Kāneʻohe Bay Mitigation Bank Restoration Project
2014 Baseline Assessment

Prepared By:

Hawaiʻi Department of Land and Natural Resources
Division of Aquatic Resources
Aquatic Invasive Species Team

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Executive Summary

The Hawai‘i Department of Land and Natural Resources (DLNR) Mitigation Bank was developed in response to the need for an effective method of providing remediation for harmful or adverse impacts resulting from altering aquatic habitats through civil development and maintenance projects (DLNR 2014). The mitigation bank for Hawai‘i presently includes coral reef restoration in Kāne‘ohe Bay, where the Division of Aquatic Resources (DAR) has been working since 2007 to remove invasive algae known to damage marine habitats. With the intent of receiving compensatory coral credits from the Army Corps of Engineers under the Mitigation Bank, the Hawai‘i DLNR Aquatic Umbrella Mitigation Bank Prospectus (2014) addresses how mechanical removal of algae via the Supersucker Project and urchin biocontrol effect coral recruitment and growth, as well as the re-colonization of native species in habitats previously occupied by invasive algae.

Mitigation sites in Kāne‘ohe Bay were selected based on restoration need and potential for ecological benefit. For more detail on how mitigation reefs were prioritized and selected for restoration, refer to the Hawai‘i DLNR Aquatic Umbrella Mitigation Bank Prospectus (DLNR 2014). This report serves as the baseline assessment carried out on mitigation reefs to evaluate the pre-removal state of important reef features including coral, invasive algae, rugosity, and native algae. The survey design contains four main components: fixed photo quadrat transects, benthic habitat mapping, photo plots, and coral sizing and colony counts. Based on prioritization criteria, four reefs (Reefs 10, 14, 16, 19) were selected for treatment (algae removal and urchin out-planting) activities out of the 41 patch reefs evaluated during the Kāne‘ohe Bay SNAP Assessment (Neilson et al. 2014). For the baseline assessment, three control reefs and three reference reefs were selected with similar habitat features and algae coverages for comparison with the treatment reefs.

The goal of this report is to provide a summary of the baseline condition of the mitigation reefs before restoration activities were applied. This data will be used to assess the mitigative restoration activities on designated patch reefs in terms of invasive algae cover, coral cover, coral size, and number of coral colonies. In addition, this data will be used to convert the value of the resource improvements into coral credits.

Initial findings showed that the dominant coral species are *Porites compressa* (finger coral) and *Montipora capitata* (rice coral). Coral cover ranged from 37.9 to 82.7% for treatment reefs (algae removal sites), 50.9 to 67.9% for control reefs, and 37.9 to 88.0% for reference reefs. The dominant invasive algae species in the bay were *Eucheuma denticulatum* and *Kappaphycus* spp. Invasive algae cover ranged from 5.23 to 19.6% for treatment reefs, 2.8 to 14.3% for control reefs, and 0.02 to 0.03% for reference reefs. Baseline results also indicated that control-treatment groups were similar in algae and coral and were adequate paired samples for further analysis.

Introduction

Coral reef habitats of Kāneʻohe Bay, Oʻahu, have become increasingly dominated by alien algae since its introduction in the 1970's (Russell 1983, Smith et al. 2002, Conklin and Smith 2005), with *Eucheuma denticulatum., Kappaphycus* spp*., Gracilaria salicornia,* and *Acanthophora spicifera* being the major threats. These species can quickly overtake reef habitats, reduce photosynthesis of native organisms, out-compete native species, alter water chemistry, and kill corals (Russell 1983, Conklin and Smith 2005, Chandrasekaran et al. 2008, Martinez et al. 2011). To combat these impacts, the State of Hawaiʻi's DLNR, Division of Aquatic Resources and its partners have carried out extensive invasive algae control efforts through mechanical removal using the Supersucker and biocontrol through outplanting the native sea urchin *Tripneustes gratilla*. The combination of these techniques has shown positive results at removing invasive algae and limiting regrowth to less than 1% cover, thus promoting sustained opportunities for native species to recolonize these previously occupied habitats.

Land development and harbor maintenance projects also affect aquatic resources. Therefore, mitigation has been a critical tool to help the federal government meet the national goal of "no net loss" of aquatic habitats. As a mitigation bank sponsor, DLNR will provide the requisite long-term commitment to ensure perpetual stewardship and success of restoration efforts at the bank sites. The proposed mitigation bank site in Kāneʻohe Bay will continue invasive algae management efforts already in practice. The DLNR Kāneʻohe Bay project site was selected based on proven ecological suitability for restoration using established methodologies to combat the threat of invasive algae.

The overall goal of this assessment was to collect baseline data in order to conduct future evaluations of the effectiveness of the mitigation bank invasive algae control efforts (mechanical removal and urchin biocontrol) for restoration of coral reefs in Kāneʻohe Bay. This report summarizes the baseline condition of the mitigation reefs prior to restoration. Once the control efforts have been applied, we will conduct follow-up surveys to investigate whether coral cover, coral colony size, and the number of coral colonies is increased by invasive algae management techniques, and to what extent. In addition, we will monitor invasive algae density to evaluate the effectiveness of mechanical removal and biocontrol. Further, we will photo document changes in individual coral colonies over time on mitigation reefs. The scope of this plan includes reef slope and reef flat habitats, excluding sand patches of designated control, reference, and treatment patch reefs for the mitigation bank in Kāneʻohe Bay, Oʻahu.

Site Description

Kāneʻohe Bay (the Bay) is the largest embayment in the Hawaiʻian Islands and contains a diverse array of marine ecosystems including open water, sand flat, barrier reef, patch reefs, and fringing reef (Figure 1). The large (~2.5 mile) barrier reef shelters the bay from trade wind swell, and creates ideal conditions for

coral growth. The Bay is unique in that it contains numerous patch reefs, which are distinct island-like geomorphological reef features providing habitat for an abundance of coral and marine life.

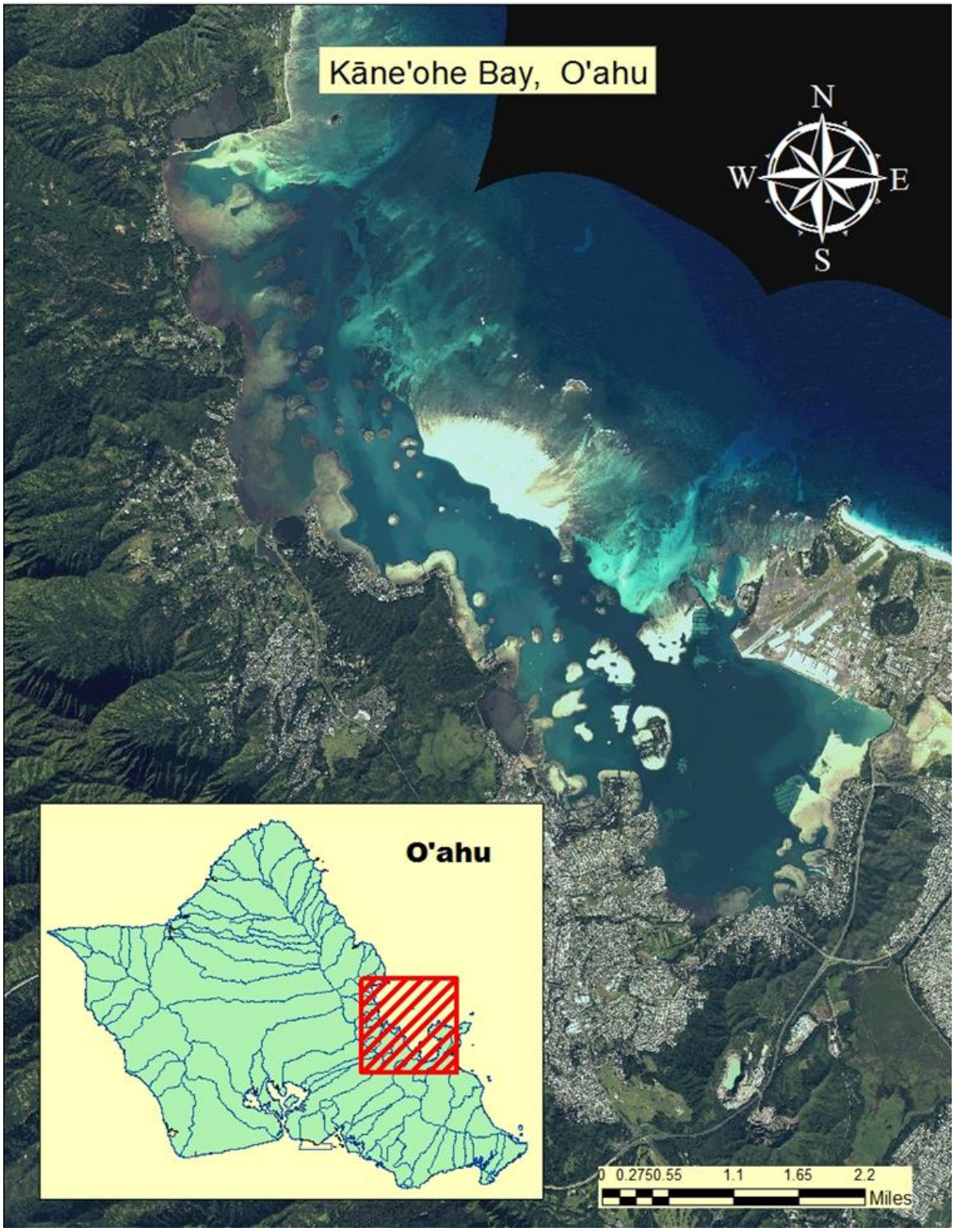

Figure 1. Satellite imagery of Kāneʻohe Bay, Oʻahu

Site Selection

DLNR selected Kāneʻohe Bay for restoration efforts based on the Bay's unique patch reef ecosystems and abundant ecological resources. In order to select individual patch reefs for the Mitigation Bank site, DLNR conducted a multi-step evaluation that quantified the benthic composition of patch reefs in the Bay (Neilson et. al. 2014). Using satellite imagery and past survey data as a reference, reefs composed of low coral cover and no invasive algae cover were designated as "low priority", and removed from management consideration. The remaining patch reefs were then identified for a bay-wide rapid-assessment survey (a snapshot, or "SNAP" survey) to map coral and invasive algae (*Eucheuma* spp. and *Kappaphycus* spp.) density and distribution in the Bay.

DLNR surveyed forty-one patch reefs from February to April 2014, and established a Kāneʻohe Bay coral and invasive algae distribution dataset (Neilson et. al. 2014). The resulting data was displayed using ArcGIS software, which showed the variable distribution of both invasive algae and coral throughout the Bay's patch reefs. Reefs were ranked for management priority based on a high co-occurrence of both live coral and invasive algae. The four highest priority reefs were designated as treatment reefs for mechanical algae removal using the Supersucker barge and biocontrol using native sea urchin out-plantings. Each treatment reef was paired with both a control and reference reef.

Treatment (Restoration), Control, and Reference Reef Designation

For the bank site, DLNR selected four patch reefs (Reefs 10, 14, 16, 19) as treatment reefs (Figure 2). These reefs have the potential for the most ecological benefit from restoration. DLNR will restore these reefs by mechanical removal of invasive algae and biocontrol with sea urchin out-planting.

DLNR designated three reefs within the Bay as control reefs (Reefs 9, 15, 23). Control reefs are in the same geographic area as the restoration reefs, and have similar reef area as well as coral and invasive algae cover. The control reefs will demonstrate the condition of the resources over time without restoration efforts, and can be used as a baseline for calculating the restoration credit gain of the project. Any potential modifications to the bank site's credit earnings will be based on a comparison between the treatment reefs and control reefs.

DLNR designated three reefs as reference reefs (Reefs 12, 17, 22). The reference reefs have high coral cover and little to no invasive algae. Reference reefs represent the restoration target condition, and will be used to determine optimal performance standards for the bank site.

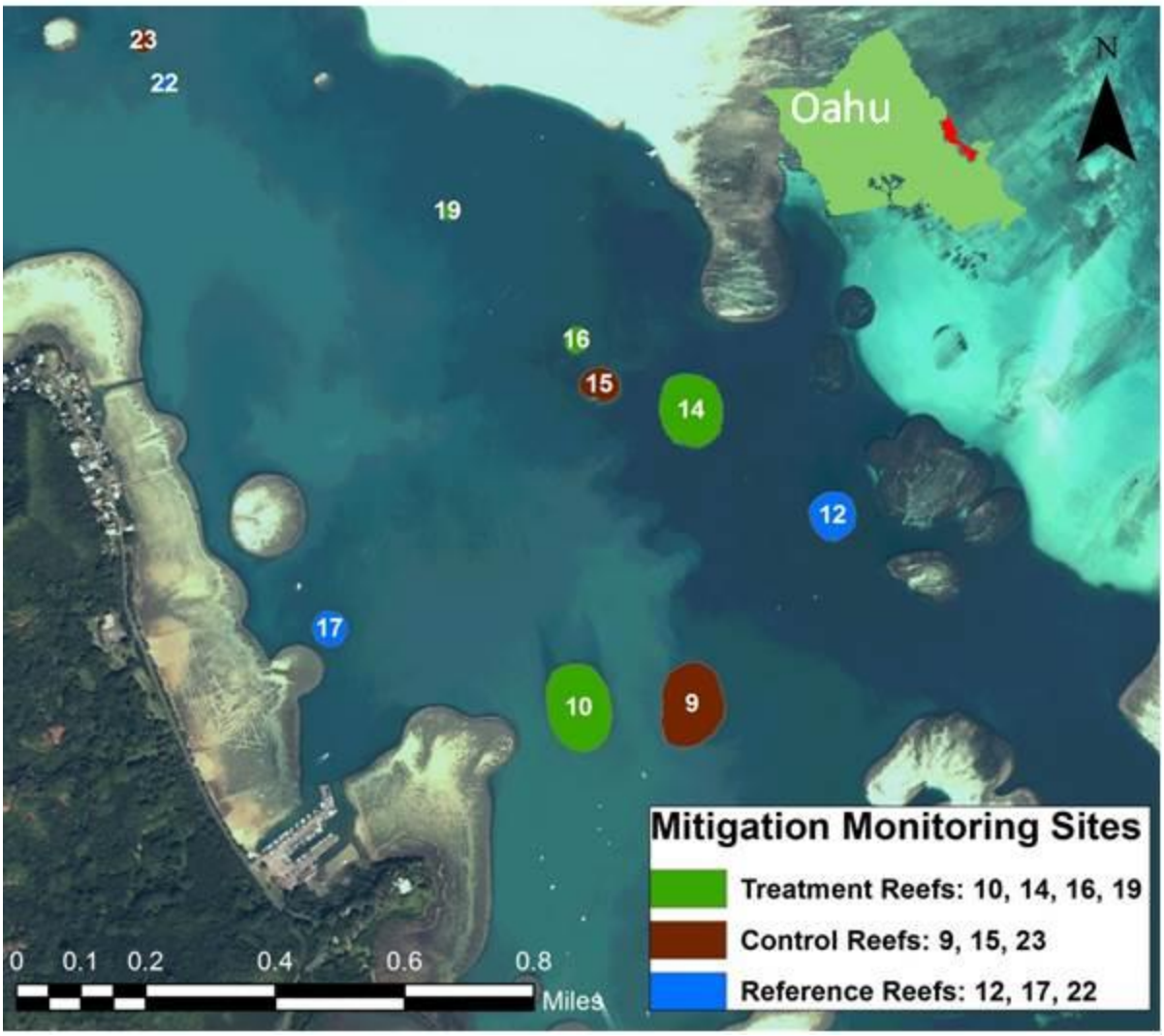

Figure 1. Kāneʻohe Bay, Oʻahu site map for mitigation bank treatment, control, and reference reefs.

Methods

Sampling Design

The sampling design was adapted from methods developed and tested by the Hawaiʻi Division of Aquatic Resources (DAR), the Coral Reef Assessment and Monitoring Program (CRAMP), Fisheries Ecology Research Lab (FERL), and The Nature Conservancy of Hawaiʻi. Field methods were tested and modified to maximize cost-effectiveness and statistical power, and produce photo-documented results. This survey design contains four main components: fixed photo quadrat transects; permanent photo plots; coral colony sizing and counts; and benthic habitat mapping.

Fixed Photo Quadrat Transects

Fixed transects (10 m) were installed on treatment, control, and reference reefs using stainless steel eye pins. Transect locations were chosen using a stratified random sampling approach generated through ArcGIS. Each patch reef was stratified by habitat type including reef slope, reef flat, and sand. Large sand patches consisting of greater than two square meters were excluded from the survey area. The number of transects for each site was determined using 0.80 power test to detect a 15% increase in mean coral cover with an alpha of 0.1. Reef flat transects were placed parallel to the reef slope along a consistent contour which was identified at 30 cm below the average reef flat depth at mean lower low water (MLLW). A camera was secured on a custom PVC Quadrat frame fixed 50 cm above the benthos and captured a 40 cm x 50 cm photo frame. Photos were taken every 50 cm on both sides of the transect tape totaling 40 photos per 10 m transect. Using Coral Point Count with Excel extensions (CPCe), percent cover by benthic species or type was generated from transect photos. Mean percent cover and standard deviation were calculated by habitat type and reef. Survey transect maps are included in Appendix A.

Algae Height

Invasive algae canopy height was measured within each 40 cm x 50 cm photo frame along each 10 m transect. The tallest vertical section of algae was recorded within each quadrat. Mean algae volume was calculated by multiplying the mean algae height by the area and the percent cover (determined from the CPCe analysis) of each invasive algae species. Mean algae height and standard deviation were calculated by habitat type and reef.

Rugosity

A brass rugosity chain was placed beside the transect tape following the reef benthos and letting the chain fall between the interstitial space. A rugosity index was created from the ratio of the distance measured on the tape to the length of chain (Friedlander and Parrish 1998).

Photo Plots

Fixed photo plots (2 x 2 m) were installed in three locations on each reef, with two plots on the reef flat and one on the reef slope. Plot locations were determined by areas that had a high co-occurrence of algae and coral. Permanent stainless steel eye pins were placed in both the southwest and northeast corners to orient and re-locate the 2 x 2 m plot. A photo mosaic of multiple 40 cm x 50 cm overlapping photos captured the entire photo plot area. Using Microsoft Image Composite Editor Software, a representative composite photo was stitched together.

Coral Sizing

Coral colony size measurements and counts were conducted within the same permanent photo plots described above. Each individual coral colony occurring within the plot was identified by species and measured by size class across the longest axis (<5 cm, 5-10 cm, 11-20 cm, 21-40 cm, 61-80 cm, 81-100 cm, 101-120 cm, and >120 cm). Individual coral colonies were identified as a single skeletal mass with living

tissue (Nugues and Roberts 2003). Coral colonies were counted if more than 50% of the colony lay inside the quadrat.

Benthic Habitat Mapping

Benthic mapping surveys were conducted using techniques described in the "Kāneʻohe Bay Snap-Assessment Report" (Neilson et al. 2014), with modifications to increase the sample density and incorporate more habitat features. Surveyors spaced approximately 5 m apart, swam transects across the reef placing a 50 cm measuring stick haphazardly every 5 m and taking a GPS waypoint. Each patch reef was surveyed to the slope edge to depths of approximately 4 m, recording percent cover of live coral, *Eucheuma/Kappaphycus, Gracilaria/Acanthophora,* sand, rubble, and pavement, based on the benthic composition below the measuring stick. Percent cover was classified into bins of 0%, 1 – 10%, 11 – 50%, 51 – 75%, and 76 – 100%. Reef habitats were mapped in ArcGIS using the "Inverse Distance Weighted" tool and the "Reclassify" tool to produce percent cover data and maps for the designated benthic categories.

Fish Surveys

Visual fish census estimates were conducted along four 25 x 5 m belt transects per reef. Two 10 m benthic transects were combined with an additional 5 m gap. Belt transect locations are identified by reef in Appendix A. Surveyors swam 10-minute timed transects, recording individual fish by species and size class within 2.5 m on each side of the transect tape. Fish were counted according to the following size classes: 0 – 5 cm, 5 – 10 cm, 10 – 15 cm, 15 – 20 cm, and > 20 cm. Total length was estimated to the nearest 1 mm for any fish larger than 20 cm.

Results

Site Selection

Ten reefs were surveyed from July to November, 2014. Treatment, control, and reference reefs were grouped based on similarity of geographic location and coverage of coral, *Eucheuma* spp. and *Kappaphycus* spp. (Table 1). A total of 120 transects and 30 photo plots were surveyed.

Table 1. Groupings for treatment, control and reference reefs. Reef 15 serves as the control for treatment reefs 14 and 16 and reef 12 serves as the reference for reefs 14, 15, and 16. Ed/Ks = *Eucheuma*/*Kappaphycus* spp.

Reef Groupings		
Treatment	Control	Reference
R10 (25.8% coral, 1.61% Ed/Ks)	R9 (30.2% coral, 2.20% Ed/Ks)	R17 (24.7% coral, 0.002% Ed/Ks)
R14 (24.1% coral, 6.28% Ed/Ks)	R15 (50.4% coral, 7.14% Ed/Ks)	R12 (74.7% coral, 0.024% Ed/Ks)
R16 (58.5% coral, 5.13% Ed/Ks)	R15 (50.4% coral, 7.14% Ed/Ks)	R12 (74.7% coral, 0.024% Ed/Ks)
R19 (82.2% coral, 2.70% Ed/Ks)	R23 (42.9% coral, 0.31% Ed/Ks)	R22 (80.7% coral, 0% Ed/Ks)

Fixed Photo Quadrat Transects

Coral Cover

Coral cover was variable and ranged from 37.9 to 88% on the ten reefs surveyed. Percent coral cover on treatment reefs ranged from 37.9 to 82.7% (mean of 59.2 ± 9.72%). Control reefs ranged from 50.9 to 67.9% (mean 56.7 ± 5.60%) (Figure 3, Appendix B Table 1). Percent coral cover on reference reefs ranged from 37.9 to 88.0% (mean of 69.5 ± 15.9%). Treatment Reef 19 and reference reefs 12 and 22 had the highest proportion of coral cover (>80%). While treatment Reef 14 and reference Reef 17 had the lowest coral cover (37.9%).

Coral cover was generally higher on reef slope habitats compared to reef flat for all reefs with exception of Reef 22, where reef flat coral cover was 1% higher (Figure 3). Percent coral cover of treatment reef slopes ranged from 44.5 to 88.3% and reef flats ranged from 32.5 to 79.8%. Coral cover on control reef slopes ranged from 73.5 to 90.2%, while the flats ranged from 31.9 to 65.1% (Figure 3, Appendix B Table 2). Reference reef slopes ranged from 84.6 to 87.3% and reef flats ranged from 14.0 to 88.4%.

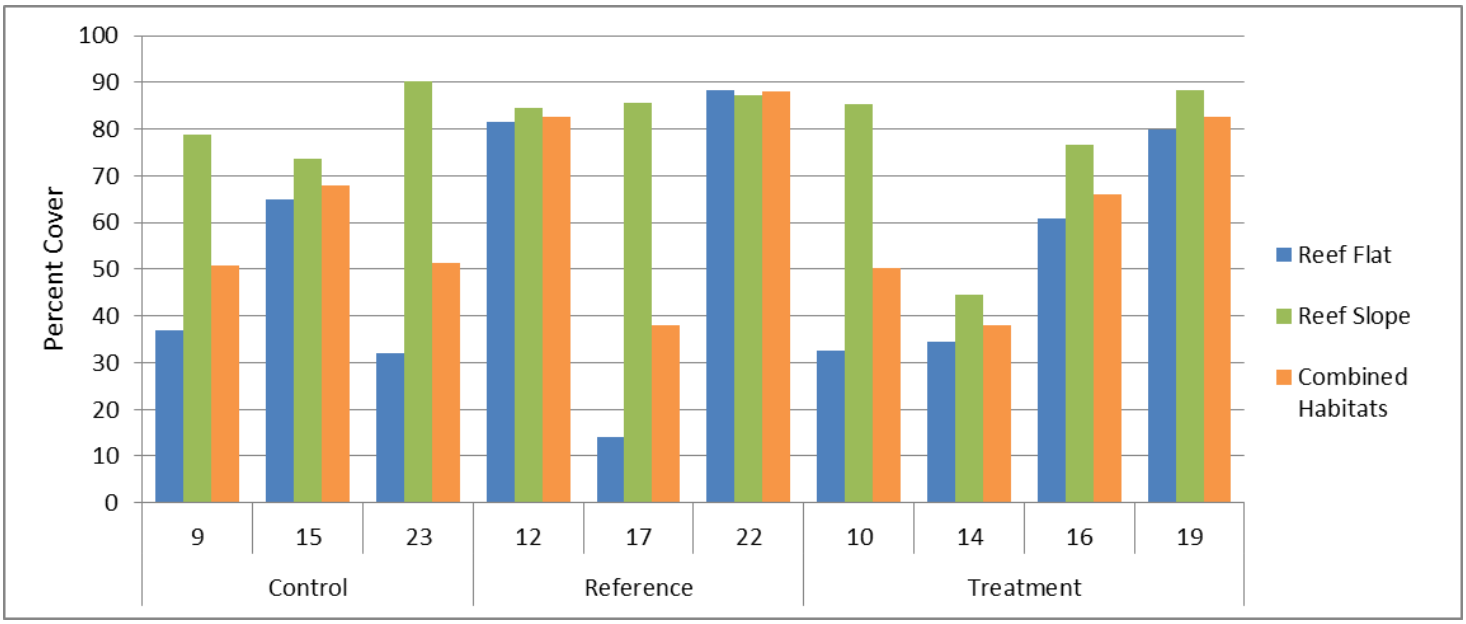

Figure 2. Mean percent coral cover of reef flats, reef slopes, and total reef average (combined habitats) per m^2 from CPCe photo transect analysis and differentiated by reef designations (control, reference, and treatment).

Invasive Algae Cover

Invasive algae were distributed at varying densities throughout the ten reefs surveyed ranging from 0.02% to 27.4% when all invasive species and combined habitats (slope and flat) were analyzed together (Figure 4, Appendix B Table 1). *Eucheuma denticulatum*/*Kappaphycus* spp. Ed/Ks were generally higher on the reef flats compared to slopes; except for treatment Reef 14 which had slightly higher coverage on the slopes (Appendix B Table 3). Mean Ed/Ks cover on treatment reefs was 10.03 ± 3.23%. Treatment reef slopes ranged from 1.20 to 26.99% for Ed/Ks, while the flats ranged from 7.25 to 15.83%. Ed/Ks on

control reefs ranged from 2.81 to 14.3%, with the slopes ranging 0.03 to 9.17% and the flats ranging from 4.19 to 17.5%. Ed/Ks was only found on the slopes of one reference reef (Reef 17 mean of 0.03 ± 0.03), while the flats had low coverage on all three reference reefs (0.02 to 0.05%). *Gracilaria* salicornia/*Acanthophora spicifera* Gs/As coverage was generally low (range 0.00% to 7.88%) and was found only on three of the ten reefs surveyed Reefs 9, 10, 14 (Appendix B Table 4). No Gs/As was found on reference reefs.

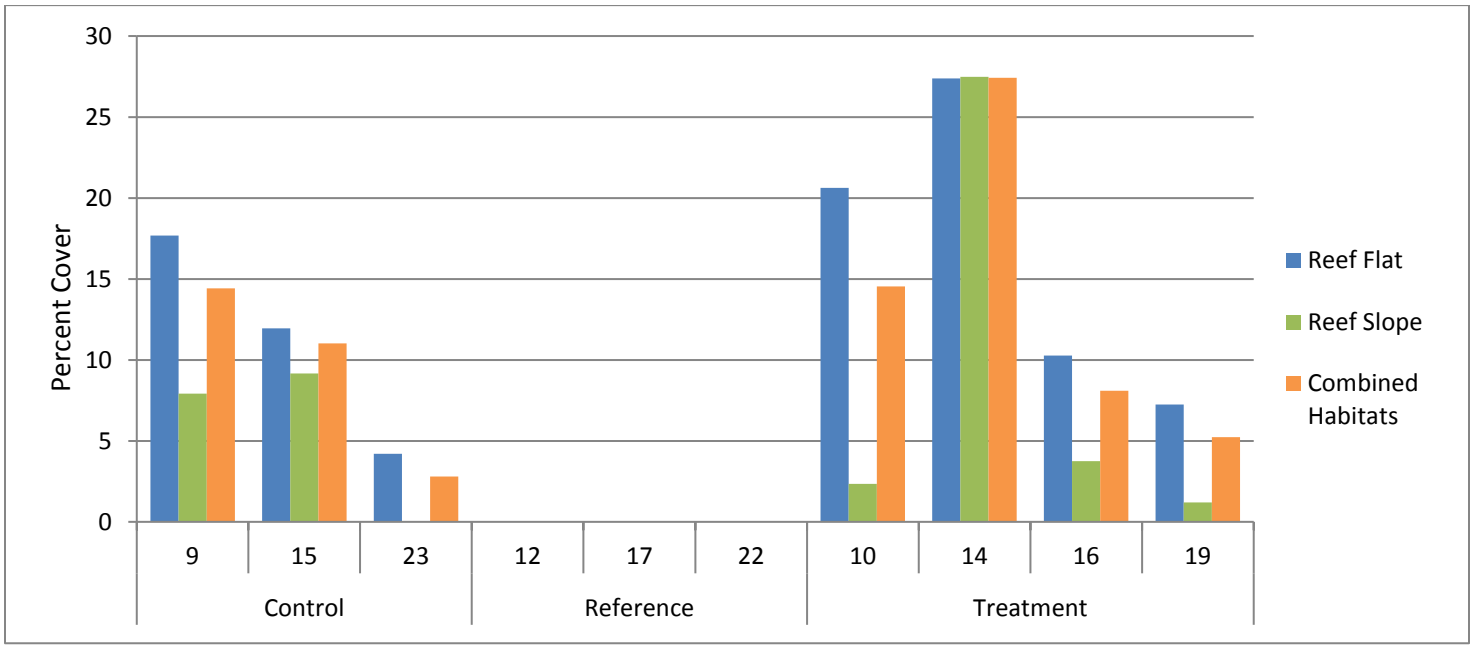

Figure 4. Mean percent invasive algae (Ed/Ks, Gs/As) cover on reef slopes, reef flats, and combined slope and flat habitats and differentiated by reef designations (Control, Reference, and Treatment).

Invasive Algae Height and Volume

Mean invasive algal height for both habitats combined (reef flat and reef slope) on mitigation reefs in Kāneʻohe Bay ranged from 0 to 11.88 cm (Figure 5, Appendix B Table 5). Treatment reefs ranged from 6.66 to 9.40 cm (mean of 8.13 ± 0.57 cm). Control reefs ranged from 3.07 to 11.88 cm (mean 8.19 ± 0.86 cm). On the reference reefs, invasive algae were only detected on Reef 12 (mean of 0.08 ± 0.04 cm).

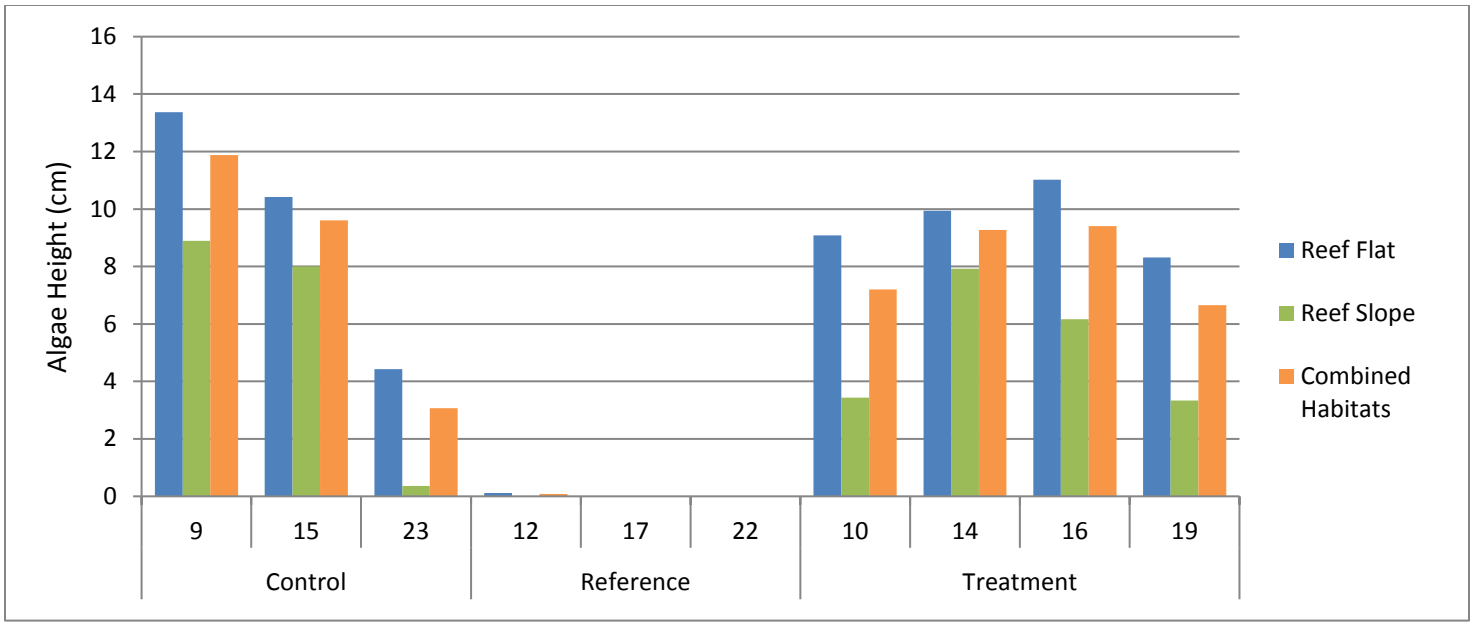

Figure 5. Mean invasive algae height (cm) for reef flat, reef slope, and combined habitats.

Mean algal volume on mitigation reefs in Kāneʻohe Bay ranged from 0.0 to 0.4 cm^3 (Table 2). Treatment reefs and control reefs ranged from 0.1 to 0.4 cm^3 (mean of 0.3 ± 0.1 cm^3). Reef 12 was the only reference reef found to have invasive algae within the transect (mean of $6.3 \times 10^{-4} \pm 5.2 \times 10^{-4}$).

Table 2. Mean invasive algae volume (m^3) and standard error per reef.

Designation	Reef	Mean Volume (cm^3)	Mean Volume (cm^3) per Reef Designation
Control	9	0. 4 ± 0. 1	0. 3 ± 0. 1
	15	0. 3 ± 0. 1	
	23	0. 1 ± 0. 03	
Reference	12	$6.3 \times 10^{-4} \pm 5.2 \times 10^{-4}$	$0.0 \pm 2.1 \times 10^{-4}$
	17	--	
	22	--	
Treatment	10	0. 3 ± 0. 1	0. 3 ± 0. 1
	14	0. 4 ± 0. 1	
	16	0. 2 ± 0. 04	
	19	0. 1 ± 0. 03	

Rugosity

Rugosity in Kāneʻohe Bay ranged from 0.25 to 0.36 on treatment reefs, 0.24 to 0.30 on control reefs, and 0.25 to 0.38 on reference reefs (Table 3). The mean value for all reefs was 0.29 ± 0.02. Reference Reef 12 was found to be the most rugose, at 0.38, while control Reef 23 was found to be the least rugose, at 0.24. Rugosity was generally higher on reef slopes than reef flats except Reefs 12, 22, and 16.

Table 3. Mean rugosity index calculated over total reef area and slope versus flat habitats.

Type	Reef	n	Rugosity per Reef	Rugosity per Reef Slope	Rugosity per Reef Flat
Control	9	12	0.29	0.31	0.28
	15	12	0.30	0.32	0.28
	23	12	0.24	0.34	0.20
Reference	12	12	0.38	0.37	0.39
	17	12	0.25	0.34	0.20
	22	12	0.34	0.33	0.34
Treatment	10	12	0.27	0.30	0.25
	14	11	0.25	0.28	0.24
	16	12	0.36	0.35	0.37
	19	12	0.26	0.30	0.24

Photo Plots

Three, 2 x 2 m photo plots were photographed and measured at all mitigation reefs for a combined total survey area of 120 m^2. Refer to Appendix A for locations of each photo plot. Figure 6 is an example of a stitched composite photo (Reef 10, plot 25) before and after invasive algae removal.

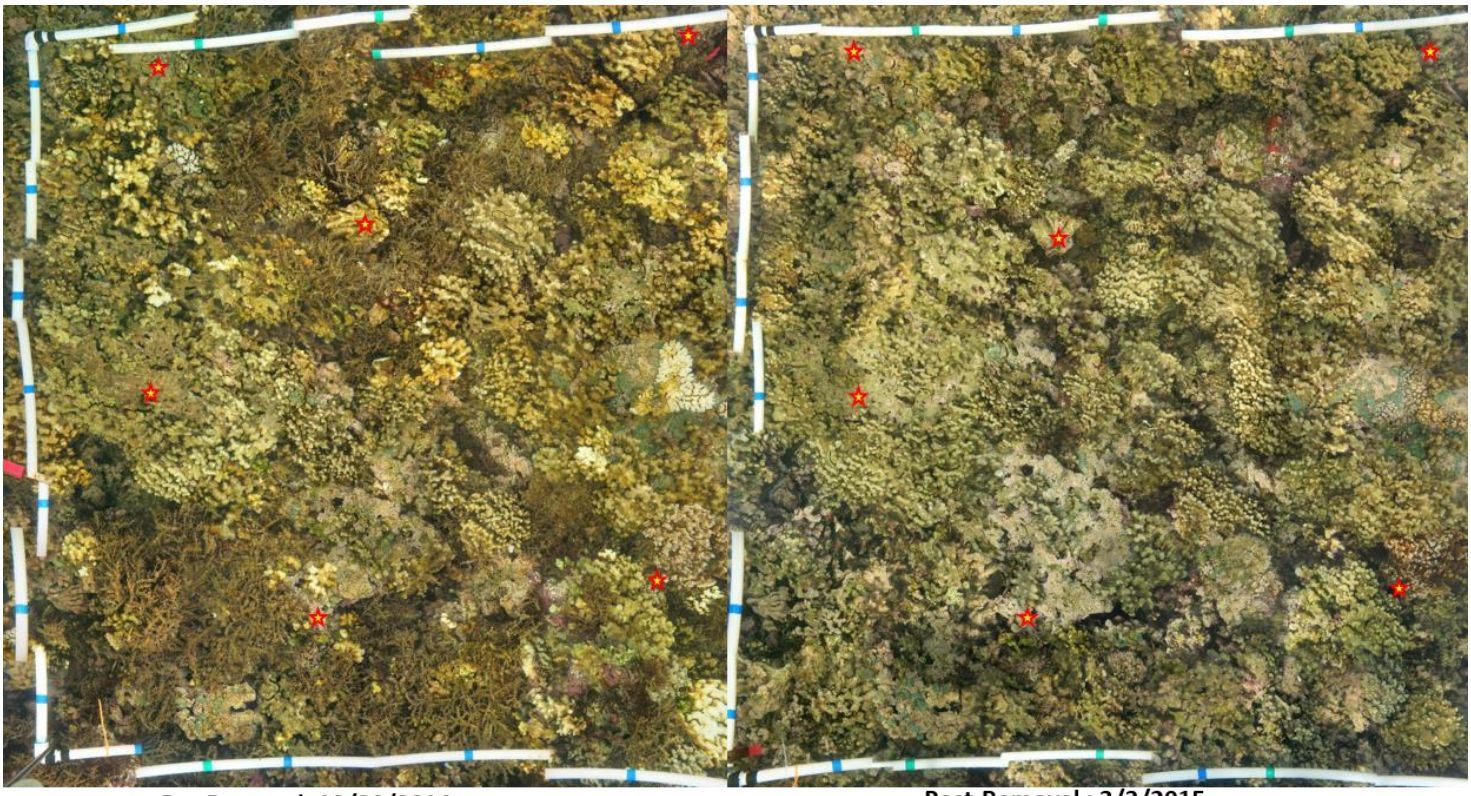

Figure 6. Reef 10, photo plot 25 (2 x 2 m) composite stitched photos pre and post removal. Stars indicate identical points on the photos.

Coral Colony Counts and Size Classes

A total of 10 unique species were documented in coral plots on all reefs combined, encompassing 3524 individual coral colonies. The mean number of coral colonies ranged from 14.5 to 52.0 colonies per m^2 on the 10 survey reefs. Coral colonies on treatment reefs ranged from 31.1 to 40.5 colonies per m^2 (mean 34.5 ± 2.11), control reefs ranged from 20.3 to 52.0 colonies per m^2 (mean 32.6 ± 9.81), and reference reefs ranged from 14.5 to 39.3 colonies per m^2 (mean 27.9 ± 7.22). Reef 23 had the highest number of coral colonies (52.0/m^2) and Reef 12 had the lowest number of coral colonies with 14.5 per m^2. *Porites compressa* was the most prevalent coral species and ranged from 17.7 to 38.3 colonies per m^2 for treatment reefs, 6.67 to 48.3 colonies per m^2 for control reefs, and 3.25 to 32.0 colonies per m^2 for reference (Figure 7). *Montipora capitata* was the second most prevalent coral species and ranged from 1.92 to 10.6 colonies per m^2 on treatment reefs, 1.75 to 18.2 colonies per m^2 on control reefs, and 7.25 to 10.9 colonies per m^2 on reference reefs. Treatment Reef 16 was found to have the highest coral diversity with 7 unique species observed during surveys. Mean coral colonies per m^2 by species are reported in Appendix C, Table 1, and Table 2 for all species surveyed.

Coral colony size distribution varied among all of the size classes, but the majority of colonies were less than 5 cm (32.5%). The three largest size classes (60 to >120 cm) comprised 1.7% of corals surveyed. The majority of *P. compressa* colonies (34%) and *M. capitata* (29.2%) occurred within the 10 – 20 cm size class (Figure 8). Refer to Appendix C Table 3 for a complete list of species and size class distributions.

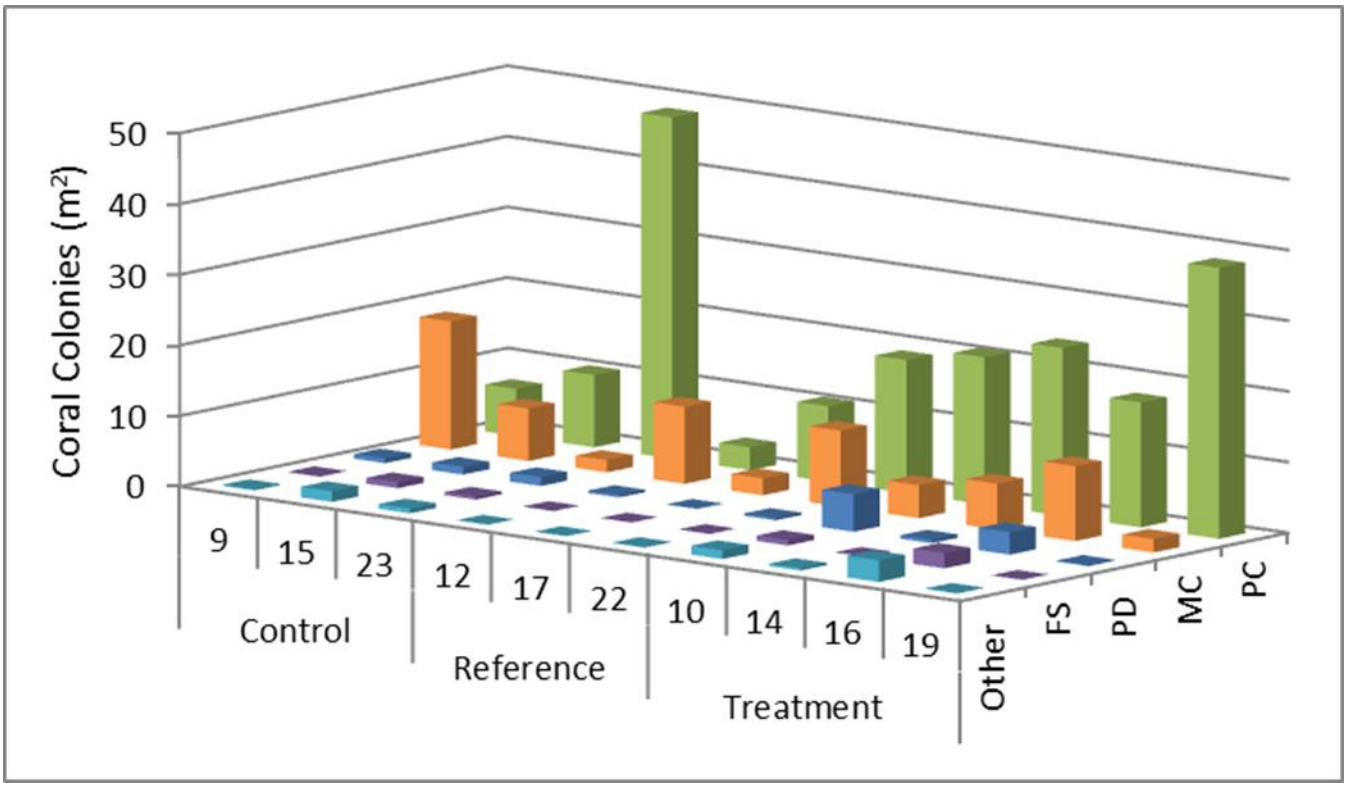

Figure 7. Summary of mean coral colonies per m^2 for the most abundant coral species in Kāneʻohe Bay by reef designation (PC – *Porites compressa*, MC – *Montipora capitata*, PD – *Pocillopora damicornis*, FS – *Fungia scutaria*). Column "Other" is a sum of the averages for *Pocillopora meandrina, Montipora patula*, *Leptastrea purpurea*, *Pavona varians*, *Cyphastrea ocelina*, and *Psammocora stellata*.

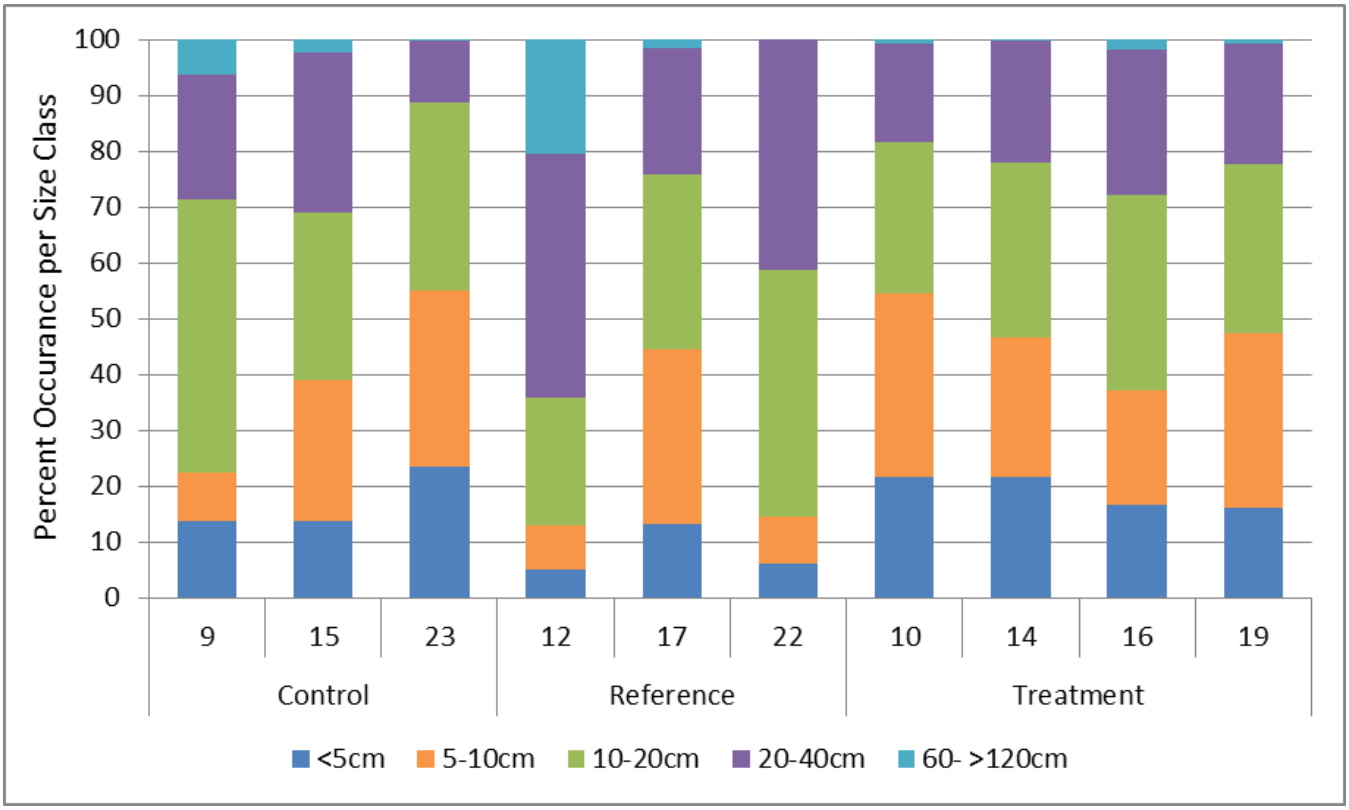

Figure 8. Proportion of *P. compressa* per size class on each reef. Size classes 60-80, 80-120, and >120 cm were condensed and reported together as 60 to >120 cm in this graph.

Benthic Habitat Mapping

Benthic habitat mapping of coral cover ranged from 24.1% to 82.2% on treatment reefs, 30.2% to 50.4% on control reefs, and 24.7% to 80.7% on reference reefs (Figure 9, Table 4). Refer to Appendix D for coverage maps of all benthic categories surveyed. Reef 19 had the highest coral cover (82.2%) and Reefs 14 and 17 had the lowest (24.1%, 24.7% respectively). Based on benthic mapping results, Reef 15 had the highest *Eucheuma/Kappaphycus* cover (7.14%). Reef 14 had the highest *Gracilaria/Acanthophora* (3.21%) cover.

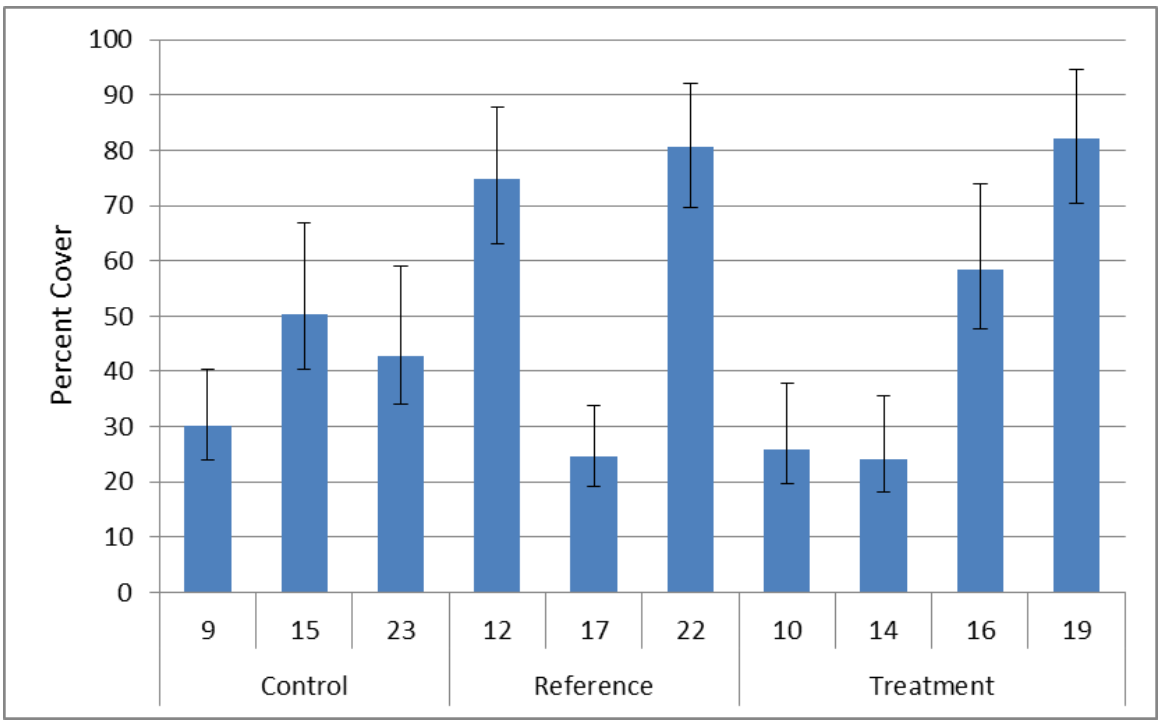

Figure 9. Percent coral cover from benthic habitat mapping surveys. Error bars indicate the high and low range of percent cover, differentiated by reef designations (control, reference, and treatment).

Table 4. Mean percent cover of habitat mapping data for coral, invasive algae, pavement, rubble, and sand per reef.

Designation	Reef	Area (m^2)	Coral Cover	Ed/Ks Cover	Gs/As Cover
Control	9	26,984	30.2% (range: 24.0 to 40.3%)	2.20% (range: 1.14 to 4.60%)	0.73% (range: 0.42 to 1.46%)
	15	6,680	50.4% (range: 40.4 to 66.8%)	7.14% (range: 3.87 to 15.7%)	0% (range: 0 to 0%)
	23	2,760	42.9% (range: 34.0 to 59.1%)	0.31% (range: 0.10 to 0.73%)	0% (range: 0 to 0%)
Reference	12	11,019	74.7% (range: 63.2 to 87.8%)	0.024% (range: 0.008 to 0.056%)	0% (range: 0 to 0%)
	17	6,234	24.7% (range: 19.3 to 33.8%)	0.002% (range: 0.001 to 0.005%)	0% (range: 0 to 0%)
	22	978	80.7% (range: 69.6 to 92.1%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)
Treatment	10	29,050	25.8% (range: 19.6 to 37.8%)	1.61% (range: 0.74 to 3.59%)	0.58% (range: 0.29 to 1.24%)
	14	23,566	24.1% (range: 18.3 to 35.5%)	6.28% (range: 3.70 to 13.0%)	3.21% (range: 1.79 to 6.51%)
	16	3,171	58.5% (range: 47.6 to 74.0%)	5.13% (range: 2.50 to 12.0%)	0% (range: 0 to 0%)
	19	1,094	82.2% (range: 70.3 to 94.6%)	2.70% (range: 1.15 to 6.37%)	0% (range: 0 to 0%)

Designation	Reef	Area (m^2)	Pavement	Rubble	Sand
Control	9	26,984	17.1% (range: 13.0 to 24.9%)	4.58% (range: 2.80 to 8.77%)	19.3% (range: 15.4 to 25.9%)
	15	6,680	5.47% (range: 3.00 to 11.5%)	2.41% (range: 1.54 to 4.28%)	2.76% (range: 1.84 to 4.56%)
	23	2,760	40.1% (range: 33.0 to 49.8%)	0.62% (range: 0.30 to 1.36%)	0.48% (range: 0.23 to 1.03%)
Reference	12	11,019	4.19% (range: 2.32 to 8.40%)	1.97 % (range: 1.24 to 3.53%)	3.15% (range: 2.32 to 4.72%)
	17	6,234	62.1% (range: 52.5 to 73.6%)	0.12% (range: 0.06 to 0.26%)	0.17% (range: 0.11 to 0.28%)
	22	978	1.49% (range: 0.78 to 3.13%)	0.27% (range: 0.11 to 0.64%)	0.79% (range: 0.38 to 1.65%)
Treatment	10	29,050	25.0% (range: 19.7 to 34.3%)	2.56% (range: 1.44 to 5.16%)	16.9% (range: 13.4 to 22.7%)
	14	23,566	7.53% (range: 4.52 to 14.9%)	11.3% (range: 7.38 to 21.0%)	9.36% (range: 6.53 to 15.6%)
	16	3,171	3.64% (range: 1.70 to 8.08%)	1.10% (range: 0.47 to 2.42%)	1.74% (range: 0.92 to 3.59%)
	19	1,094	1.36% (range: 0.52 to 3.15%)	0.54% (range: 0.30 to 1.05%)	0.33% (range: 0.20 to 0.64%)

Fish Survey

Fish surveys were conducted from September 11 – 16, 2014. An area of 500 m^2 was surveyed on each reef. A total of 61 unique species were documented on all reefs combined, encompassing 7,580 individual fish. Treatment reefs were found to have 25 to 32 unique fish species and 353 to 1,334 individual fish per transect. Control reefs had 27 to 34 fish species and a total of 706 to 786 individual fish per transect (Figure 10, Table 5). Reference reefs were found to have 27 to 32 fish species and 473 to 1331 individual fish per transect surveyed. Reef 17 and Reef 10 had the highest occurrence of fish surveyed. The majority of fish were in the 5 – 10 cm size class. Reef 15 had the highest number of fish species (34 species) (Table 5). A complete list of species reported on each reef and size class has been provided in Appendix E, Table 1.

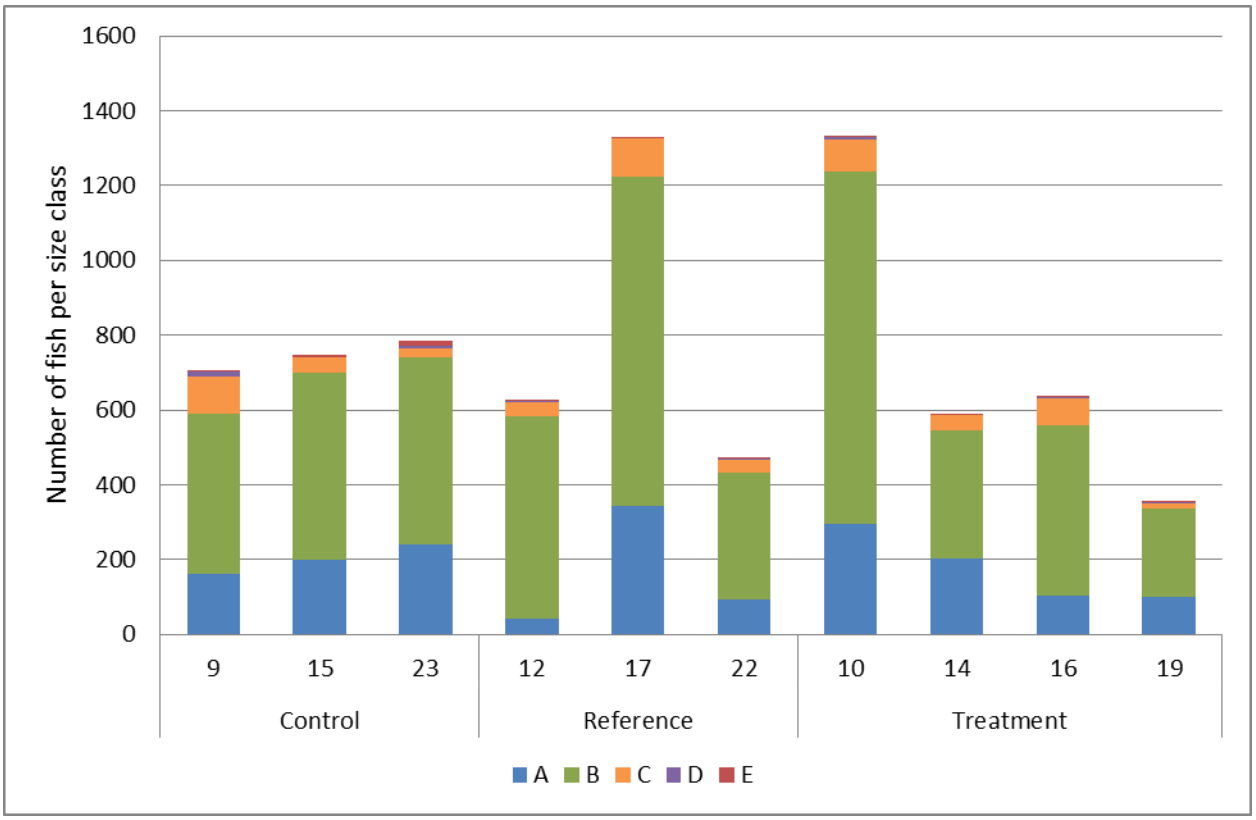

Figure 10. Number of individual fish per reef, per size class. (A=0-5cm, B=5-10cm, C=10-15cm, D=15-20cm, E=>20cm).

Table 5. Total fish count per reef and number of species.

Designation	Size Classes	A 0 - 5 cm	B 5 - 10 cm	C 10 - 15 cm	D 15 - 20 cm	E > 20 cm	Total Fish/Reef	Number of Fish Species
Control	Reef 9	163	427	101	11	4	706	27
	Reef 15	199	501	41	1	5	747	34
	Reef 23	242	498	26	4	16	786	31
Reference	Reef 12	42	541	39	2	1	625	27
	Reef 17	344	878	103	0	6	1331	28
	Reef 22	93	339	36	1	4	473	32
Treatment	Reef 10	296	941	86	8	3	1334	31
	Reef 14	202	343	40	2	1	588	25
	Reef 16	103	457	72	3	2	637	32
	Reef 19	100	235	14	3	1	353	28
Grand Total		1784	5160	558	35	43	7580	61

Discussion

Mitigation reef survey groupings (treatment, control, reference) were adequate in terms of similarity of coral cover, invasive algae cover, and rugosity. These groupings will be used to assess changes in coral cover, CCA, macro algae, and fish biomass in the future.

Coral surveys indicated that the two most abundant species in Kāneʻohe Bay were *Porites compressa* and *Montipora capitata,* and these would be the primary coral species to benefit from restoration activities. Invasive algae cover on treatment reefs averaged approximately 10%. Therefore, we expect that invasive algae control efforts will allow these previously occupied habitats to be colonized by native organisms.

Fish survey data reflect a large number of reef fish within the smaller size classes. Although prior surveys were not conducted on these reefs for comparison, DAR, HIMB, and TNC divers noted a large reef fish recruitment event throughout the 2014 summer in Kāneʻohe Bay. Future fish surveys may substantiate this observation.

Conclusion

This report serves as the baseline assessment for algae removal and urchin biocontrol within the Kāneʻohe Bay Mitigation Bank. This data will be used to assess the mitigative restoration activities on designated patch reefs in terms of invasive algae cover, coral cover, coral size, and number of coral colonies. In addition, this data will be used to quantify the value of the resource improvements into credits.

Follow-up surveys will be conducted annually (August-November) to assess changes in coral and invasive algae cover as a result of invasive algae control activities.

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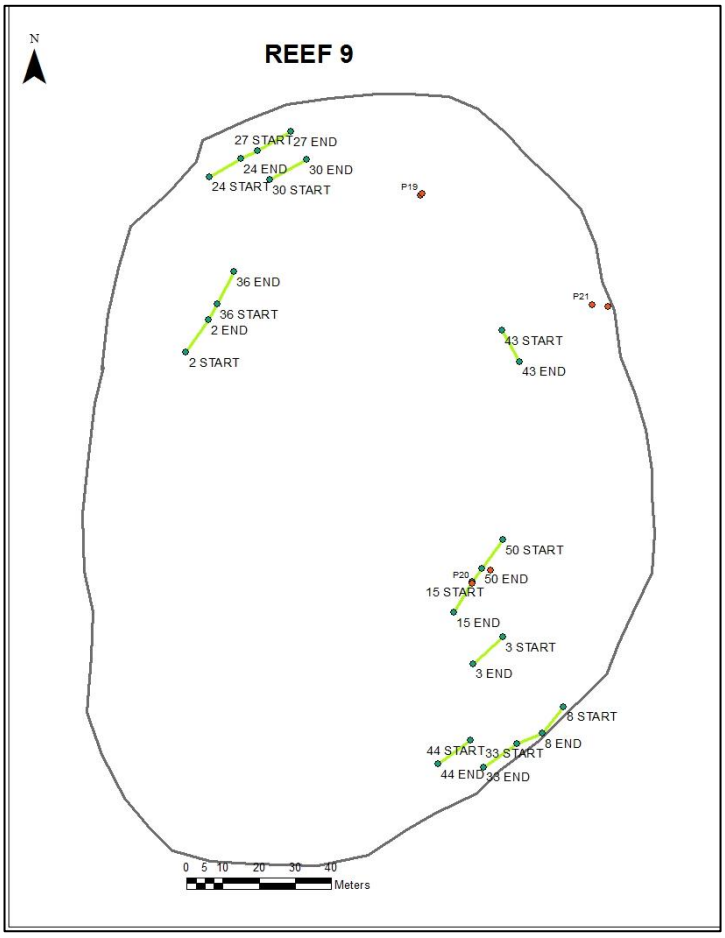
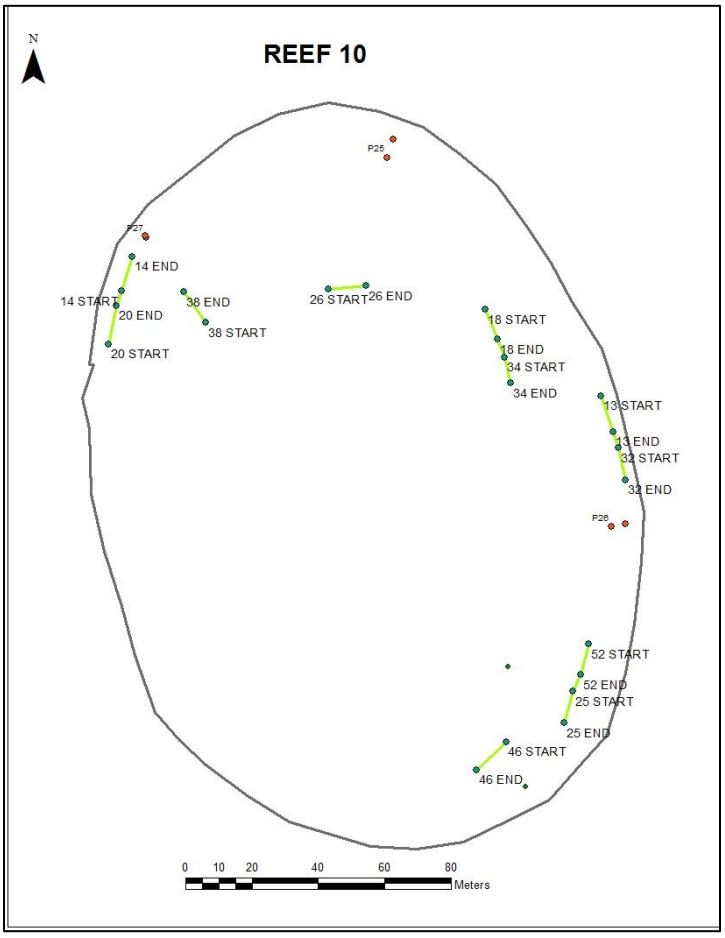
Appendices

Appendix A: Individual patch reef survey transects and photo plot locations.

Survey transects and photo plot locations for each patch reef included in the Kāneʻohe Bay Mitigation Bank Restoration Project.





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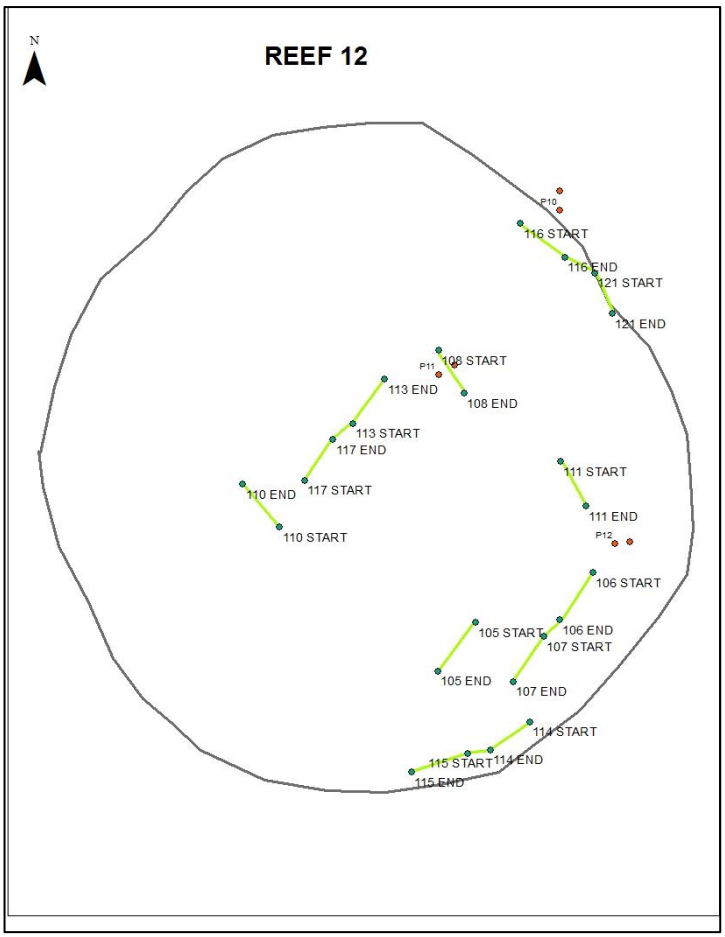

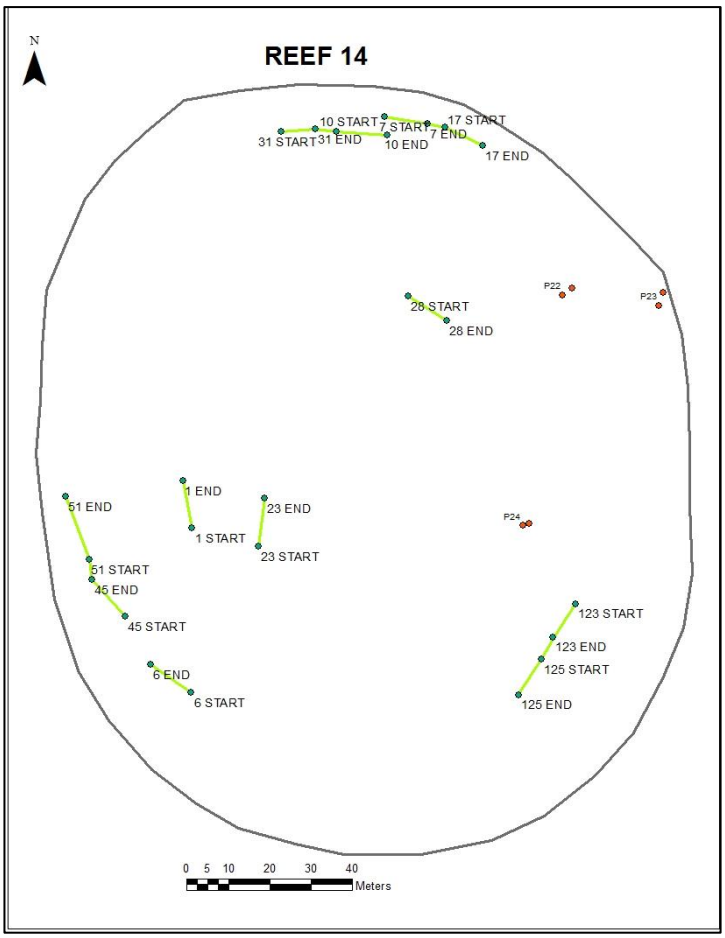

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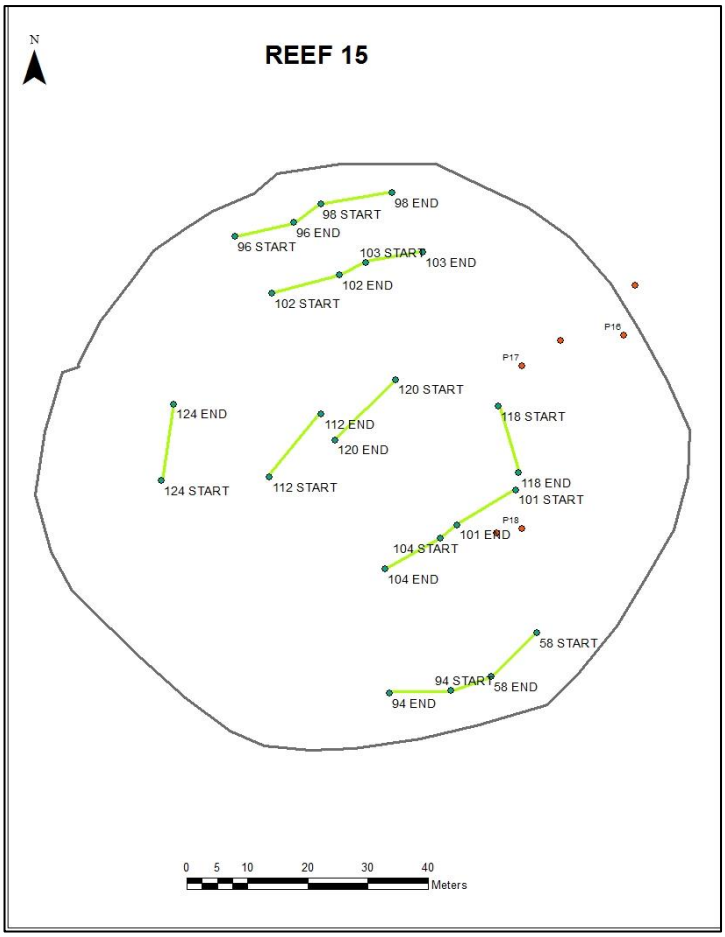

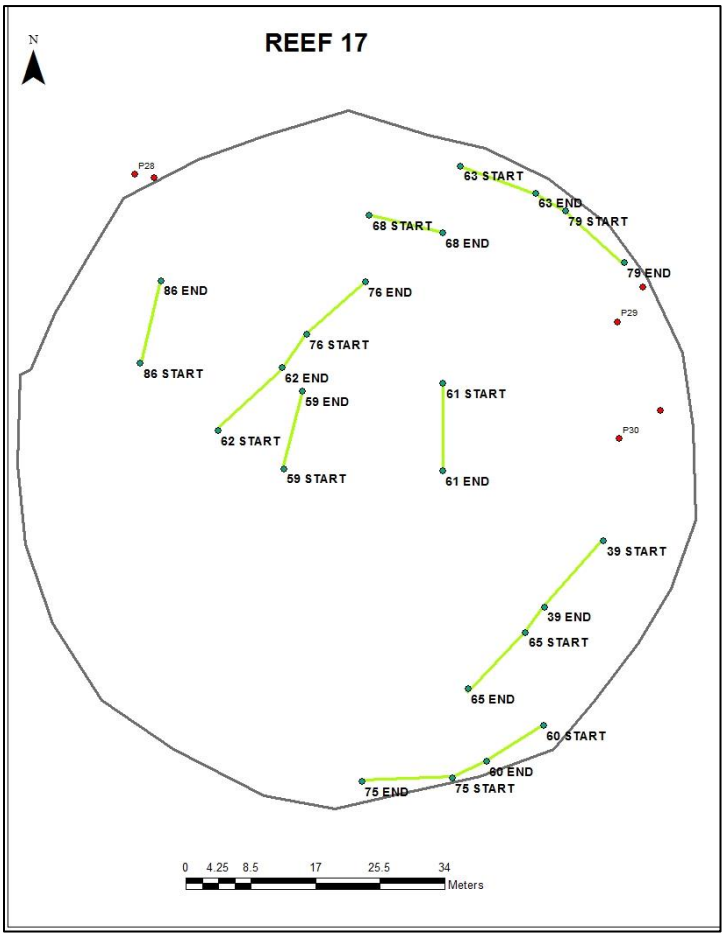

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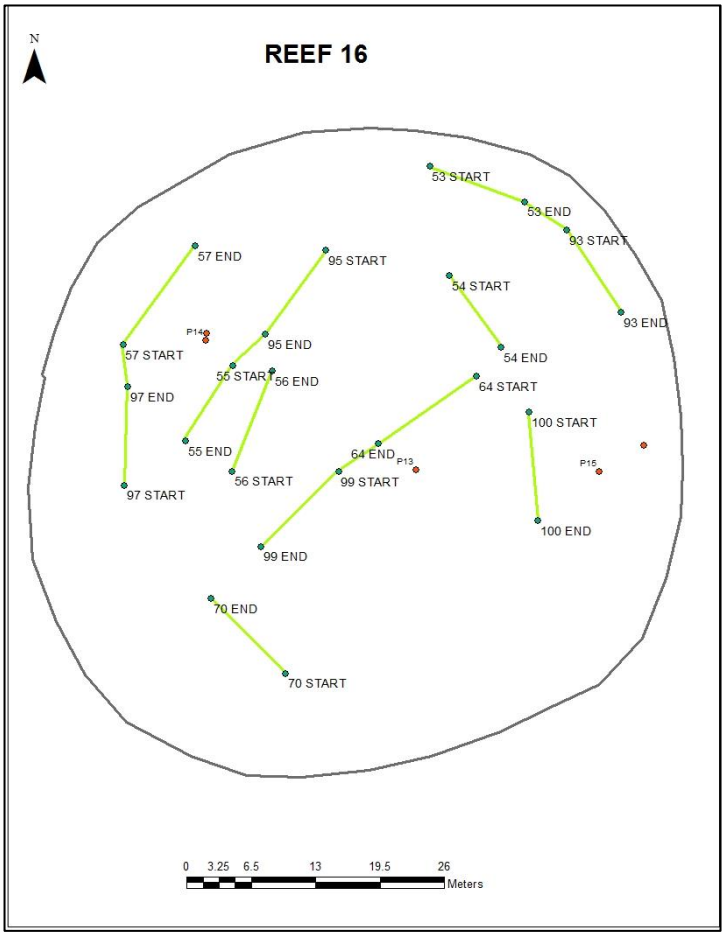

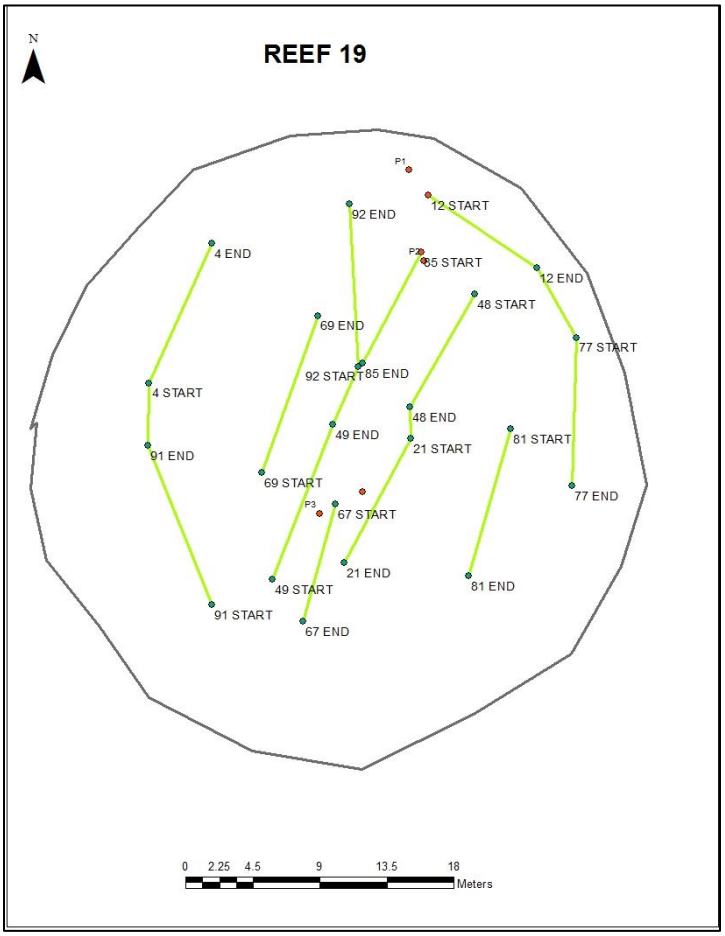

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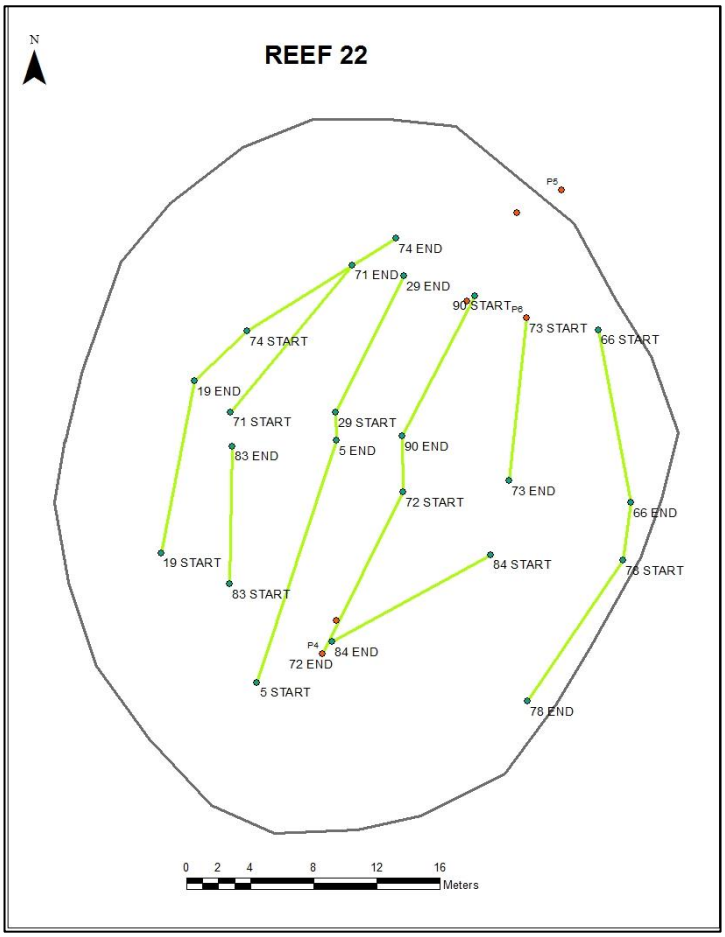
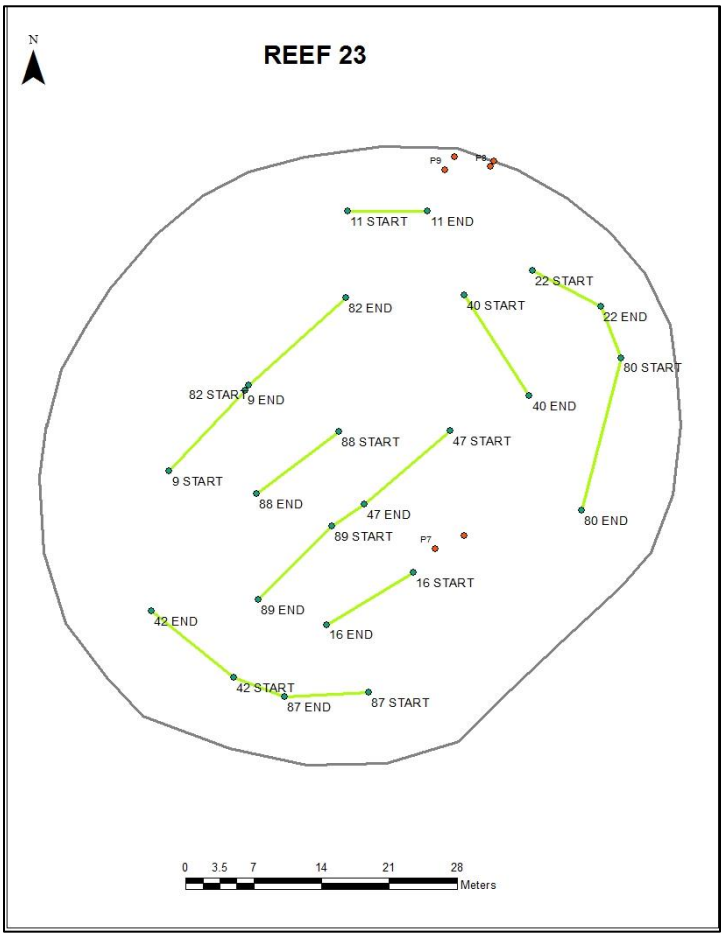




Appendix B: CPCe summary tables.

Table 1. Mean percent coral, *Eucheuma denticulatum/Kappaphycus spp*., and *Gracilaria salicornia/Acanthophora spicifera* cover per m^2 from CPCe data output with standard error by patch reef.

Designation	Reef	Area (m^2)	Coral Cover	Ed/Ks Cover	Gs/As Cover
Control	9	28,343	50.85 ± 7.95	14.3 ± 2.70	0.13 ± 0.13
	15	7,732	67.88 ± 3.48	11.02 ± 1.50	0.0 ± 0.0
	23	3,119	51.30 ± 9.64	2.81 ± 1.54	0.0 ± 0.0
Reference	12	11,854	82.60 ± 1.84	0.02 ± 0.01	0.0 ± 0.0
	17	6,881	37.88 ± 10.37	0.02 ± 0.01	0.0 ± 0.0
	22	1,016	88.04 ± 1.98	0.03 ± 0.03	0.0 ± 0.0
Treatment	10	30,098	50.12 ± 8.49	7.26 ± 2.72	7.27 ± 3.68
	14	22,122	37.87 ± 5.20	19.55 ± 4.17	7.88 ± 4.14
	16	4,303	66.09 ± 3.42	8.09 ± 1.32	0.0 ± 0.0
	19	1,023	82.65 ± 1.88	5.23 ± 1.23	0.0 ± 0.0

Table 2. Mean percent coral cover and standard error along reef flats and reef slopes, and differentiated by control, reference and treatment reefs.

Designation	Reef	Coral Flat	Coral Slope	Mean Flat	Mean Slope
Control	9	36.87 ± 8.00	78.83 ± 2.14	44.61 ± 10.33	80.83 ± 4.91
	15	65.07 ± 4.48	73.51 ± 4.86		
	23	31.88 ± 7.55	90.15 ± 1.37		
Reference	12	81.59 ± 2.63	84.61 ± 1.71	61.34 ± 23.74	85.83 ± 0.79
	17	14.03 ± 2.26	85.58 ± 4.64		
	22	88.41 ± 2.37	87.30 ± 4.08		
Treatment	10	32.49 ± 5.98	85.39 ± 2.04	51.94 ± 11.32	73.67 ± 10.05
	14	34.57 ± 7.63	44.46 ± 1.96		
	16	60.86 ± 3.95	76.54 ± 1.27		
	19	79.83 ± 1.91	88.28 ± 2.49		

Table 3. Mean percent *Eucheuma denticulatum*/*Kappaphycus* spp. (Ed/KS) cover and standard error documented along reef flats and reef slopes, and differentiated by control, reference and treatment reefs.

Designation	Reef	Ed/Ks Flat	Ed/Ks Slope	Mean Flat	Mean Slope
Control	9	17.49 ± 3.50	7.93 ± 1.55	11.21 ± 3.86	5.71 ± 2.86
	15	11.95 ± 2.13	9.17 ± 1.33		
	23	4.19 ± 2.18	0.03 ± 0.03		
Reference	12	0.03 ± 0.02	0.0 ± 0.0	0.03 ± 0.01	0.01 ± 0.01
	17	0.02 ± 0.02	0.03 ± 0.03		
	22	0.05 ± 0.05	0.0 ± 0.0		
Treatment	10	9.71 ± 3.80	2.35 ± 1.41	10.76 ± 1.81	8.57 ± 6.16
	14	15.83 ± 4.37	26.99 ± 8.64		
	16	10.26 ± 1.44	3.74 ± 0.35		
	19	7.25 ± 1.35	1.20 ± 0.30		

Table 4. Mean percent *Gracilaria salicornia*/*Acanthophora spicifera* (Gs/As) cover and standard error documented along reef flats and reef slopes, and differentiated by control, reference and treatment reefs.

Designation	Reef	Gs/As Flat	Gs/As Slope	Mean Flat	Mean Slope
Control	9	0.19 ± 0.19	0.0 ± 0.0	0.06 ± 0.06	0.0 ± 0.0
	15	0.0 ± 0.0	0.0 ± 0.0		
	23	0.0 ± 0.0	0.0 ± 0.0		
Reference	12	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	17	0.0 ± 0.0	0.0 ± 0.0		
	22	0.0 ± 0.0	0.0 ± 0.0		
Treatment	10	10.91 ± 5.13	0.0 ± 0.0	5.62 ± 3.25	0.13 ± 0.13
	14	11.56 ± 5.88	0.50 ± 0.42		
	16	0.0 ± 0.0	0.0 ± 0.0		
	19	0.0 ± 0.0	0.0 ± 0.0		

Table 5. Mean invasive algae height.

Designation	Reef	Flat	Slope	Mean Combined	Designation Mean ± SE
Control	9	13.37	8.89	11.88	8.19 ± 0.86
	15	10.41	8.00	9.61	
	23	4.43	0.36	3.07	
Reference	12	0.12	0	0.08	0.03 ± 0.01
	17	0	0	0	
	22	0	0	0	
Treatment	10	9.09	3.43	7.20	8.13 ± 0.57
	14	9.94	7.93	9.27	
	16	11.02	6.17	9.40	
	19	8.32	3.33	6.66	

Appendix C: Photo plot summary tables.

Table 1. Mean number of coral colonies per (m^2) by reef.

Reef	Designation	PC	PD	PM	MC	MP	FS	LP	PV	CO	PS
9	Control	6.67	0.67	-	18.2	-	0.08	0.08	-	-	-
15	Control	10.3	1.08	-	7.42	-	0.83	-	0.58	0.08	-
23	Control	48.3	1.25	-	1.75	0.17	0.42	-	-	-	0.08
12	Reference	3.25	0.33	-	10.9	-	-	-	-	-	-
17	Reference	10.7	-	-	2.42	-	-	-	-	-	-
22	Reference	18.8	0.33	-	10.8	0.08	-	-	-	-	-
10	Treatment	20.8	5.33	-	4.67	0.25	0.75	0.25	-	-	-
14	Treatment	23.8	0.50	0.25	6.50	-	-	-	0.08	-	-
16	Treatment	17.7	3.17	-	10.6	0.67	2.17	-	0.17	0.08	-
19	Treatment	38.3	0.17	-	1.92	-	-	-	0.08	-	-

Table 2. Average coral colonies and standard error per reef for all species.

Reef	Designation	Combined Sum (m^2)	Designation Average
9	Control	25.7	32.6 ± 9.81
15	Control	20.3	
23	Control	52.0	

Reef	Designation	Combined Sum (m^2)	Designation Average
12	Reference	14.5	27.9 ± 7.22
17	Reference	39.3	
22	Reference	30.0	
10	Treatment	32.1	34.5 ± 2.11
14	Treatment	31.1	
16	Treatment	34.5	
19	Treatment	40.5	

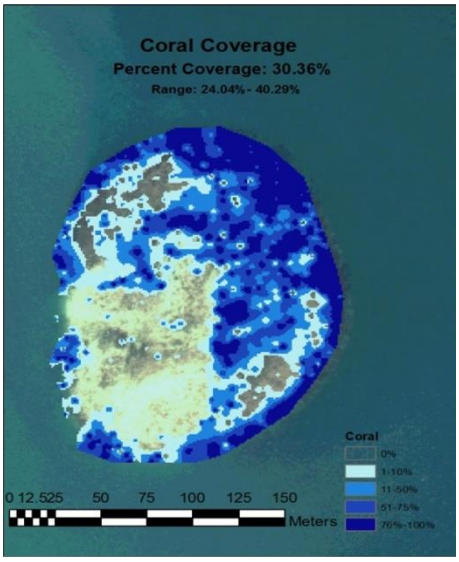
Table 3. Proportion of coral colonies per m^2 by patch reef for each species and size class identified

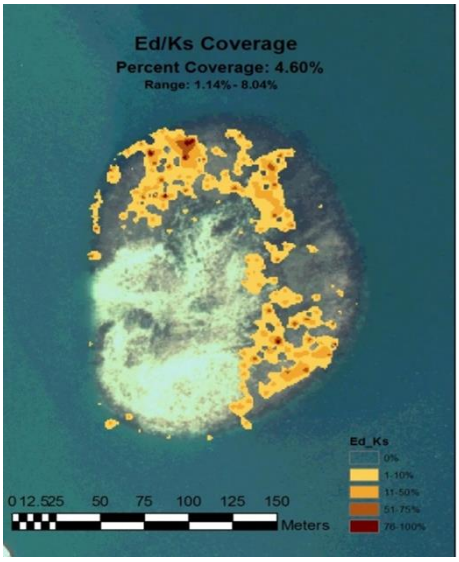
Reef	Coral spp.	<5cm	5-10cm	10 - 20cm	20-40cm	60-80cm	80-100cm	>120cm
Reef 9	PC	13.8	8.8	48.8	22.5	3.8	2.5	0
	MC	46.8	29.4	13.3	9.2	0.9	0.5	0
	FS	0	0	100	0	0	0	0
	PD	25	50	25	0	0	0	0
	LP	100	0	0	0	0	0	0
Reef 10	PC	21.6	32.8	27.2	17.6	0	0.8	0
	MC	32.1	21.4	23.2	23.2	0	0	0
	MP	0	33.3	33.3	0	0	33.3	0
	LP	100	0	0	0	0	0	0
	FS	22.2	11.1	66.7	0	0	0	0
	PD	20.3	51.6	26.6	1.6	0	0	0
Reef 12	PC	5.1	7.7	23.1	43.6	15.4	2.6	2.6
	MC	5.3	29.8	42.7	16.0	4.6	1.5	0
	PD	100	0	0	0	0	0	0
Reef 14	PC	21.8	24.9	31.2	21.8	0.4	0	0
	MC	11.5	25.6	39.7	21.8	1.3	0	0
	PD	50	33.3	16.7	0	0	0	0
	PV	0	0	100	0	0	0	0
	PM	33.3	0	66.7	0	0	0	0
Reef 15	PC	13.8	25.2	30.1	28.5	2.4	0	0
	MC	20.2	28.1	25.8	21.3	4.5	0	0
	PV	28.6	28.6	14.3	28.6	0	0	0
	PD	53.8	30.8	7.7	7.7	0	0	0
	FS	0	70	30	0	0	0	0
	CO	100	0	0	0	0	0	0
Reef 16	PC	16.5	20.8	34.9	25.9	1.4	0.5	0
	MC	17.3	30.7	31.5	20.5	0	0	0

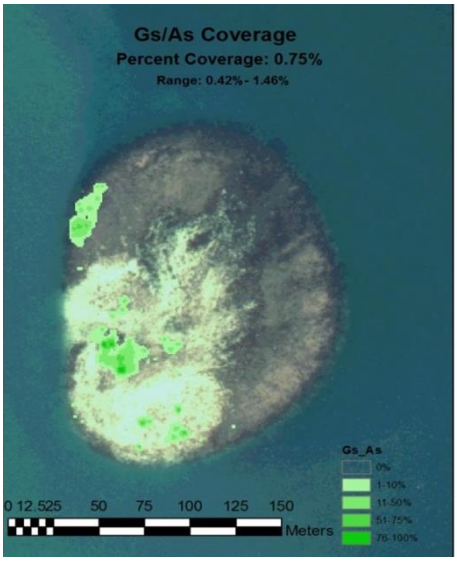
	Coral spp.	<5cm	5-10cm	10 - 20cm	20-40cm	60-80cm	80-100cm	>120cm
Reef 16	FS	19.2	15.4	65.4	0	0	0	0
	PD	57.9	34.2	7.9	0	0	0	0
	PV	100	0	0	0	0	0	0
	MP	50	50	0	0	0	0	0
	CO	100	0	0	0	0	0	0
Reef 17	PC	13.3	31.3	31.3	22.7	0.8	0.8	0
	MC	6.9	41.4	24.1	27.6	0	0	0
Reef 19	PC	16.1	31.3	30.2	21.7	0.7	0	0
	MC	26.1	30.4	30.4	13.0	0	0	0
	PD	0	100	0	0	0	0	0
	PV	100	0	0	0	0	0	0
Reef 22	PC	6.2	8.4	44.2	41.2	0	0	0
	MC	10.9	20.2	23.3	45.7	0	0	0
	MP	0	0	100	0	0	0	0
	PD	25	75	0	0	0	0	0
Reef 23	PC	23.4	31.7	33.4	11.2	0.2	0	0
	MC	23.8	23.8	38.1	14.3	0	0	0
	MP	0	100.0	0	0	0	0	0
	FS	40	20	40	0	0	0	0
	PD	80	13.3	6.7	0	0	0	0
	PS	0	100	0	0	0	0	0

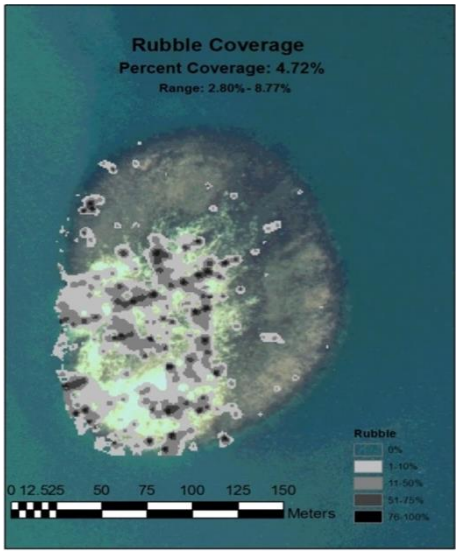
Appendix D: Individual patch reef coverage maps of coral coverage, *Eucheuma/Kappaphycus* (Ed/Ks), *Gracilaria salicornia/Acanthophora spicifera* (Gs/As), Rubble, Sand, and Hard Bottom.

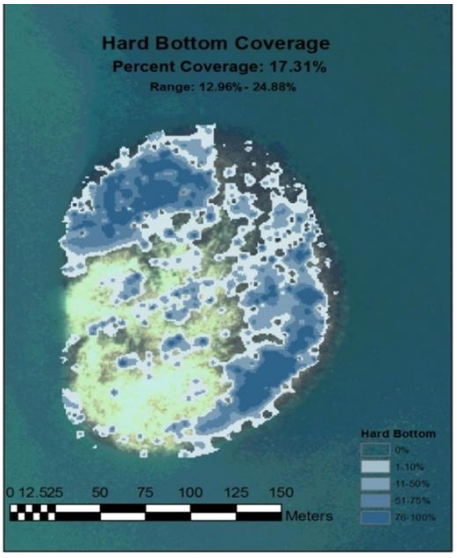
Reef 9 (Control Reef)

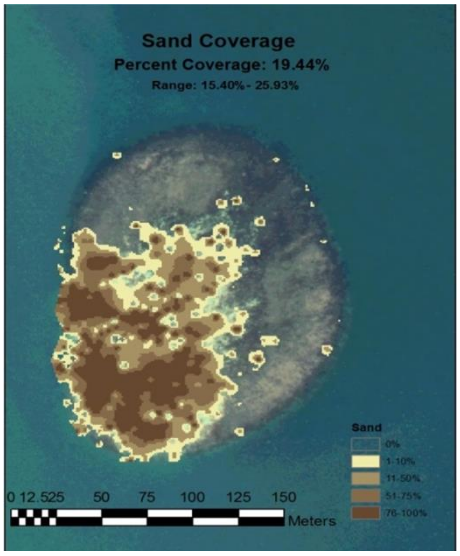






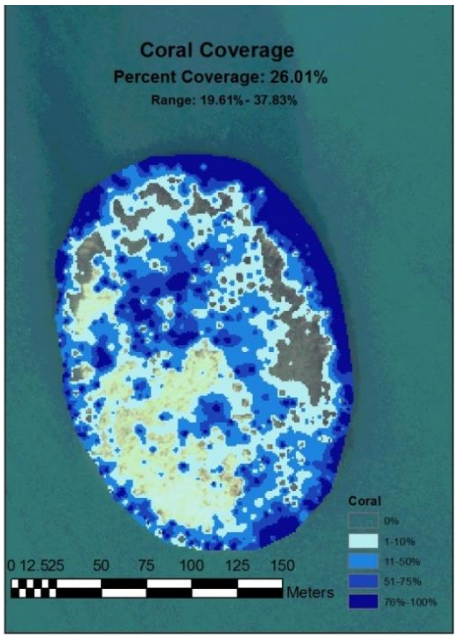


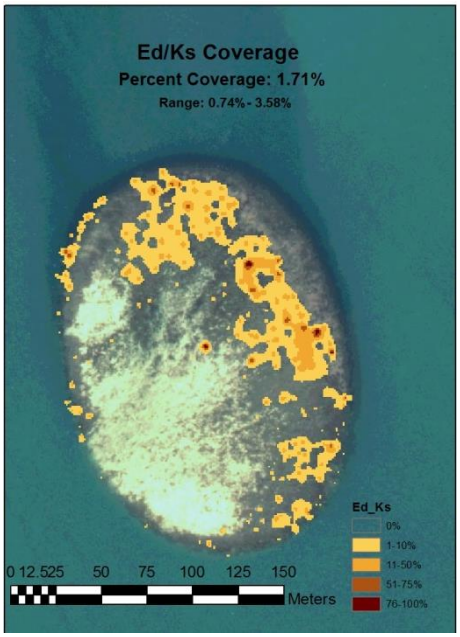


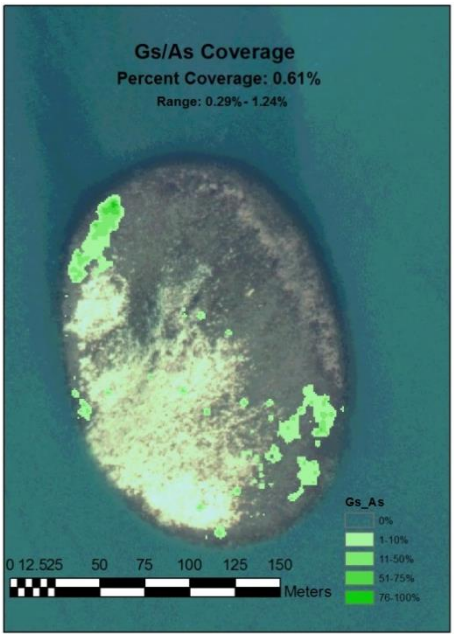


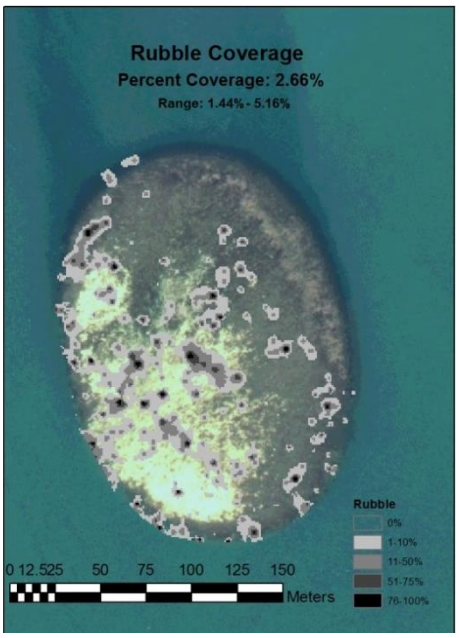
Appendix D: cont'd.

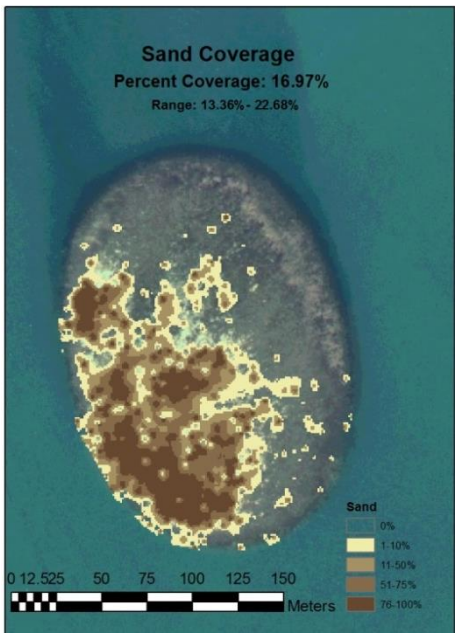
Reef 10 (Treatment Reef)

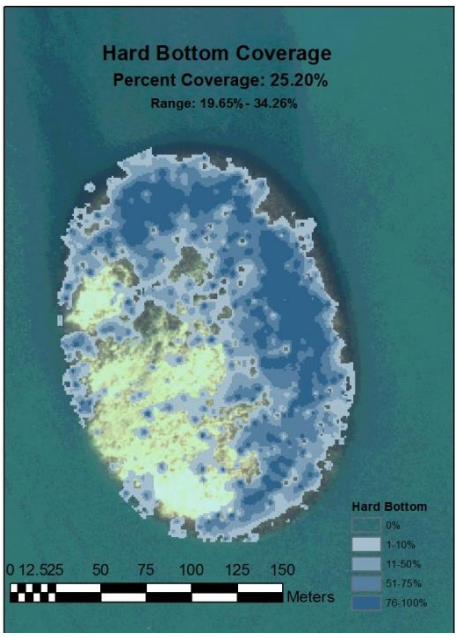






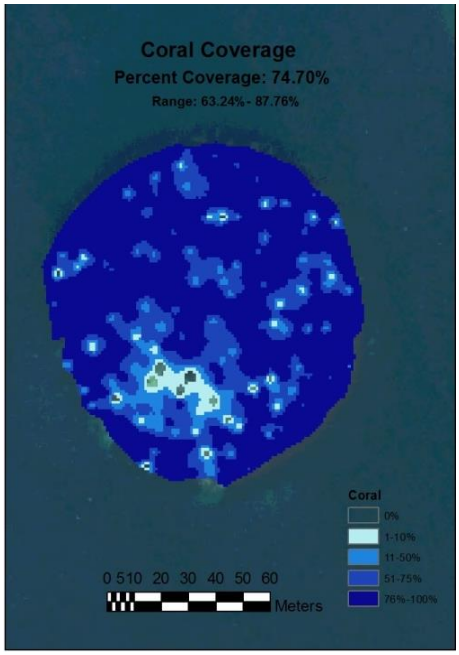


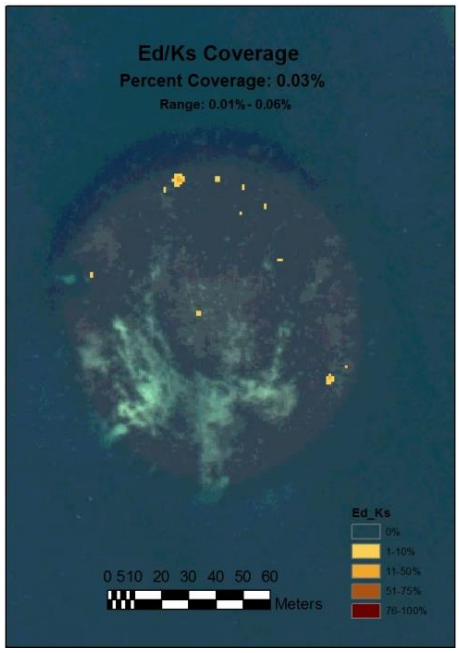


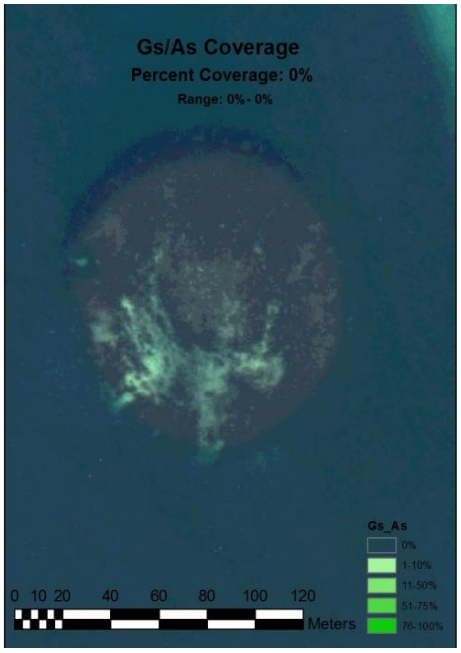


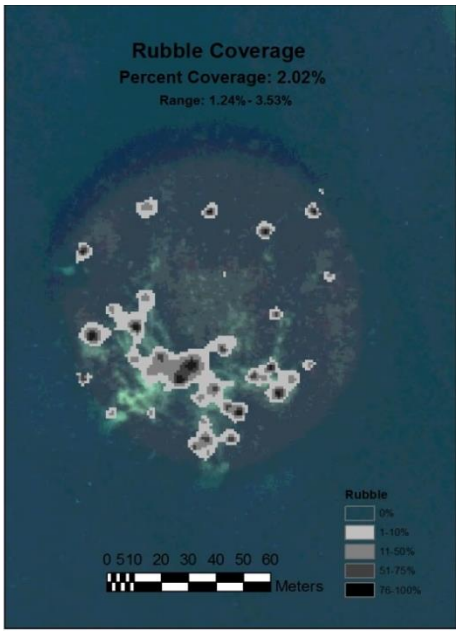
Appendix D: cont'd.

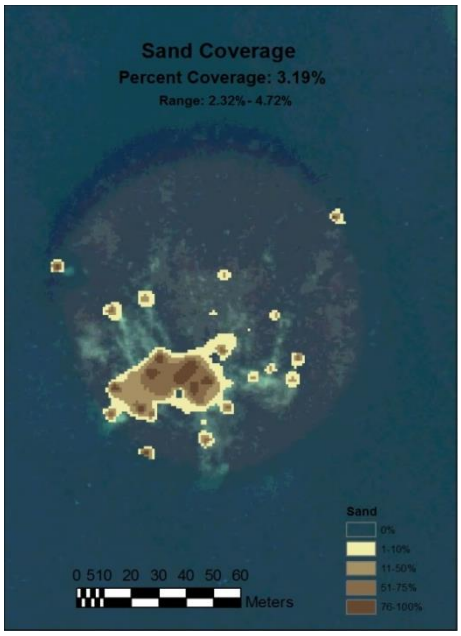
Reef 12 (Reference Reef)

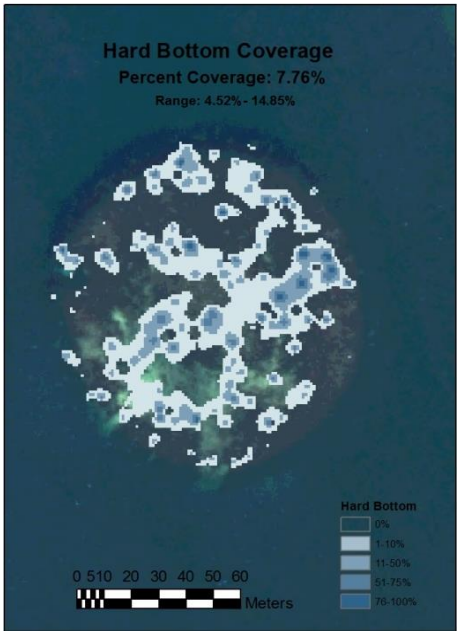






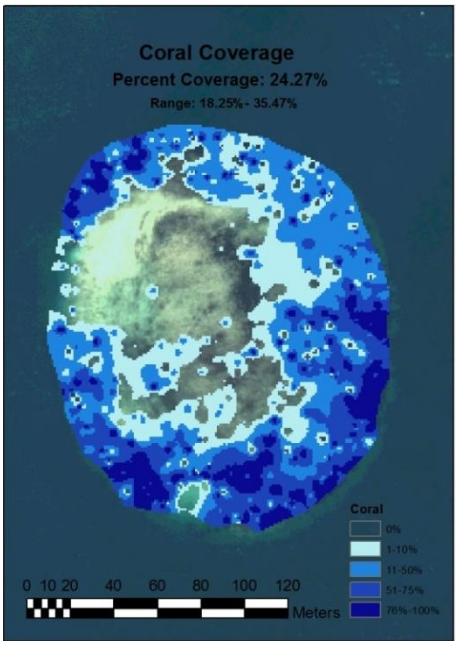


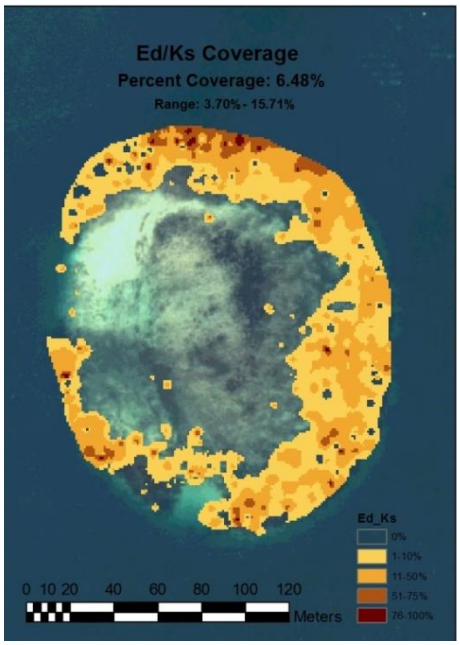


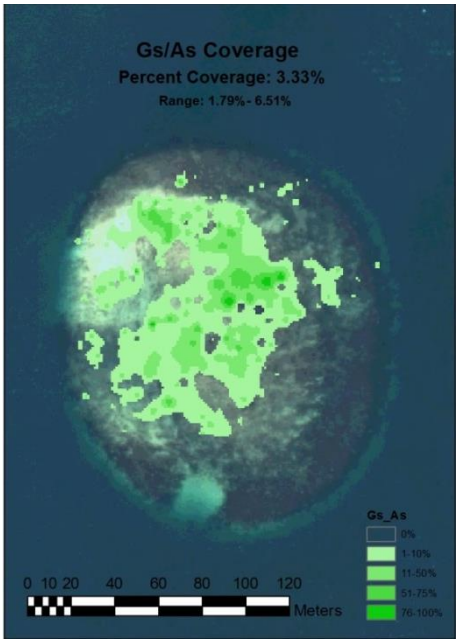


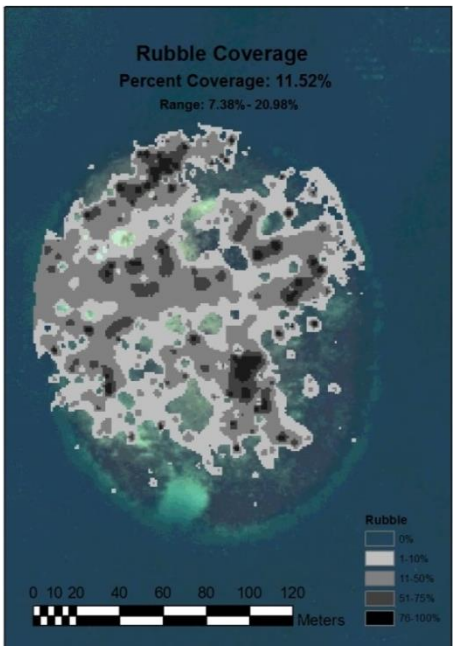
Appendix D: cont'd.

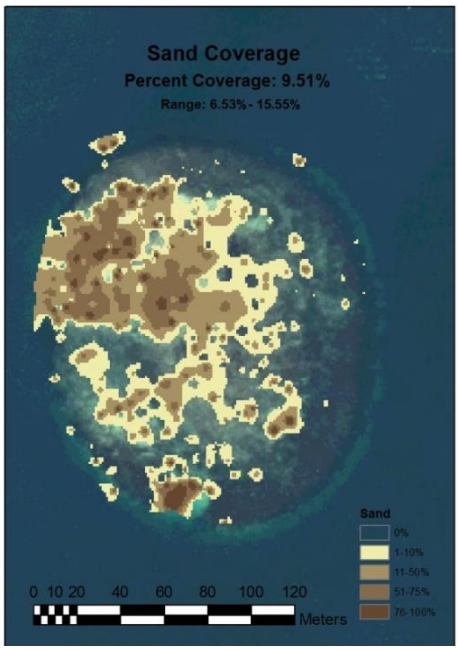
Reef 14 (Treatment Reef)

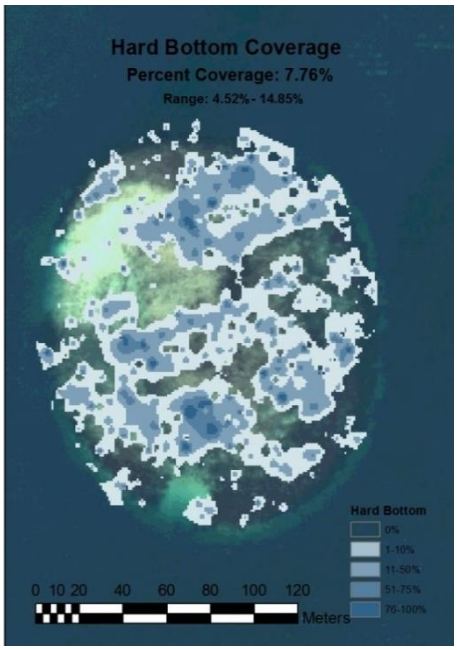






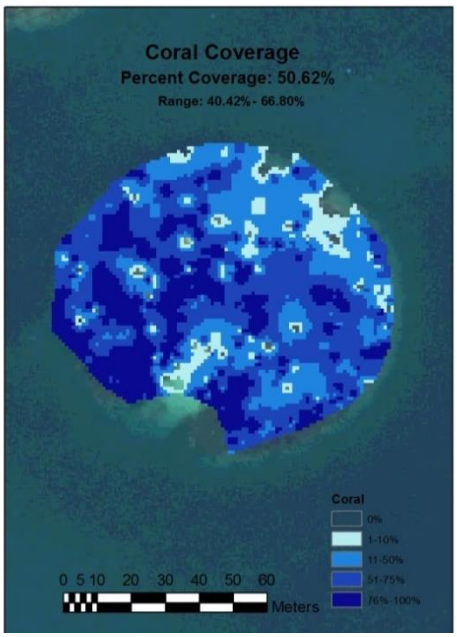


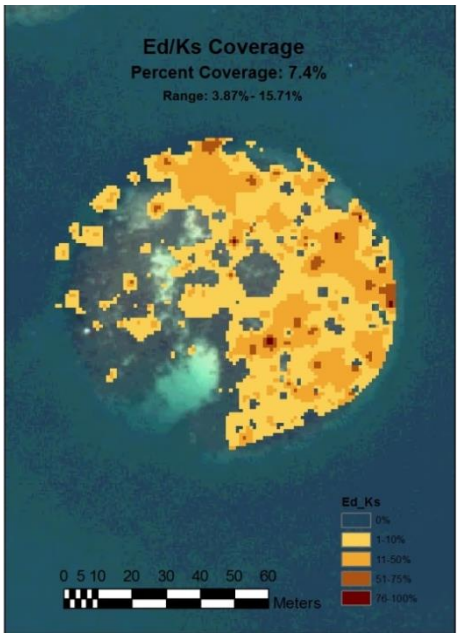


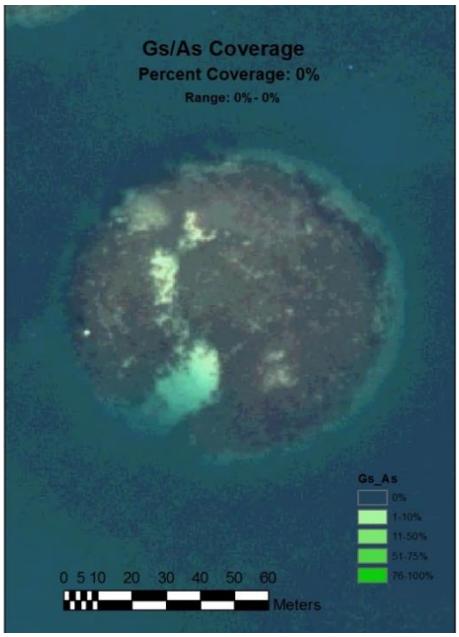


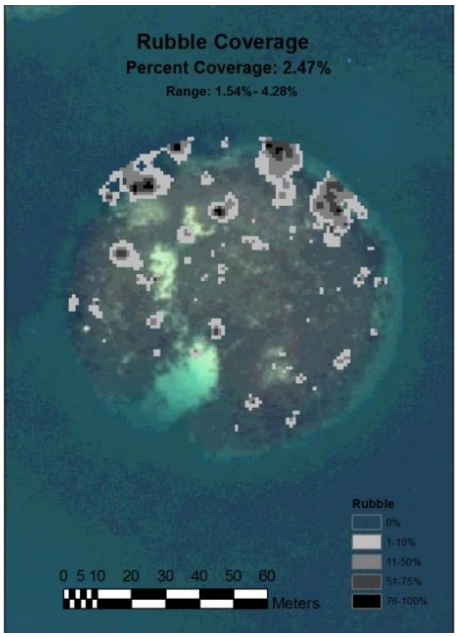
Appendix D: cont'd.

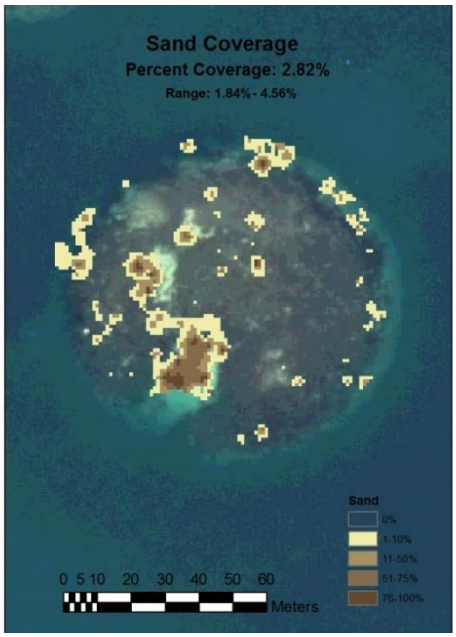
Reef 15 (Control Reef)

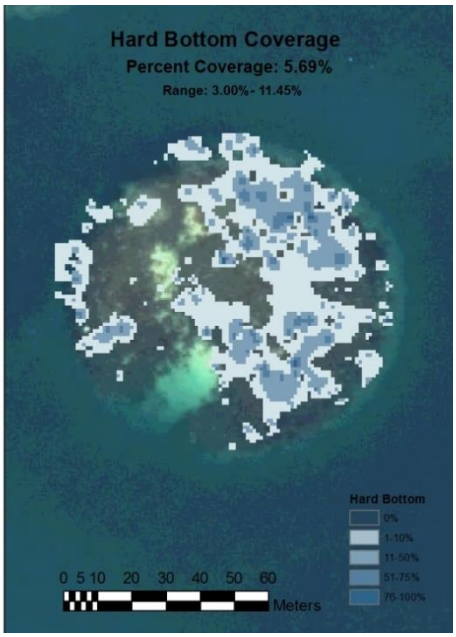






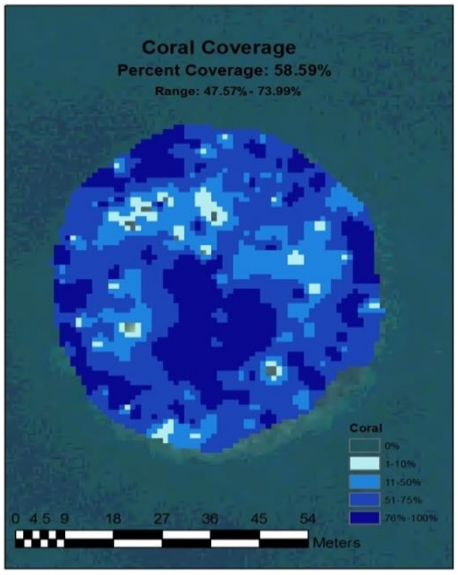


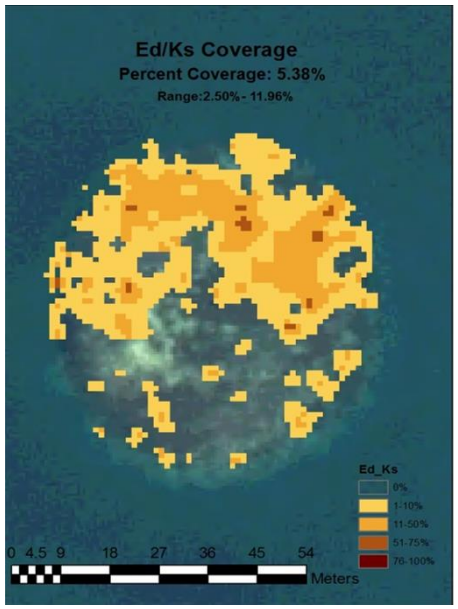


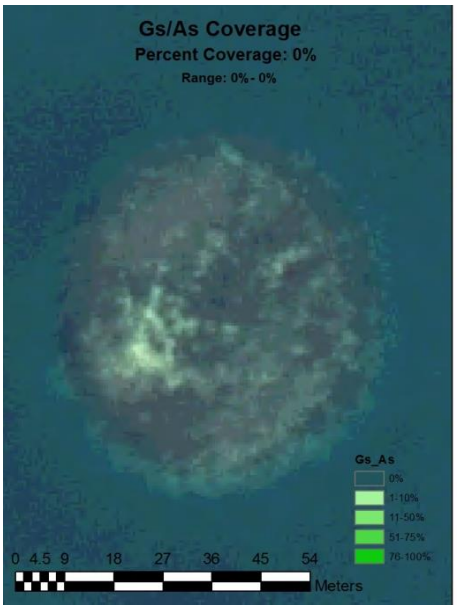


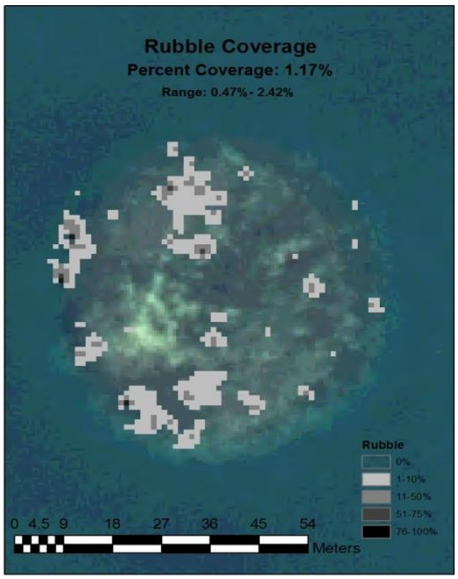
Appendix D: cont'd.

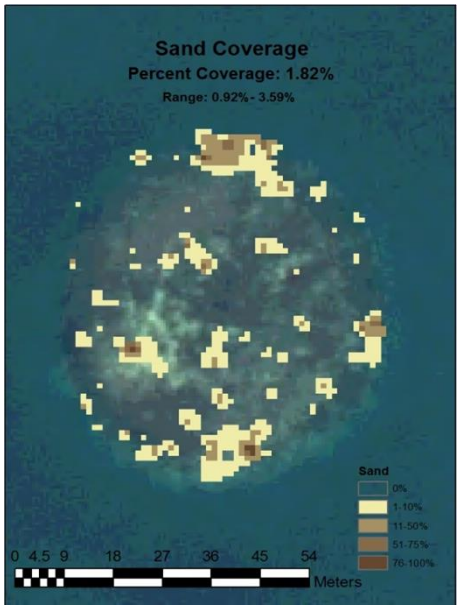
Reef 16 (Treatment Reef)

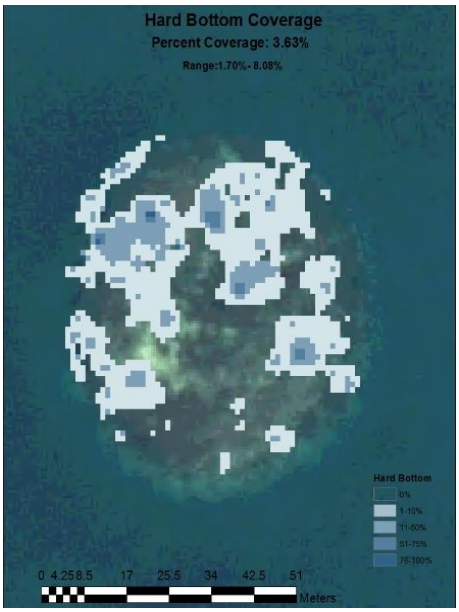






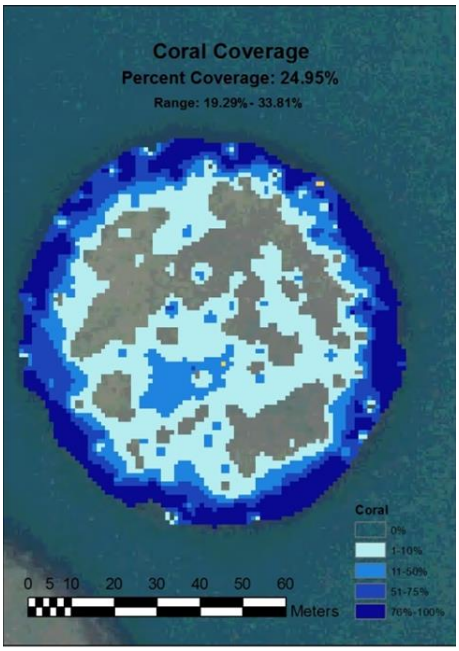


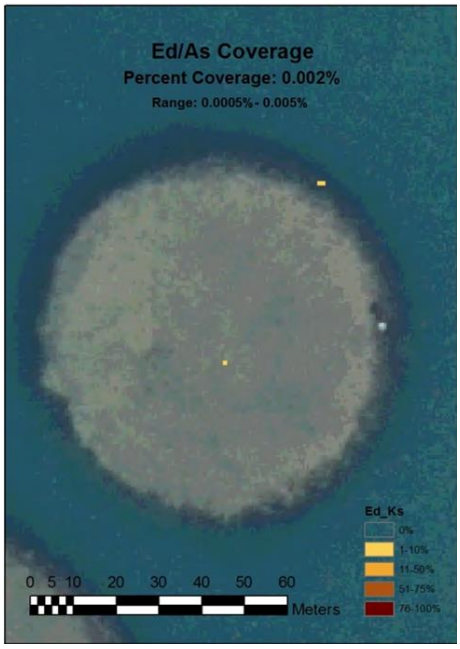


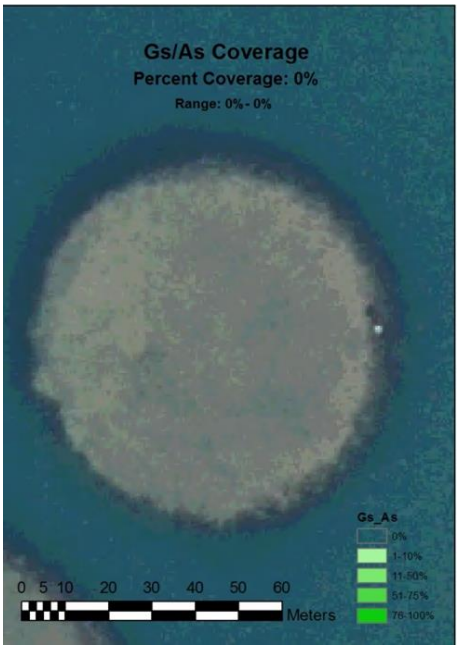


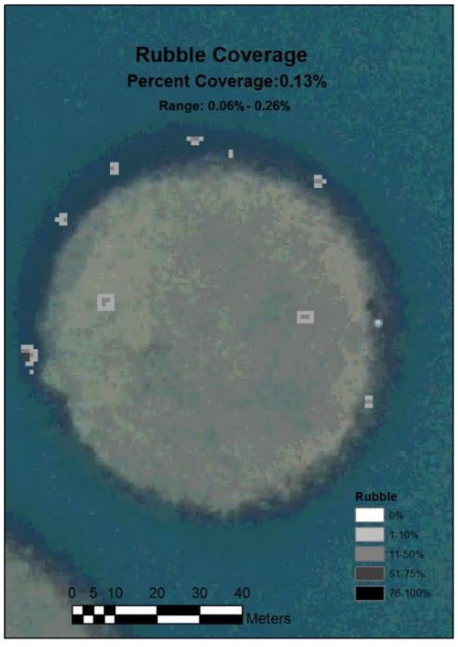
Appendix D: cont'd.

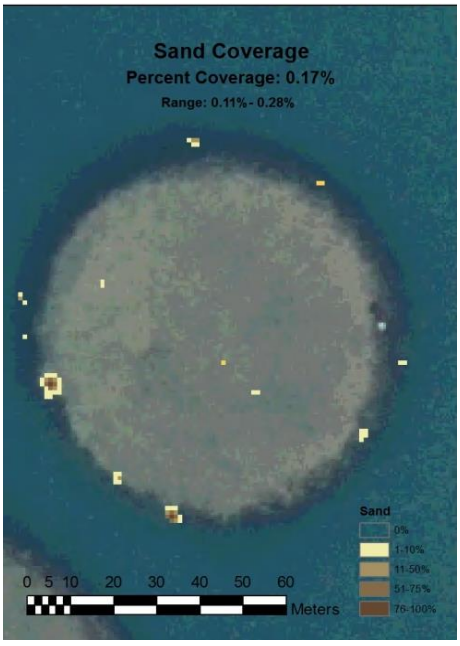
Reef 17 (Reference Reef)

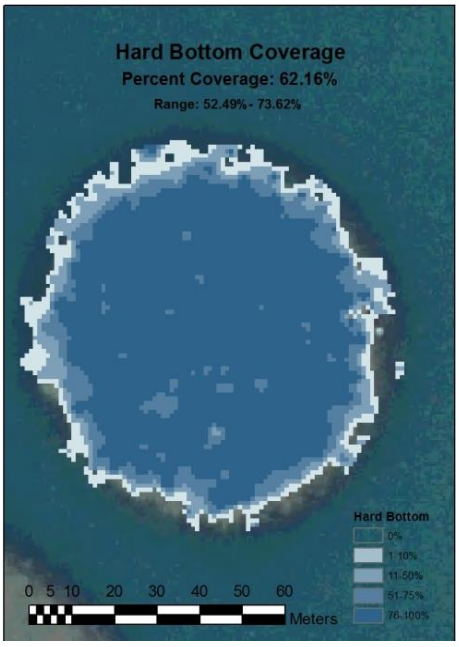






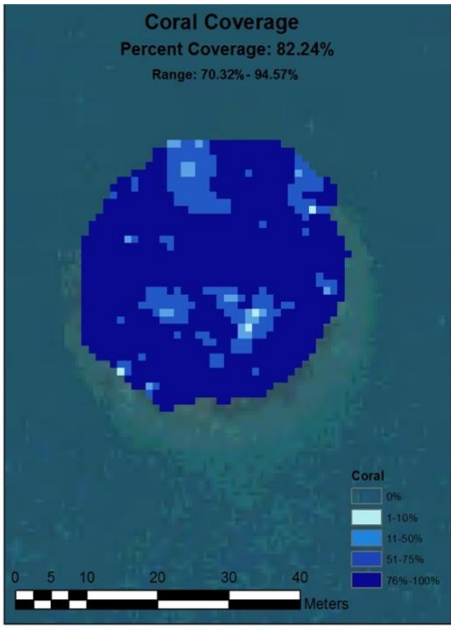


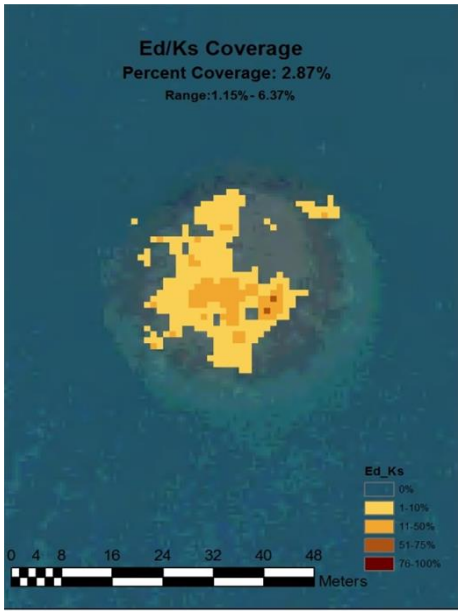


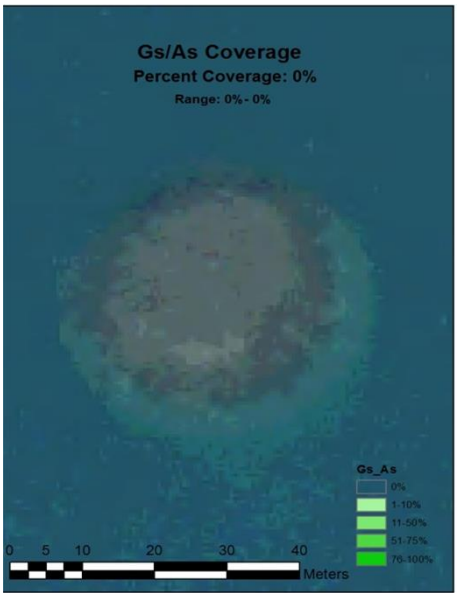


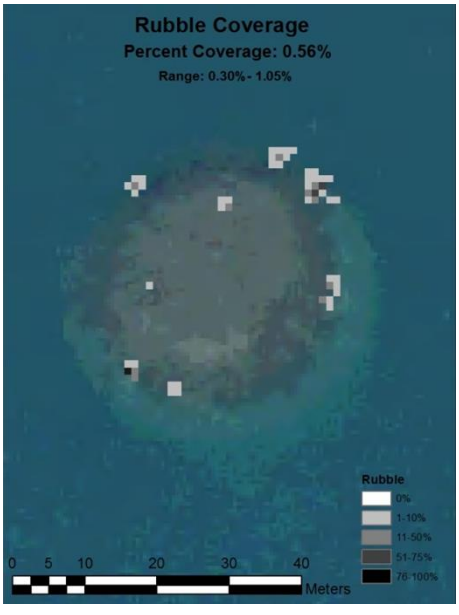
Appendix D: cont'd.

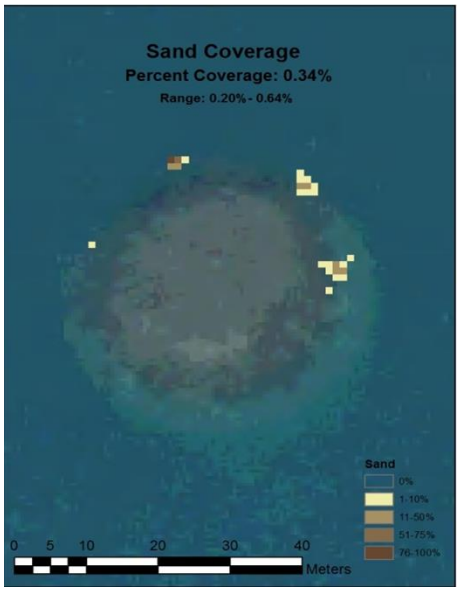
Reef 19 (Treatment Reef)

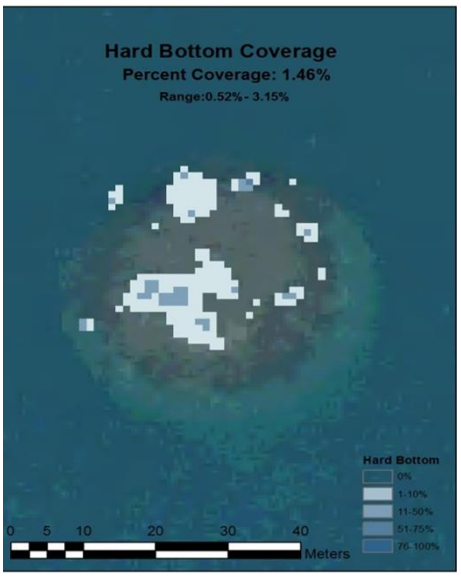






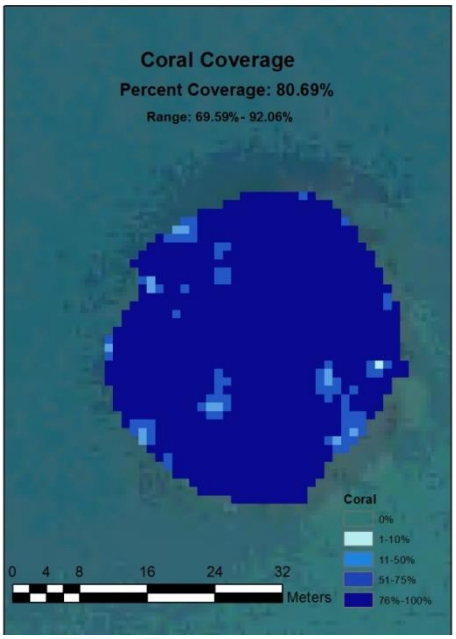


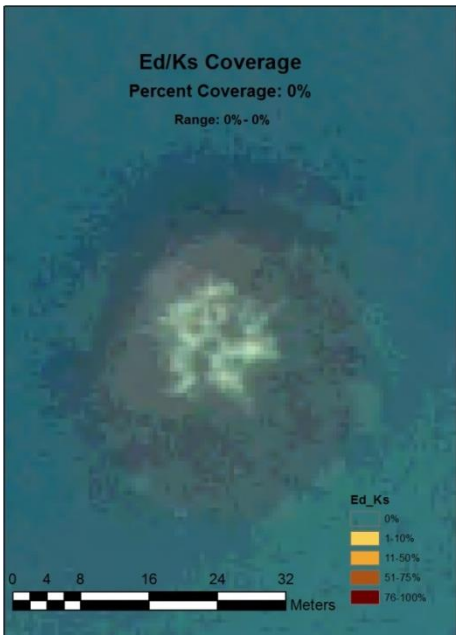


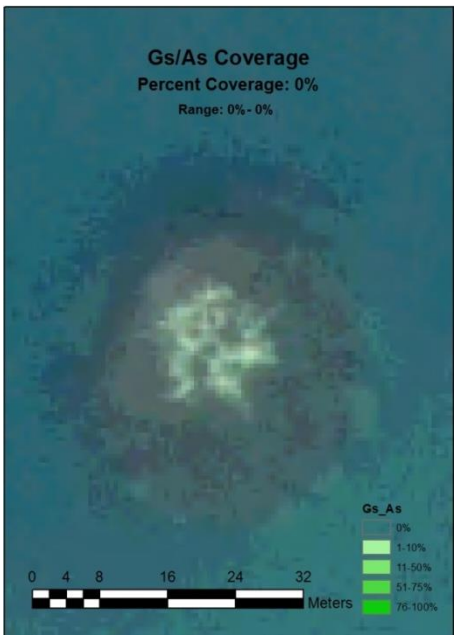


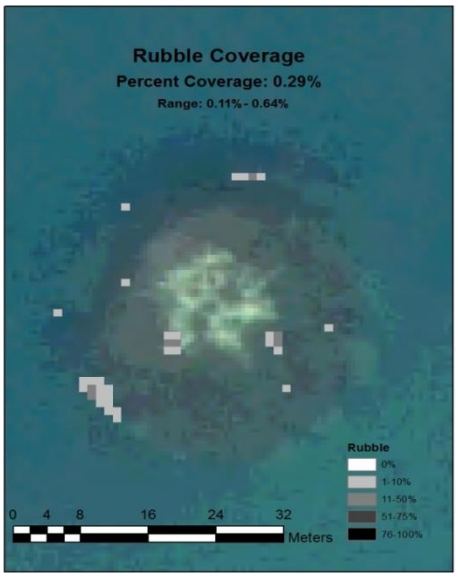
Appendix D: cont'd.

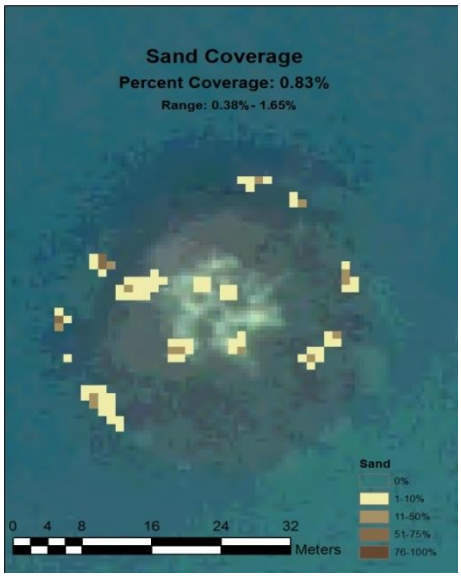
Reef 22 (Reference Reef)

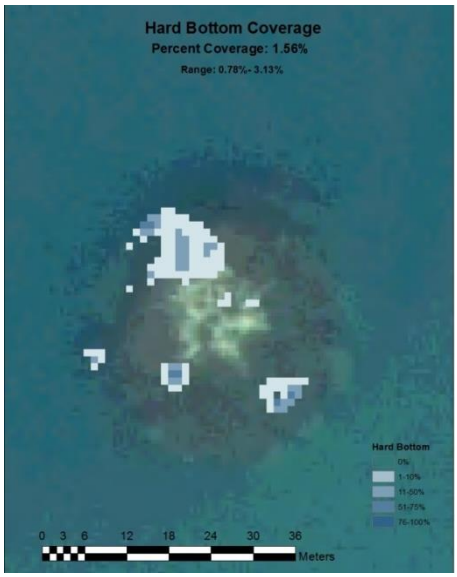






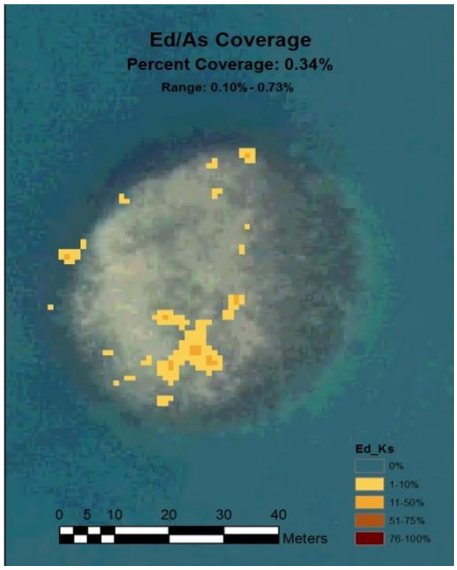


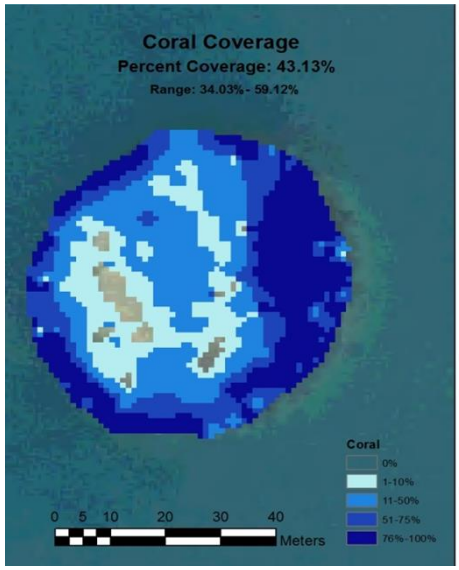


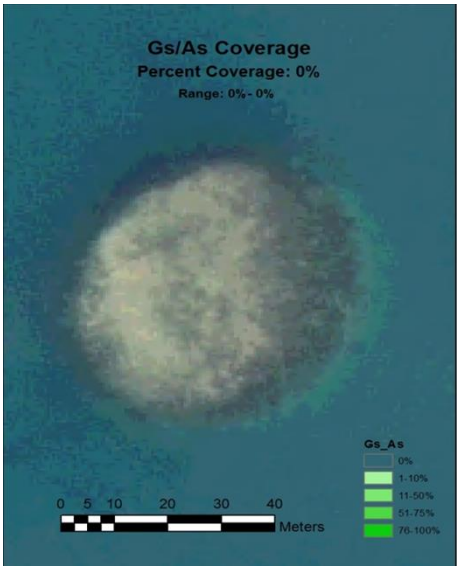


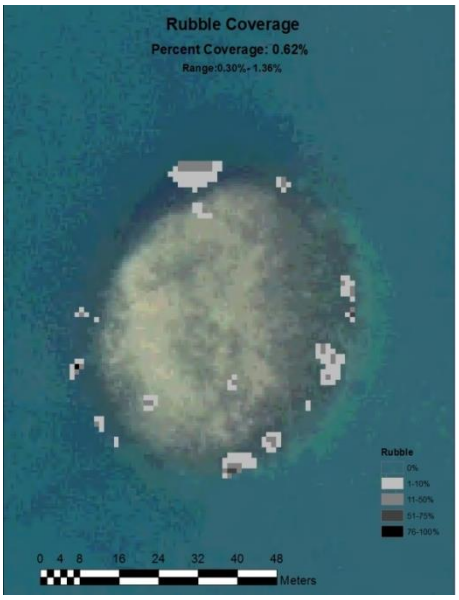
Appendix D: cont'd.

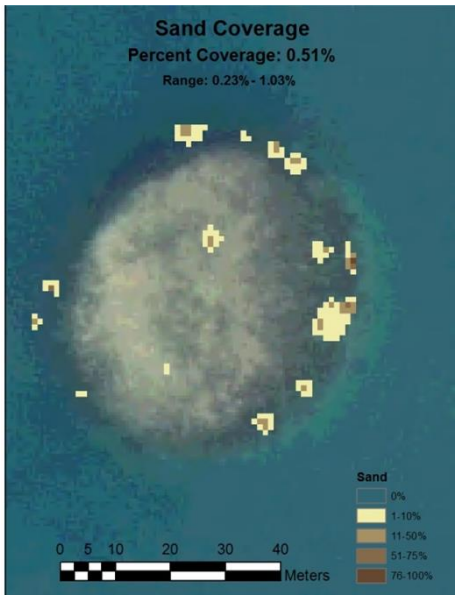
Reef 23 (Control Reef)

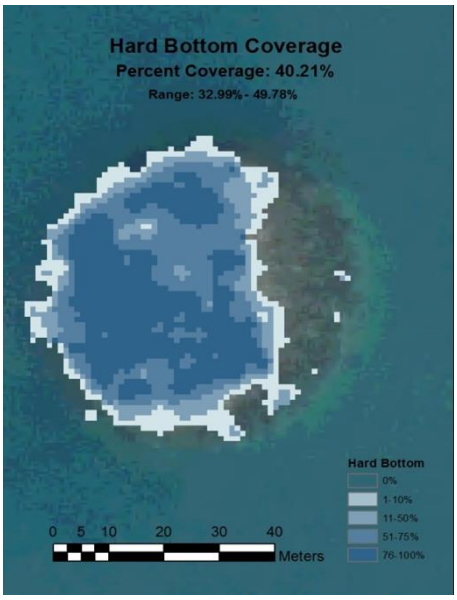












Appendix E: Fish size frequency classes.

Table 1. Fish size frequency classes.

Reef 9					
Species Code	**Reef Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AB	2	28	4	0	0
AN	0	2	0	0	0
ANF	0	0	1	0	0
AT	6	36	1	0	0
BM	0	1	0	0	0
CA	2	15	1	0	0
CM	0	3	1	0	0
CO	0	1	0	0	0
CQ	2	1	0	0	0
CS	18	61	32	3	0
CST	1	9	7	0	0
DA	0	4	0	0	0
FC	0	0	0	0	4
FL	0	1	0	0	0
GV	0	6	5	0	0
LP	0	2	0	0	0
MF	0	6	16	1	0
NU	0	6	3	0	0
PJ	0	1	0	0	0
SB	0	4	1	0	0
TD	4	19	17	5	0
ULF	0	0	0	1	0
UP	127	168	3	0	0
US	0	12	1	0	0
ZC	0	29	1	0	0
ZF	0	5	3	1	0
ZV	1	7	4	0	0
Total	**163**	**427**	**101**	**11**	**4**

Reef 10					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AA	0	7	2	0	0
AB	12	104	11	2	0
AC	0	0	0	1	0
ANF	0	2	0	0	0
AT	3	35	1	0	0
CA	0	9	2	0	0
CLU	0	0	1	0	0
CM	0	3	0	0	0
CO	0	3	0	0	0
CQ	0	2	0	0	0
CS	45	66	19	0	0
CST	0	8	9	0	0
DA	0	8	0	0	0
FC	0	0	0	0	3
GV	0	1	0	0	0
MV	0	1	0	0	0
NB	0	1	0	0	0
NL	0	2	0	0	0
NU	0	22	3	0	0
PI	4	0	0	0	0
PJ	0	1	0	0	0
PM	0	0	2	0	0
SB	0	3	1	0	0
SM	0	4	0	0	0
TBL	0	0	1	0	0
TD	0	28	28	5	0
TT	0	1	0	0	0
UP	232	599	1	0	0
ZC	0	4	0	0	0
ZF	0	13	0	0	0
ZV	0	14	5	0	0
Total	**296**	**941**	**86**	**8**	**3**

Reef 12					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AB	3	24	0	0	0
AC	0	0	0	0	1
AT	1	7	0	0	0
CA	0	9	3	0	0
CL	0	3	0	0	0
CLU	0	4	2	0	0
CM	0	23	1	0	0
CO	0	2	4	0	0
CQ	0	1	0	0	0
CS	10	81	20	2	0
CST	1	13	1	0	0
DA	0	39	0	0	0
FL	0	2	0	0	0
GV	0	30	2	0	0
IP	1	2	0	0	0
LP	1	1	0	0	0
MV	0	12	0	0	0
PI	0	7	0	0	0
PM	0	2	1	0	0
PS	0	2	0	0	0
SM	0	6	0	0	0
TD	1	31	3	0	0
ULF	0	0	1	0	0
UP	24	187	0	0	0
ZC	0	13	0	0	0
ZF	0	31	0	0	0
ZV	0	9	1	0	0
Total	**42**	**541**	**39**	**2**	**1**

Reef 14					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AB	2	18	0	0	0
AC	0	0	0	0	1
AT	2	19	1	0	0
CA	1	5	0	0	0
CH	0	1	0	0	0
CHU	0	1	0	0	0
CL	0	1	0	0	0
CM	0	11	0	0	0
CO	0	1	0	0	0
CS	3	39	9	1	0
CST	0	2	6	0	0
DA	0	5	0	0	0
GV	3	9	4	0	0
MF	0	0	3	0	0
NB	2	1	0	0	0
NU	0	3	1	0	0
PI	0	1	0	0	0
PS	0	2	0	0	0
SB	6	5	1	0	0
SM	0	3	1	0	0
TD	3	17	8	1	0
UP	175	176	4	0	0
US	1	2	0	0	0
ZC	0	0	2	0	0
ZF	4	21	0	0	0
Total	**202**	**343**	**40**	**2**	**1**

Reef 15					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AA	0	40	0	0	0
AB	1	46	1	0	0
AC	0	0	0	1	3
AT	0	10	0	0	0

Reef 15					
Species Code	Size Class				
	A = 0 - 5 cm	B = 5 - 10 cm	C = 10 - 15 cm	D = 15 - 20 cm	E = > 20 cm
BA	0	1	4	0	0
CA	0	11	2	0	0
CL	0	2	0	0	0
CLI	0	1	0	0	0
CM	0	11	0	0	0
CO	0	4	0	0	0
CQ	0	4	0	0	0
CS	0	25	15	0	0
CST	0	10	4	0	0
DA	2	38	0	0	0
FC	0	0	0	0	2
FL	0	2	0	0	0
GV	0	6	2	0	0
LF	0	2	0	0	0
LP	0	1	0	0	0
MF	0	1	0	0	0
MV	0	11	0	0	0
NA	0	2	0	0	0
NU	0	3	0	0	0
PI	0	2	0	0	0
PJ	0	5	0	0	0
PM	0	4	0	0	0
PS	0	9	0	0	0
SB	0	5	0	0	0
SM	0	1	0	0	0
TD	3	23	6	0	0
UP	192	144	5	0	0
ZC	0	29	2	0	0
ZF	0	42	0	0	0
ZV	1	6	0	0	0
Total	**199**	**501**	**41**	**1**	**5**

Reef 16					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AAC	0	1	0	0	0
AB	0	32	0	0	0
AC	0	0	0	1	2
ACO	0	1	0	0	0
AH	0	0	1	0	0
CA	0	4	1	0	0
CH	0	1	0	0	0
CM	1	39	1	0	0
CO	0	2	0	0	0
CPA	0	0	1	0	0
CS	3	17	8	0	0
CST	1	21	7	1	0
DA	0	36	0	0	0
FL	0	5	0	0	0
GV	0	9	1	0	0
MF	0	55	24	0	0
NA	0	1	0	0	0
NB	0	1	0	0	0
NL	0	3	0	0	0
NU	0	7	2	0	0
PI	0	6	0	0	0
PJ	0	2	0	0	0
PO	0	5	0	0	0
PS	0	1	0	0	0
SB	1	6	0	0	0
SD	0	0	1	0	0
SM	0	4	0	0	0
TD	4	18	9	1	0
UP	92	104	0	0	0
ZC	0	25	9	0	0
ZF	1	39	6	0	0
ZV	0	12	1	0	0
Total	**103**	**457**	**72**	**3**	**2**

Reef 17					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AA	0	385	0	0	0
AB	8	22	0	0	0
AC	0	0	0	0	2
AT	23	23	2	0	0
BA	0	0	1	0	0
CA	1	13	2	0	0
CL	0	1	0	0	0
CLU	0	10	2	0	0
CM	0	4	0	0	0
CO	0	2	4	0	0
CS	0	128	48	0	0
CST	0	16	3	0	0
DA	0	4	0	0	0
FC	0	0	0	0	4
GV	0	5	5	0	0
LF	0	2	7	0	0
MB	0	6	0	0	0
MV	0	0	24	0	0
PI	0	4	0	0	0
SB	0	2	0	0	0
SM	0	4	0	0	0
TD	0	29	2	0	0
TT	0	0	2	0	0
UP	311	179	0	0	0
US	0	1	0	0	0
ZC	0	10	0	0	0
ZF	0	21	0	0	0
ZV	1	7	1	0	0
Total	**344**	**878**	**103**	**0**	**6**

Reef 19					
Species Code	**Size Class**				
	A = 0 - 5 cm	**B = 5 - 10 cm**	**C = 10 - 15 cm**	**D = 15 - 20 cm**	**E = > 20 cm**
AA	0	16	0	0	0
AAC	0	2	0	0	0
AB	4	5	0	0	0
AC	0	0	0	2	0
ANF	0	2	0	0	0
AT	0	7	0	0	0
CA	0	6	1	0	0
CJ	0	1	0	0	0
CLU	0	2	0	0	0
CM	1	30	0	0	0
CO	0	1	0	0	0
CQ	0	1	0	0	0
CS	1	15	1	0	0
CST	0	10	3	0	0
DA	0	31	0	0	0
GM	0	0	0	0	1
GV	0	4	2	0	0
NB	0	3	0	0	0
NU	0	6	2	0	0
PJ	1	5	1	0	0
PS	0	4	0	0	0
SB	0	2	0	0	0
SM	1	4	0	0	0
TD	1	13	0	1	0
UP	89	45	0	0	0
ZC	0	13	3	0	0
ZF	2	4	1	0	0
ZV	0	3	0	0	0
Total	**100**	**235**	**14**	**3**	**1**

Reef 22					
Species Code	Size Class				
	A = 0 - 5 cm	B = 5 - 10 cm	C = 10 - 15 cm	D = 15 - 20 cm	E = > 20 cm
AA	1	1	0	0	0
AB	0	128	0	0	0
AT	2	3	0	0	0
CA	3	14	1	0	0
CF	0	1	0	0	0
CL	2	1	0	0	0
CLI	0	1	0	0	0
CLU	0	1	0	0	0
CM	0	39	5	0	0
CQ	0	7	0	0	0
CS	0	13	15	0	0
CST	2	8	2	0	0
DA	7	21	0	0	0
FC	0	0	0	1	3
GM	0	0	0	0	1
GV	0	2	2	0	0
LK	0	0	1	0	0
MF	0	0	7	0	0
NB	0	1	0	0	0
NL	0	1	0	0	0
NU	0	2	0	0	0
PJ	1	11	0	0	0
PS	0	3	0	0	0
SB	1	1	0	0	0
SM	0	1	0	0	0
TD	1	6	1	0	0
UG	0	0	1	0	0
ULF	0	0	1	0	0
UP	68	10	0	0	0
ZC	0	23	0	0	0
ZF	3	29	0	0	0
ZV	2	11	0	0	0
Total	**93**	**339**	**36**	**1**	**4**

Reef 23					
Species Code	Size Class				
	A = 0 - 5 cm	B = 5 - 10 cm	C = 10 - 15 cm	D = 15 - 20 cm	E = > 20 cm
AA	0	2	0	0	0
AB	2	41	3	0	0
AT	0	30	0	0	0
CA	1	16	0	0	0
CF	0	1	0	0	0
CLU	0	2	0	0	0
CM	0	22	0	0	0
CMP	0	0	0	0	2
CQ	1	2	0	0	0
CS	0	54	4	0	0
CSA	0	0	0	1	0
CST	2	9	4	0	0
DA	0	22	0	0	0
FC	0	0	0	0	14
FL	0	1	0	0	0
GV	0	5	1	1	0
MV	0	0	5	0	0
NB	0	2	0	0	0
NL	0	1	0	0	0
NU	0	6	1	0	0
PJ	0	10	0	0	0
PM	0	2	0	0	0
PS	0	2	0	0	0
SM	0	3	0	0	0
TD	1	7	3	2	0
TT	0	0	1	0	0
UP	235	187	0	0	0
US	0	28	0	0	0
ZC	0	9	0	0	0
ZF	0	30	4	0	0
ZV	0	4	0	0	0
Total	**242**	**498**	**26**	**4**	**16**
Grand Total	**1784**	**5160**	**558**	**35**	**43**

Table 2. Fish acronym identification by species.

AIS Fish Code	Scientific Name	AIS Fish Code	Scientific Name
AA	*Abudefduf abdominalis*	KS	*Kuhlia sandvicensis*
AAC	*Acanthurus achilles*	KX	*Kuhlia xenura*
AB	*Acanthurus blochii*	LF	*Lutjanus fulvus*
AC	*Aulostomus chinensis*	LFO	*Lactoria fornasini*
ACH	*Anampses chrysocephalus*	LK	*Lutjanus kasmira*
ACO	*Antennarius commerson*	LP	*Labroides phthirophagus*
AD	*Acanthurus dussumieri*	MB	*Myripristis berndti*
AG	*Albula glossodonta*	MF	*Mulloidichthys flavolineatus*
AH	*Arothron hispidus*	MV	*Mulloidichthys vanicolensis*
AI	*Atherinomorus insularum*	NA	*Naso spp.*
AL	*Acanthurus leucopareius*	NB	*Naso brevirostris*
AN	*Acanthurus nigroris*	NH	*Naso hexacanthus*
ANA	*Aetobatus narinari*	NL	*Naso lituratus*
ANF	*Acanthurus nigrofuscus*	NO_DATA	*NO_DATA*
AO	*Acanthurus olivaceus*	NONE	*NO_FISH*
AS	*Asterropteryx semipunctata*	NT	*Novaculichthys taeniourus*
ASP	*Albula spp.*	NU	*Naso unicornis*
AT	*Acanthurus triostegus*	OM	*Ostracion meleagris*
AV	*Abudefduf vaigiensis*	OU	*Oxycheilinus unifasciatus*
AVI	*Albula virgata*	PA	*Paracirrhites arcatus*
AX	*Acanthurus xanthopterus*	PC	*Pseudojuloides cerasinus*
BA	*Bodianus albotaeniatus*	PI	*Plectroglyphidodon imparipennis*
BB	*Bodianus bilunulatus*	PIN	*Parupeneus insularis*
BG	*Blenniella gibbifrons*	PJ	*Plectroglyphidodon johnstonianus*
BM	*Bothus mancus*	PM	*Parupeneus multifasciatus*
CA	*Chaetodon auriga*	PMA	*Psilogobius mainlandi*
CE	*Chaetodon ephippium*	PO	*Pseudocheilinus octotaenia*
CF	*Chaetodon fremblii*	PP	*Parupeneus pleurostigma*
CH	*Chromis hanui*	PS	*Pevagor spilosoma*
CHA	*Chromis agilis*	PT	*Pseudocheilinus tetrataenia*
CHN	*Chanos chanos*	SB	*Stethojulis balteata*
CHU	*Chaetodon unimaculatus*	SBA	*Sphyraena barracuda*
CHW	*Ctenochaetus hawaiiensis*	SC	*Selar crumenophthalmus*
CI	*Cheilio inermis*	SD	*Scorpaenopsis diabolus*
CJ	*Canthigaster jactator*	SH	*Sphyraena helleri*
CL	*Chaetodon lunula*	SL	*Sepioteuthis lessoniana*
CLI	*Chaetodon lineolatus*	SLE	*Sphyrna lewini*
CLU	*Chaetodon lunulatus*	SLY	*Scomberoides lysan*
CM	*Chaetodon miliaris*	SM	*Stegastes marginatus*
CMC	*Chaetodon multicinctus*	SP	*Scarus psittacus*

AIS Fish Code	Scientific Name	AIS Fish Code	Scientific Name
CMP	*Caranx melampygus*	SR	*Scarus rubroviolaceus*
CO	*Chaetodon ornatissimus*	SX	*Sargocentron xantherythrum*
COV	*Chromis ovalis*	TBL	*Thalassoma ballieui*
CP	*Cirrhitus pinnulatus*	TD	*Thalassoma duperrey*
CPA	*Cephalophilis argus*	TT	*Thalassoma trilobatum*
CPE	*Chlorurus perspicillatus*	TTR	*Taenianotus triacanthus*
CQ	*Chaetodon quadrimaculatus*	UB	*Unknown Butterfly*
CS	*Chlorurus sordidus*	UBA	*Sphyraena spp.*
CSA	*Cantherhines sandwichiensis*	UBL	*Unknown Blennie*
CST	*Ctenochaetus strigosus*	UC	*Apogon spp.*
CV	*Coris venusta*	UD	*Unknown Damsel*
CVA	*Cirripectes vanderbilti*	UE	*Unknown Eel*
DA	*Dascyllus albisella*	UF	*Unknown Frogfish*
DHC	*Diodon holocanthus*	UG	*Unknown Goatfish*
DHY	*Diodon hystrix*	UGO	*Unknown Goby*
EN	*Echidna nebulosa*	UHF	*Unknown Hawkfish*
FB	*Foa brachygramma*	UJ	*Unknown Jack*
FC	*Fistularia commersonii*	ULF	*Unknown Lizardfish*
FF	*Forcipiger flavissimus*	UO	*Unknown Octopus*
FL	*Forcipiger longirostris*	UP	*Unknown Parrotfish*
GA	*Gnatholepis anjerensis*	UPO	*Unknown Porcupinefish*
GC	*Gnatholepis cauerensis*	UPU	*Unknown Puffer*
GF	*Gymnothorax flavimarginatus*	US	*Unknown Surgeon/Tang/Unicorn*
GM	*Gymnothorax meleagris*	USQ	*Unknown Squirrel/Soldier*
GS	*Gnathanodon speciosus*	UT	*Upeneus taeniopterus*
GU	*Gymnothorax undulatus*	UW	*Unknown Wrasse*
GV	*Gomphosus varius*	ZC	*Zanclus cornutus*
GZ	*Gymnomuraena zebra*	ZF	*Zebrasoma flavescens*
HO	*Halichoeres ornatissimus*	ZV	*Zebrasoma velifer*
IP	*Iniistius pavo*		