undocumented sand patches, it was determined the locations of a subset of transects should be revised. Specifically, transect locations were modified to ensure transects were within the hardbottom and coral reef habitat types they were intended to characterize and to omit areas of probable sand features.

A total of 15 transects were identified as likely to contain sand features based on the side scan data and previous site visits (39, 40, 50, 72, 73, 74, 75, 76, 77, 78, 80, 131, 163, 170, and 181). The following process was used to modify the locations of these 15 transects prior to resurveying:

1. The transect was shifted north, south, east, or west the minimum distance necessary to ensure the transect was entirely within the intended habitat and did not include any mapped sand features;
2. If shifting the transect north, south, east or west did not result in the transect being entirely within the intended habitat (due to constraints such as the habitat boundary and adjacent transects), the orientation of the transect was changed (i.e. from west-to-east, north-to-south, etc.);
3. If the steps above (alone or in combination) did not result in the transect being entirely within the intended habitat, the transect was relocated to the closest area within the habitat that did not currently contain transects or mapped sand features. The BAG data was used to ensure the transect was positioned in a manner that maximized the likelihood it would be entirely within the intended habitat type and not include any sand features.

The locations of the original and revised transects can be seen in Figures 6 – 9.

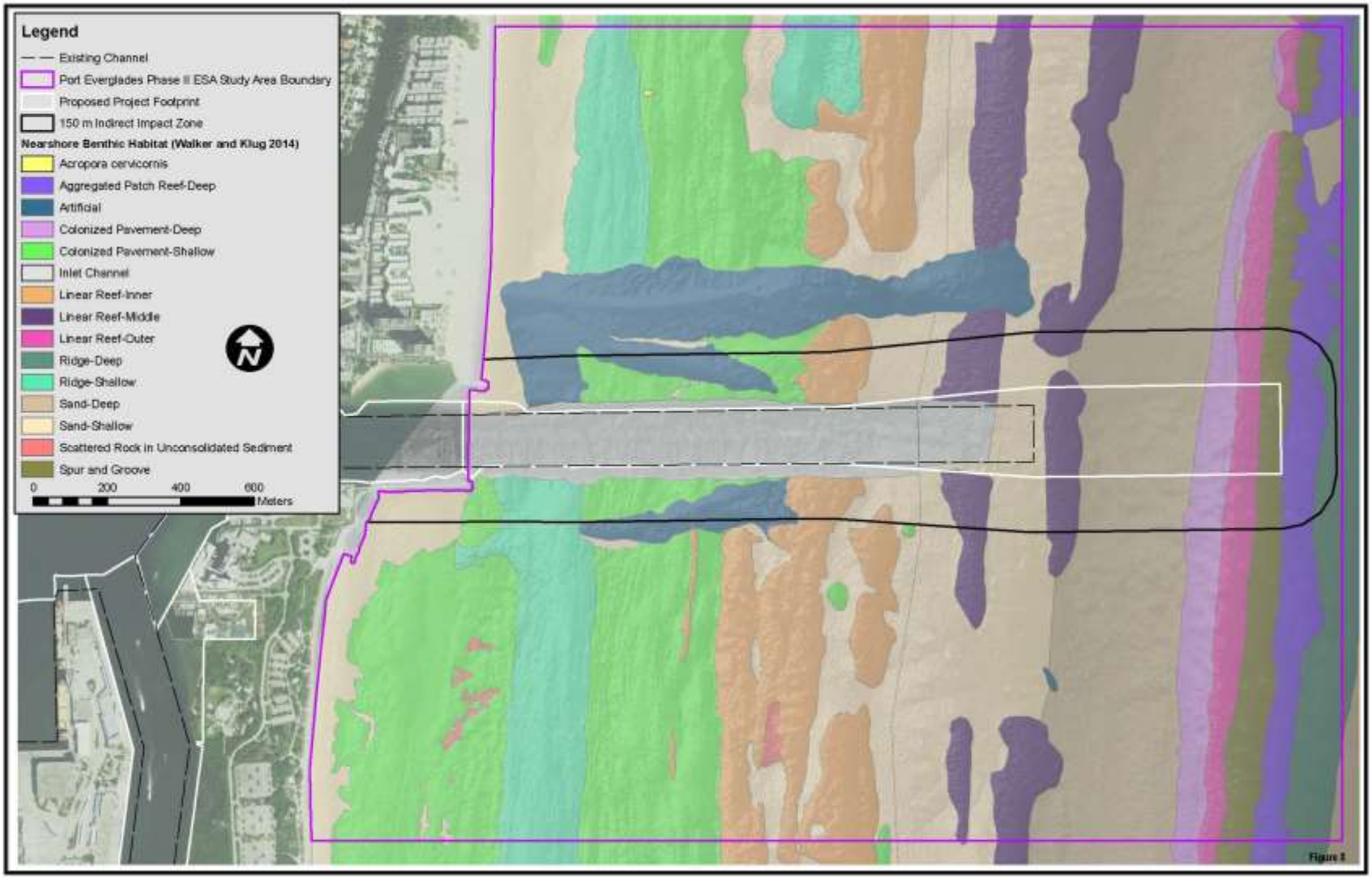

Figure 4. Walker and Klug (2014) benthic habitat map.

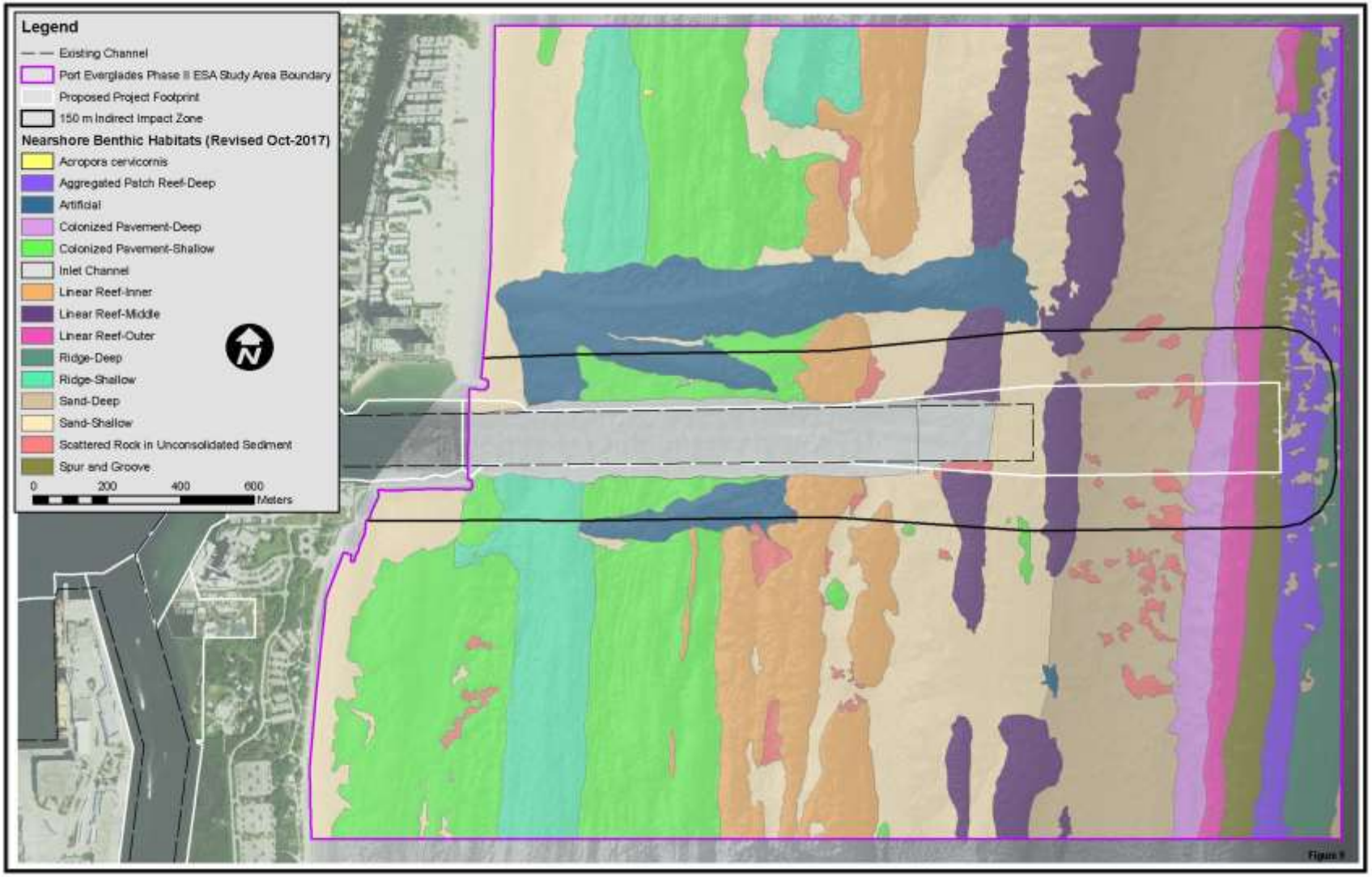

Figure 5. Benthic habitat map revised with multibeam and side-scan sonar data from 2016.

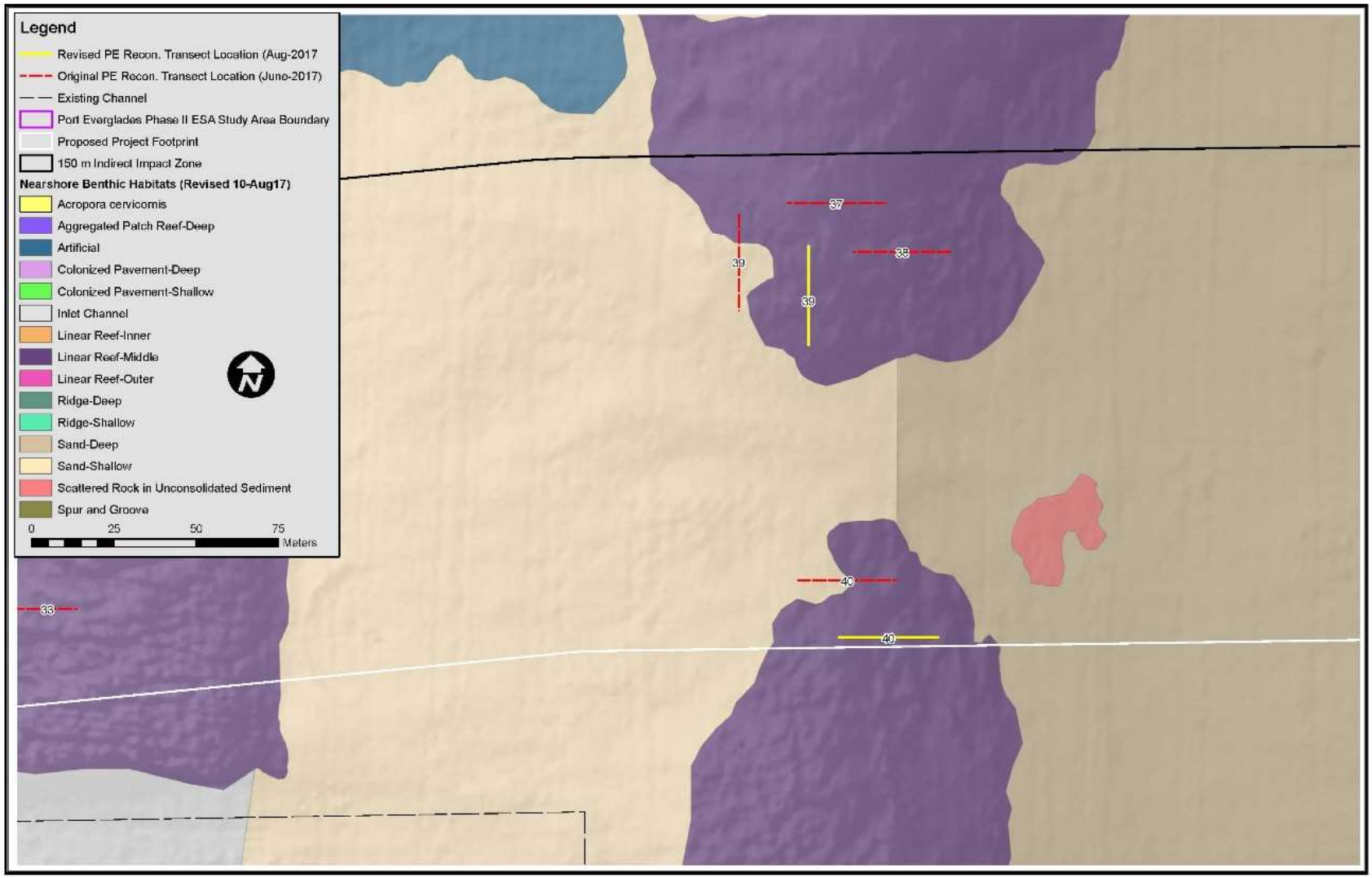

Figure 6. Original (red) and revised (yellow) transect locations for recon transects 39 and 40.

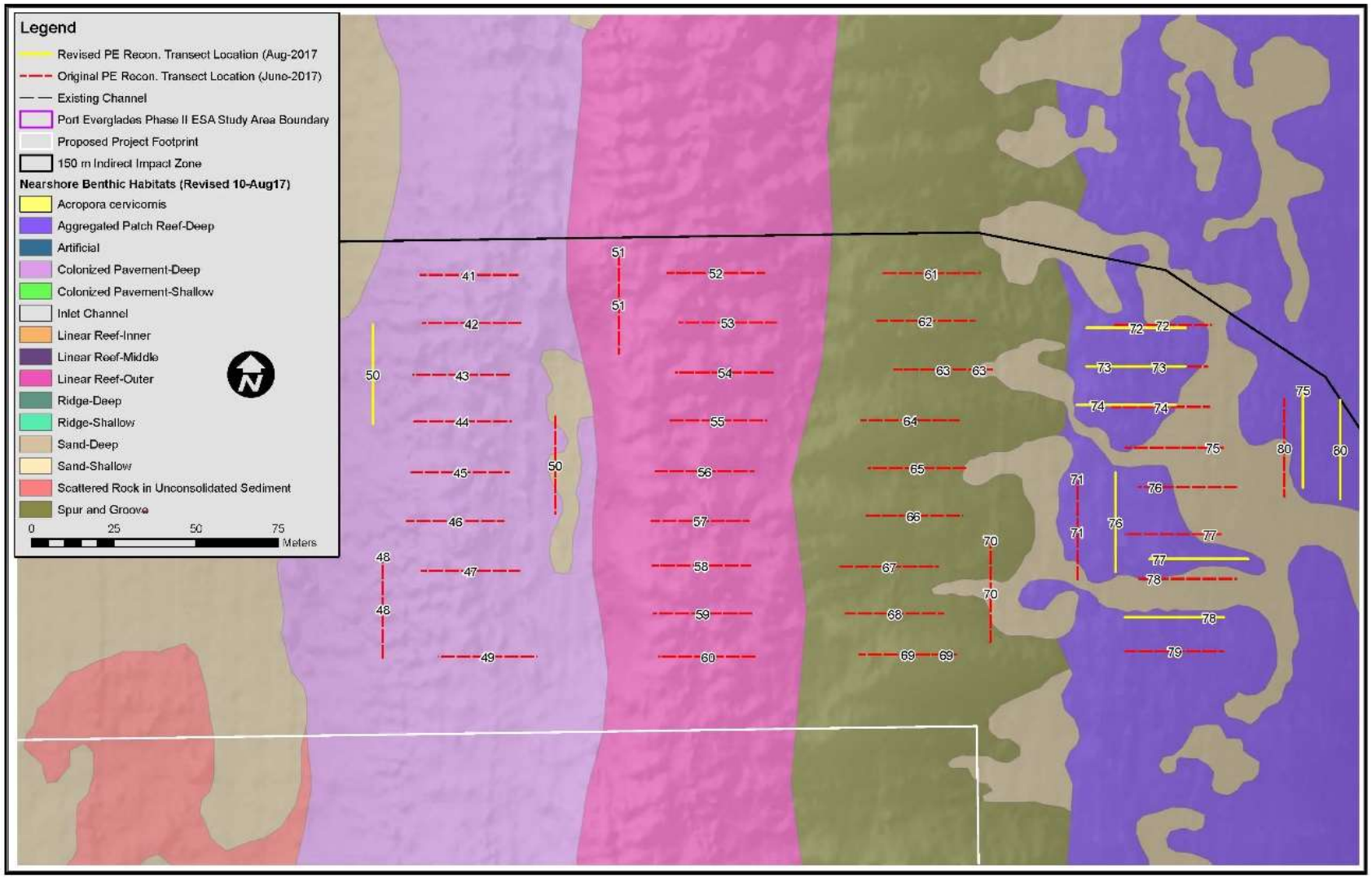

Figure 7. Original (red) and revised (yellow) transect locations for recon transects 50, 72-78 and 80.

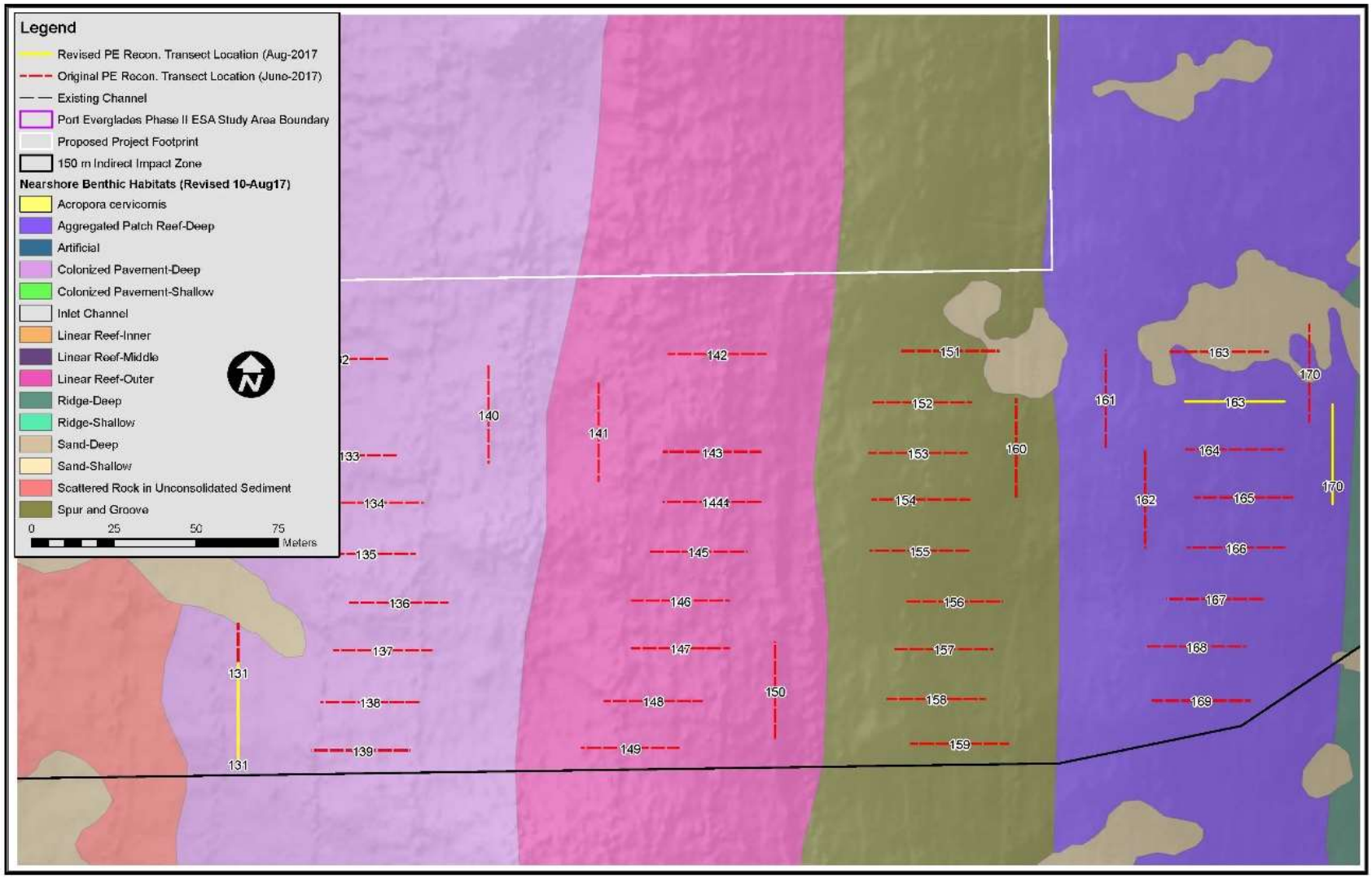

Figure 8. Original (red) and revised (yellow) transect locations for recon transects 131, 163, and 170.

Figure 9. Original (red) and revised (yellow) transect locations for recon transect 181.

Although the modification of transect locations using the process above was to ensure transects would be entirely within the intended habitat, it was still possible the transects could be positioned in an area containing sand features because of limitations of mapping results or operational constraints. Therefore, the following protocol was implemented in the field if the planned transect location was not fully within the intended habitat or contained a sand feature:

1. If the beginning of a transect was not located on the intended habitat (*i.e.* sand) and the intended habitat (*i.e.* hardbottom) was nearby and visible to the divers, the buoy was moved to the intended habitat. The distance and direction of the habitat from the start anchor point was recorded and used to estimate the new transect origin. If possible, the transect was laid out along the original compass heading. However, if the orientation of the transect deviated from the planned transect orientation, the modified compass heading (orientation) of the transect was recorded. Adjustment of the transect orientation was necessary to ensure transects remained within the intended habitat for areas with alternating high and low relief-features (*e.g.* spur and groove), where transects were placed along the central axes of high-relief features (*i.e.* reef or hardbottom substrate) so sandy areas were avoided. In-water adjustment to transect locations to ensure placement on the intended habitat was consistent with the methods employed by Brandt *et. al.* (2009) and Aronson *et. al.* (1994).
2. If the beginning of the transect was within the intended habitat but the transect extended beyond the habitat (*i.e.* transect extended into a sand feature), the transect was reoriented in the direction containing the least sand features possible.

Five of the relocated transects (39, 40, 80, 170, 181) had already been surveyed prior to the implementation of this addendum. These sites were characterized by high sand cover and buried or partially buried hardbottom organisms. Only data from re-positioned site locations were analyzed in this report.

In total 22 sites were repositioned due to extensive sand features, 15 were identified from the combined Walker and Klug (2014) habitat map with the addition of August 8, 2017 side scan sonar data, and seven sites (43, 45, 46, 79, 156, 157, and 167) were re-positioned in the field when extensive sand was observed (Figure 10).

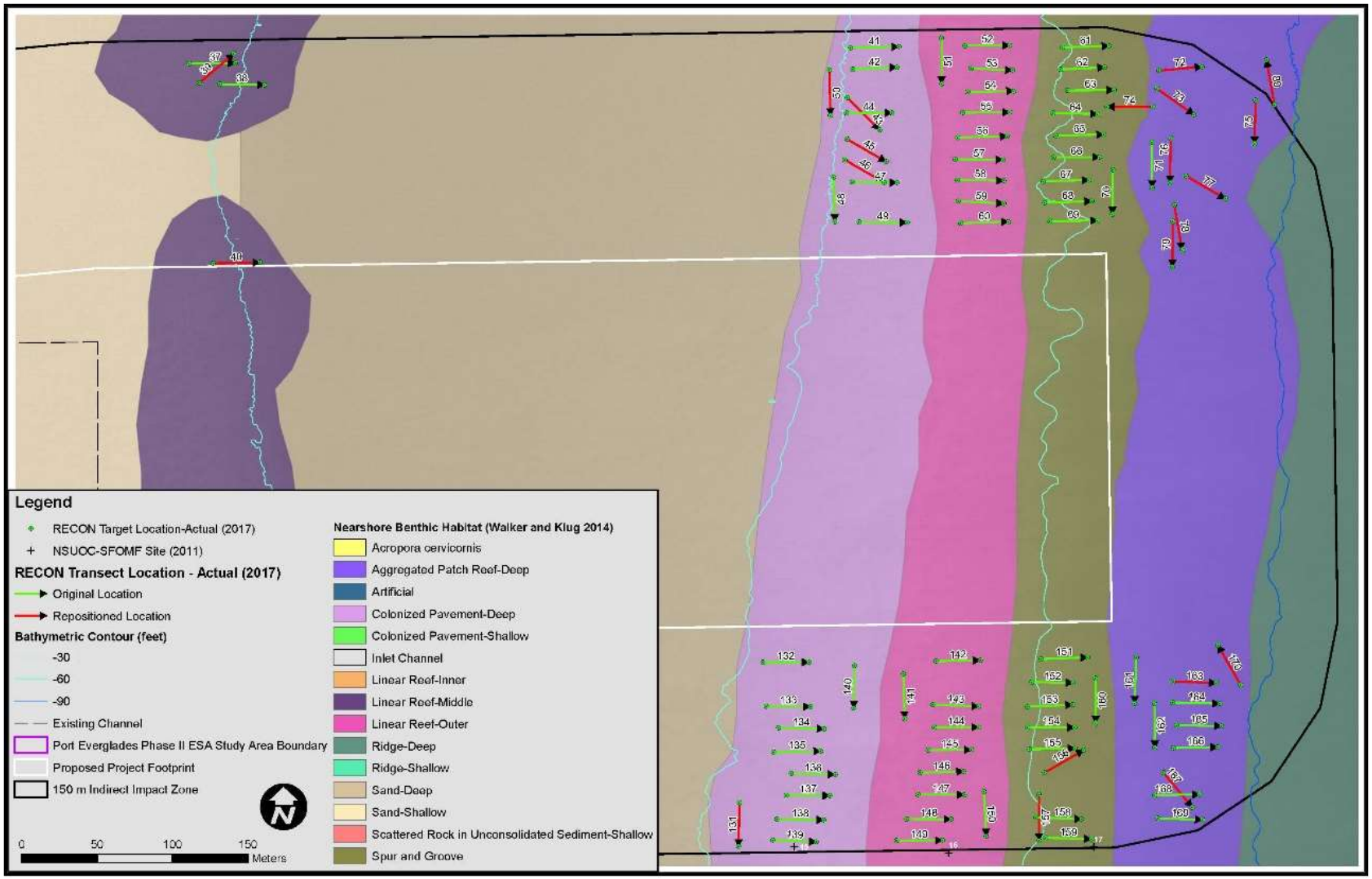

Figure 10. Actual transect locations and orientations of relocated transect locations after completion of reconnaissance surveys. Note: Site 181 is not pictured here but was relocated and surveyed per the revised coordinates (see Figure 9).

Twenty-one of the 22 repositioned sites were located within the 150 m (492.13 ft) mixing zone and represent 12.4% (21 out of 170) of all reconnaissance sites within the mixing zone. Within the mapped habitats, the northern outer reef colonized pavement and the northern and southern outer reef patch reef habitats were particularly affected having 4 of 10 (40%) transects in the outer reef northern colonized pavement habitat, 9 of 10 (90%) transects in the northern outer reef patch reef and 3 of 10 (30%) transects in the southern outer reef patch reef habitats needing to be re-positioned due to extensive sand. One of the 22 sites in the middle linear reef area of the EFH zone also needed to be re-positioned due to extensive sand. The abundance of sand encountered in areas previously documented as reef habitat is a natural feature of the near-channel reefs. Photos illustrating the benthic conditions at these sites are shown in Figures 11 – 16. Although sand-only areas were noted, instances of buried octocorals, sponges, and corals under several cm of sand were common. The presence of large, living benthic invertebrates sticking out of sand (Figures 12, 13, 16, and 17) indicates these areas at one time were un-buried and due to natural sand movement have become sand-dominated habitat. The time-frame of this cycle of burial and un-burial is unknown within the Port Everglades mixing zone, although both seasonal sand movement (DCA 2017) and possible storm-induced sand movement have been documented in Southeastern Florida benthic communities (Figure 17, Gilliam 2006). Removal of sand over buried hardbottom communities can result in the exposure of apparently unaffected hardbottom communities (Figure 11 C&D, Lybolt and Tate 2008).

The documentation of seven (7) additional sites that had extensive sand habitat not identified in either the Walker and Klug (2014) or the combined Walker and Klug (2014) and August, 2017 side-scan data suggests these habitats are difficult to quantify using traditional mapping techniques and may change over time. Note the combined Walker and Klug (2014) and side-scan data document the extent of benthic habitats prior to the passage of Hurricane Irma on September 10th, 2017. The effect of the passage of Hurricane Irma on the amount and position of sand-dominated habitat within the mixing zone is unknown.

Figure 11. Sand section at MI-181-LR

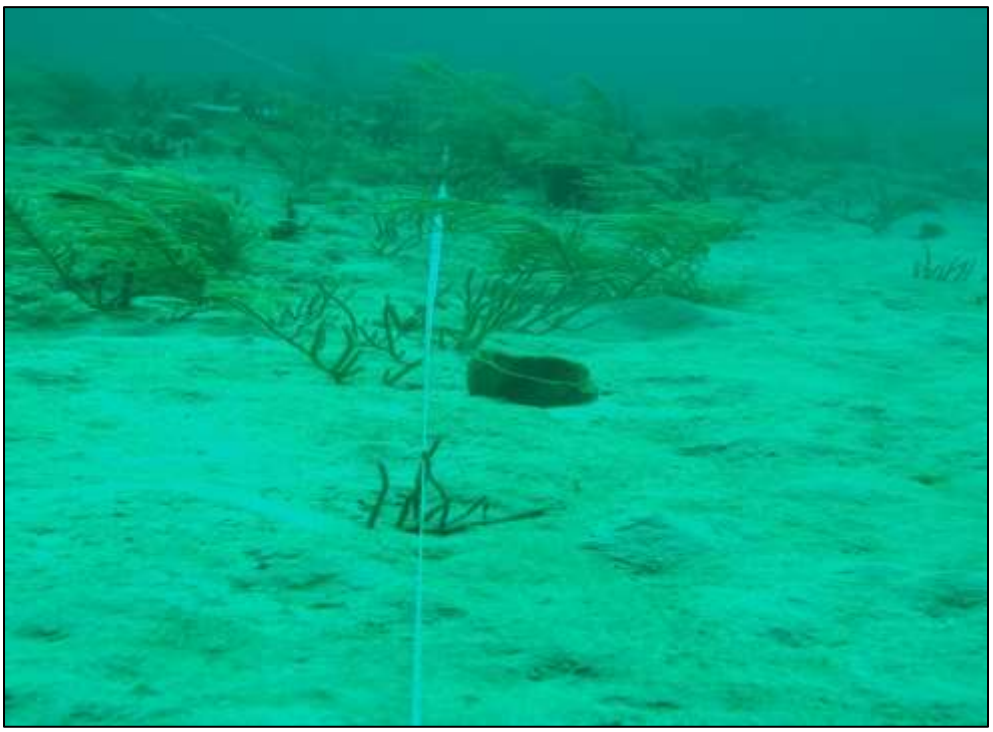

Figure 12. Partially buried octocorals and sponges at sand-hardbottom interface at MI-181-LR.

Figure 13. Sand section at MI-39-LR.

Figure 14. Sand and rubble section at OU-170-PR

Figure 15. Buried (left) and unburied (right) *S. bournoni* and *Aplysina insularis* at MI-181-LR.

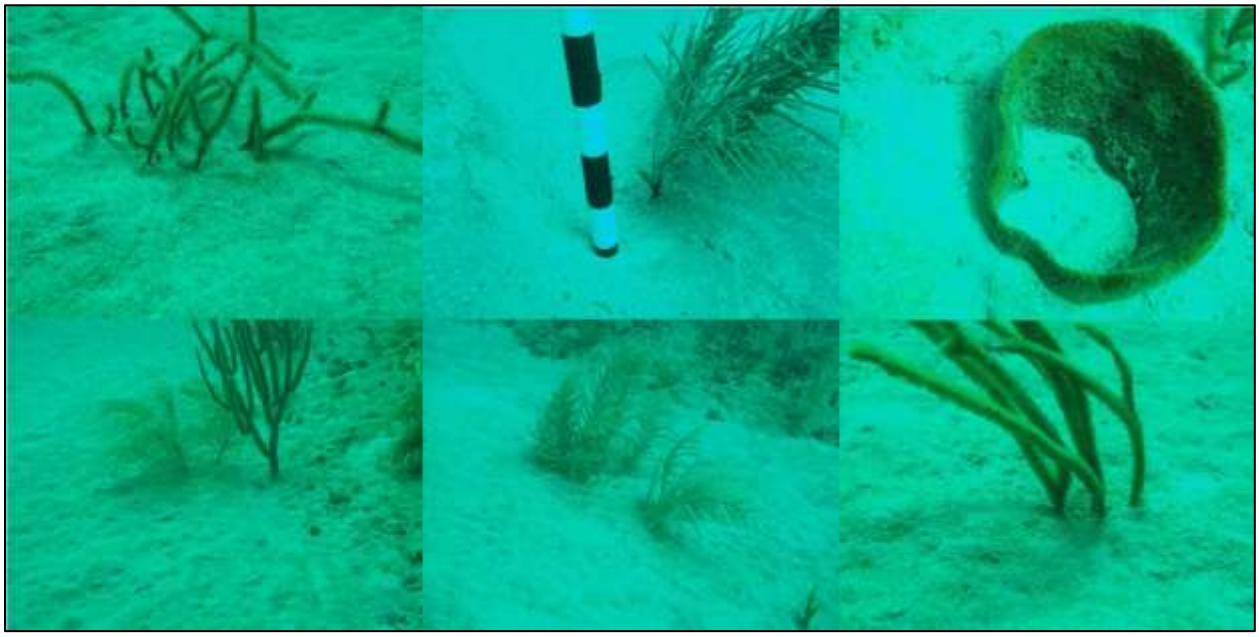

Figure 16. Partially buried octocorals and sponges at MI-181-LR.

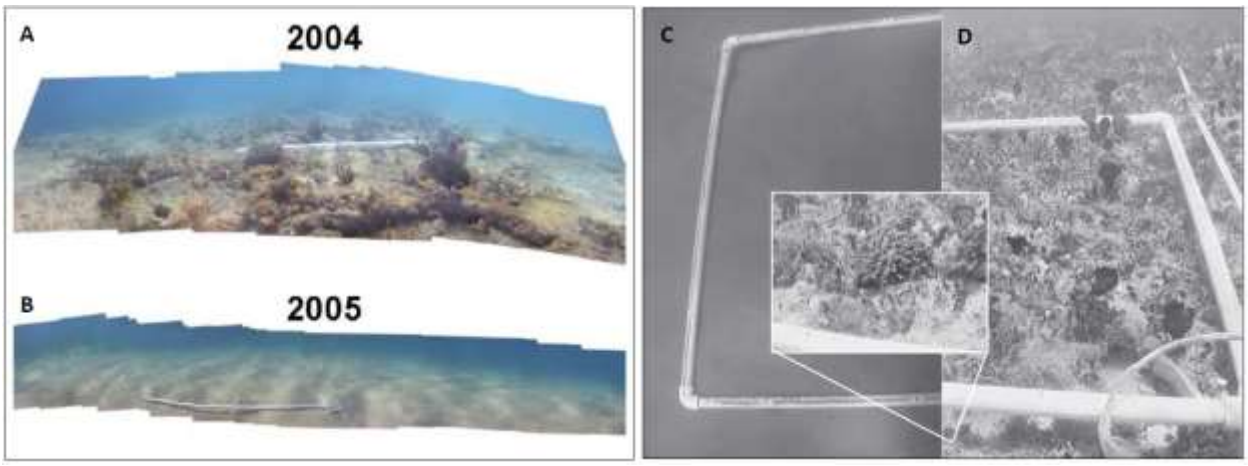

Figure 17. SECREMP site PB1 in 2004 and covered by a natural sand wave in 2005 (A & B). The possible cause of sand movement between photos was the passage of Hurricanes Jeanne and Frances (from Gilliam 2006). (C&D) rapid removal of sandbar reveals unaffected hardbottom community in Palm Beach County, including 10 cm stony coral *Oculina diffusa* (from Lybolt and Tate 2008).

3.0 RESULTS

3.1 Qualitative Descriptions of Assessment Area

Reconnaissance survey results were grouped based on their location along the channel from west to east and by their habitat type. Result groupings are separated based on whether the site is located in the nearshore hardbottom and inner reef (westernmost sites), middle reef, and outer reef (easternmost) locations. Table 1 provides information on the number of transects sampled in each habitat, the location of the transects north or south of the channel, and whether or not the site was located within the 150m mixing zone or was an EFH site.

3.1.1 Nearshore Hardbottom and Inner Reef

Reconnaissance sites in the nearshore hardbottom and inner reef consisted of four habitat types: colonized pavement (CP), artificial (AR), linear reef (LR), and ridge reef (RR). A total of 83 sites were located in the nearshore hardbottom and inner reef. Of these sites, 70 sites were located within the 150 m (492.13 ft) mixing zone and 13 sites were located within the EFH zone. A total of 40 sites were located north of the entrance channel with the remaining 43 sites located south of the entrance channel. Depth at these sites ranged from 3.35-12.80 m (11-42 ft). Of these nearshore hardbottom and inner reef sites, 58 were surveyed prior to Hurricane Irma, that impacted Southeast Florida from September 8-10th, 2017, and the remaining 25 sites were surveyed after the storm.

3.1.1.1 Artificial

A total of 19 survey sites were located within artificial habitat: Ten sites were located on the north side of the entrance channel and 9 on the south side. All of these sites were located within the 150 m (492.13 ft) mixing zone, and depth ranged from 4.37-8.23 m (14-27 ft). These sites were characterized by relief ranging from zero to 45 cm (0 to17.72 in) (from quadrat data)

although relief was likely higher in some areas. Habitat at these sites consisted predominantly of rubble with some large boulders, small areas of colonized hardbottom, and occasional patches of sand (Figure 18). Hardbottom was present at some sites. Worm rock was observed occasionally and predominantly on the north side of the entrance channel (Figure 19). No seagrass was observed at any of these sites. *Xestospongia muta* (*X. muta*) abundance was low (six observed within the belt transects at these sites). Approximately 79,334 m^2 (19.6 acres) of the inner and middle artificial habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

Figure 18. Artificial habitat sites located north (top) and south (bottom) of the channel.

Figure 19. Worm rock built by the Sabellariid worm (*Phrag*matopoma *caudata)* IN-10-AR.

3.1.1.2 Colonized Pavement

A total of 27 survey sites were located within colonized pavement habitat: 13 survey sites were located on the north side of the entrance channel and 14 on the south side. A total of 22 sites were located within the 150 m (492.13 ft) mixing zone. The remaining five sites were located in the EFH zone (three north of the channel and two south of the channel). Depth ranged from 3.35-8.53 m (11-28 ft). These sites were characterized by relief ranging from one to 32 cm (.39-12.60 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of rubble with large boulders, colonized hardbottom, and occasional patches of sand (Figure 20). Areas of hardbottom were more prevalent compared to the artificial reef sites. There was no apparent difference in habitat between northern and southern sites or between mixing zone and EFH sites. No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the second highest observed (23 observed within the belt transects at these sites) compared to other inner reef habitat types. Approximately 90,084 m^2 (22.3 acres) of the inner colonized pavement habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

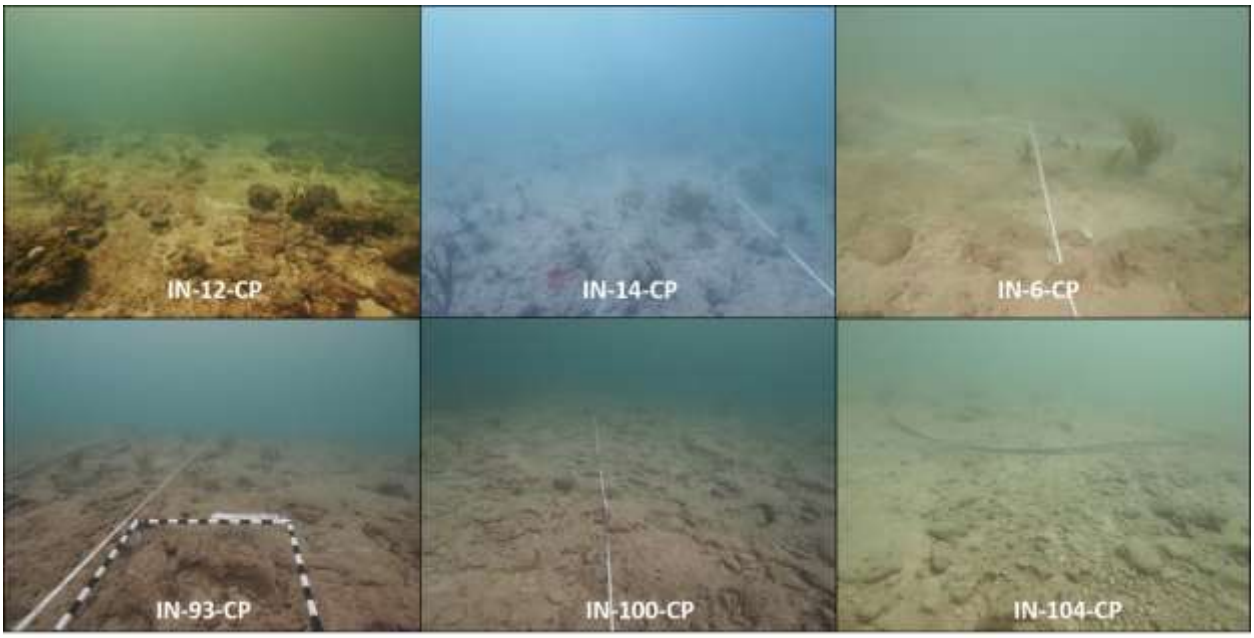

Figure 20. Colonized pavement habitat sites located north (top) and south (bottom) of the channel.

3.1.1.3 Linear Reef

A total of 22 survey sites were located within the linear reef habitat on the inner reef: 13 on the north side of the entrance channel and nine on the south side. A total of 19 sites were located within the 150 m (492.13 ft) mixing zone. The remaining three sites were located in the EFH zone (all north of the channel). Depth ranged from 6.71-12.80 m (22-42 ft). These sites were characterized by relief ranging from zero to 53 cm (0 to 20.89 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted primarily of colonized hardbottom with rubble, and occasional patches of sand (Figure 21). There was no apparent

difference in habitat between the northern and southern sites or between mixing zone and EFH sites. No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the highest observed (62 observed within the belt transects at these sites) compared to other inner reef habitat types. Approximately 47,034 m^2 (11.6 acres) of the inner linear reef habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

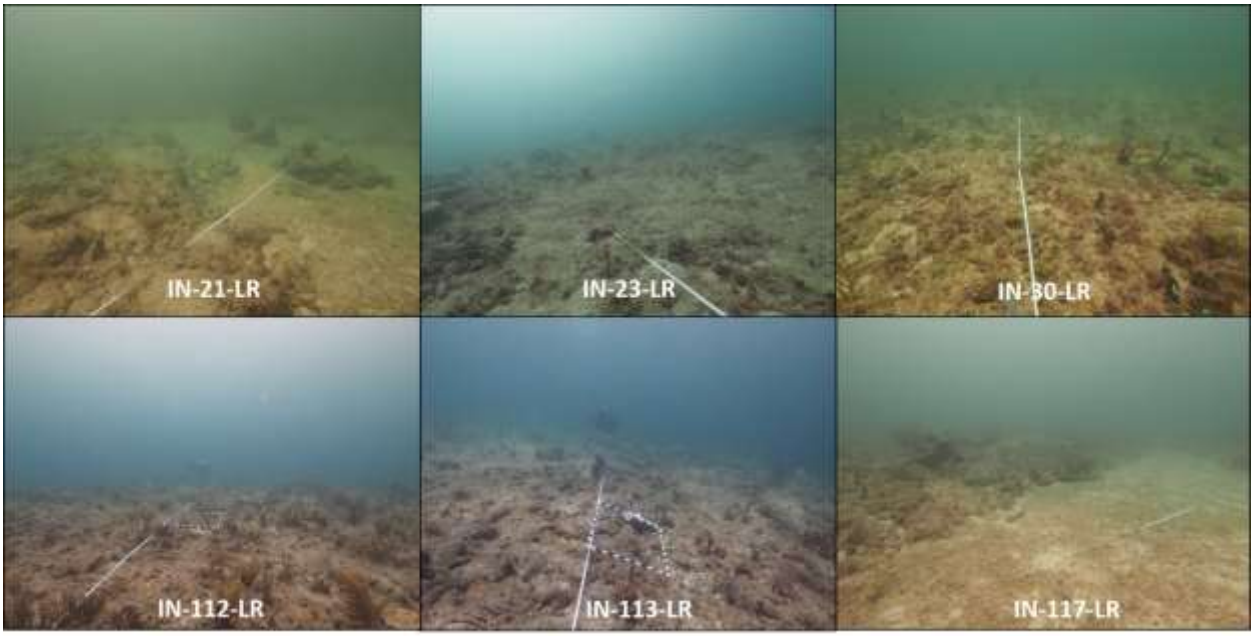

Figure 21. Inner reef linear reef habitat sites located north (top) and south (bottom) of the channel.

3.1.1.4 Ridge Reef

A total of 15 survey sites were located within the ridge reef habitat: four on the north side of the entrance channel and 11 on the south side. A total of 10 sites were located within the 150 m (492.13 ft) mixing zone. The remaining five sites were located in the EFH zone (four north of the channel and one south of the channel). Depth ranged from 3.35-9.45 m (11-31 ft). These sites were characterized by relief ranging from zero to 45 cm (0 to 17.72 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted primarily of colonized hardbottom with rubble. No worm rock or seagrass was observed at any of these sites. *Acropora cervicornis* was observed at multiple EFH sites (IN-171-RR, IN-173-RR, and IN-195-RR) both north and south of the entrance channel, in some cases in very large thickets (Figure 22). No *A. cervicornis* was observed at sites within the 150 m (492.13 ft) mixing zone. *X. muta* abundance was the lowest observed (one individual observed within the belt transects at these sites) compared to other nearshore hardbottom and inner reef habitat types. Approximately 27,224 m^2 (6.7 acres) of the inner ridge reef habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

Figure 22. Inner reef ridge reef habitat sites located north (top) and south (bottom) of the channel.

3.1.2 Middle Reef

Reconnaissance sites at the middle reef consisted of two habitat types: artificial (AR) and linear reef (LR). A total of 27 sites were located in the middle reef. Of these sites, 20 sites were located within the 150 m (492.13 ft) mixing zone and seven sites were located in the EFH zone. A total of 17 middle reef sites were located north of the entrance channel with the remaining 10 sites located south of the entrance channel. Depth at these sites ranged from 10.67-19.51 m (35-64 ft). Of these sites, 24 were surveyed prior to Hurricane Irma while the remaining three sites were surveyed after the storm.

3.1.2.1 Artificial

A total of one survey site was located within the artificial habitat on the middle reef on the north side within the 150 m (492.13 ft) mixing zone. Depth at this site ranged from 11.59-12.50 m (38-41 ft). This site was characterized by relief ranging from 8 to 35 cm (3.15 to 13.78 in) (from quadrat data) although relief was likely higher in some areas. Habitat consisted of rubble, small boulders, and sandy hardbottom (*i.e.* sand veneer over hardbottom) (Figure 23). No worm rock or seagrass was observed at this site. *X. muta* abundance was relatively low (five individuals observed within the belt transect at this site). Approximately 79,334 m^2 (19.6 acres) of the inner and middle reef artificial habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

Figure 23. Middle reef artificial habitat site MI-183-AR located on the north side of entrance channel in the 150-m mixing zone.

3.1.2.2 Linear Reef

A total of 26 survey sites were located within the linear reef habitat on the middle reef: 16 on the north side of the entrance channel and 10 on the south side. A total of 20 sites were located within the 150 m (492.13 ft) mixing zone. The remaining six sites were located in the EFH zone (all north of the channel). Depth ranged from 10.67-19.51 m (35-64 ft). These sites were characterized by relief ranging from 0-50 cm (0-19.69 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of colonized hardbottom interspersed with sand patches (Figure 24). No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was relatively high (210 observed within the belt transects at these sites) with similar abundances recorded on both the north and south sides of the channel (112 and 98, respectively). Approximately 91,798 m^2 (22.7 acres) of the middle linear reef habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

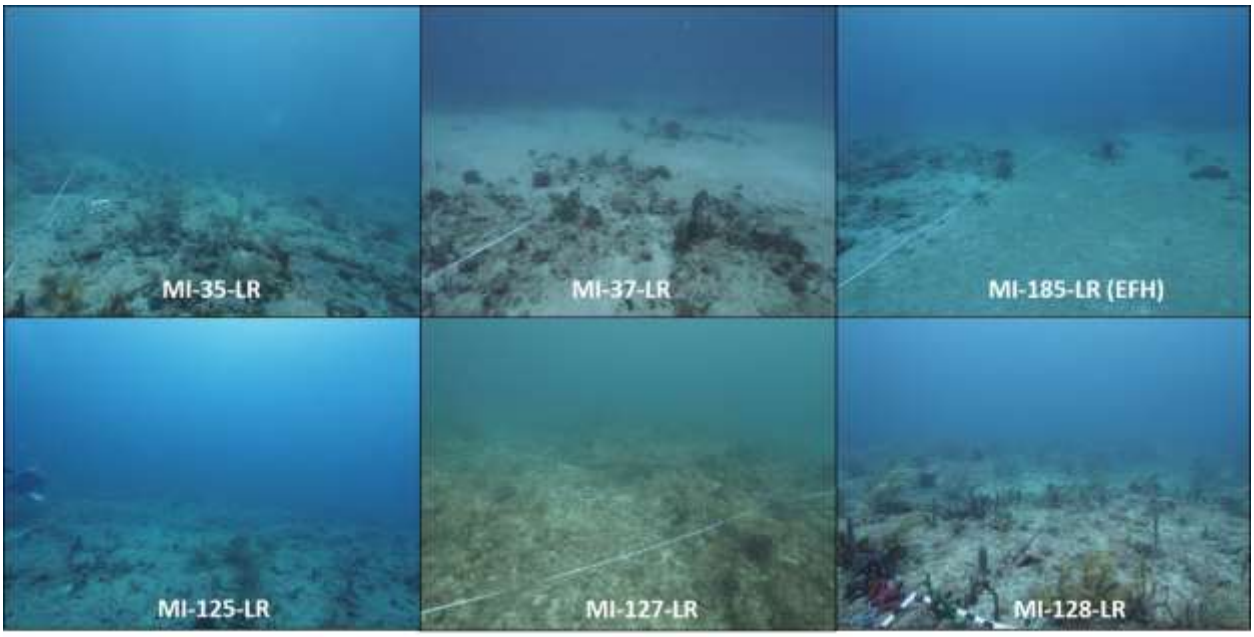

Figure 24. Middle reef linear reef habitat sites located north (top) and south (bottom) of the channel.

3.1.3 Outer Reef

Reconnaissance sites at the outer reef consisted of four habitat types: aggregated patch reef (PR), colonized pavement (CP), linear reef (LR), and spur and groove (SG). A total of 85 sites were located in the outer reef. Of these sites, 80 sites were located within the 150 m (492.13 ft) mixing zone and five sites were located in the EFH zone. A total of 45 outer reef sites were located north of the entrance channel with the remaining 40 sites located south of the entrance channel. Depth at these sites ranged from 13.12-27.13 m (43-89 ft). Of these sites, 53 were surveyed prior to Hurricane Irma while the remaining 32 sites were surveyed after the storm.

3.1.3.1 Aggregated Patch Reef

A total of 21 sites were located within the aggregated patch reef habitat on the outer reef: 11 on the north side of the entrance channel and 10 on the south side. A total of 20 sites were located within the 150 m (492.13 ft) mixing zone. The remaining site was located in the EFH zone (north the channel). Depth ranged from 14.63-19.51 m (48-64 ft). These sites were characterized by relief ranging from 2 to 55 cm (0.79 to 21.65 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of patches of colonized hardbottom interspersed with sandy areas (Figure 25). No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the highest out of all the outer reef habitats (244 observed within the belt transects at these sites) with similar abundances recorded on both the north and south sides of the channel (140 and 104, respectively). Approximately 47,958.16 m^2 (11.8 acres) of the aggregated patch reef habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

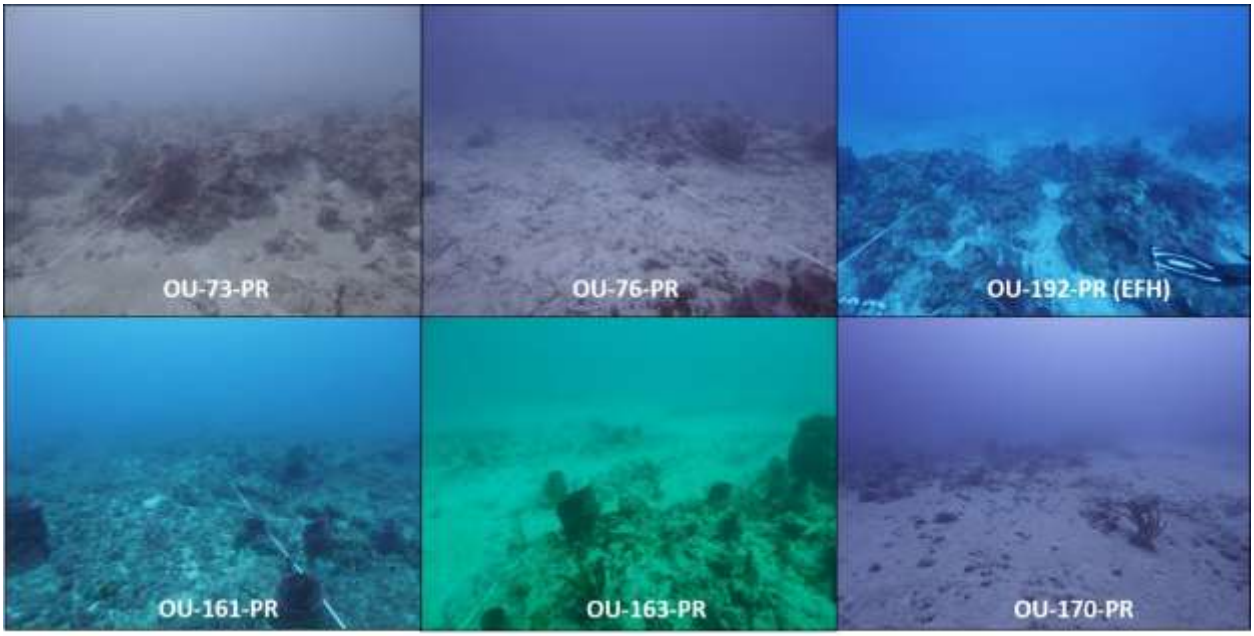

Figure 25. Outer reef aggregated patch reef sites located north (top) and south (bottom) of the channel.

3.1.3.2 Colonized Pavement

A total of 21 sites were located within the colonized pavement habitat on the outer reef: 11 on the north side of the entrance channel and 10 on the south side. A total of 20 sites were located within the 150 m (492.13 ft) mixing zone. The remaining site was located in the EFH zone (north of the channel). Depth ranged from 13.10-19.20 m) (43-63 ft). These sites were characterized by relief ranging from 1 to 100 cm (.39 to 39.37 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of colonized hardbottom with rubble and sandy areas (Figure 26). No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the lowest out of all the outer reef habitats (166 observed within the belt transects at these sites) with abundances on the north side approximately double compared to the south side of the channel (111 and 55, respectively). Approximately 50,013.67 m^2 (12.4 acres) of the outer colonized pavement habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

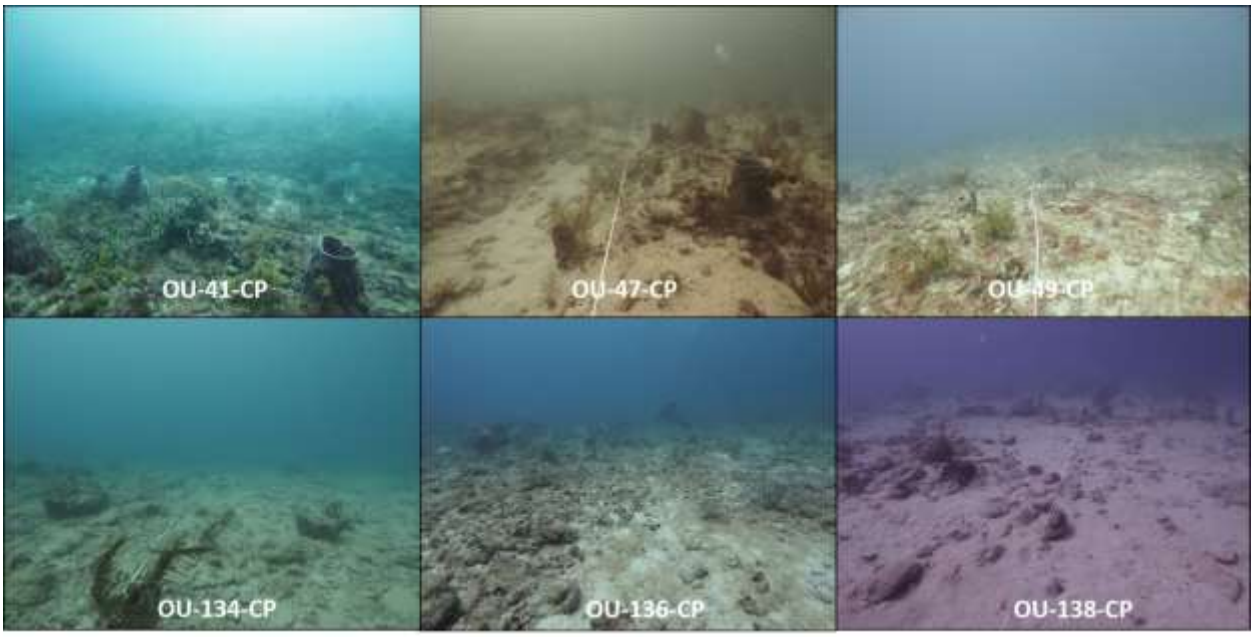

Figure 26. Outer reef colonized pavement habitat sites located north (top) and south (bottom) of the channel.

3.1.3.3 Linear Reef

A total of 23 survey sites were located within the linear reef habitat on the outer reef: 13 on the north side of the entrance channel and 10 on the south side. A total of 20 sites were located within the 150 m (492.13 ft) mixing zone. The remaining three sites were located in the EFH zone (north of the channel). Depth ranged from 21.64-27.13 (71-89 ft). These sites were characterized by relief ranging from 0 to 93 cm (0 to 36.61 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of colonized hardbottom with occasional sand patches (Figure 27). At two sites (OU-144-LR and OU-145-LR) impacts which appeared to have been caused by an anchor/chain drag were observed and photographed on August 22, 2017. Multiple colonized boulders and sponges had been toppled and areas of hardbottom had been scraped to the hardbottom. Port Everglades personnel were notified and the information with photographs was forwarded to FDEP personnel via email (Pers. comm. Precht, August 2017). No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the second highest within this habitat type (211 observed within the belt transects at these sites) with slightly higher abundances recorded on the north side compared to the south side of the channel (125 and 86, respectively). Approximately 39,574 m^2 (9.8 acres) of the outer linear reef habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

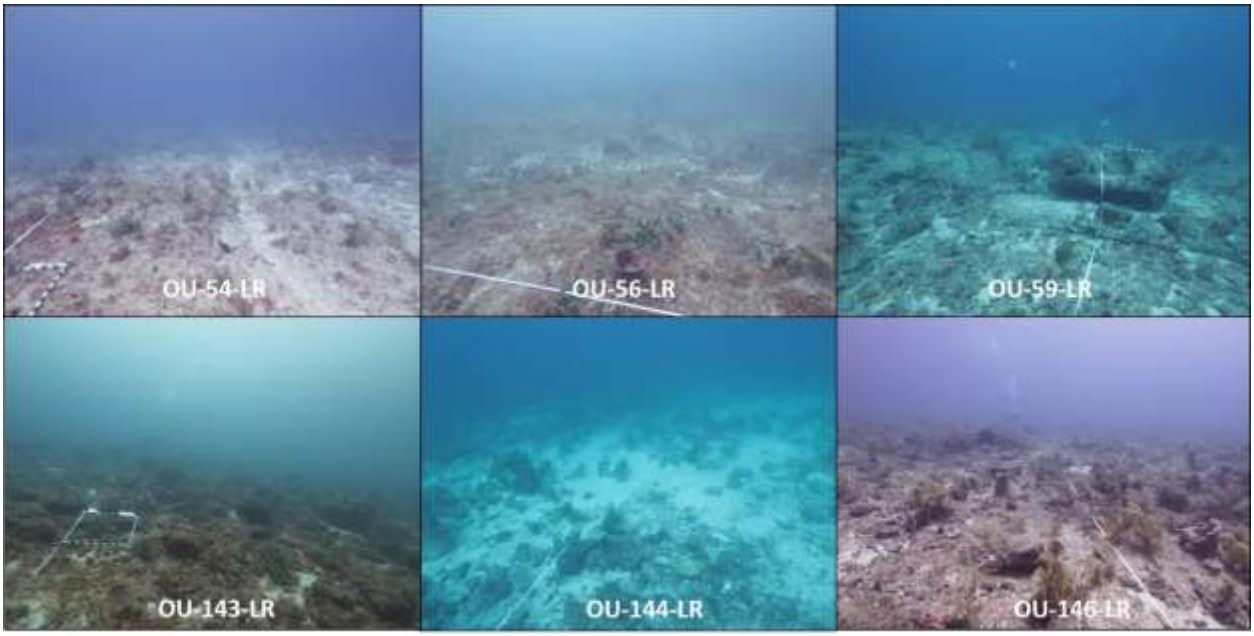

Figure 27. Outer reef linear reef habitat sites located north (top) and south (bottom) of the channel.

3.1.3.4 Spur and Groove

A total of 20 survey sites were located within the spur and groove habitat on the outer reef: 10 on the north side of the entrance channel and 10 on the south side. All of these sites were located within the 150 m (492.13 ft) mixing zone (No EFH sites). Depth ranged from 16.46-21.95 m (54-72 ft). These sites were characterized by relief ranging from 3 to 63 cm (1.18 to 24.80 in) (from quadrat data) although relief was likely higher in some areas. Habitat at these sites consisted of colonized hardbottom with occasional spurs and grooves with sandy areas in the low-lying areas (*i.e.* grooves) (Figure 28). No worm rock or seagrass was observed at any of these sites. *X. muta* abundance was the third highest within this habitat type (204 observed within the belt transects at these sites) with similar abundances recorded on both the north and south sides of the channel (100 and 104, respectively). Approximately 39,031 m^2 (9.6 acres) of the spur and groove habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

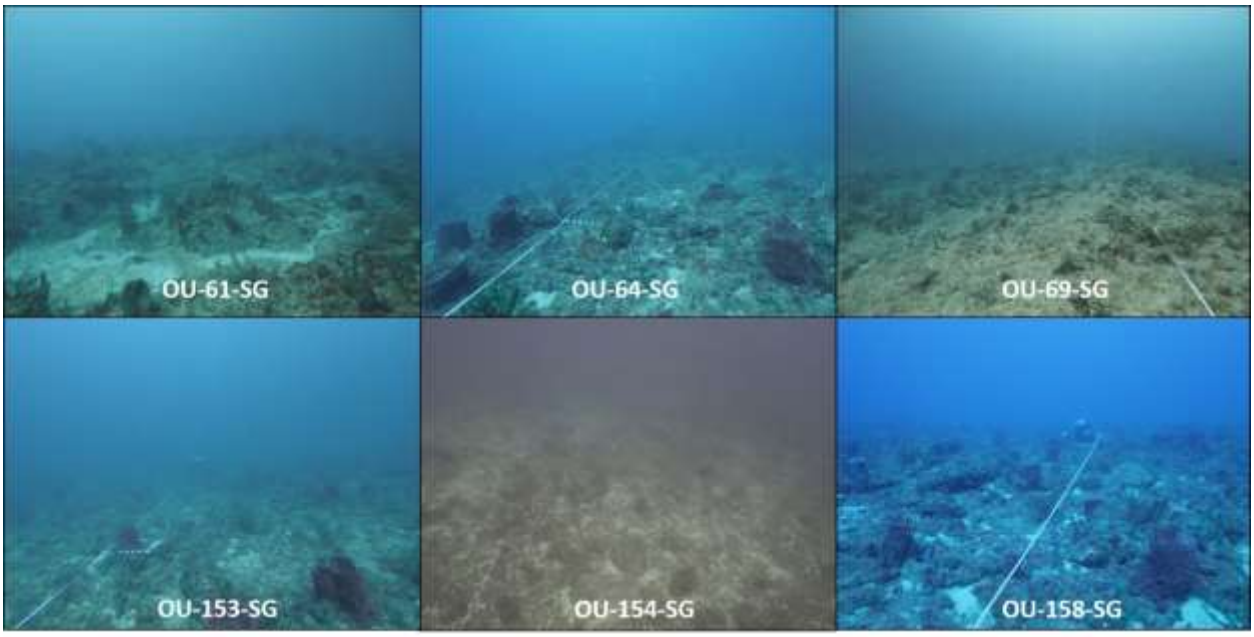

Figure 28. Outer reef spur and groove habitat sites located north (top) and south (bottom) of the channel.

3.1.3.5 Ridge Reef Deep

The outer reef habitat labeled ridge reef deep (Figure 1) that exists in 30.48-60.96 m (100-200 ft) of water was not surveyed by divers in the present survey due to depth restrictions and diver safety concerns. In 2001, the habitat, then called the Third Reef Transitional Complex, was surveyed using color video mounted on a towfish (Dodge et al. 2001) prior to the installation of a natural gas pipeline. In this previous survey, it was estimated that 90% of the Third Reef Transitional Complex is sand with 10% low-relief (<0.30m (<1 ft)) hardbottom (Dodge et al. 2001). Organism densities were lower in the Third Reef Transitional Complex than other outer reef habitats with soft corals and sponges being the dominant invertebrates within the habitat. No zooxanthellate corals were observed in the habitat in 2001 (Dodge et al. 2001). Approximately 16,596 m^2 (4.1 acres) of the ridge reef deep habitat lies within the 150 m (492.13 ft) mixing zone of the current survey (Walker and Klug 2014).

3.2 Hurricane Irma

From September 8-10, 2017 Hurricane Irma, a strong Category 3 storm, crossed over the south Florida peninsula bringing strong onshore winds and waves to the southeast Florida coast (Figure 29). Preliminary observations of reef habitats from the Florida Keys north to Broward County show damage to reef flora and fauna. In addition, large volumes of reef sediments were displaced. The “white” optical properties of the fine-grained carbonate sediments placed in suspension by the passage of the storm are clearly visible in the pre- and post-storm images (Figure 30). The reef landscape was altered by the passage of this storm, which redistributed sediments and affected the benthic communities.

Figure 29. Satellite image of Hurricane Irma on September 10th making its second Florida landfall off the southwest coast.

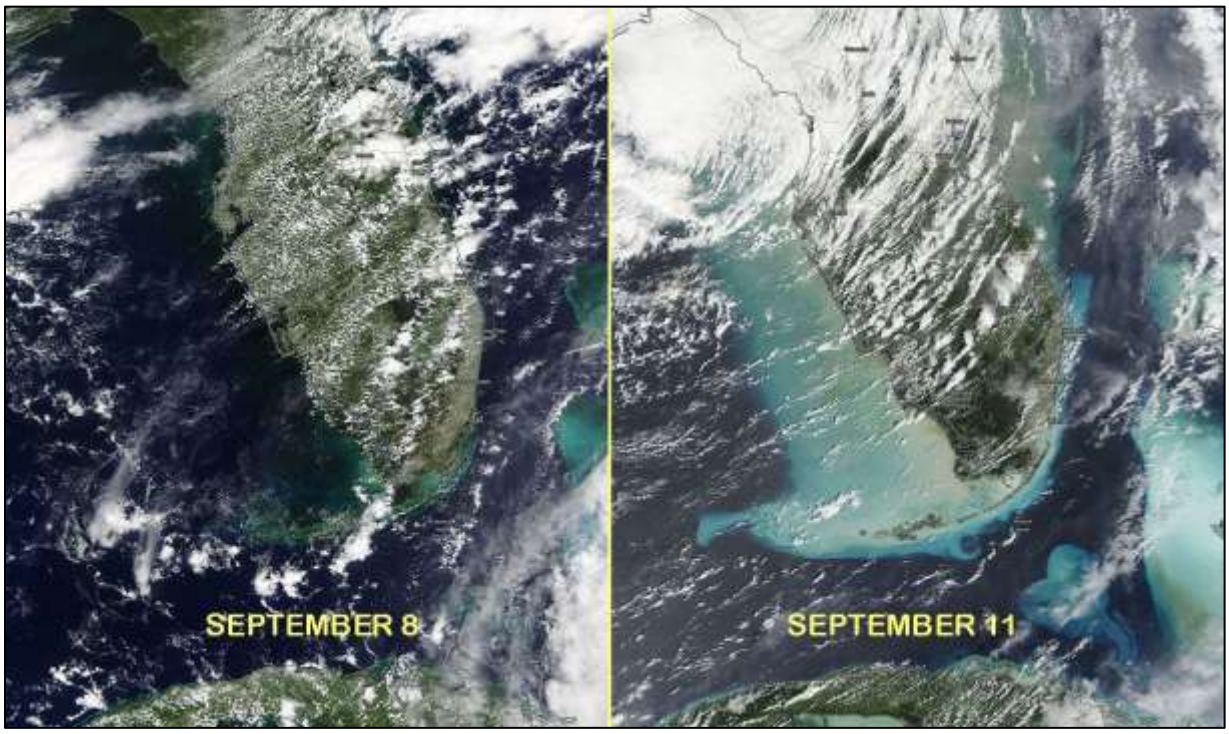

Figure 30. Satellite image of the south Florida peninsula pre-Hurricane Irma on September 8th (left panel) and post-Hurricane Irma on September 11th (right panel). Note shelf-wide increases in turbidity.

Post-hurricane in water surveys on September 18, 2017 at OU-57-LR (outer reef, LR habitat to the north of the channel) revealed significant removal of macroalgae, physical damage to corals, octocorals, and sponges. Physical damage included breakage of sponges and abrasion of living surfaces including corals (Figure 31). New barren spaces, covered with a fine white sediment veneer, overturned rubble and broken limestone were observed. Storm deposits and displacement of sand on the reefs near Port Everglades were also reported (Figure 31).

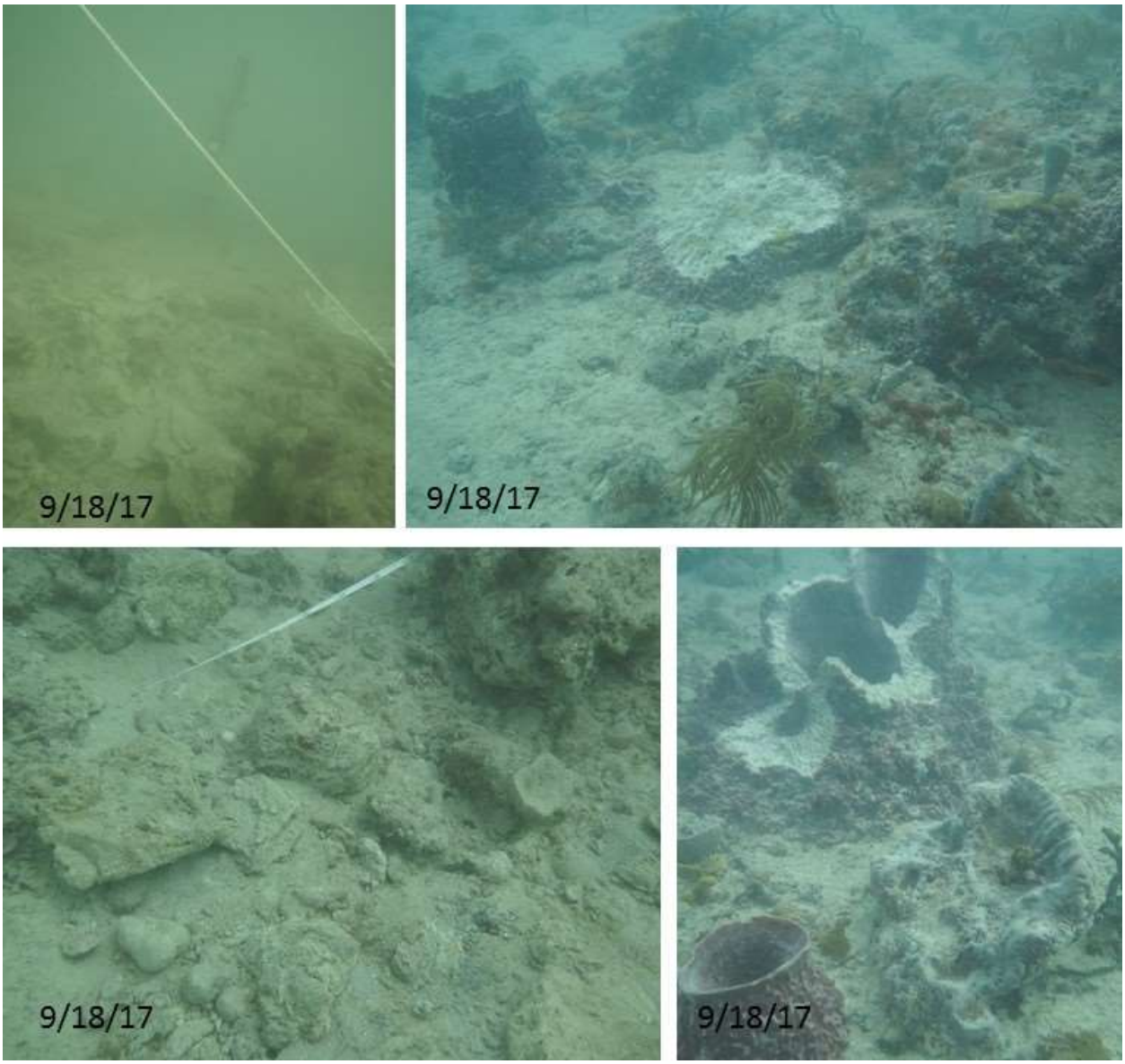

Figure 31. Post-Hurricane Irma damages at site OU-57-LR on September 17, 2018. Damages include: changes to the substratum, widespread sedimentation, and damage to benthic organisms, especially sponges.

3.2.1 Environmental Effect of Hurricane Irma within the Project Area.

Maximum winds from Hurricane Irma at Port Everglades were recorded as 84 mph on September 10, 2017 (NDBC 2017). Turbidity recorded in the pre-storm period at these locations ranged from 3-7 NTU in the nearshore and was usually between 1 and 2 NTU offshore. Turbidity recorded by YSI sondes in the project vicinity (Figure 32) were 99 NTU at the nearshore sonde, and 193 NTU at the offshore sonde, during Hurricane Irma on September 10 (nearshore) and September 11 (offshore) (Figures 33 - 34)., indicating a substantial storm effect on turbidity at the level of the reef.

3.2.2 Benthic Community Changes due to Hurricane Irma within the Project Area

None of the reconnaissance sites were visited both prior-to and following the passage of Hurricane Irma to document differences in the benthic community. However, of the 10 sites within the hardbottom and inner reef colonized pavement habitat to the north of the Port Everglades channel, 5 of the sites were surveyed prior to Hurricane Irma and 5 were surveyed after the passage of the storm. Since an equal number of surveys were conducted in this habitat before and after the passage of Hurricane Irma, comparisons of benthic metrics from this habitat were used to illustrate the changes to the benthic community within the project as a result of Hurricane Irma. The number sites sampled prior-to and following the passage of Hurricane Irma is broken down by reef type, habitat, and side of the channel in Table 5.

In terms of percent cover of benthic resources there were substantial changes to benthic categories following the passage of Hurricane Irma. In particular, the dominant benthic category “turf with sediment” increased following the passage of the hurricane from 38.1% at sites surveyed before the storm to 54.0% at sites surveyed after Irma (Figure 35). This increase in turf with sediment was likely the result of the near complete loss of all macroalgae in the colonized pavement habitat (13.5% prior to Irma and 1.2% after the storm) as well as a loss of cyanobacterial cover (3.5% to 0.4%) and dispersal of sediment by the hurricane (Figure 35). The composition of sediment found prior to the storm also changed slightly from more mixed sediment to slightly more sandy sediment following the passage of the hurricane. The changes in benthic cover measured here show benthic cover of reef habitats is not static and many of these categories can undergo significant change due to natural disturbance events. The changes in benthic cover can be seen when comparing quadrat photos from the five sites visited prior to Hurricane Irma and those visited following the storm (Figure 36). In the photos of colonized pavement sites visited following Hurricane Irma, the colored macroalgae and turf algae present in the sites surveyed before the hurricane are gone and have been replaced with a grey/white sandy veneer. This visual change in habitat appearance can also occur seasonally when summer stands of macroalgae die-off and substrate appears bare once again.

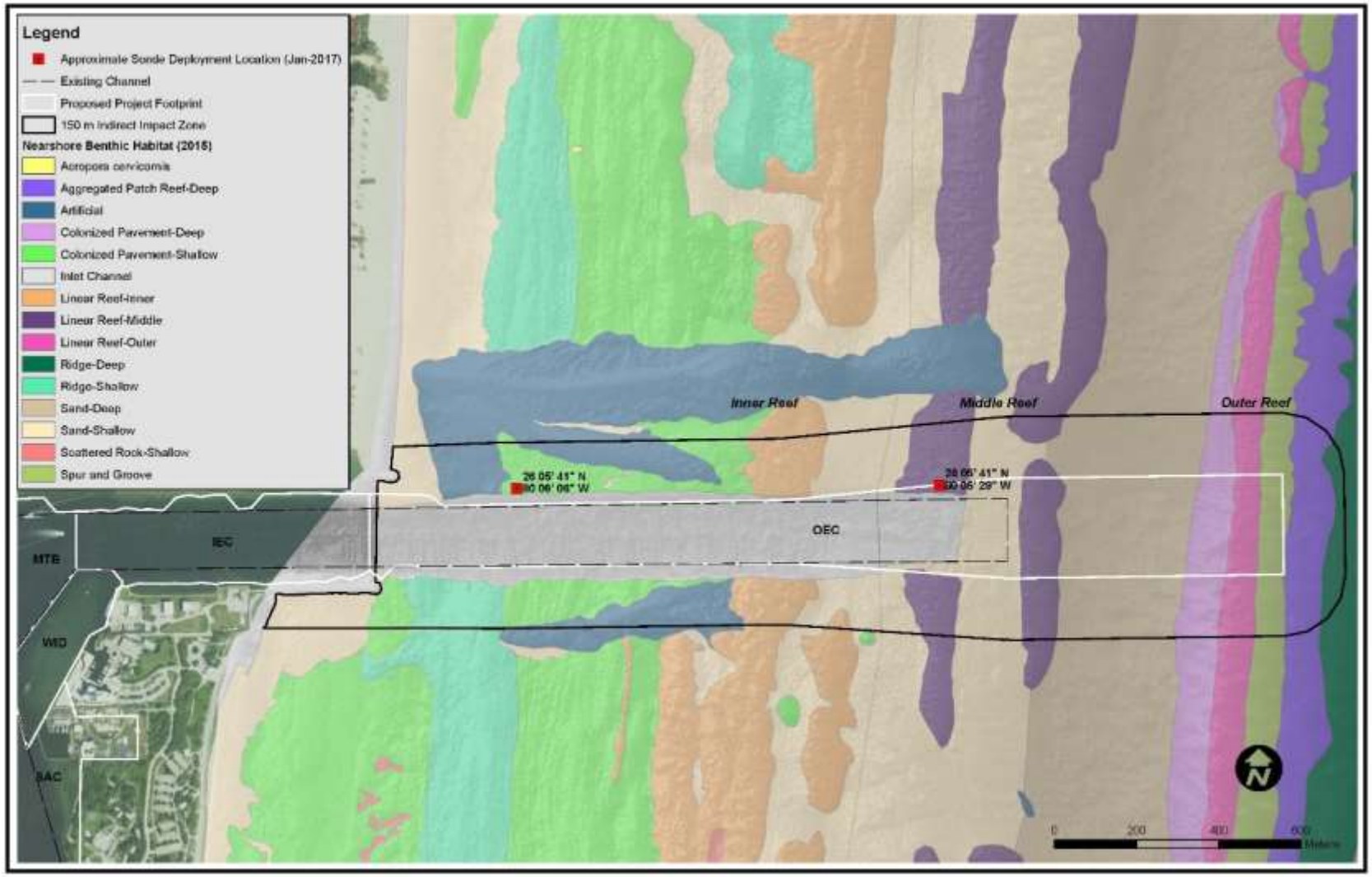

Figure 32. Turbidity monitoring station locations, north of the Port Everglades Channel where YSI EXO sondes are deployed for continual data collection.

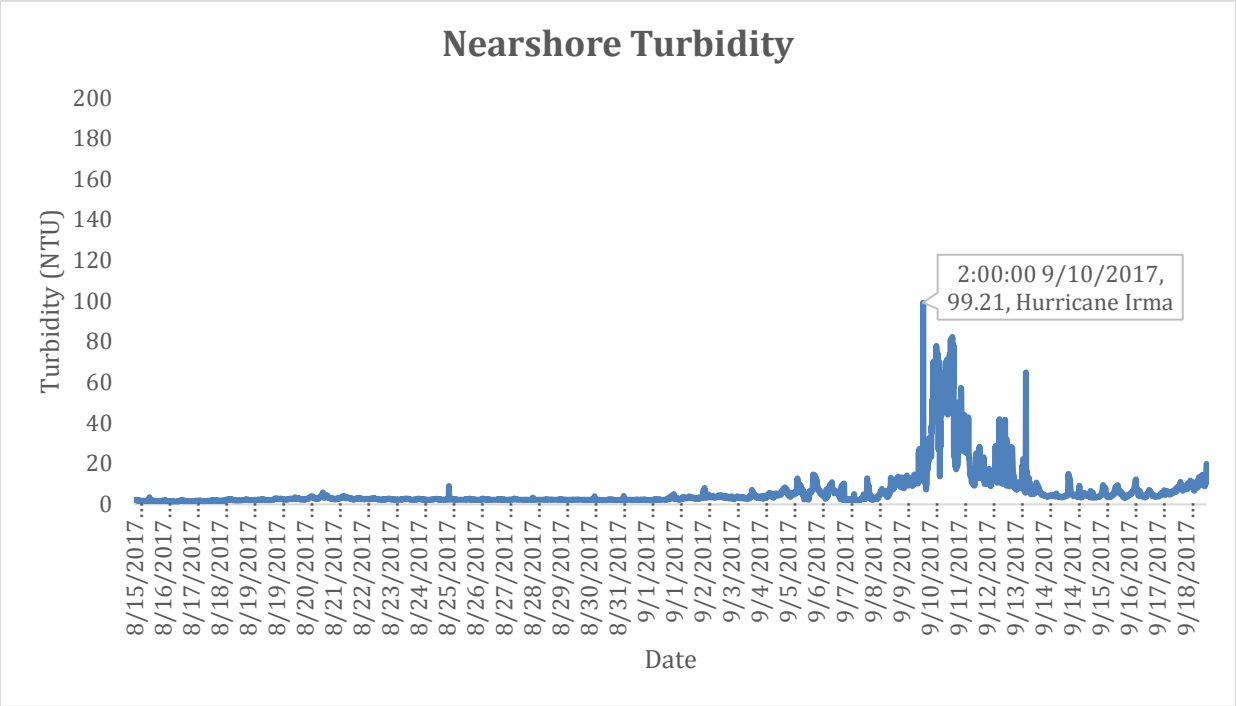

Figure 33. Turbidity (NTU) at nearshore site from August 15, 2017 through September 19, 2017.

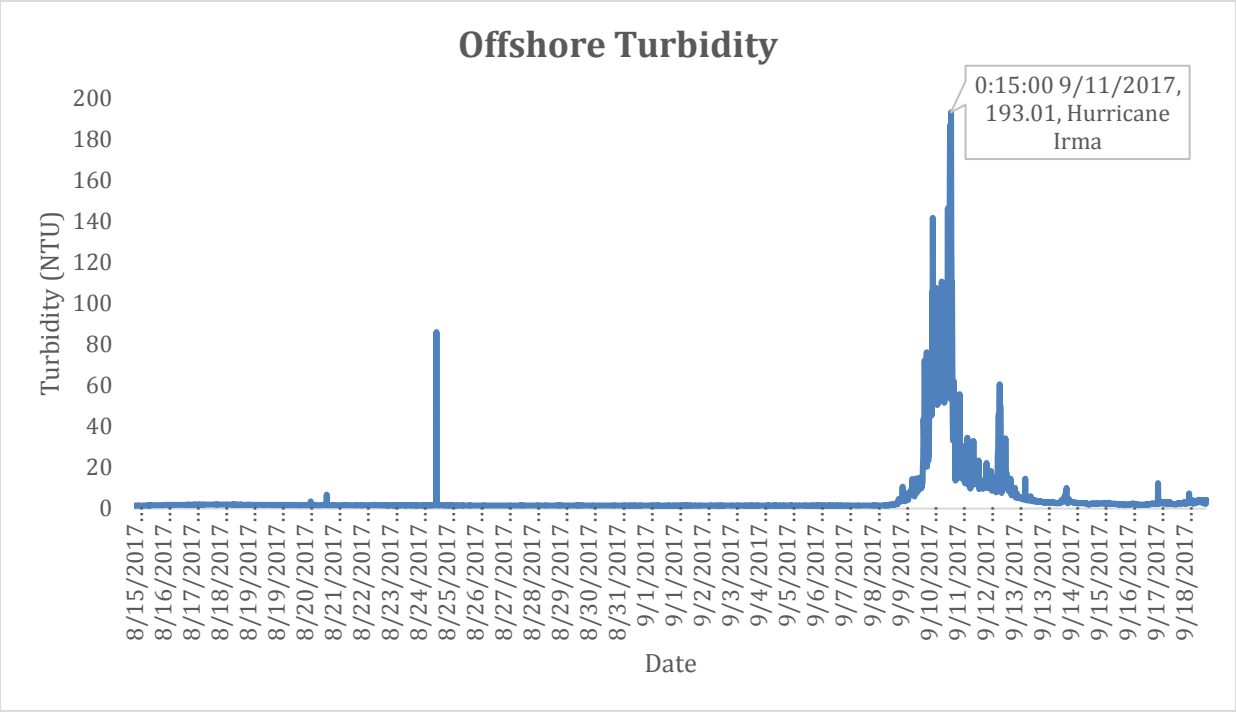

Figure 34. Turbidity (NTU) at offshore site from August 15, 2017 through September 19, 2017.

Table 5. The number of reconnaissance sites surveyed before and after the passage of Hurricane Irma within each reef, habitat, and side of the channel.

Reef	Habitat	Area	Side of Channel	Total Sites	Pre-Irma	Post-Irma
Inner	Artificial (AR)	150-m Mixing Zone	North	10	7	3
			South	9	9	0
		EFH	North	0	0	0
			South	0	0	0
	Colonized Pavement (CP)	150-m Mixing Zone	North	10	5	5
			South	12	4	8
		EFH	North	3	3	0
			South	2	2	0
	Linear Reef (LR)	150-m Mixing Zone	North	10	10	0
			South	9	9	0
		EFH	North	3	3	0
			South	0	0	0
	Ridge Reef (RR)	150-m Mixing Zone	North	0	0	0
			South	10	1	9
		EFH	North	4	4	0
			South	1	1	0
	TOTAL			**83**	**58**	**25**
Middle	Artificial (AR)	150-m Mixing Zone	North	0	0	0
			South	0	0	0
		EFH	North	1	1	0
			South	0	0	0
	Linear Reef (LR)	150-m Mixing Zone	North	10	8	2
			South	10	10	0
		EFH	North	6	5	1
			South	0	0	0
	TOTAL			**27**	**24**	**3**
Outer	Aggregated Patch Reef (PR)	150-m Mixing Zone	North	10	1	9
			South	10	6	4
		EFH	North	1	1	0
			South	0	0	0
	Colonized Pavement (CP)	150-m Mixing Zone	North	10	2	8
			South	10	3	7
		EFH	North	1	1	0
			South	0	0	0
	Linear Reef (LR)	150-m Mixing Zone	North	10	8	2
			South	10	10	0
		EFH	North	3	3	0
			South	0	0	0
	Spur and Groove (SG)	150-m Mixing Zone	North	10	10	0
			South	10	8	2
		EFH	North	0	0	0
			South	0	0	0
	TOTAL			**85**	**53**	**32**

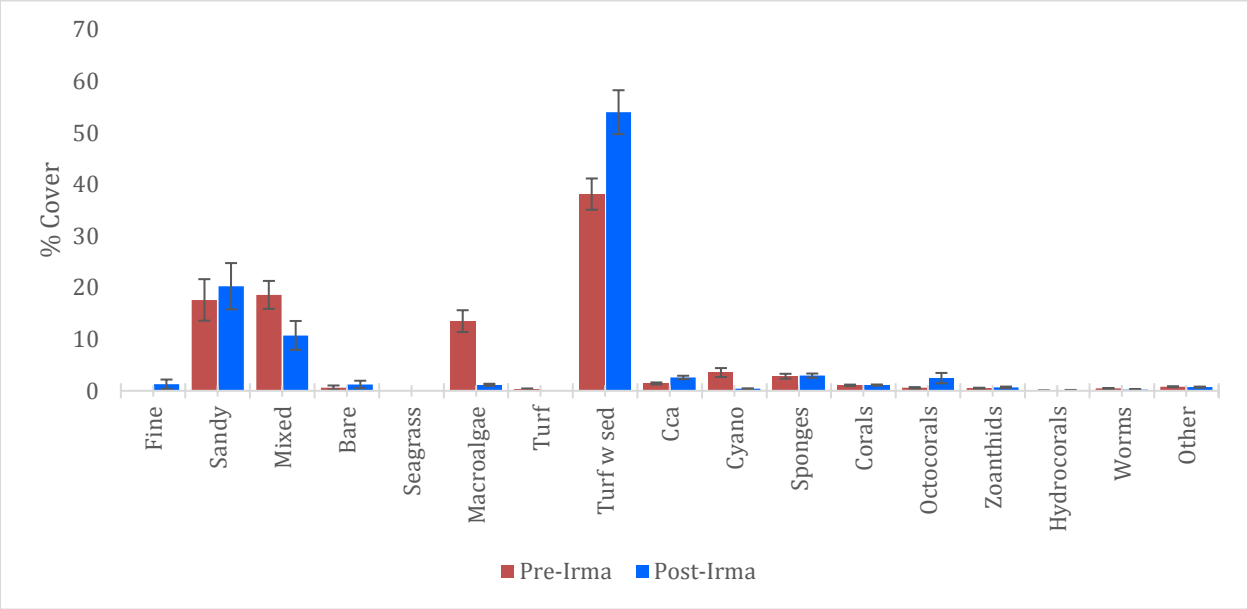

Figure 35. Mean benthic cover of dominant benthic categories (+/- one std error) from five sites surveyed prior to hurricane Irma and five site surveyed following the passage of the storm in the northern hardbottom and inner reef colonized pavement habitat.

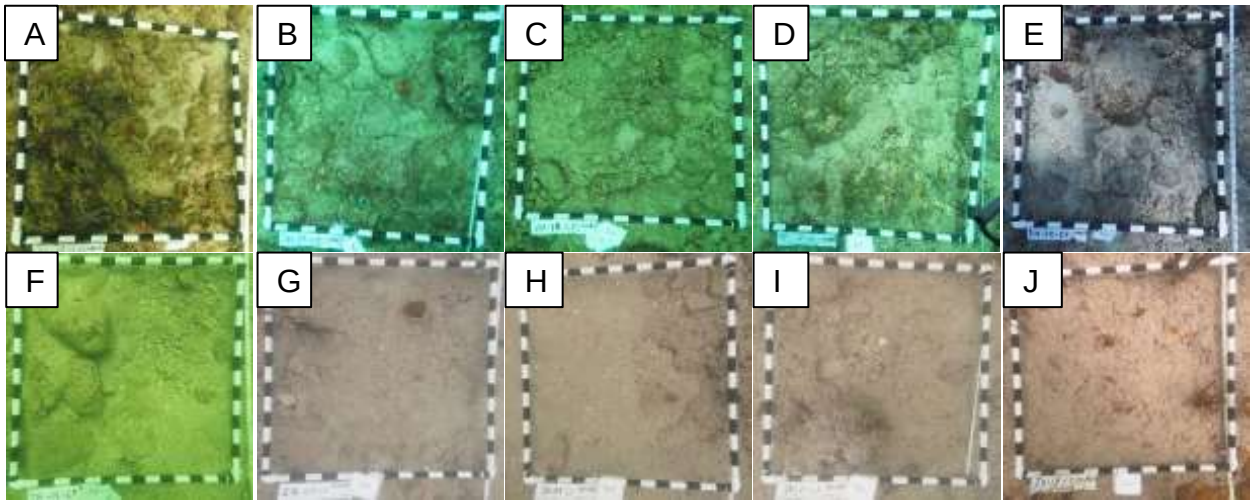

Figure 36. Photos of the 5m quadrat from the five colonized pavement north sites sampled prior to Hurricane Irma (IN-12-CP (A), IN-17-CP(B), IN-18-CP (C), IN-19-CP (D), IN-20-CP (E) and the five sites samples following the storm (IN-6-CP (F), IN-8-CP (G), IN-9-CP (H), IN-11-CP (I), IN-14-CP (J)).

Comparison of the total number of corals surveyed (all sizes) within the 30 m x 1 m (98.42 x 3.28 ft) belt transect at sites surveyed before and after the hurricane also changed after the storm. The number of corals increased substantially with the mean number of corals going from 32.2 corals/survey to 122.8 corals/survey following the passage of Hurricane Irma (Figure 37). The nearly four-fold increase in the number of corals within the colonized pavement habitat is likely the combined result of sand movement within the habitat, exposing new areas of hardbottom, and the loss of macroalgae and cyanobacteria that may obscure the view of small corals (Edmunds et al. 1998, Edmunds, Bruno, and Carlon 2004). Photos of newly uncovered depressions found within the colonized pavement habitat following the passage of Hurricane Irma are shown in Figure 38, note the numerous small coral colonies that were likely recently uncovered due to sand movement from Hurricane Irma.

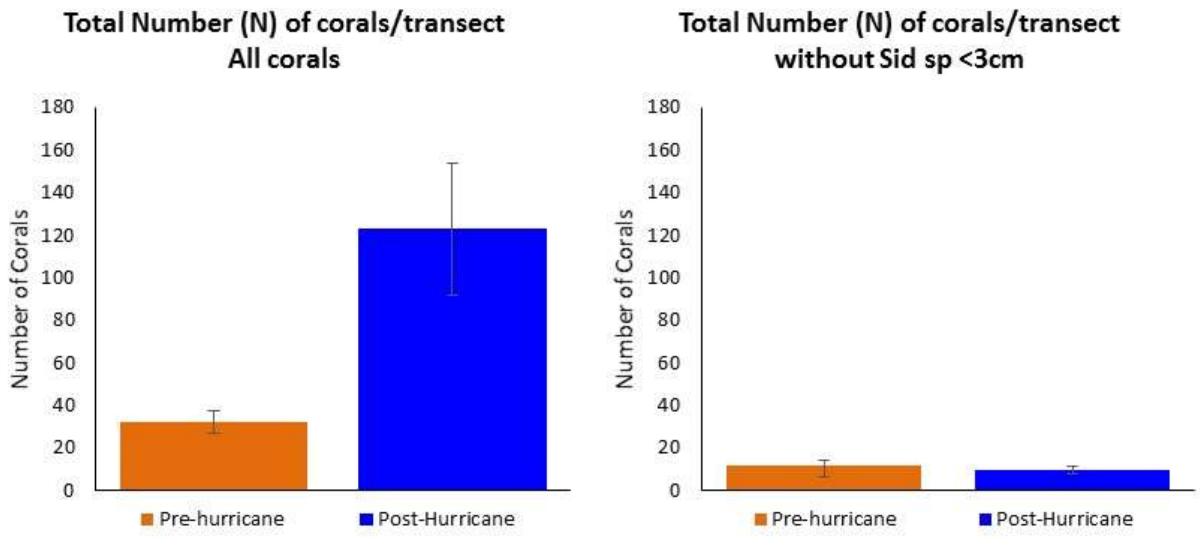

Figure 37. Mean numbers of all corals (left) and corals >3cm (right) at CP north sites in the nearshore hardbottom and inner reef area of the Port Everglades channel.

Figure 38. Recently uncovered sand channels and small *Siderastrea sp.* at IN-14-CP after the passage of Hurricane Irma.

The increased number of corals between sites surveyed before and after the hurricane is due to an increase in the number of small *Siderastrea sp*. corals. If all *Siderastrea sp*. corals 3 cm (1.18 in) or less are removed from the analysis, the mean number of corals is nearly identical between pre and post hurricane survey time periods (11.9 and 9.6 corals/survey respectively) (Figure 38). Thus, in the colonized pavement habitat it is likely the uncovering of previously buried sand channels and the removal of macroalgae caused the increased number of small *Sidereastrea sp*. corals surveyed. It is likely these dynamic changes would have been observed in other habitat/reef types as well as a result of Hurricane Irma, however no other habitat type had equal numbers of sites in pre and post hurricane periods for comparisons.

The number of sponges per quadrat increased following the passage of Hurricane Irma. Substantial increases were documented in encrusting (from 4.3 to 7.6 sponges/quad) and ball sponges (from 0.1 to 4.1 sponges/quad) at sites surveyed following Hurricane Irma (Figure 39). The increase in ball and encrusting sponges following the passage of the Hurricane is likely the result of the removal of sand, macroalgae and cyanobacteria from the surface of cryptic sponges that makes them more visible for counts in the wake of the strong storm.

The only sponge category that saw a decline based on time period was the tube/vase category. This category is made of much larger upright individuals that are likely more susceptible to physical damage from hurricanes than small cryptic or low-lying species.

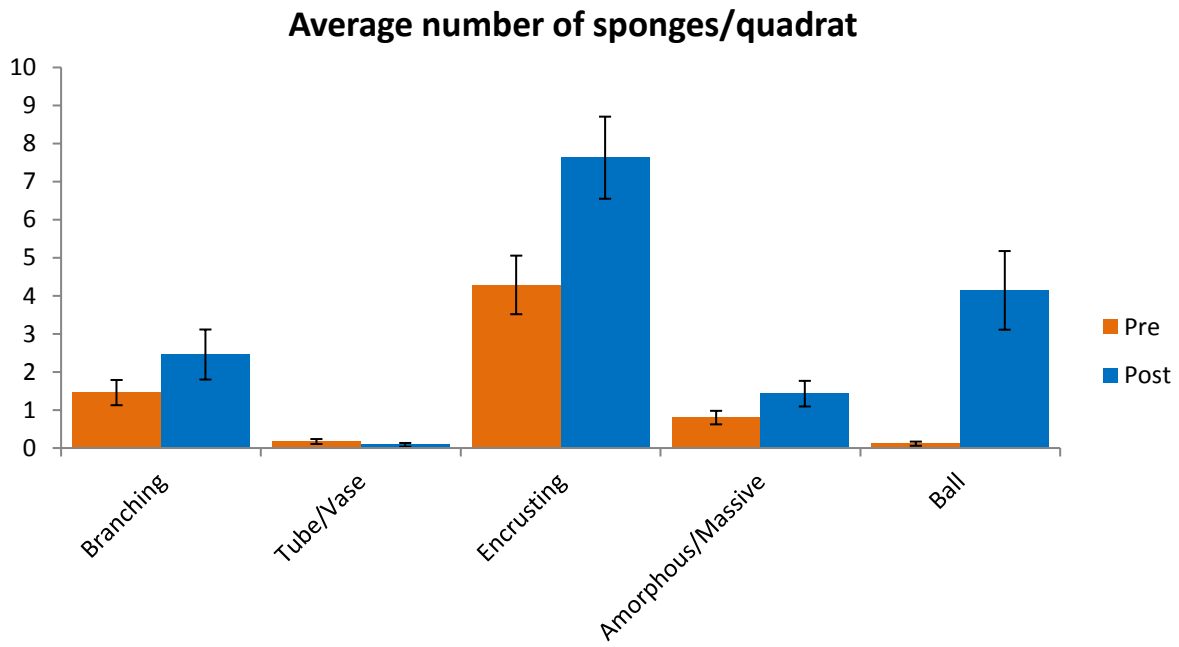

Figure 39. Mean number of sponges before and after the passage of Hurricane Irma from CP north habitat.

The total number of octocorals was higher at the five sites sampled following the passage of Hurricane Irma (79 octocorals) compared with the sites sampled prior to the storm (44 octocorals). The largest difference in mean octocoral abundance within the northern colonized pavement habitat was an increase in *Erythropodium* following the passage of Hurricane Irma (Figure 40). However, *Erythropodium* was only found at one of the five sites surveyed following Hurricane Irma and as a result, the differences noted in octocoral numbers may simply reflect large site-specific differences in octocoral abundance.

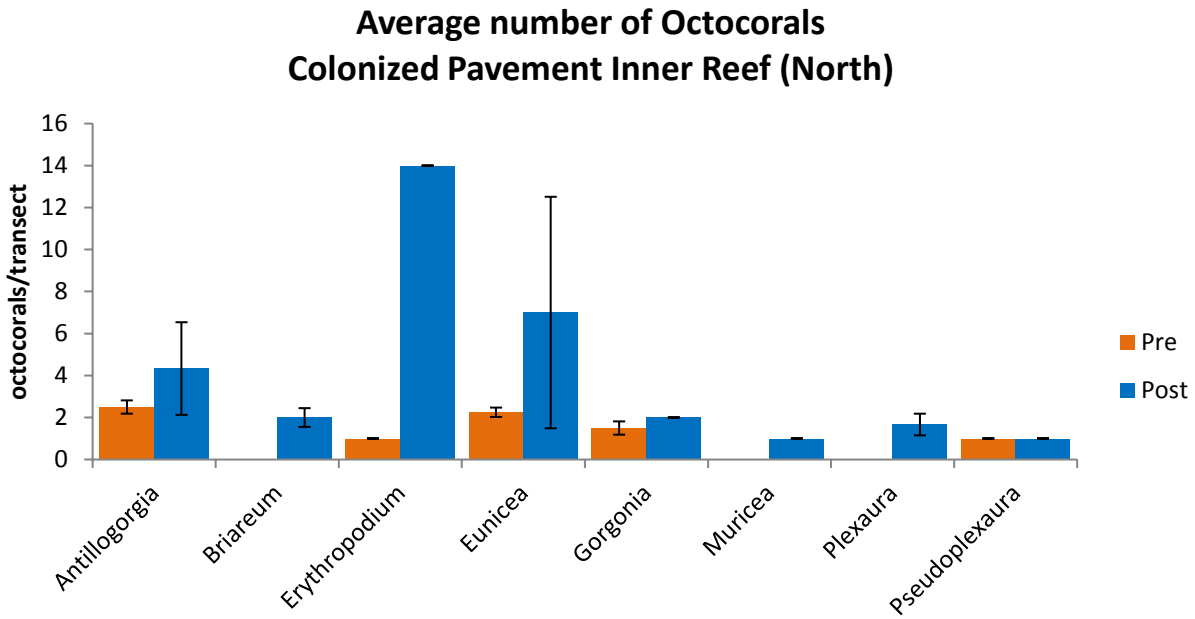

Figure 40. Mean number of octocorals sampled prior to and after Hurricane Irma at CP north habitat (nearshore hardbottom and inner reef area).

Overall, substantial changes in benthic cover, as well as numbers of corals, sponges, and octocorals were noted in the nearshore hardbottom and inner reef CP north habitat following the passage of Hurricane Irma. However, the results above are not an exhaustive assessment of the impact of Hurricane Irma within the project area since no reconnaissance sites were re-surveyed post-Irma to provide direct quantification of gains or losses to the benthic community. In addition, the changes noted in the northern CP habitat summarized above may not be applicable to all other habitats within the survey area.

3.3 DCA 2017 Reconnaissance Survey Results

The following sections provide a summary of the benthic cover, coral, sponge, octocoral communities, and maximum sediment depth within surveyed habitats near the Port Everglades channel. Estimates of the acres of habitat (by type) within the 150 mixing zone and out to 1050m to the north and 1020m to the south of the Port Everglades channel, as well as supplementary data tables for all graphs within this section are provided for reference in Appendix E. It should be noted that the habitat estimates provided in Appendix E include approximately 9.58 acres of artificial habitat within the sand bypass area that was not included in habitat estimates from the *Endangered Species Act Listed Coral Species Survey and Results* (DCA 2018b).

3.3.1 Functional Group Percent Cover

To increase legibility, the functional group percent cover results have been split into two groups with substrate, algae categories, and general invertebrate cover being shown in Figure 41 and the cover of dominant benthic invertebrates being depicted separately in Figure 42. Functional group percent cover data for each survey transect is provided in Appendix F.

Turf with sediment was the dominant benthic category in 21 out of 27 surveyed habitats with sand and macroalgal categories dominating four surveyed habitats (Figure 41). Sponge cover was the dominant benthic invertebrate at all but three surveyed habitats with octocorals having second highest invertebrate cover. Coral cover was consistently low across all surveyed habitats with cover not exceeding 2.9%.

Sampling of sites within habitats was unevenly distributed between pre and post-hurricane Irma time periods and the results below are pooled without regard to sampling date. However, in the CP north habitat (hardbottom and inner reef area) where equal numbers of sites were surveyed before and after the hurricane, cover of macroalgae, cyanobacteria, sand, and turf with sediment were found to change due to the passage of Hurricane Irma. Please see Section 3.2 for a discussion of the potential effects of Hurricane Irma on functional group percent cover.

3.3.1.1 Nearshore Hardbottom and Inner Reef

At all nearshore hardbottom and inner reef habitats except the CP south EFH sites, turf with sediment was the dominant benthic category making up as much as 67.9% of the habitat benthos (CP south, Figure 41A). The proportion of the benthos covered by sand was highly variable with mixed and sandy sediment making up 36% of the benthic cover of the artificial north habitat but only 9.4% of the artificial south habitat (Figure 41A). Areas of EFH surveyed outside the 150 m (492.13 ft) indirect effect zone did not necessarily resemble the sites of the same habitat surveyed near the channel. In particular, the colonized pavement sites surveyed outside the 150 m (492.13 ft) survey zone had increased levels of macroalgae (34.4% at the EFH site compared to 4.4% at sites of the same habitat near the channel) and lower levels of turf with sediment (21.7% at CP South EFH location compared to 67.9% at sites near the channel) than sites of the same habitat and side located near the channel (Figure 41A).

The total cover of all benthic invertebrates ranged from 4.4% at AR north to 23.0% at LR north EFH sites (Figure 42). Coral cover was low with cover ranging from 0.8% at AR north to 2.9% at RR north EFH sites. Sponges were the dominant benthic invertebrate with respect to cover at 10 out of 11 surveyed habitats in the nearshore hardbottom and inner reef and cover ranged from 1.5% at AR north to 10.2% at LR north EFH sites (Figure 42A). Octocorals were the second most dominant benthic invertebrate with octocoral cover ranging from 0.2% at AR north to 9.9% at LR north EFH sites (Figure 42A).

3.3.1.2 Middle Reef

At all middle reef habitats, turf with sediment was the dominant benthic category making up as much as 55.3% of the habitat benthos (AR North EFH sites, Figure 41B). The proportion of the benthos covered by sand was highly variable with mixed and sandy sediment making up 33.5% of the benthic cover of the linear reef north EFH sites but only 13.9% of the cover at artificial reef north EFH sites (Figure 41B). Macroalgae cover ranged from 11.6% in the LR north habitat sites to 19.6% at LR south habitat sites.

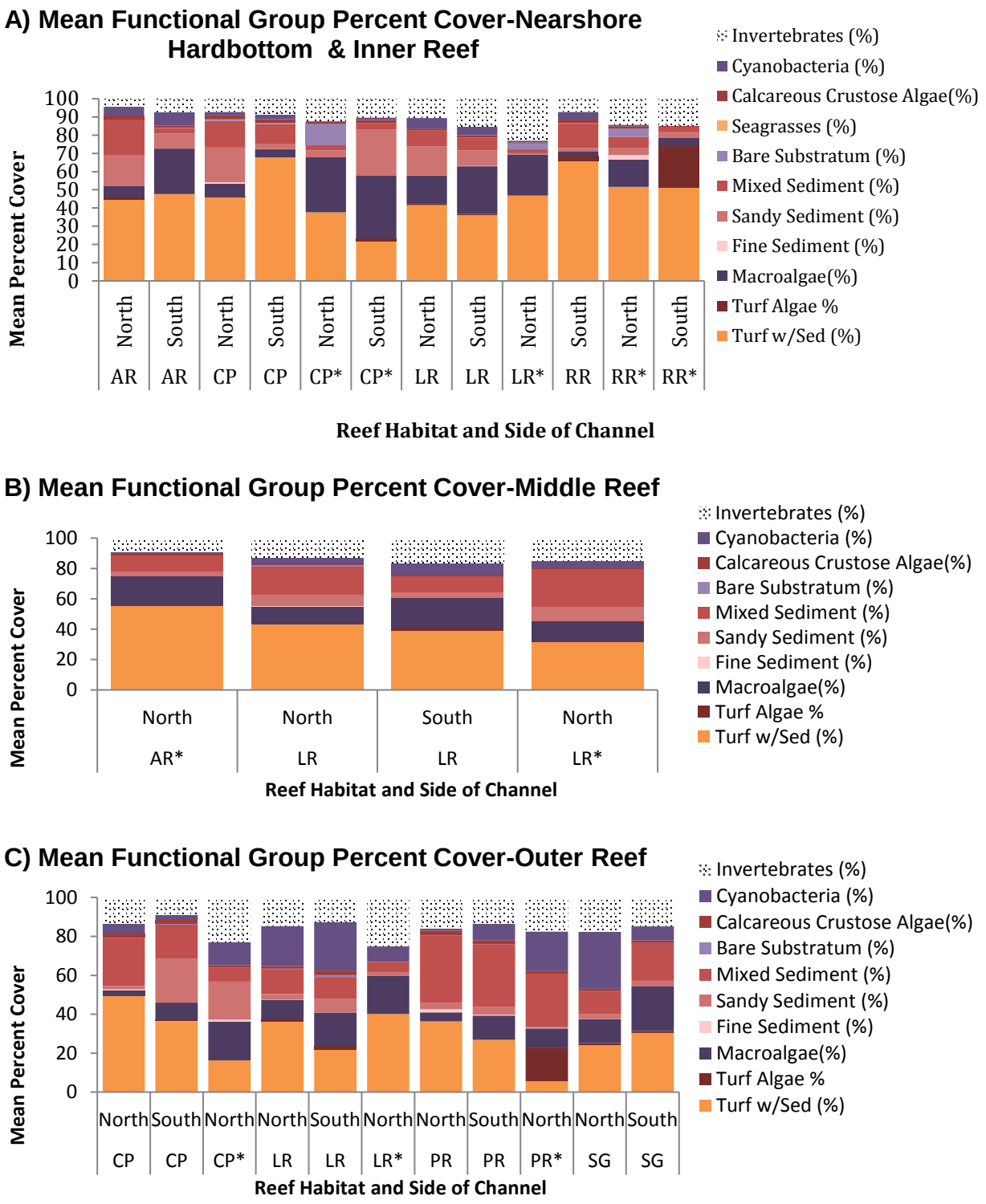

Figure 41. Functional group percent cover as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites. Invertebrate category includes corals, octocorals, sponges, etc. For a breakdown of the percent cover of benthic invertebrates see Figure 42.

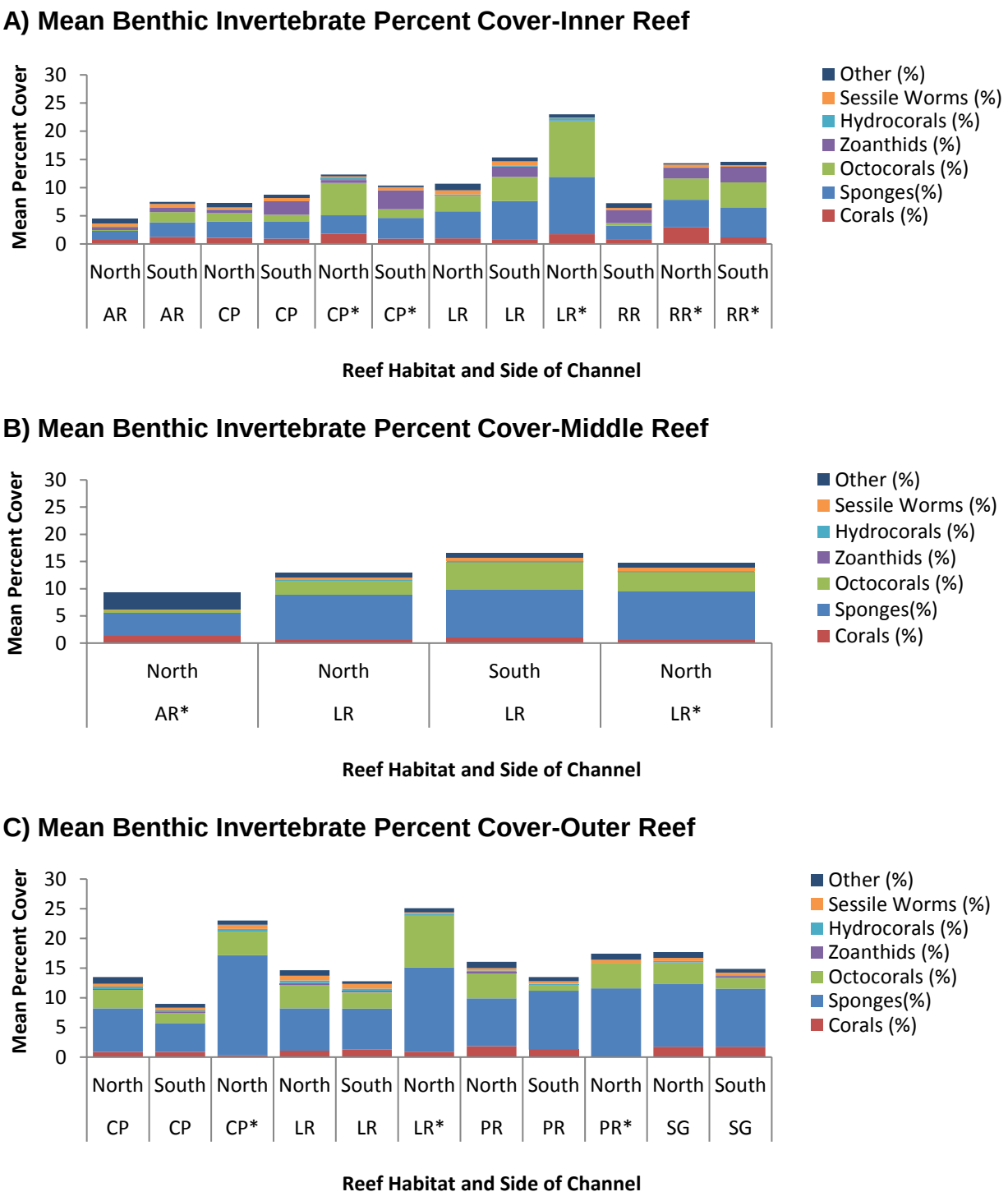

Figure 42. Functional group percent cover of dominant benthic invertebrates as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

The total cover of all benthic invertebrates ranged from 9.2% at AR north EFH sites to 16.6% at LR south sites in the middle reef (Figure 42B). Coral cover was low across all middle reef habitats with cover ranging from 0.6% at LR north sites to 1.4% at AR north EFH sites. Sponges were the dominant benthic invertebrate with respect to cover at 4 out of 4 surveyed habitats and cover ranged from 4.4% at AR north EFH sites to 8.8% at LR north EFH sites (Figure 42B). Octocorals were the second most dominant benthic invertebrate at 3 of 4 middle reef surveyed habitats with octocoral cover ranging from 0.4% at AR north EFH sites to 5.1% at LR south sites (Figure 42B).

3.3.1.3 Outer Reef

Turf with sediment was the dominant benthic category at 6 of 11 outer reef surveyed habitats making up as much as 49.5% of the habitat benthos (CP north, Figure 41C). Sand and bare substrate were the dominant categories in the remaining outer reef surveyed habitats (Figure 41C). The proportion of the benthos covered by sand was highly variable with mixed and sandy sediment making up 38.1% of the benthic cover of PR north sites but only 7% of the cover at LR north EFH sites (Figure 41C). Macroalgae cover ranged from 2.5% at CP north sites to 19.8% at CP north EFH sites. Percent cover of EFH sites were distinct from sites of the same habitat located near the channel (Figure 41C).

The total cover of all benthic invertebrates ranged from 8.9% at CP south sites to 25.1% at LR north EFH sites in the outer reef (Figure 42C). Coral cover was low across all outer reef habitats with cover ranging from 0.0% at PR north EFH sites to 1.8% at PR north sites. Sponges were the dominant benthic invertebrate with respect to cover at all 11 surveyed habitats and cover ranged from 6.8% at LR south sites to 16.8% at CP north EFH sites (Figure 42C). Octocorals were the second most dominant benthic invertebrate in the outer reef surveyed habitats with octocoral cover ranging from 1.0% at PR south sites to 8.6% at LR north EFH sites (Figure 42C).

3.3.2 Coral Density and Size Structure

Coral density was low across all reef types ranging from 0.6 corals/m^2 (/10.76 sf) at the outer reef north CP EFH sites to 2.6 corals/m^2 (/10.76 sf) at the nearshore hardbottom north CP habitat (Figure 43). Coral colony size structure varied by reef type with corals 0-3 cm (0-1.18 in) dominating the nearshore hardbottom and inner reef habitats. A more equal distribution of coral size classes was documented across middle and outer reef habitats (Figure 44). Coral density and coral community size structure data for each survey transect is provided in Appendix G.

Three coral species listed as threatened under the ESA were encountered during the survey, *Acropora cervicornis, Orbicella annularis, and Orbicella faveolata*. *A. cervicornis* was found at three EFH sites: IN-171-RR, IN-173-RR, and IN-195-RR. No *A. cervicornis* were found within the 150 m (492.13 ft) mixing zone. One colony of *O. annularis* was noted in the outer reef spur and groove habitat at site OU-152-SG. Nine colonies of *Orbicella faveolata* were documented at individual sites during the reconnaissance surveys. One colony of *O. faveolata* was documented in the nearshore hardbottom and inner reef area (at site IN-111-AR), one colony in the middle reef (at site MI-36-LR), and seven colonies were found at separate sites in the outer reef (sites OU-44-CP, OU-59-CP, OU-60-LR, OU-73-PR, OU-80-PR, OU-152-SG and OU-159-SG). All *O. faveolata* corals were found at sites within the 150 m (492.13 ft) mixing zone. No other threatened coral species were documented during the surveys.

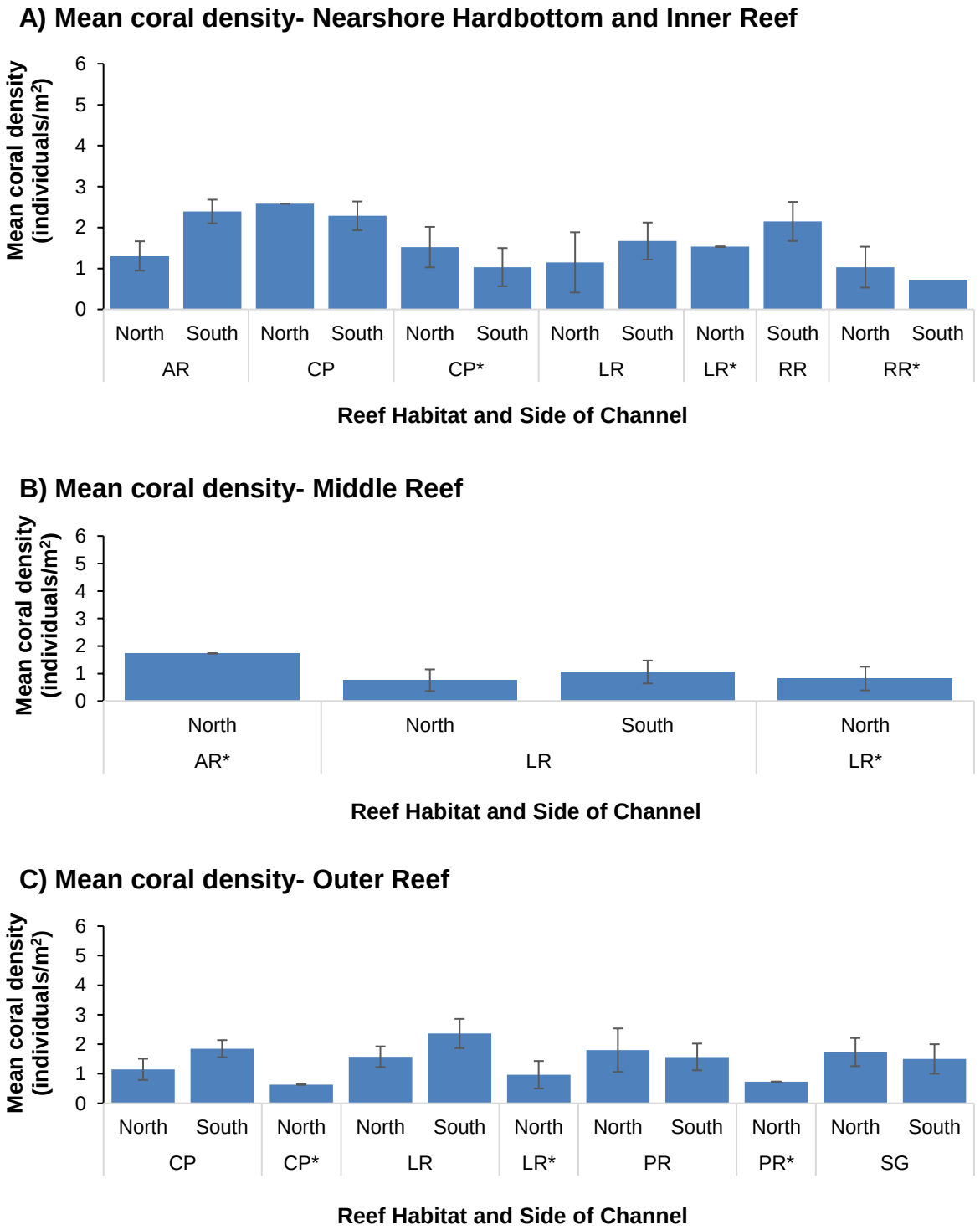

Figure 43. Coral density +/- one SD as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

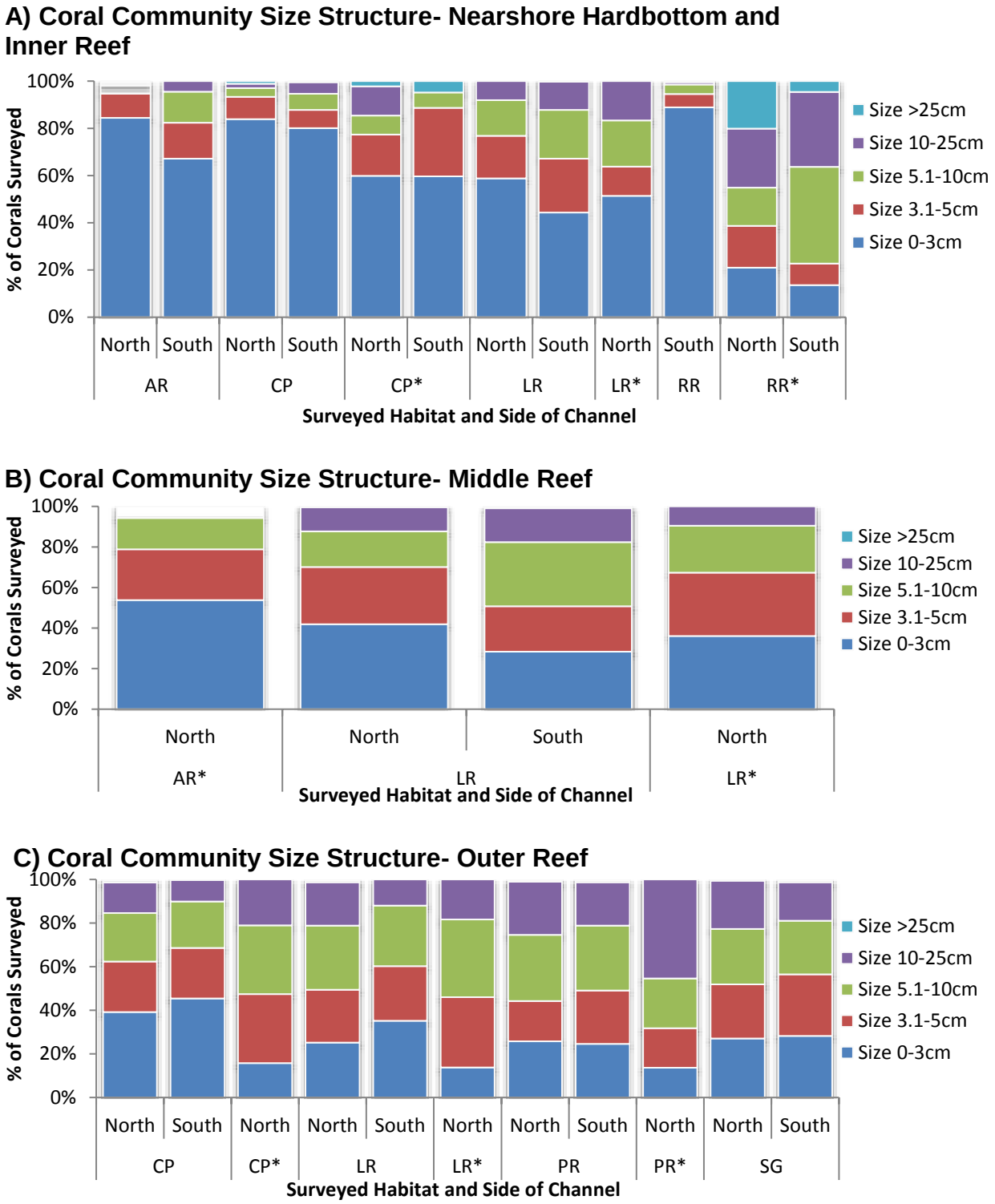

Figure 44. Coral community size structure as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

Analysis of sites visited prior to and after Hurricane Irma revealed a nearly 4-fold increase in the number of visible corals following the passage of the storm (See section 3.2 for information on the effects of Hurricane Irma on coral abundance). Despite the large variability in recorded coral abundance linked to the passage of Hurricane Irma, sampling of sites within habitats was unevenly distributed between pre and post-hurricane Irma time periods and the results below are pooled without regard to sampling date.

3.3.2.1 Nearshore Hardbottom and Inner Reef

Coral density ranged from 0.7 corals/m^2 (10.76 sf) at RR south EFH sites to 2.6 corals/m^2 (10.76 sf) at CP north sites (Figure 43A). The CP north habitat density may be explained by a large number of small *Siderastrea sp*. corals <3 cm noted as a result of the passage of Hurricane Irma. The coral community size distribution was highly skewed with up to 89% of corals being made up of the smallest sized corals (0-3 cm (0-1.18 in) in diameter, RR north) (Figure 44A). The coral community size distribution of EFH sites was often different than sites of the same habitat located near the channel. For example, the RR south habitat had 89% of corals coming from the smallest size class (0-3 cm (0-1.18 in)), compared to only 14% at the RR south EFH sites (Figure 44A). The increase in the proportion of small corals at sites near the channel maybe due to habitat preference for small corals or conversely, a lack of larger corals able to survive the harsh conditions of the near-channel habitat. Large corals >25 cm (>9.84 in) were only a significant category at RR north EFH sites, where healthy thickets of *A. cervicornis* were documented.

3.3.2.2 Middle Reef

Coral density in the middle reef ranged from 0.7 corals/m^2 (10.76 sf) at LR north sites to 1.7 corals/m^2 (10.76 sf) at AR north EFH sites (Figure 43B). The middle reef had a more even coral community size distribution than nearshore hardbottom and inner reef surveyed habitats with only 54% of corals documented in the smallest size class (AR north EFH, Figure 44B). The largest size class of corals, those >25 cm (>9.84 in), represented 1.3% or less of middle reef coral communities (LR south, Figure 44B).

3.3.2.3 Outer Reef

Coral density on the outer reef ranged from 0.6 corals/m^2 (10.76 sf) at CP north EFH sites to 2.4 corals/m^2 at LR south sites (Figure 43C). The outer reef had the most even coral community size distribution of the three reef types with no size category exceeding 45% of the coral community size structure of any sampled habitat (Figure 44C). Large corals, >25 cm (>9.84 in), were still very rare making up less than 1.4% of any coral community size distribution (Figure 44C). The coral community size distribution of EFH sites located beyond the 150 m (492.13 ft) indirect effect boundary was often different than sites of the same habitat located near the channel. For example, the LR north habitat had 25% of corals in the smallest size class (0-3 cm (0-1.18 in)), compared to 13.8% at the LR north EFH sites (Figure 44C). The increase in the proportion of small corals at sites near the channel maybe due to habitat preference for small corals or conversely, a lack of larger corals able to survive the harsh conditions of the near-channel habitat.

3.3.3 Sponge Community and Size Structure

The sponge community was evaluated within sampled quadrats with counts of sponges being categorized by morphotype and size class. Sponge morphotypes include: tube/vase, amorphous/massive, branching, and encrusting. Size classes were broken into the following four categories: 0-10 cm, 10.1-25 cm, 25.1-50 cm and >50 cm (0-3.94 in, 3.98-9.84 in, 9.88-19.69 in, >19.69 in). A depiction of the proportion of sponges within each morphotype is presented in Figure 45 and the sponge community size structure is shown in Figure 46. *Xestospongia* were enumerated within the 30 x 1 m (98.42 x 3.28 ft) belt transect and their abundance among habitats is shown in Figure 47 and size structure information per habitat is shown in Figure 48. Sponge data by morphotypes and size class as well as *Xestospongia* counts by size class are provided for each survey transect in Appendix H.

Sponge communities were dominated by encrusting sponges at 16 out of 27 surveyed habitats. Of the remaining surveyed habitats, branching sponges were dominant in 8 habitats, amorphous/massive sponges dominated in two habitats and ball sponges were dominant in one surveyed habitat (Figure 45). Sponge size structure was highly skewed, with the majority of sponges measuring between 0-10 cm (0-3.94 in) in all habitats. Sponge size increased from inshore to offshore, including *Xestospongia.* Abundance also increased with distance from shore with outer reef habitats having greater abundance of sponges than inner reef habitats.

Comparison of a sub-sample of sites prior to and after the hurricane revealed more than a doubling of the number of encrusting sponges (4.2 encrusting sponges/quad to 7.6 following the storm) and an increase in the number of ball sponges following Hurricane Irma when compared to sites sampled prior to the storm (0.3 to 4.1 ball sponges following the storm). Divers photographed several sheered *Xestospongia* at sites sampled after the hurricane, but due to low abundance of these sponges in the nearshore hardbottom and inner reef colonized pavement habitat where comparisons of pre and post hurricane impacts were made, this effect was not possible to quantify.

3.3.3.1 Nearshore Hardbottom and Inner Reef

The nearshore hardbottom and inner reef had the highest proportion of encrusting sponges of any sampled habitat making up as much as 77.6% of the sampled sponge community (AR north, Figure 45A). Branching sponges were the next most dominant sponge type making up as much as 41.6% of the sponge community (LR north EFH sites, Figure 45A). The rest of the nearshore hardbottom and inner reef sponge community was made up of amorphous/massive sponges (up to 33.6% at CP north EFH sites), ball sponges (up to 31.9% at RR north EFH sites), and tube/vase sponges (less than 4.2% of the sampled sponge community, Figure 45A). Sponge size structure was highly skewed towards small individuals, with up to 97% of sponges measuring between 0 and 10 cm (0-3.94 in) (Figure 46A). *Xestospongia* abundance was much lower in the nearshore hardbottom and inner reef than any other reef type with mean abundance ranging from 0.0 sponges/transect to 4.3 sponges/transect (Figure 47A). The size distribution of *Xestospongia* was dominated by sponges in the 1-10 cm (.39-3.94 in) and 10.1-25 cm (3.98-9.84 in) size categories (Figure 48A).

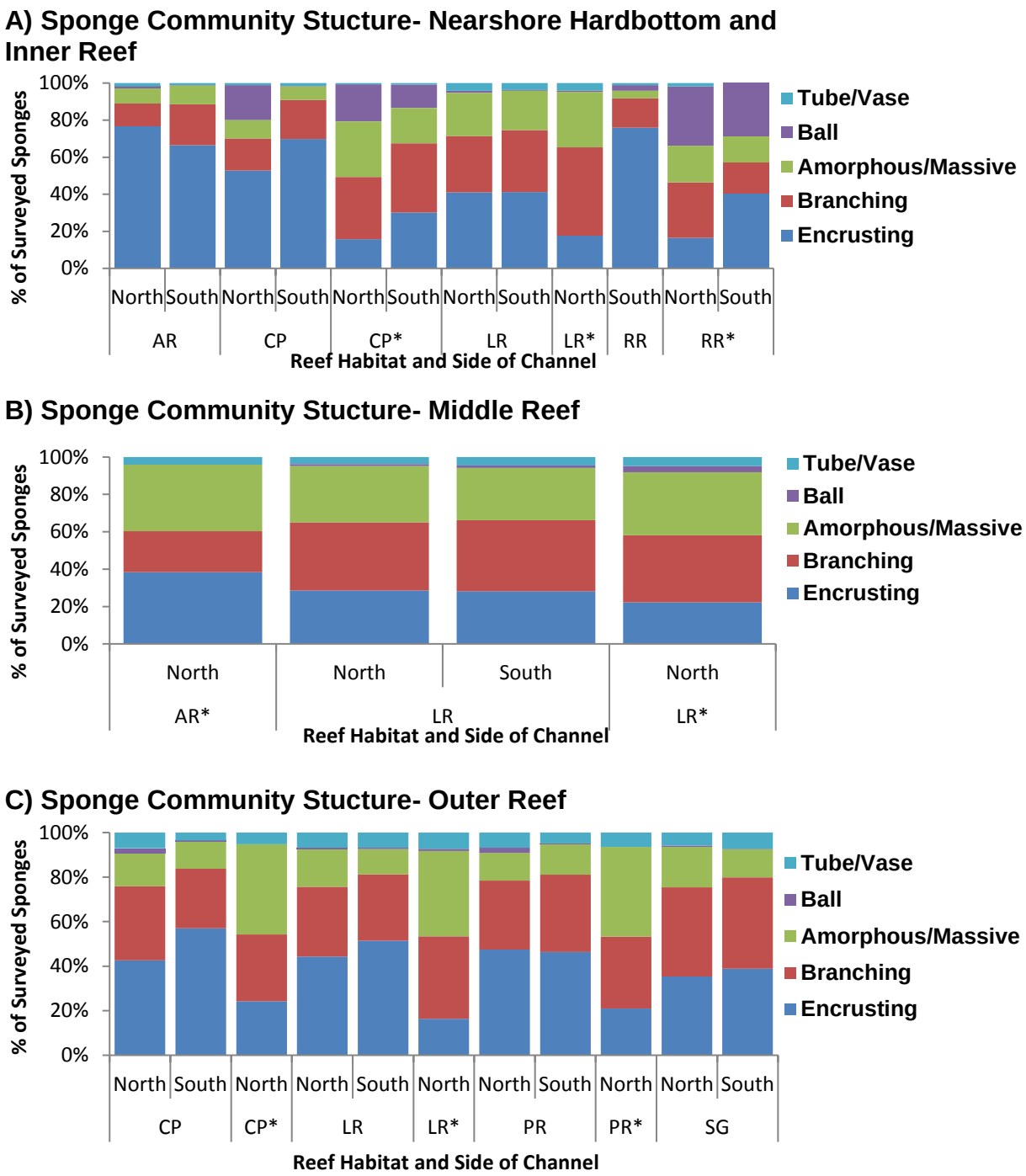

Figure 45. Sponge community structure in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

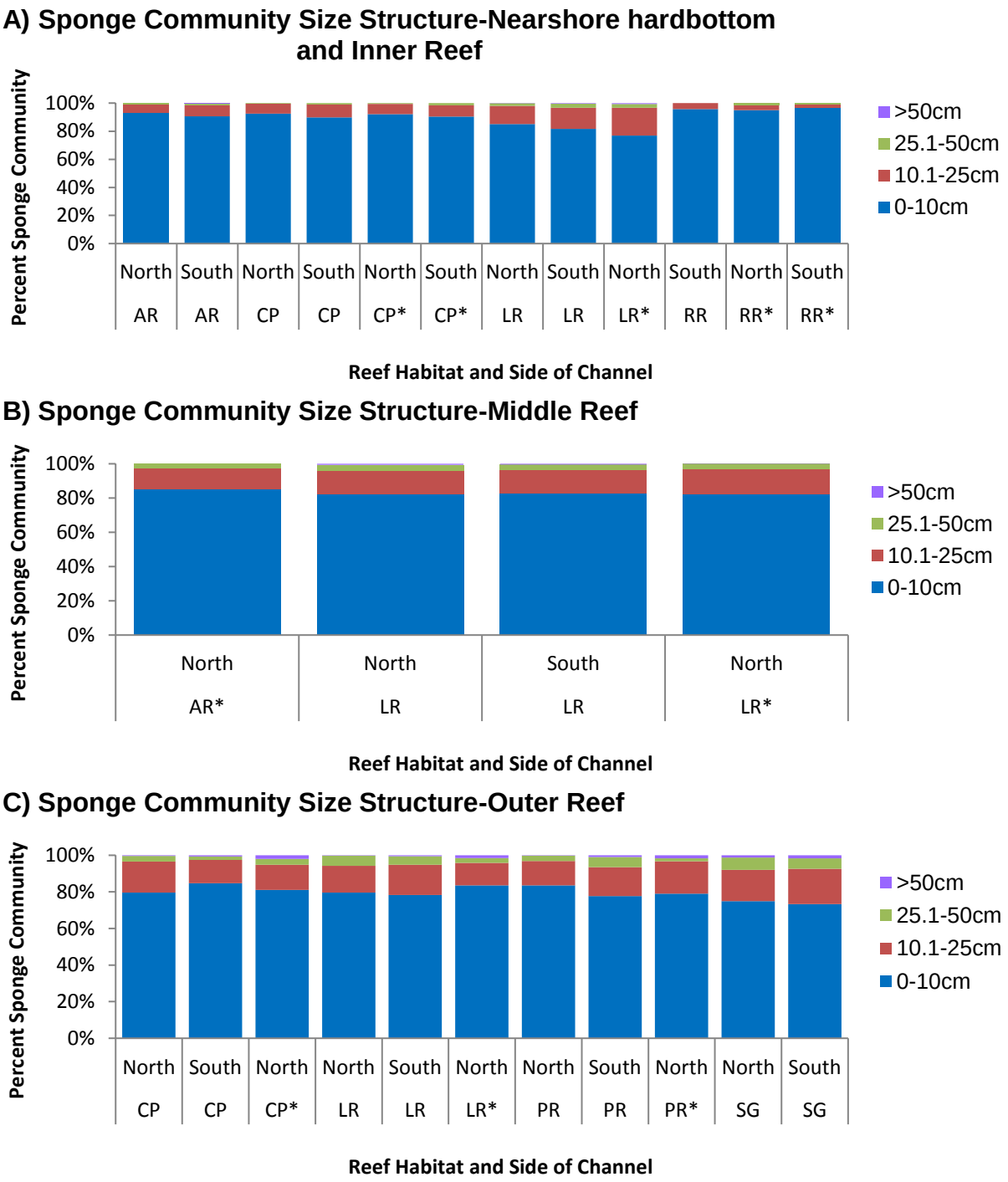

Figure 46. Sponge community size structure as documented in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

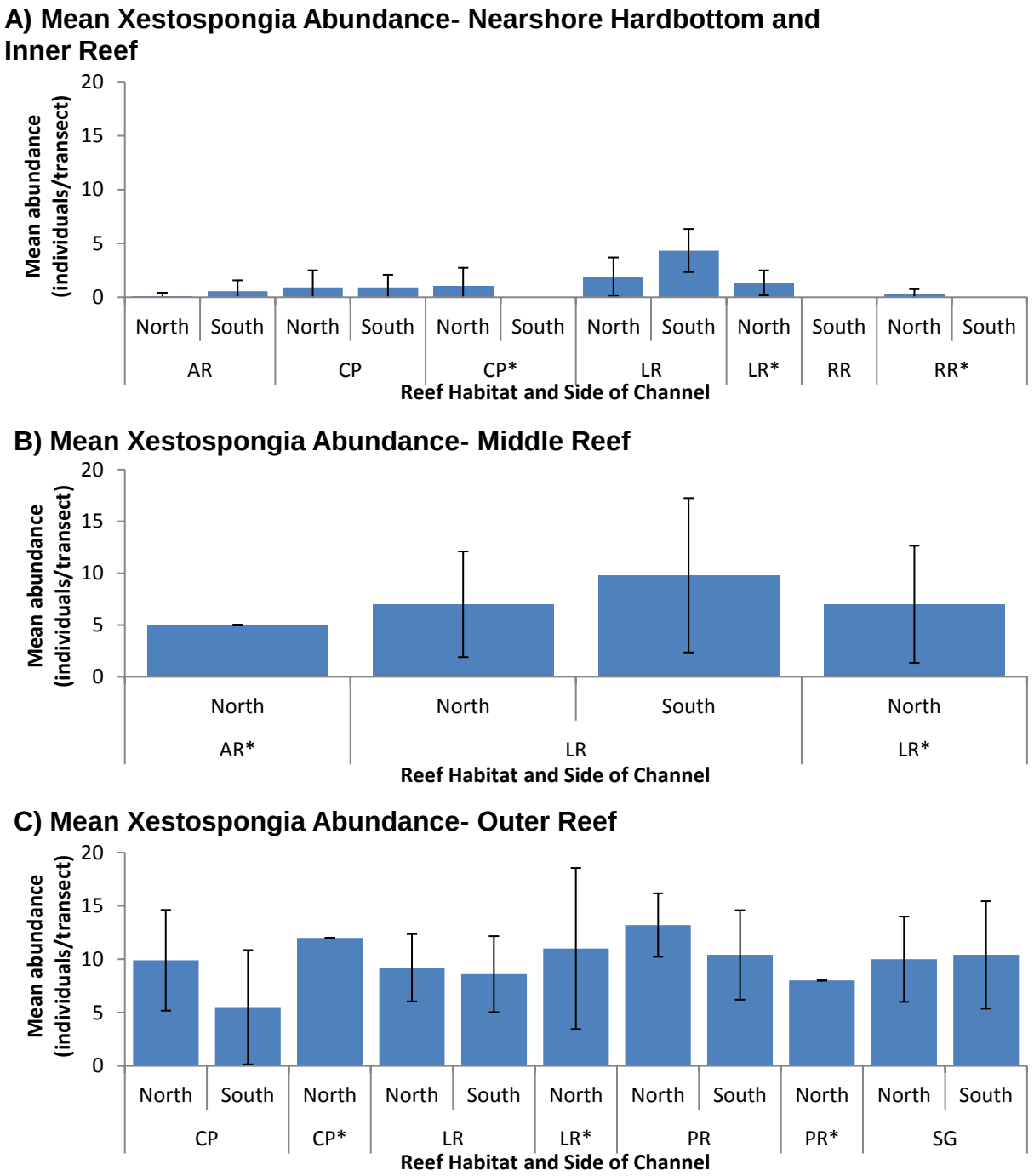

Figure 47. Mean *Xestospongia* abundance +/- one standard deviation in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

Figure 48. ***Xestospongia*** **population size structure as documented in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.**

3.3.3.2 Middle Reef

Sponge morphotypes on the middle reef were more evenly distributed when compared to the nearshore hardbottom and inner reef survey sites (Figure 45B). Encrusting sponges made up as much as 38.4% of sponges at middle reef sites (AR north EFH sites, Figure 45B). Branching sponges made up as much as 38.0% of middle reef sponge communities (LR south, Figure 45B). The rest of the middle reef sponge community was made up of amorphous/massive sponges (up to 35.6% at AR north EFH sites), ball sponges (up to 35.6% at AR north EFH sites), and tube/vase sponges (less than 4.8% of the sampled sponge community, Figure 45B). Sponge size structure on the middle reef was also dominated by small individuals, with up to 83% of sponges measuring between 0 and 10 cm (0-3.94 in) (Figure 46B). *Xestospongia* abundance was higher in the middle reef when compared to the nearshore hardbottom and inner reef habitats with mean abundance ranging from 5.0 sponges/transect to 9.8 sponges/transect (Figure 47B). The size distribution of *Xestospongia* in the middle reef was dominated by sponges in the 1-10 cm (.39-3.94 in) and 10.1-25 cm (3.98-9.84 in) size categories but sponges between 25.1-50 cm (9.88-19.69 in) generally made up a larger proportion of the sampled sponge community than in the nearshore hardbottom and inner reef sampled habitats (Figure 48B).

3.3.3.3 Outer Reef

Sponge communities in the outer reef were dominated by small encrusting and branching sponges at sites closest to the channel and small amorphous/massive sponges dominated at EFH sites. Encrusting sponges made up as much as 57.0% of the sponge community at outer reef sites (CP south, Figure 45C). Branching sponges made up as much as 37% of outer reef sponge communities (LR north EFH sites, Figure 45C). The rest of the outer reef sponge community was made up of amorphous/massive sponges (up to 40.5% at CP north EFH sites), ball sponges (up to 2.2% at CP north EFH sites), and tube/vase sponges (less than 7.0% of the sampled sponge community, Figure 45C). Sponge size structure on the outer reef was dominated by small individuals, with up to 84.7% of sponges measuring between 0 and 10 cm (0-3.94 in) (Figure 46C*). Xestospongia* abundance was highest in the outer reef when compared to the nearshore hardbottom, inner, and middle reef habitats with mean abundance ranging from 5.5 sponges/transect to 13.2 sponges/transect at outer reef sampling areas (Figure 47C). The size distribution of *Xestospongia* in the outer reef was dominated by sponges in the 1-10 cm (.39-3.94 in) and 10.1-25 cm (3.98-9.84 in) cm size categories but sponges between 25.1-50 cm ((9.88-19.69 in) were found in all outer reef sampled habitats and sponges >50 cm (19.69 in) were found at 10 out of 11 sampled habitats (Figure 48B).

3.3.4 Octocoral Community and Size Structure

Octocoral communities in all three reef habitats were dominated by four genera of octocorals and included: *Antillogorgia, Briareum, Erythropodium*, and *Eunicea*. Octocorals in the nearshore hardbottom and inner reef tended to be dominated by colonies 0-10cm in size. While small corals continued to dominate in middle and outer reef habitats, a larger proportion of octocorals in the 10-20, 20-30, and 30-40 cm (3.94-7.87, 7.87-11.81, 11.81-15.75 in) size classes were documented in the offshore habitats. Octocoral count data for each genera and size class are provided for each survey transect in Appendix I.

3.3.4.1 Nearshore Hardbottom and Inner Reef

The nearshore hardbottom and inner reef habitats supports a diverse octocoral community dominated by four types: *Antillogorgia*, *Briareum*, *Erythropodium*, and *Eunicea*. *Antillogorgia* made up as much as 33.3% of the sampled octocoral community in the nearshore hardbottom and inner reef (AR north, Figure 49A). *Briareum* made up as much as 35.9% of octocoral communities (CP north EFH sites, Figure 49A). *Erythropodium* was most dominant at CP south sites making up 42.1% of the octocoral community there and *Eunicia* dominated CP north sites making up 44.9% of the octocoral community there. Octocoral size structure was highly skewed in the nearshore hardbottom and inner reef with the dominant category of octocorals being those between 0-10 cm size followed by those 10-20 cm (3.94-7.87 in) and 20-30 cm (7.87-11.81 in). In the AR north habitat octocorals between 0-10 cm (0-3.94 in) made up 73.7% of all octocorals sampled (Figure 50A).

3.3.4.2 Middle Reef

The middle reef habitat was slightly less diverse than the nearshore hardbottom and inner reef with fewer rare types such as *Plexaura* and *Pterogorgia* (Figure 49B). The middle reef octocoral community was dominated by four types: *Antillogorgia*, *Briareum*, *Erythropodium*, and *Eunicea*. *Antillogorgia* made up as much as 60% of the sampled octocoral community in the middle reef (AR north EFH sites, Figure 49B). *Briarium* made up a similar percentage within the octocoral community in the LR north and south and EFH sites ranging from 11.3-11.8% of the sampled communities (Figure 49B). *Erythropodium* was most dominant at LR south sites making up 42.7% of the octocoral community there and *Eunicia* made up a large proportion of AR north EFH sites and LR north EFH sites making up 40.0% and 41.3% of the octocoral communities respectively. Octocoral size structure was less highly skewed than in the nearshore hardbottom and inner reef, however the dominant category of octocorals were between 0-10 cm (0-3.94 in). The largest proportion of 0-10 cm (0-3.94 in) octocorals was documented in the LR north habitat where they made up 54.0% of all octocorals sampled (Figure 50B).

3.3.4.3 Outer Reef

The outer reef habitat supported the most diverse octocoral community with at least one member of each of the main groups surveyed within the reef (Figure 49C). The outer reef octocoral community was dominated by four generagenus: *Antillogorgia*, *Briareum*, *Erythropodium*, and *Eunicea*. *Antillogorgia* made up as much as 68.9% of the sampled octocoral community in the outer reef (LR south, Figure 49C). *Briareum* made up as much as 33.4% of the outer reef octocoral community (PR north, Figure 49C). *Erythropodium* was most dominant at LR north EFH sites making up 54.4% of the octocoral community there and *Eunicia* made up a large proportion of PR north EFH sites making up 65.4% of the octocoral community in that habitat. Octocoral size structure also skewed towards smaller colonies in the other reef with up to 62.5% of the octocoral community at LR north being made of colonies between 0-10 cm (0-3.94 in) (Figure 50C).

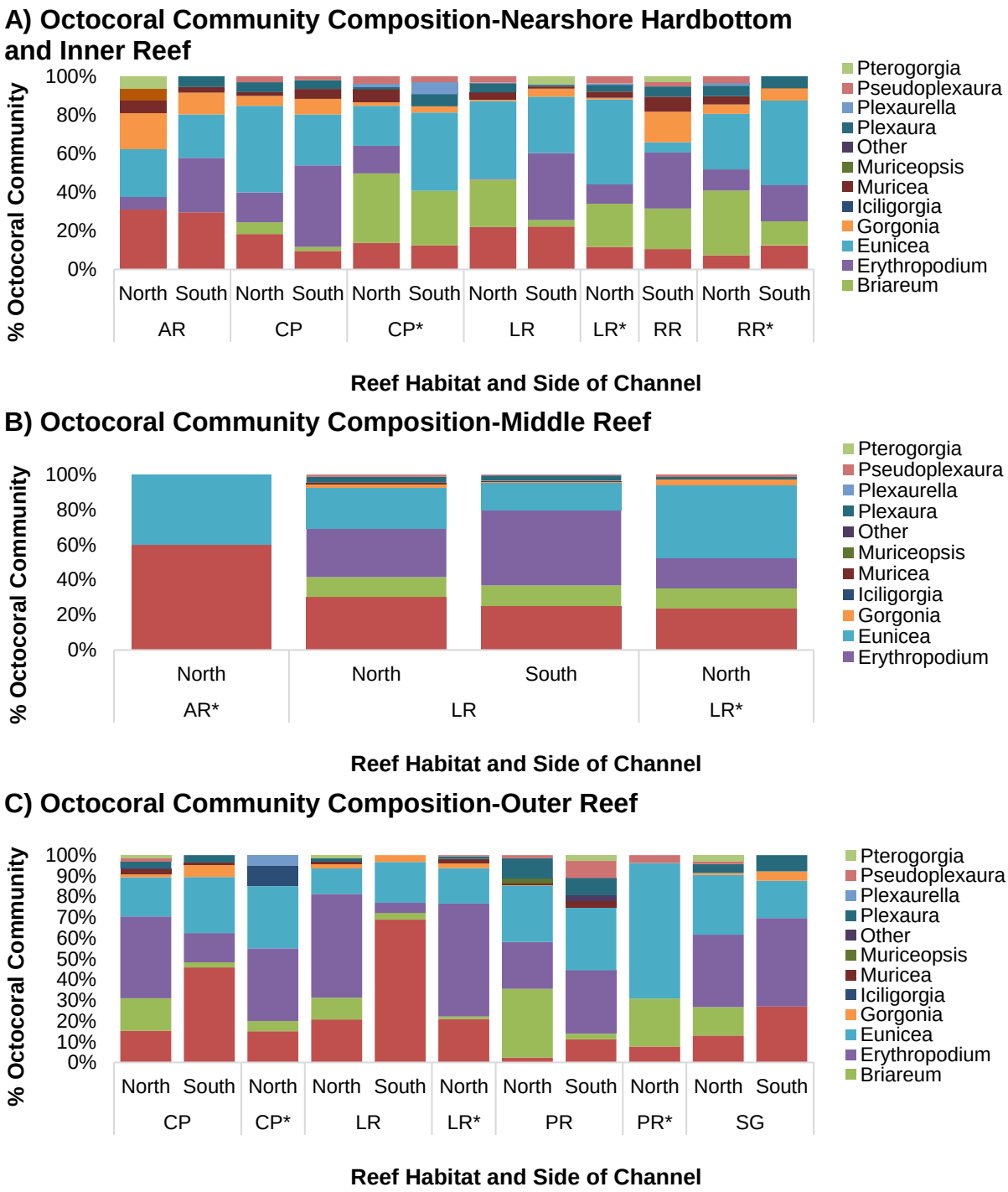

Figure 49. Octocoral community structure by genus in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

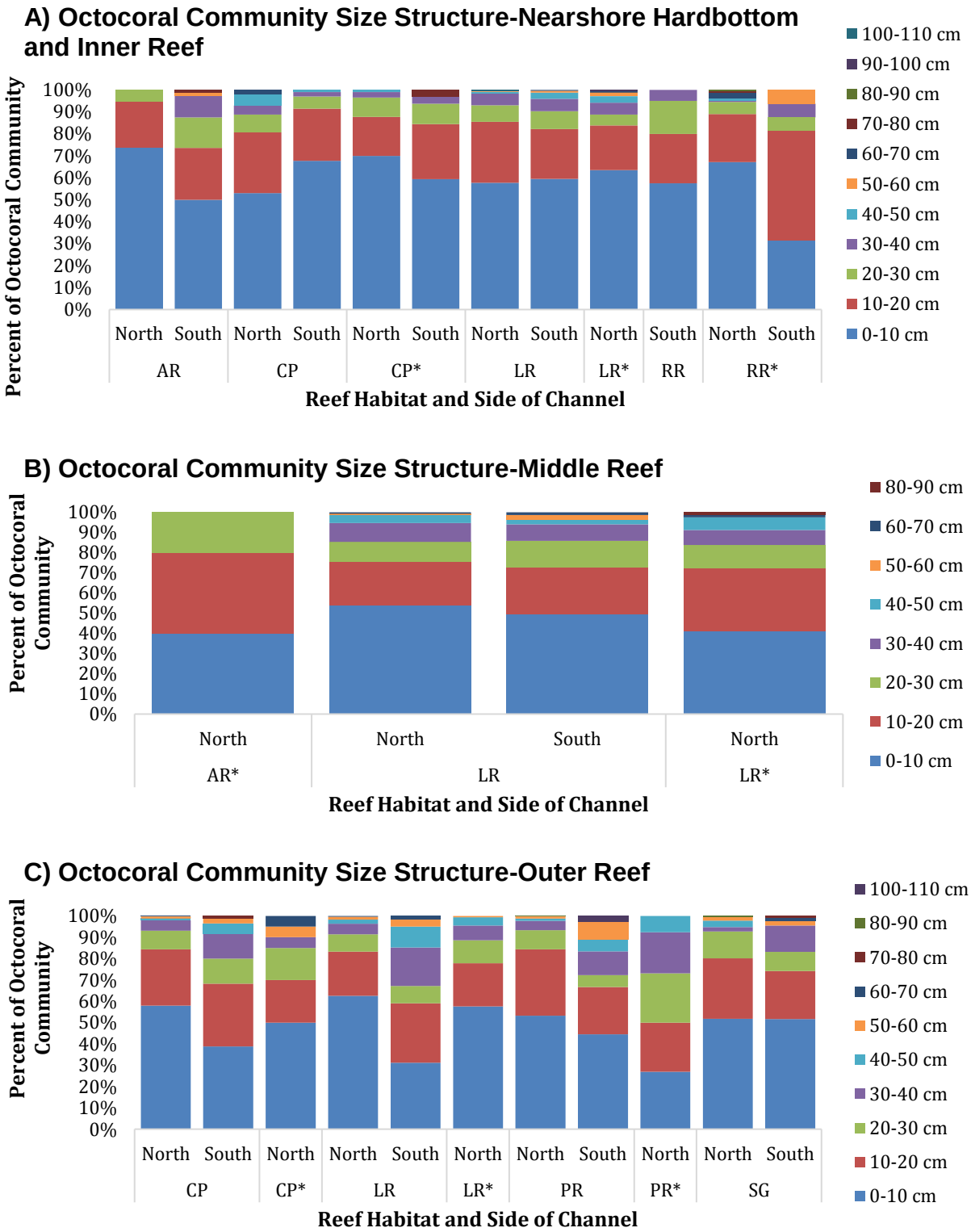

Figure 50. Octocoral community size structure as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

3.3.5 Maximum Sediment Depth

Maximum sediment depth varied by habitat across reef types. The maximum sediment depth was 21 cm (8.27 in) on the nearshore hardbottom and inner reef, 30 cm (11.81 in) on the middle reef and 24 cm (9.45 in) on the outer reef habitat. Maximum sediment depth data for each survey transect are provided in Appendix J.

3.3.5.1 Nearshore Hardbottom and Inner Reef

Maximum sediment depth varied by habitat within the nearshore hardbottom and inner reef ranging from 3 cm (1.18 in) (RR south EFH) to 21 cm (8.27 in) (LR south) (Figure 51A). Maximum sediment depth at EFH sites was either equal to channel-side sites of the same habitat (CP habitat) or lower (LR and RR habitats). Mean maximum sediment depth ranged from 1.4 cm (.55 in) (LR north EFH) to 3.6 cm (1.42 in) (CP south EFH) (Figure 51A).

3.3.5.2 Middle Reef

Maximum sediment depth varied by habitat within the middle reef ranging from 11 cm (4.33 in) (AR north EFH) to 30 cm (11.81 in) (LR north) (Figure 51B). Maximum sediment depth at EFH sites in the LR habitat was lower (17 cm, 6.69 in) than at sites of the same habitat located near the channel (30 cm, 11.81 in). Mean maximum sediment depth ranged from 3.7 cm (1.46 in) (LR south) to 5.9 cm (2.32 in) (AR north EFH) (Figure 51B).

3.3.5.3 Outer Reef

Maximum sediment depth varied by habitat within the outer reef ranging from 5 cm (1.97 in) (LR north EFH) to 24 cm (9.45 in) (SG north) (Figure 51C). Maximum sediment depth at EFH sites was either equal to channel-side sites of the same habitat (CP habitat) or lower (LR and PR habitats) within the outer reef. Mean maximum sediment depth ranged from 2.0 cm (.79 in) (LR north EFH) to 9.2 cm (3.62 in) (SG north) (Figure 51C).

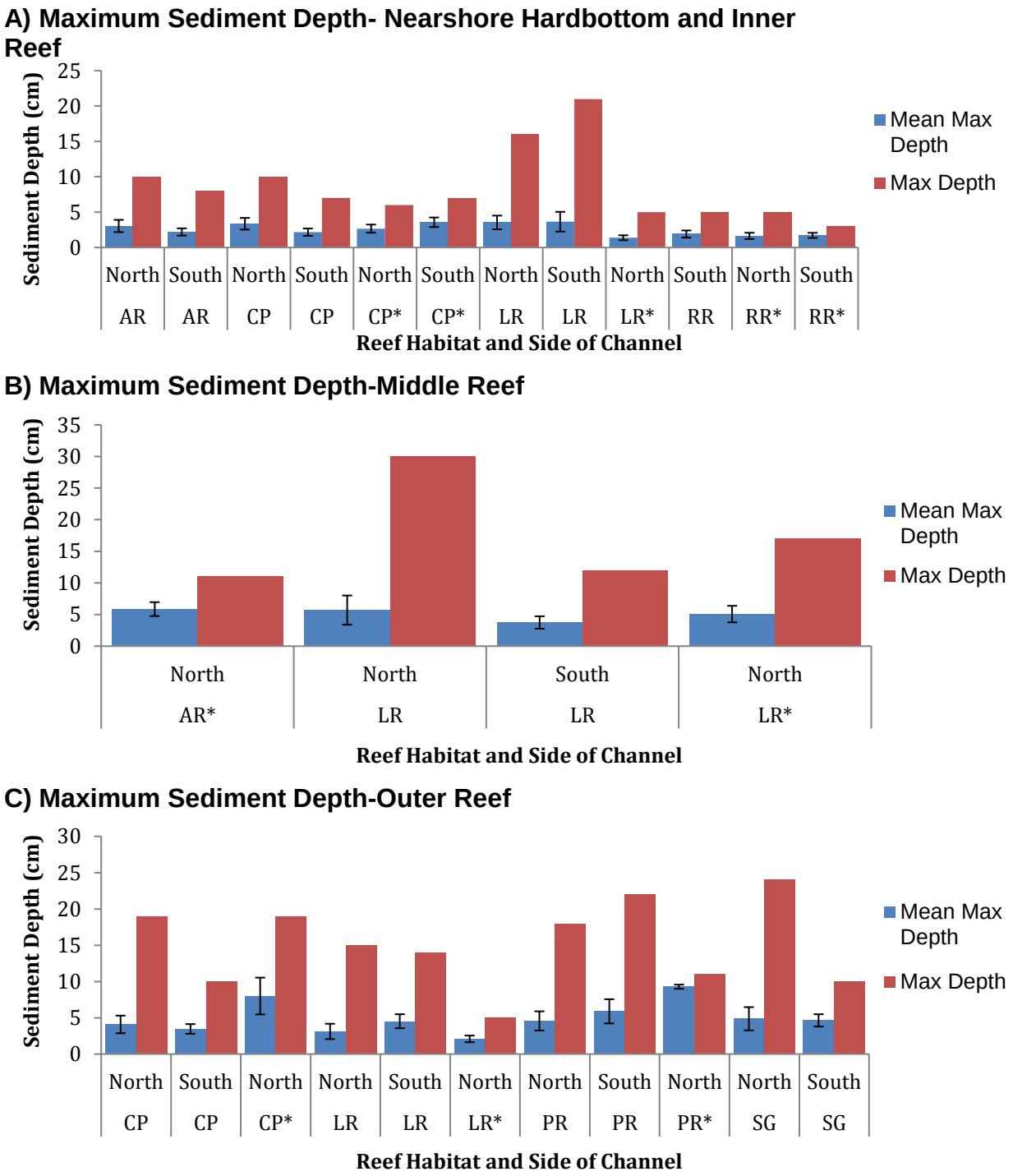

Figure 51. Maximum sediment depth and mean maximum sediment depth +/- one standard deviation as measured in the nearshore hardbottom and inner reef (A), middle reef (B), and outer reef (C). (*) denotes EFH sites.

4.0 DISCUSSION

Several trends were observed across dominant benthic invertebrate groups when comparing communities across reef type. Details are given below.

4.1 Community Size Structure

There was an increase in the proportion of small individuals in the nearshore hardbottom and inner reef when compared to the middle and outer reef areas. This trait was conserved across stony corals, sponges, *Xestospongia*, and octocorals. The proportion of large individuals tended to increase as distance from the shore increased. The predominance of smaller sized individuals in nearshore reef types may be related to increased tidal flow, or the influence of other nearshore factors such as runoff and changes in salinity. Large corals have also suffered recent mortality due to a region-wide white-plague disease epidemic beginning in September, 2014 (Precht et al. 2016) but there has been no documented increase in disease-related mortality at near-channel sites when compared to far-field controls (DCA 2017).

4.2 150 m (492.13 ft) Mixing Zone vs. EFH: Distance from the Channel

Community structure of organisms surveyed for EFH, located beyond the 150 m (492.13 ft) impact area, were often different than those sites of the same habitat located near the channel. In general, the benthic community was dominated by larger individuals at sites located beyond the 150 m (492.13 ft) impact area. In addition, maximum sediment depth was generally higher closer to the channel than at EFH sites of the same habitat. These differences may indicate the existence of a channel-effect at sites directly adjacent to the Port Everglades channel. Due to the limited number of surveys performed in each habitat for EFH, direct comparisons of benthic community metrics between EFH and near-channel sites of the same habitat were not made.

4.3 Hurricane Irma Effects

Hurricane Irma caused dramatic changes to benthic communities near the Port Everglades channel. In particular, the number of small corals that were surveyed, predominantly *Siderastrea* sp. <3 cm (<1.18 in), and small encrusting sponges increased at sites visited after the passage of the hurricane. Percent cover of macroalgae and cyanobacteria declined considerably which may have increased the visibility of small and cryptic organisms. Divers noted the movement of large amounts of sediment, including a fine white veneer of sediment on the reef habitats after the storm, and removal of sand from sand patches and channels, which exposed bare rock.

The number of small corals <3 cm (<1.18 in) varied greatly under natural conditions. Nearly four times the number of corals were surveyed in the CP north habitat after the passage of Hurricane Irma than at sites of the same habitat surveyed before the storm, and nearly all of the variability was due to small corals <3 cm (<1.18 in). Including small corals in estimates of abundance or density may generate uncertainty in the ability to assess benthic health changes related to potential project activities, since small coral density is so variable. Because the number of larger corals <3 cm (<1.18 in) is not as heavily influenced by storms, large coral counts would appear to be a more reliable index of benthic community health.

Direct quantification of the impact of Hurricane Irma on benthic resources near the channel would be most efficiently accomplished through direct surveys of sites both before and after the passage of the storm to remove the between-site variability of our current analysis.

4.4 Comparison with Other Studies

The Southeast Coral Reef Evaluation and Monitoring Project (SECREMP) in 2014 found coral density of sites in Broward County ranged from 0.61 corals/m^2 (/10.76 sf) to 12.27 corals/m^2 (/10.76 sf) when counting coral colonies 4 cm (1.57 in) (and greater (Gilliam et al 2015). Coral density from the reconnaissance survey was lower than Broward SECREMP sites ranging between 0.03 corals/m^2 (/10.76 sf) and 1.83 corals/m^2 (/10.76 sf) when only considering colonies 4 cm (1.57 in) and greater. 2014 SECREMP surveys pre-date the region-wide bleaching and disease events that began in the Fall of 2014 (Precht et al. 2016, Hayes et al. 2017, USCRTF 2017) and none of the SECREMP sites are adjacent to established channels. Despite these differences, coral density in Broward County is low and sponges are the dominant benthic invertebrate at most sites by density and cover metrics.

4.5 Threatened Species

Only three threatened coral species were documented in reconnaissance surveys, *A. cervicornis, O. annularis,* and *O. faveolata*. *A. cervicornis* was only documented at EFH sites whereas one *O. annularis* and nine *O. faveolata* were documented in the 150 m (492.13 ft) mixing zone surrounding the Port Everglades channel. These results coincide with the recent Endangered Species Act (ESA) surveys of the Port Everglades channel that documented *A. cervicornis* was abundant in specific inner reef habitats outside the 150 m (492.13 ft) indirect impact area and *O. faveolata* colonies were rare, but had been found within the indirect impact area of the Port Everglades channel (DCA 2018b). The documentation of a single *O. annularis* colony within the indirect impact area was an addition to the corals documented in the 2017 ESA surveys (DCA 2018b).

4.6 Natural Sediment Environment

Comparison of maximum sediment depth at Port Everglades and PortMiami show that near-channel locations generally have higher maximum sediment depths than those located away from the channel, and that natural sediment depth can be as much as 30 cm (11.81 in) at near-channel locations. The range of maximum sediment depth values in the nearshore hardbottom and inner reef sites at Port Everglades ranged from 3.0 cm (1.18 in) at RR south EFH site (site IN-195-RR), located 950m (3,116.8 ft) away from the Port Everglades channel, to 21 cm (8.27 in) at LR south (IN-118-LR) (located 50m (164.0 ft) from the channel). At PortMiami during the one-year post-construction impact assessment, nearshore hardbottom maximum sediment depth had nearly the same range of values, from 2.7 cm (1.01 in) at the habitat control HBSC1-CP (1650m (5,413.4 ft) from the channel) to 22.5 cm (8.85 in) at site 7a-150, located 150m from the channel (DCA 2017). Natural maximum sediment depth in the middle reef was greater at near-channel locations at Port Everglades (30 cm (11.81 in) at site MI-38-LR), when compared to the near-channel sites at PortMiami (15.0 cm (5.9 in) at R2N1-LR) (DCA 2017). Maximum sediment depth was similar on outer reef sites near the channel at both port locations (maximum sediment depth at near-channel PortMiami locations was 28 cm (11.0 in) at R3N1-LR compared to 24 cm (9.45 in) at SG north at Port Everglades (OU-65-SG) (DCA 2017). The documentation of the natural variability in maximum sediment depth at near-channel habitats is an important baseline from which future changes can be assessed.

5.0 REFERENCES

Aronson, R.B., P.J. Edmunds, W.F. Precht, D.W. Swanson and D.R Levitan. 1994. Large-scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive techniques. Atoll Research Bulletin No. 421.

Brandt, M. E., N. Zurcher, A. Acosta, J. S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multiagency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.

DCA (Dial Cordy and Associates Inc.) 2017. One-Year Post-Construction Impact Assessment for Hardbottom Middle and Outer Reef Benthic Communities at Permanent Sites. FDEP Final Order #0305721-001-BI. 2012. Miami Harbor Phase III Federal Channel Expansion Project. 166 pp. Florida Department of Environmental Protection, Tallahassee, FL

DCA (Dial Cordy and Associates Inc.) 2018a. Technical Memorandum: Port Everglades PED Phase 2. Task 2.1.3 Prepare Updated Reef Map Using Corps HR Sidescan and Multi-beam Survey Data. 18 pp.

DCA (Dial Cordy and Associates Inc.) 2018b. Endangered Species Act Listed Coral Species Survey and Results (DRAFT). RLI #R1049105R1. Port Everglades Navigation Improvement Project. 44 pp. David Miller and Associates (VA) and Broward County Port Everglades Department (FL).

Dodge, R.E., Thornton, S.L., Gilliam, D.S., and Shaul. R. 2001. Biological Survey Report for the Calypso Natural Gas Pipeline: Shore Approach Route North of Port Everglades Entrance Channel with Landing South of Port Everglades Entrance Channel .NCRI Report : 1 -55. http://nsuworks.nova.edu/occ_facreports/26.

Edmunds, P.J., Aronson, R.B., Swanson, D.W., Levitan, D.R. and Precht, W.F., 1998. Photographic versus visual census techniques for the quantification of juvenile corals. *Bulletin of Marine Science*, *62*(3), pp.937-946.

Edmunds, P.J., Bruno, J.F. and Carlon, D.B., 2004. Effects of depth and microhabitat on growth and survivorship of juvenile corals in the Florida Keys. *Marine Ecology Progress Series*, *278*, pp.115-124.

Gilliam, D.S. et al. 2006. Southeast Florida Coral Reef Evaluation and Monitoring Project 2005 Year 3 Final Report. Florida DEP Contract #G0099. Miami Beach, FL. pp. 26.

Gilliam, D.S., Walton, C.J, Brinkhuis, V., Ruzicka, R., and M. Colella. 2015. Southeast Florida Coral Reef Evaluation and Monitoring Project 2014 Year 12 Final Report. Florida DEP Report #RM085. Miami Beach, FL. pp. 43.

Hayes, N.K., Walton, C.J., Brinkhuis, V., Ruzika, R., and Gilliam, D.S. 2017. SECREMP Southeast Florida Coral Reef Evaluation and Monitoring Project. FDEP-CRCP 2017, Research and Academic Learning Exchange. FDEP - Florida Coastal Office Published on February 2, 2017. https://www.youtube.com/watch?v=3Aj_VIOhJQo&list=PLraw0H6njzME6cabdw1vRg7

Interagency Working Group (IWG). 2017. Reconnaissance Survey Protocol Port Everglades Navigation Improvements Project.

Kosmynin, Edwards, Peterson, and Biggs. 2016. Standard Operation Procedures For Nearshore Hardbottom Monitoring Of Beach Nourishment Projects. Florida Department of Environmental Protection. 1 – 60.

Lybolt, M., and Tate, S., 2008. Rapid changes in nearshore habitat: is resource burial an appropriate measure of project impact?. Shore and Beach 76(1):1-5.

Makowski, C., Prekel, S.E., Lybolt, M.J., Baron, R. M. 2009. The Benthic Ecological Assessment for marginal reefs (BEAMR) Method. Journal of Coastal Research. Vol. 25 Issue 2. 515-522.

National Data Buoy Center (NDBC) 2017. http://www.ndbc.noaa.gov/station_history.php?station=fwyf1

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

USACE (United States Army Corps of Engineers). 2015. Final Feasibility Report and Environmental Impact Statement: Port Everglades Harbor Navigation Study. Broward County, FL. pp. 44, 99-100, 109, 111, 115.

USCRTF. 2017. Status and Lessons Learned from a Large-Scale Coral Disease Outbreak. 38thMeeting of the USCRTF, Ft. Lauderdale, Florida, 8/11/2017. https://www.coralreef.gov/meeting38/docs/status_lessons_learned_coral_disease_outbreak.pdf

Walker, B.K. and Klug, K. 2014. Southeast Florida Shallow-Water Habitat Mapping & Coral Reef Community Characterization. Florida DEP Coral Reef Conservation Program Report: 1 - 71. http://nsuworks.nova.edu/occ_facreports/87.

APPENDIX A

Reconnaissance Survey Protocol and Addendum

APPENDIX B

Reconnaissance Survey Site Coordinates

APPENDIX C

Reconnaissance Survey Datasheet Templates

APPENDIX D

Reconnaissance Transect Sand and Hardbottom Calculations

APPENDIX E

Supplementary Data Tables

APPENDIX F

Reconnaissance Transect Summary
Percent Cover

An Excel version of this appendix has also been provided

APPENDIX G

Reconnaissance Transect Summary
Corals

An Excel version of this appendix has also been provided

APPENDIX H

Reconnaissance Transect Summary
Sponges

An Excel version of this appendix has also been provided

APPENDIX I

Reconnaissance Transect Summary
Octocorals

An Excel version of this appendix has also been provided

APPENDIX J

Reconnaissance Transect Summary
Sediment

An Excel version of this appendix has also been provided