Kaneohe Bay, Oahu

Snap-Assessment Report

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Executive Summary

The proliferation of introduced invasive algae throughout Kaneohe Bay poses a major threat to coral reef ecosystems. As a result, extensive invasive algal management has been carried out over the past decade. Given the bay-wide distribution of invasive algae, it is essential that management also be conducted on a bay-wide scale. This allows managers to prioritize control efforts and invest resources to areas that have the greatest ecological gain. In order to implement a bay-wide management approach, current coral and invasive algae data are needed to make informed decisions.

A bay-wide snap-assessment survey was carried out to map coral and invasive algae cover of patch reefs in the bay. The primary objectives of this project were to:

1) Provide essential data to inform bay-wide management decisions aimed at controlling the spread of *Eucheuma spp*. and *Kappaphycus spp*. and to conserve or restore coral reef ecosystems in Kaneohe Bay.

2) Select patch reefs for inclusion in the State of Hawaii's proposed mitigation bank prospectus.

3) Provide baseline data to monitor coral and invasive algal trends in Kaneohe Bay overtime.

Forty-one patch reefs were surveyed from February to April 2014 and a Kaneohe Bay coral and invasive algae distribution dataset was established. Results showed that invasive algae were distributed throughout the bay at variable densities. Coral distribution was also variable, with high coral densities found on patch reefs throughout the bay. Mitigation reefs were selected by use of a prioritization ranking structure that weighted reefs with a high co-occurrence of live coral and invasive algae (*Eucheuma spp.* and *Kappaphycus spp.*). These reefs were believed to have the highest potential for invasive algae restoration. This prioritized ranking was used to select four treatment reefs for immediate removal efforts and inclusion into the mitigation bank prospectus. The snap-assessment results were also used to select control and reference monitoring sites. The survey methodology was found to provide accurate and repeatable coral and invasive algal cover estimates and will provide a valuable data set for tracking changes in coral and algal distribution over time.

It is recommended that the snap-assessment survey, in combination with prioritization models, is used to construct a bay-wide invasive algae action-plan that incorporates a variety of management strategies and objectives. It is also recommended that the snap-assessment surveys are repeated annually or bi-annually to track coral and invasive algae trends in the bay over time.

Introduction

Coral reef habitats of Kaneohe Bay, Oahu have become increasingly dominated by alien algae since introduction in the 1970's (Russel 1983, Smith et al. 2002, Conklin and Smith 2005). Several species of alien algae, particularly *Eucheuma spp., Kappaphycus spp., and Gracilaria salicornia*, are a major threat. These species dominate reef habitats, out-compete native species, reduce photosynthesis of native organisms, alter water chemistry, and kill corals (Russell 1983, Conklin and Smith 2005, Chandrasekaran et al. 2008, Martinez et al. 2011). In addition, these species are able spread and proliferate if left unchecked (Rodgers and Cox 1999, Conklin and Smith 2005). Given these destructive effects and since *Eucheuma spp.* and *Kappaphycus spp.* currently have not dispersed widely outside of Kaneohe Bay, there is a strong incentive to actively control their spread.

Therefore, the State of Hawaii's, Department of Land and Natural Resources, Division of Aquatic Resources and its partners, The Nature Conservancy, University of Hawaii, and National Oceanic and Atmospheric Administration have carried out extensive control efforts through mechanical removal by use of the supersucker and biocontrol by outplanting the native sea urchin *Tripneustes gratilla*.

Currently, invasive algae have colonized a large portion of the patch reefs and fringing reefs in the bay to various levels of coverage (Smith et al. 2002, Conklin and Smith 2005). Given the expansive distribution of invasive algae, a bay-wide approach is essential to prioritize management efforts. Current invasive algae and coral distribution data is important to implement an action plan. Therefore, a bay-wide assessment was carried out by the University of Hawaii with funding from the Division of Aquatic Resources and help from The Nature Conservancy of Hawaii.

A snapshot ("snap") assessment rapidly assesses important reef characteristics. Data is compiled into a single database where reef attributes can easily be compared, sorted, prioritized, ranked, and decision support tools can be deployed to guide future management efforts. The primary objectives of this project were to:

- Provide essential coral and invasive algae data to inform bay-wide decision making in order to preserve and restore native coral reef ecosystems in Kaneohe Bay and control the spread of *Eucheuma spp*. and *Kappaphycus spp*.
- Select patch reefs for inclusion in the proposed State of Hawaii proposed mitigation bank prospectus.
- Provide baseline data that could be used to monitor coral and invasive algae trends in Kaneohe Bay overtime.

Methods

Site Description

Kaneohe Bay is a 60 km^2 embayment, located on the east-shore of Oahu, Hawaii and has a barrier reef, fringing reef, and numerous patch reef habitats (Figure 1).

Site Selection

All patch reefs across the bay were evaluated for coral and invasive algal coverage as possible inclusion in the snap-assessment (Figure 1). Survey reefs were selected using satellite imagery and past survey data. Reefs included in the snap-assessment had high to moderate coral cover or a known presence of *Eucheuma/Kappaphycus*. Patch reefs excluded from the survey were primarily composed of sand habitats or no known presence of *Eucheuma/Kappaphycus*. Barrier and fringing reefs were excluded from the survey because current management techniques are not yet suited to treat expansive reef areas. Several patch reefs with no known presence of *Eucheuma/Kappaphycus* presence, but with high potential coral reef habitat were surveyed for baseline data of unaffected reefs. Forty-one patch reefs were surveyed to estimate coral and invasive algae cover.

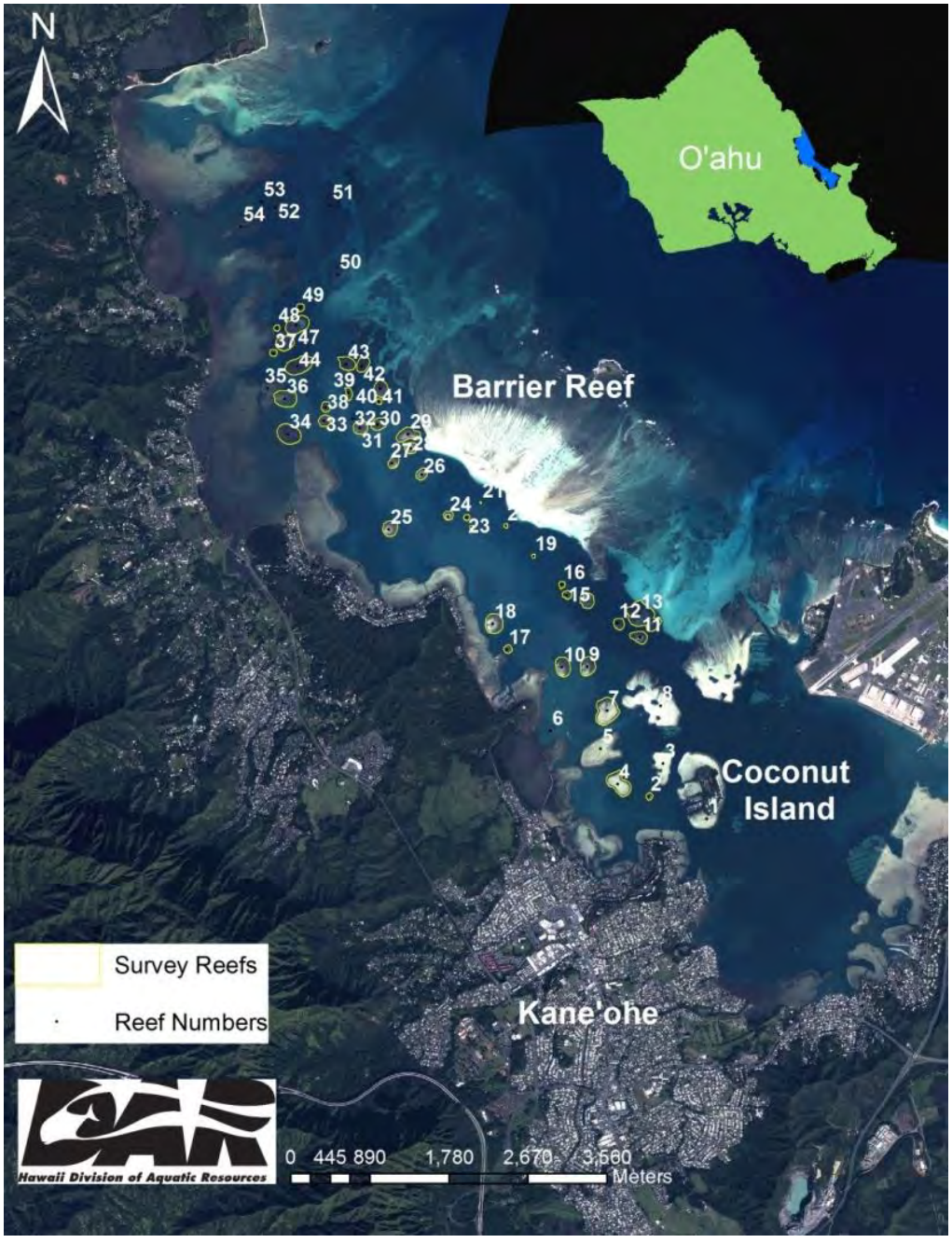

Figure 1. Kaneohe Bay, Oahu. Reefs outlined in yellow were surveyed as part of the snap-assessment.

Survey Methods

Surveyors, spaced approximately 5-10 m apart, swam transects across the reef and randomly placed a 0.5 m measuring stick every 5-10 m (Figure 2). Surveyors swam multiple passes across the reef to sample the reef's flat, crest and slope

to depths of ≤ 3 m. Surveyors made every attempt to avoid bias by haphazardly selecting survey points by placing the stick at regular intervals and not looking at the reef bottom when placing the survey stick on a point.

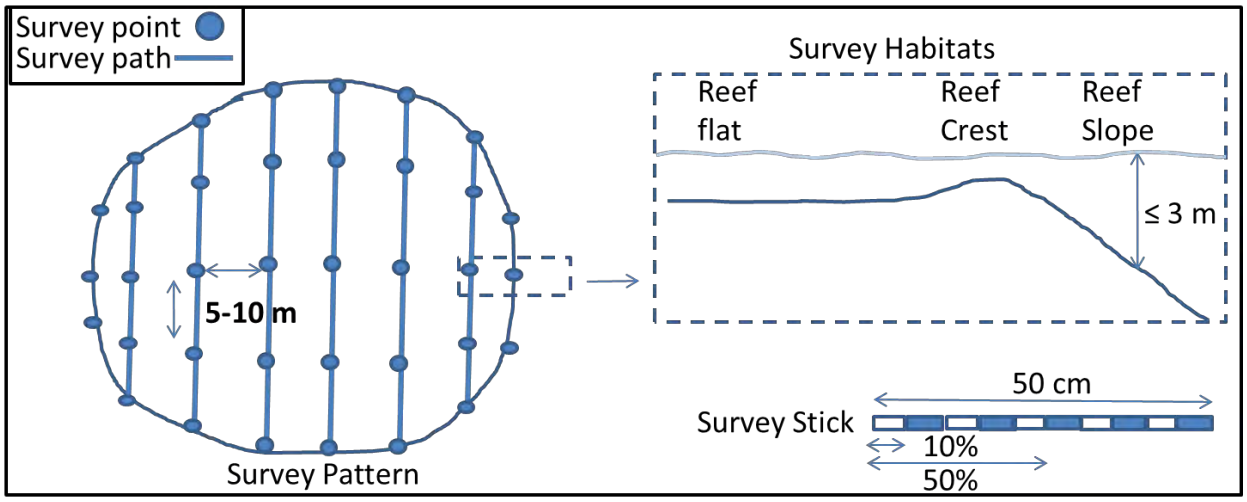

Figure 2. Snap assessment survey pattern, survey point, survey path, survey habitats, and survey stick.

At each survey point, a waypoint was taken using a GPS, the habitat (slope, crest, and flat) and percent cover (live coral, *Eucheuma/Kappaphycus, and Gracilaria/Acanthophora*) were estimated based on the benthic composition below the measuring stick. Invasive algae were grouped into two categories: 1) *Eucheuma* and *Kappaphycus* and 2) *Gracilaria* and *Acanthophora* (composed of *Gracilaria salicornia* and *Acanthophora spicifera*).

The measuring stick was partitioned into ten, 5 cm increments. Coral and algae data was categorized into four separate cover classes accumulated across the stick (Table 1). If live coral was visible beneath the algae, it was recorded. Therefore, it was possible to have greater than 100% accumulative cover of benthic types. In addition, the presence of large coral heads (coral colony > 160 cm) was noted (yes/no) if the stick lay above one.

Table 1. Cover classification for the snap-assessment survey. Cover was accumulated across the 50 cm survey stick for each cover category. Cover code was recorded on the datasheet for each associated percent cover class.

Percent cover	Length	Cover Code
0%	0 cm	0
1-10%	0.1-5 cm	1
11-50%	5-25 cm	2
51-100%	25-50 cm	3

Ease of mechanical removal of *Eucheuma/Kappaphycus* was also estimated (“1” easy, “2” moderate, “3” difficult). This measurement was a qualitative assessment of the area visible around the surveyor and not limited to the survey stick. Ease of removal could also be used as a presence/absence survey for *Eucheuma* and *Kappaphycus*. “3” was defined as a site with multiple algae attachment points, algae growing within rubble, or growing within coral branches. “1” was defined as a site with few attachment points, growing on solid dead coral substrate and dislodges easily. “2” would have

qualities in between easy and difficult. Surveyors also recorded the presence of coral species uncommon in Kaneohe Bay and took photographs of each patch reef to document the various reef characteristics and habitat features.

Reef flat depth was estimated by taking an average of 20 depth measurements across the reef flat. Depth measurements were averaged for each reef and then standardized to mean lower low water (MLLW) using NOAA historical tide charts.

Data Management and Mapping

GPS latitude and longitude locations were downloaded and associated survey data entered. The resulting dataset was, checked for errors, compiled in an MS Access database, and exported to an ArcGIS geodatabase. Coral, *Eucheuma/Kappaphycus*, *Gracilaria/Acanthophora*, ease of removal, and habitat type were mapped using ArcGIS software for each reef. Interpolated raster coverage maps of the reef were created using the ArcGIS inverse distance weighting (IDW) tool, which averages each 1 m^2 pixel based on the 12 closest surrounding survey data points. Refer to Appendix A for individual reef coverage maps.

Data Summaries

Reef coverage was used to estimate percent cover and area of coral and invasive algae for each patch reef surveyed. Percent cover was estimated by multiplying the area estimated by the IDW interpolation of each cover class (0%, 1%, 1-10%, 11-50%, 51-100%) times the low (1, 11, 51%), median (5, 20, 75%), and high (10, 50, 100%) coral cover class and then dividing by the total reef area. In addition, algal removal planning information was estimated including reef area, supersucker algal removal time, and urchin stocking levels. Reef area was estimated based on the survey area.

Management Prioritization

An ArcGIS based decision-support tool, Weighted Overlay Tool, was used to prioritize reefs in order to select patch reefs with a high co-occurrence of coral and *Eucheuma/Kappaphycus*. Interpolated coverage maps were added into the model as equal influence factors. Percent cover categories are summarized in Table 2. Every square meter of patch reef was assigned a priority value based on the co-occurrence of coral and *Eucheuma/Kappaphycus* influence factors.

Table 2. Influence factors inputted into the Weighted Overlay Model.

Influence Factor	Percent Cover
low priority	0%
low/medium priority	1-10%
medium/high priority	11-50%
high priority	51-100%

Prioritization of reefs was carried out by comparing the relative proportion of medium/high and high priority area of each reef and ranking the reefs accordingly, from high to low priority. Maps were examined with coral and *Eucheuma/Kappaphycus* maps to evaluate the accuracy of the Weighted Overlay Tool prioritization model.

Survey Error Determination /Map Coverage Overlay Analysis

Three reefs (Reefs 19, 23, 26) were randomly selected to re-survey within two-weeks of the initial survey in order to evaluate the repeatability of the survey and ground truth the ArcGIS interpolated coverage maps. Estimates of percent coral and algae coverage were compared between survey 1 and survey 2 to estimate survey error. Map coverage errors

were assessed by overlaying interpolated map coverages for each reef and species coverage. The raster calculator was used to evaluate how well the coverage maps between survey 1 and 2 matched.

Results

Coral Cover

Forty-one patch reefs were surveyed from February-April 2014 and over 14,000 data points were collected. Coral cover was variable throughout the bay and ranged from 75% to 12 % (Table 3, Figure 3, Appendix A). Reefs 19 and 21 had the highest proportion of coral cover. The total estimated coral area was 263,069 m^2 (range: 170,877 to 397,720 m^2) of patch reefs surveyed.

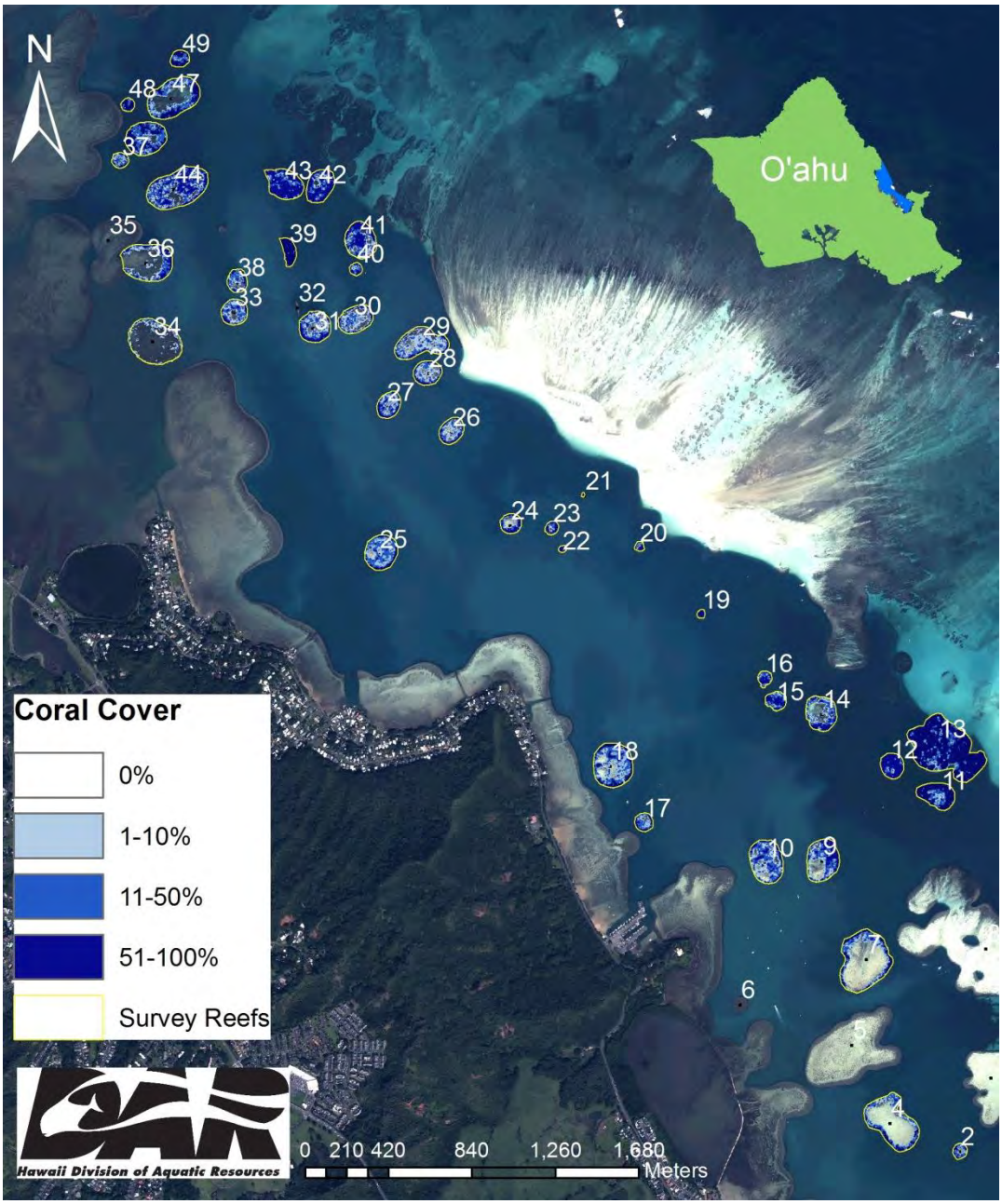

Figure 3. Kaneohe Bay coral cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Table 3. Coral cover, *Eucheuma/Kappaphycus* (Ed/Ks), *Gracilaria/Acanthophora* (Gs/As), Percent of reef classified as high priority, prioritization rank, and mitigation bank designation of surveyed patch reefs in Kaneohe, Oahu. Percent cover is reported as median

REEF	AREA (m^2)	Coral Cover	Ed/Ks Cover	Gs/As Cover	% High Priority	Rank	Designation
2	4,472	27.5% (range: 17.11 to 47.64%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	
4	48,488	12.69% (range: 7.87 to 21.62%)	0.41% (range: 0.23 to 0.78%)	0.27% (range: 0.09 to 0.55%)	0.00	31	
7	60,940	12.07% (range: 7.61 to 19.4%)	0.74% (range: 0.33 to 1.53%)	4.99% (range: 2.56 to 9.59%)	1.88	23	
9	28,343	43.43% (range: 28.81 to 62.42%)	11.54% (range: 6.93 to 20.08%)	3.48% (range: 1.88 to 6.63%)	55.70	5	Control
10	30,098	45.48% (range: 29.82 to 68%)	14.41% (range: 8.64 to 25.84%)	3.08% (range: 1.57 to 6.13%)	59.73	4	Treatment
11	19,170	56.24% (range: 37.53 to 79.62%)	0.05% (range: 0.02 to 0.11%)	0% (range: 0 to 0%)	0.55	27	
12	11,854	64.77% (range: 43.65 to 89.19%)	0.02% (range: 0 to 0.04%)	0% (range: 0 to 0%)	1.85	24	Reference
13	79,618	63.56% (range: 42.79 to 87.88%)	0.18% (range: 0.08 to 0.36%)	0% (range: 0 to 0%)	0.02	31	
14	22,122	21.77% (range: 13.68 to 35.23%)	11.4% (range: 6.74 to 21.2%)	3.42% (range: 1.55 to 7.35%)	43.51	6	Control
15	7,732	42.31% (range: 27.6 to 64.27%)	12.7% (range: 6.97 to 25.81%)	0.01% (range: 0 to 0.02%)	72.05	2	Treatment
16	4,303	41.02% (range: 26.62 to 63.24%)	10.16% (range: 5.34 to 20.66%)	0% (range: 0 to 0%)	71.51	3	Treatment
17	6,881	32.67% (range: 20.81 to 51.7%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	
18	36,495	25.26% (range: 15.76 to 41.43%)	0.58% (range: 0.23 to 1.21%)	1.98% (range: 1.06 to 3.8%)	1.66	25	
19	1,023	75% (range: 51 to 100%)	21.02% (range: 12.44 to 38.74%)	0% (range: 0 to 0%)	100.00	1	Treatment
20	1,855	45.98% (range: 30.48 to 66.22%)	1.9% (range: 0.77 to 4.09%)	0.01% (range: 0 to 0.02%)	32.02	10	
21	271	74.59% (range: 50.7 to 99.63%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	
22	1,016	70.74% (range: 47.95 to 95.44%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	Reference
23	3,119	47.28% (range: 31.11 to 70.03%)	4.35% (range: 2.27 to 8.22%)	0% (range: 0 to 0%)	41.30	7	Control
24	8,258	35.35% (range: 23.27 to 51.55%)	0.59% (range: 0.26 to 1.19%)	0.44% (range: 0.17 to 0.95%)	10.39	16	
25	23,331	24.07% (range: 14.54 to 43.33%)	0% (range: 0 to 0.01%)	0.02% (range: 0 to 0.04%)	0.00	31	
26	12,338	24.93% (range: 15.56 to 40.35%)	0.19% (range: 0.06 to 0.42%)	1.04% (range: 0.53 to 2.02%)	3.78	20	
27	12,345	31.26% (range: 19.75 to 50.54%)	0.14% (range: 0.04 to 0.3%)	0.03% (range: 0.01 to 0.08%)	4.03	19	
28	13,974	24.89% (range: 15.49 to 40.24%)	0.56% (range: 0.2 to 1.18%)	3.3% (range: 1.56 to 7.32%)	10.61	15	Control
29	29,773	16.87% (range: 9.9 to 29.59%)	1.78% (range: 0.73 to 3.73%)	1.13% (range: 0.49 to 2.36%)	8.25	17	
30	18,949	18.21% (range: 10.91 to 31.31%)	7.48% (range: 3.85 to 15.13%)	0% (range: 0 to 0%)	29.60	11	
31	20,742	28.26% (range: 17.89 to 44.56%)	0.39% (range: 0.14 to 0.82%)	0.04% (range: 0.01 to 0.1%)	5.18	18	
33	14,051	23.31% (range: 14.26 to 40.02%)	0.07% (range: 0.02 to 0.16%)	0.28% (range: 0.09 to 0.61%)	0.54	28	Reference
34	49,872	5.53% (range: 3.26 to 9.55%)	0.03% (range: 0.01 to 0.07%)	15.67% (range: 9.4 to 27.46%)	0.10	30	
36	40,612	15.55% (range: 9.79 to 25.09%)	0.03% (range: 0.01 to 0.06%)	3.02% (range: 1.41 to 6.33%)	0.47	29	
37	5,193	28% (range: 17.42 to 46.32%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	
38	8,658	27.85% (range: 17.55 to 45.51%)	6% (range: 2.92 to 12.62%)	0.97% (range: 0.4 to 2.14%)	38.83	8	
39	7,848	72.4% (range: 49.12 to 97.41%)	0.23% (range: 0.06 to 0.49%)	0% (range: 0 to 0%)	3.30	21	
40	3,228	44.43% (range: 29.06 to 66.45%)	2.67% (range: 1.1 to 5.96%)	0% (range: 0 to 0%)	23.14	12	
41	23,100	38.87% (range: 25.33 to 58.29%)	7.13% (range: 3.79 to 14.27%)	0.15% (range: 0.05 to 0.34%)	37.64	9	
42	17,693	49.12% (range: 32.51 to 71.36%)	0.08% (range: 0.02 to 0.19%)	0% (range: 0 to 0%)	1.31	26	
43	21,852	57.41% (range: 38.35 to 81.43%)	0.41% (range: 0.11 to 0.87%)	0% (range: 0 to 0%)	13.58	14	
44	47,068	33.02% (range: 21.2 to 51.44%)	2.22% (range: 1.04 to 4.63%)	0.02% (range: 0.01 to 0.04%)	13.95	13	
46	27,388	38.75% (range: 25.05 to 60.88%)	0% (range: 0 to 0%)	1.69% (range: 0.78 to 3.54%)	0.00	31	
47	40,381	23.19% (range: 14.82 to 36.56%)	0% (range: 0 to 0%)	0.3% (range: 0.11 to 0.63%)	0.00	31	
48	3,593	59.17% (range: 39.56 to 84.06%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31	
49	6,480	53.42% (range: 35.43 to 77.58%)	0.19% (range: 0.06 to 0.42%)	0% (range: 0 to 0%)	2.50	22	

***Eucheuma/Kappaphycus* Cover**

Eucheuma/Kappaphycus was distributed throughout patch reefs of varying covers ranging from 21 to 0% (Table 3, Figure 4, Appendix A). Reefs 19 and 10 had the highest proportion of *Eucheuma/Kappaphycus* cover. Eucheuma/Kappaphycus was estimated to cover 18,616 m^2 (range: 10,239 to 35,470 m^2) of patch reef habitat in the bay.

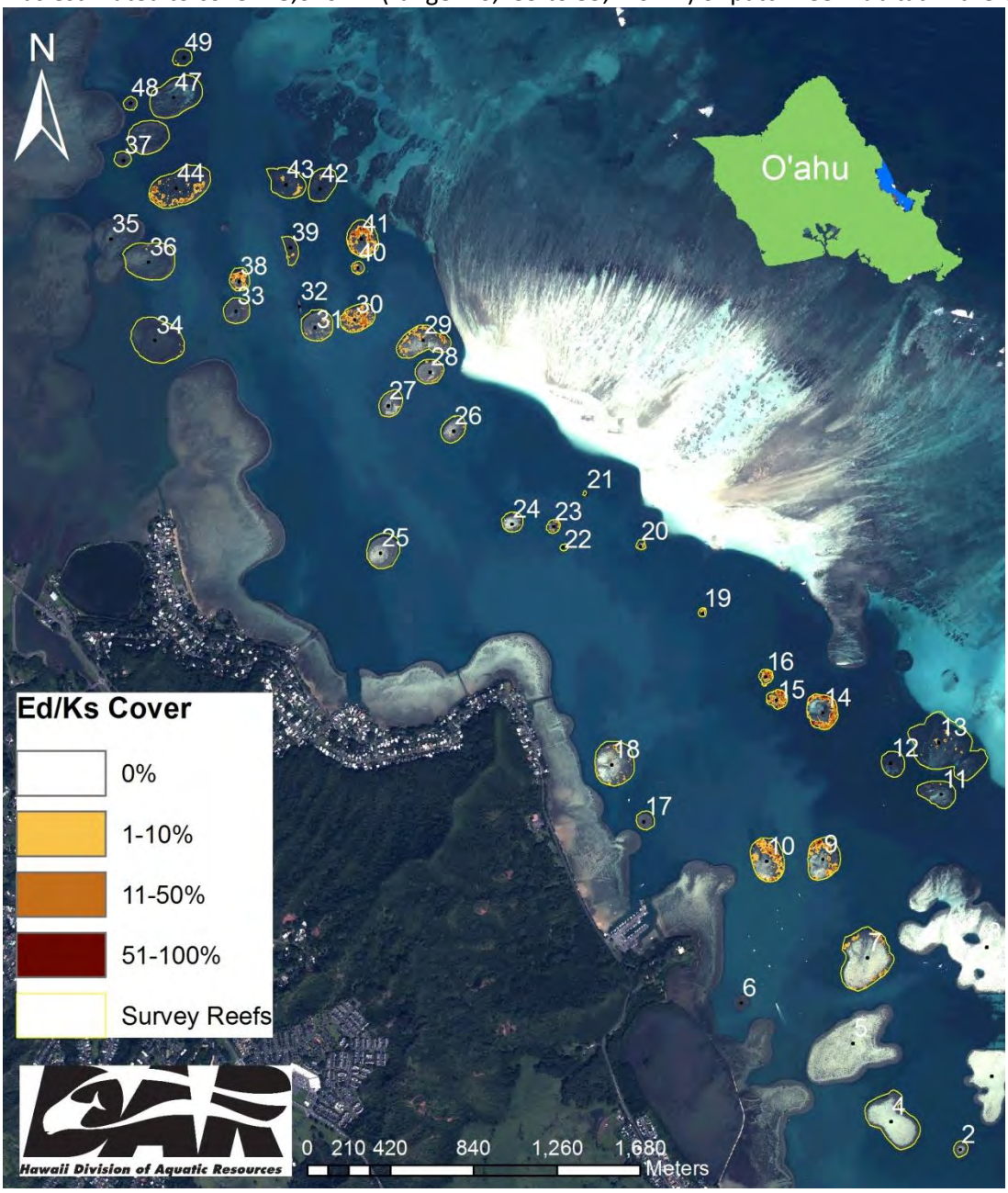

Figure 4. Kaneohe Bay Eucheuma/Kappaphycus cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Gracilaria/Acanthophora Cover

Gracilaria/Acanthophora cover was distributed throughout the bay and ranged from 15.7 to 0% on patch reefs surveyed (Table 3, Figure 5, Appendix A). Reef 34 had the greatest *Gracilaria/Acanthophora* cover of patch reefs surveyed. *Gracilaria/*Acanthophora was estimated to cover 17,227 m2 (range: 9,368 to 32,800 m2) of patch reef habitats surveyed.

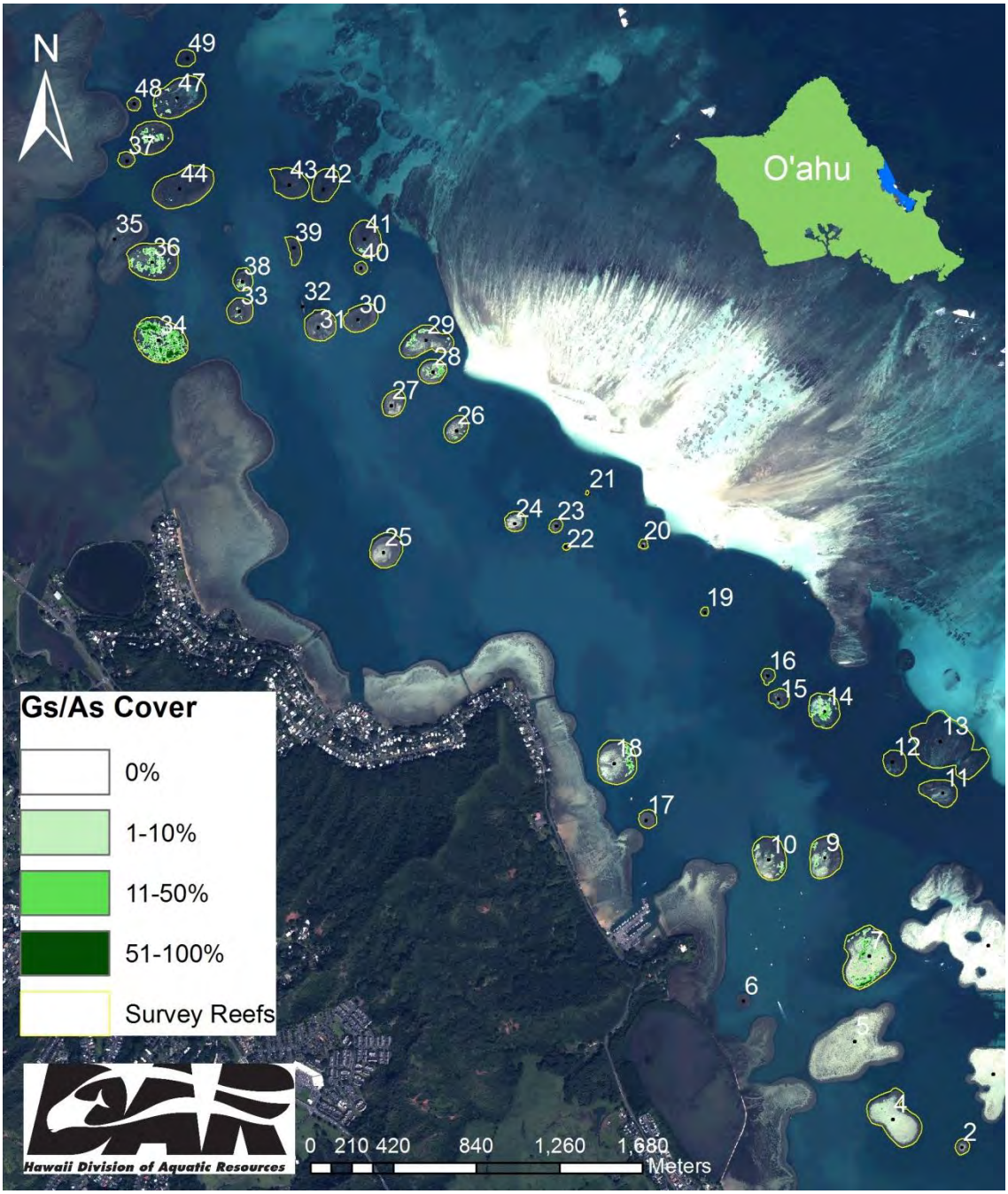

Figure 5. Kaneohe Bay *Gracilaria/Acanthophora* cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Management Prioritization

Forty-one patch reefs were prioritized and ranked based on management need with the objective to target reefs with a high co-occurrence of coral and algae (Table 3, Figure 6, Appendix A). Prioritization was based on the proportion of co-occurrence of coral and *Eucheuma/Kappaphycus* (Figure 7). Patch reefs with high coral and high algae cover (Figure 7: left side of x-axis) were prioritized accordingly.

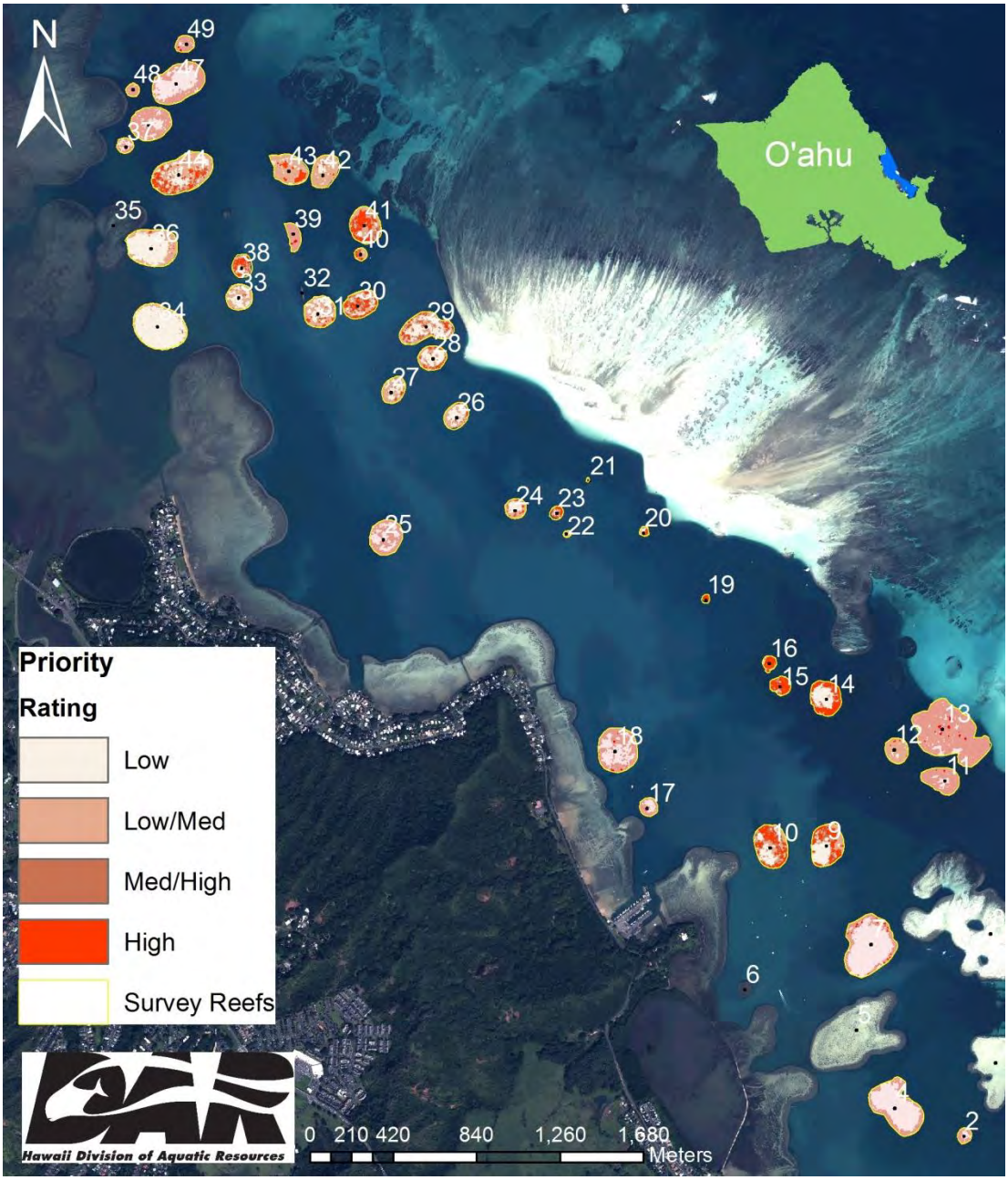

Figure 6. Management prioritization map of surveyed patch reefs. Darker shades of red represent high priority management areas. Lighter shades of red represent lower priority management areas. Reefs outlined in yellow were surveyed as part of the snap assessment.

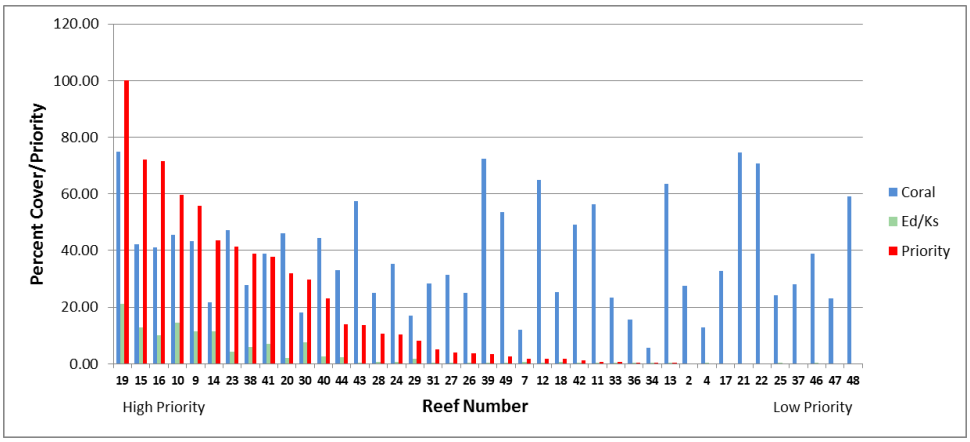

Figure 7. Percent priority, coral cover, and Eucheuma/Kappaphycus cover for patch reefs arranged from left to right along the x-axis according to reef prioritization.

Removal Planning

Reef rank, reef area, mitigation bank designation, algae removal time, urchin stocking density, and invasive algae cover were calculated as a planning tool for invasive algae management (Table 4).

Table 4. Invasive algae management planning table: reef number, reef prioritization rank, reef area, mitigation bank designation, time to remove algae, urchin stocking estimate, and percent cover of *Eucheuma/Kappaphycus* (Ed/Ks) and *Gracilaria/Acanthophora* (Gs/As).

REEF	Rank	AREA (m^2)	Designation	Removal Time (days)	Urchins ($3/m^2$)	% Ed/Ks	% Gs/As
19	1	1,023	Treatment	3	3,069	21.02	0.00
15	2	7,732	Treatment	19	23,196	12.70	0.01
16	3	4,303	Treatment	11	12,909	10.16	0.00
10	4	30,098	Treatment	75	90,294	14.41	3.08
9	5	28,343	Control	71	85,029	11.54	3.48
14	6	22,122	Control	55	66,366	11.40	3.42
23	7	3,119	Control	8	9,357	4.35	0.00
38	8	8,658		22	25,974	6.00	0.97
41	9	23,100		58	69,300	7.13	0.15
20	10	1,855		5	5,565	1.90	0.01
30	11	18,949		47	56,847	7.48	0.00
40	12	3,228		8	9,684	2.67	0.00
44	13	47,068		118	141,204	2.22	0.02
43	14	21,852		55	65,556	0.41	0.00
28	15	13,974	Control	35	41,922	0.56	3.30
24	16	8,258		21	24,774	0.59	0.44
29	17	29,773		74	89,319	1.78	1.13
31	18	20,742		52	62,226	0.39	0.04
27	19	12,345		31	37,035	0.14	0.03
26	20	12,338		31	37,014	0.19	1.04
39	21	7,848		20	23,544	0.23	0.00
49	22	6,480		16	19,440	0.19	0.00
7	23	60,940		152	182,820	0.74	4.99
12	24	11,854	Reference	30	35,562	0.02	0.00
18	25	36,495		91	109,485	0.58	1.98
42	26	17,693		44	53,079	0.08	0.00
11	27	19,170		48	57,510	0.05	0.00
33	28	14,051	Reference	35	42,153	0.07	0.28
36	29	40,612		102	121,836	0.03	3.02
34	30	49,872		125	149,616	0.03	15.67
4	31	48,488		121	145,464	0.41	0.27
13	31	79,618		199	238,854	0.18	0.00
25	31	23,331		N/A	69,993	0.00	0.02
46	31	27,388		N/A	82,164	0.00	1.69
47	31	40,381		N/A	121,143	0.00	0.30
2	N/A	4,472		N/A	N/A	0.00	0.00
17	N/A	6,881		N/A	N/A	0.00	0.00
21	N/A	271		N/A	N/A	0.00	0.00
22	N/A	1,016	Reference	N/A	N/A	0.00	0.00
37	N/A	5,193		N/A	N/A	0.00	0.00
48	N/A	3,593		N/A	N/A	0.00	0.00

Removal time was estimated at 400 m^2/day, for a 4-person supersucker crew. Biocontrol estimates were based on stocking three hatchery raised *Tripneustes gratilla* per m^2 of reef.

Survey Error Determination

Mean differences in percent cover between repeated surveys 1 and 2 were within 2.25% for coral and 4.82% for *Eucheuma/Kappaphycus* (Table 5). Mean *Gracilaria/Acanthophora* cover differed by less than 1%, however *Gracilaria/Acanthophora* was only detected on Reef 26 which prevented comparison on Reefs 19 and 23.

Table 5. Mean differences of reef estimates of percent coral, Eucheuma/Kappaphycus, Gracilaria/Acanthophora between surveys 1 and survey 2.

Species	Mean difference %	S.E. %	Range %
Coral	2.25	0.67	(1.36-3.56)
Ed/Ks	4.82	3.82	(0.10-11.91)
Gs/As	0.89*	N/A	N/A

Map Coverage Overlay Analysis

Coral, *Eucheuma/Kappaphycus, and Acanthophora/Gracilaria* map coverages showed very similar results between repeated surveys 1 and 2. The majority of reefs re-surveyed in all species differed by one cover class factor or less (Figure 8, Table 6). Reef 26 coral cover classification matched on 46% of the reef area and differed by a factor of one cover class on 44% of the reef area.

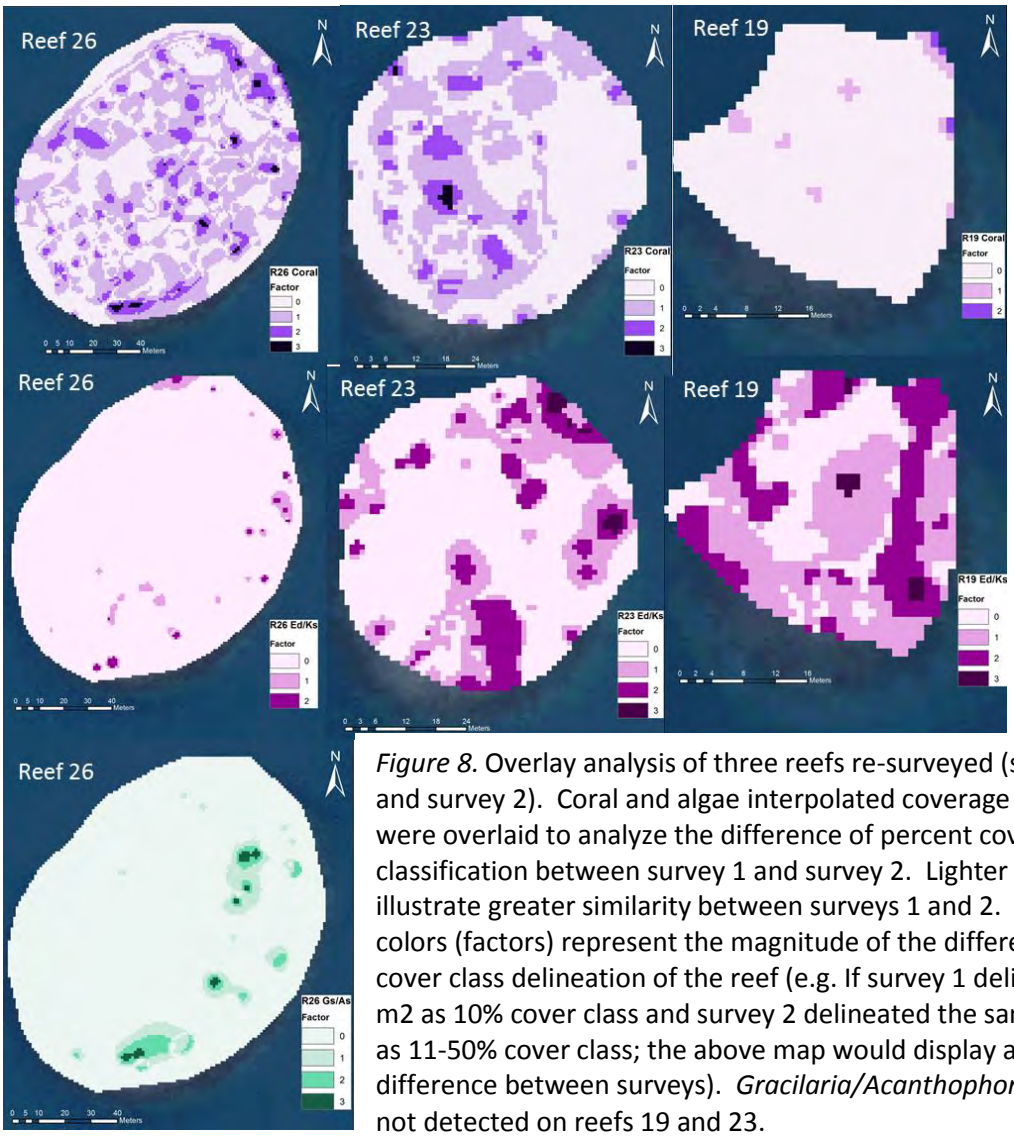

Figure 8. Overlay analysis of three reefs re-surveyed (survey 1 and survey 2). Coral and algae interpolated coverage maps were overlaid to analyze the difference of percent cover classification between survey 1 and survey 2. Lighter colors illustrate greater similarity between surveys 1 and 2. Darker colors (factors) represent the magnitude of the difference in cover class delineation of the reef (e.g. If survey 1 delineated 1 m2 as 10% cover class and survey 2 delineated the same 1 m2 as 11-50% cover class; the above map would display a 1 factor difference between surveys). *Gracilaria/Acanthophora* was not detected on reefs 19 and 23.

Table 6. Overlay analysis of survey 1 and survey 2 of Reefs 19, 23, and 26 interpolated cover classes of coral, *Eucheuma/Kappaphycus* (Ed/Ks), and *Gracilaria/Acanthophora* (Gs/As). The percent match of four cover classes was evaluated (0%, 1-10%, 11-50%, 51-100%). A factor of "0" represents a 100% match between cover classes in a particular area, a factor of "1" differs by one cover class, a factor of "2" differs by two cover classes, etc. *Gracilaria/Acanthophora* was not detected on reefs 19 and 23 in survey 1 or survey 2.

Reef	Species	Factor	% Match	Reef	Species	Factor	% Match	Reef	Species	Factor	% Match
Reef 19	Coral	0	95.76	Reef 19	Ed/Ks	0	27.50	Reef 19	Gs/As	0	100.00
Reef 19	Coral	1	3.70	Reef 19	Ed/Ks	1	45.11	Reef 19	Gs/As	1	0.00
Reef 19	Coral	2	0.54	Reef 19	Ed/Ks	2	25.76	Reef 19	Gs/As	2	0.00
Reef 19	Coral	3	0.00	Reef 19	Ed/Ks	3	1.63	Reef 19	Gs/As	3	0.00
Reef 23	Coral	0	58.49	Reef 23	Ed/Ks	0	61.99	Reef 23	Gs/As	0	100.00
Reef 23	Coral	1	35.90	Reef 23	Ed/Ks	1	23.59	Reef 23	Gs/As	1	0.00
Reef 23	Coral	2	6.92	Reef 23	Ed/Ks	2	13.33	Reef 23	Gs/As	2	0.00
Reef 23	Coral	3	0.41	Reef 23	Ed/Ks	3	1.10	Reef 23	Gs/As	3	0.00
Reef 26	Coral	0	46.20	Reef 26	Ed/Ks	0	96.78	Reef 26	Gs/As	0	91.71
Reef 26	Coral	1	43.76	Reef 26	Ed/Ks	1	2.54	Reef 26	Gs/As	1	5.50
Reef 26	Coral	2	9.33	Reef 26	Ed/Ks	2	0.68	Reef 26	Gs/As	2	2.23
Reef 26	Coral	3	0.70	Reef 26	Ed/Ks	3	0.00	Reef 26	Gs/As	3	0.55

Reef Depth

Reef flat depth ranged from 5.79 cm (reef 33) to 71 cm (reef 14) (Figure 9).

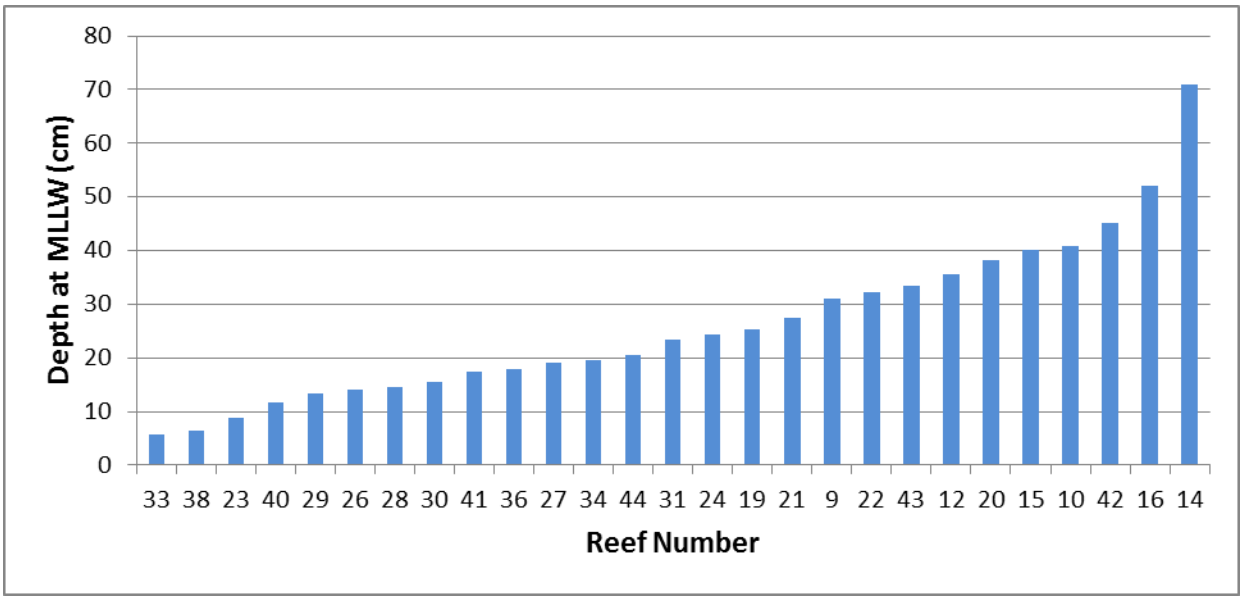

Figure 9. Reef flat depth (cm) at mean lowest low water (MLLW) at 27 Kaneohe Bay patch reefs. Reef numbers on the x-axis are arranged from low to high reef flat depth.

Uncommon Coral Species

Three uncommon coral species to Kaneohe Bay: *Montipora dilatata, Montipora patula, and Montipora flabellate;* were detected in the surveys (Table 7).

Table 7. Uncommon coral species observed in Kaneohe Bay snap-assessment surveys.

Reef #	*M. patula*	*M. flabellata*	*M. dilatata*
10		X	
11	X	X	
12		X	
13	X	X	
14	X	X	
26	X		
27	X		
31		X	
37	X		
42	X	X	
44	X	X	X
46	X	X	
47		X	
48	X		

Survey Effort

The snap assessment survey required approximately 300 man-hours plus additional data entry, data processing, mapping and analysis. The survey rate of the snap assessment was 3,500 m^2/hr per surveyor. The typical survey crew size was 6-people.

Discussion

Invasive algae Distribution

Invasive algae distribution was consistent with past studies, where *Kappaphycus/Eucheuma* and *G. salicornia* were found in varying densities throughout Kaneohe Bay (Smith et al. 2002, Conklin and Smith 2005). The Hawaii Division of Aquatic Resources (DAR) has sponsored numerous invasive algae surveys in Kaneohe Bay since 2007. Differing survey techniques prevented accurate comparison of percent cover with the snap-assessment data. Presence/absence, however, could be compared. Of the 41 patch reefs surveyed, one reef (Reef 49) was found to be newly colonized since the 2007 survey (DAR unpublished data). These surveys have also detected sparse densities of *Kappaphycus/Eucheuma* in northern Kaneohe Bay on Reefs 50, 52, 54 (2007) and Reefs 52, 54, the northern fringing reef and the north channel (2013) (unpublished DAR data).

Smith et al. (2002) invasive algae distribution surveys found *Kappaphycus spp*. had not spread outside of Kaneohe Bay. DAR surveys conducted in 2006, however, detected *Kappaphycus/Eucheuma* along the windward coast as far north as Punaluu; suggesting a northward spread (Gewecke 2008). Surveyors also found *Kappaphycus/Eucheuma* near Alii Beach Park, Haleiwa in 2013 (Stubbs et al. 2013). This population may have spread from fragments released by boats launched at Haleiwa Boat Harbor. Continued snap assessment surveys in northern Kaneohe Bay and along the windward coast could assess the current level of spread outside of the bay.

Mitigation Bank Reef Selection

Based on the prioritization ranking results and snap assessment data; treatment, control, and reference reefs were selected for inclusion into the mitigation bank prospectus. Four reefs were selected for immediate invasive algae removal (19, 15, 16, and 10). In addition, four control reefs (9, 14, 23, and 28) were selected to monitor the effectiveness of invasive algae removal on the treatment reefs. These reefs were found to have similar coral, invasive algae, proximity, and size characteristics to the treatment reef. In addition, two of these reefs (14 and 28) had historical survey data that will help contribute to long-term monitoring. Three reference sites (12, 22, and 33) had high coral cover and little or no invasive algae cover. These reefs were selected as reference sites to use as model systems for assessing post-restoration results. Undesignated reefs will likely be treated in the future based on prioritization rank and the size of the reef.

Snap Assessment Repeatability

The snap assessment surveys were designed to rapidly assess large reef areas in a short amount of time. Even though this method was rapid, our tests revealed that it was relatively robust and repeatable. The repeated survey results demonstrated adequate robustness for tracking changes in coral (± 2.5%) and invasive algae cover (± 5%) over time with use of the ArcGIS IDW interpolation tools. However, examination of the overlay analysis revealed that repeatability errors increased where gaps between survey points exceeded 10 m. Therefore, it is recommended that survey sample densities remain within 5-10 m apart.

Management Recommendations

The results of this survey should be used as a tool for developing a comprehensive invasive algae action plan for Kaneohe Bay. The invasive algae issue is a complex problem and will require a whole suite of strategies and techniques to control its spread and restore coral reef ecosystems. In addition to published research and management recommendations (Conklin and Smith 2005, Smith et al. 2002); staff from DAR, Research Corporation of the University of Hawaii, and The Nature Conservancy of Hawaii have informally discussed a number of strategies. These include:

- Target areas of high coral and high *Kappaphycus/Eucheuma* density.
- Target areas of low *Kappaphycus/Eucheuma* density and high coral density.
- Target northern incipient populations of *Kappaphycus/Eucheuma*.
- Reduce the overall standing stock and propagation of *Kappaphycus/Eucheuma* in Kaneohe Bay.
- Increase native herbivores in Kaneohe Bay.
- Monitor *Kappaphycus/Eucheuma* distribution.
- Conduct rapid response to areas outside of the bay, newly colonized by *Kappaphycus*.
- Reduce nutrification in Kaneohe Bay.
- Provide outreach and education to prevent the spread or introduction of invasive species.

The snap assessment data set and decision support tools used in this analysis could also be applied to several of the management objectives stated above. Our analysis selected mitigation bank reefs based on the objective to select areas of high co-occurrence of both coral and *Eucheuma/Kappaphycus*. Decision support tools could also be used to prioritize reefs based on high coral and low *Eucheuma/Kappaphycus* cover to prioritize efforts towards preventing *Eucheuma/Kappaphycus* spread where high coral coverage is at stake.

We also recommend that the snap assessment survey is repeated annually or bi-annually to track invasive algae and coral distribution trends and evaluate management techniques. In addition, patch reefs not included in this 2014 assessment, fringing reefs, and the barrier reef should also be surveyed. The snap assessment could also be applied to other coral reef habitats within the Hawaiian Islands. In addition to areas dominated by invasive algae; this technique

could be applied to other at risk areas such as shipping channels (which are susceptible to ship groundings), coral disease outbreaks and coral bleaching sites.

Conclusions

This project successfully developed a rapid and robust coral reef monitoring techniques that can be applied to a large area in a fairly short amount of time. In addition, this dataset provides essential data and decision support tools for developing a bay-wide invasive algae action plan to guide future management efforts. Further, the survey results provide baseline information to compare, past, present, and future coral and invasive algae trends in Kaneohe Bay.

Acknowledgements

We would like to acknowledge the field survey team: Jono Blodgett, Cathy Gewecke, Brian Neilson, Andrew Purves, Brad Stubbs, Kendall Tejchma , and Travis Thyberg. We would like to thank The Nature Conservancy of Hawaii for their help in conducting the snap-assessment surveys. We would also like to thank Kate Cullison, David Gulko, Zac Forsman, Frazer McGilvray, and Kim Peyton for their contribution in developing the survey methodology.

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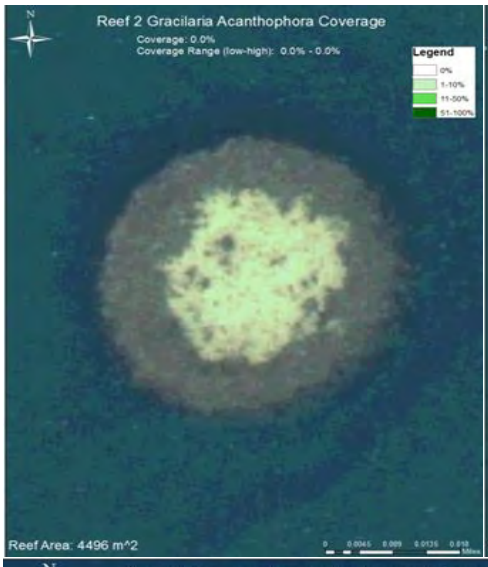
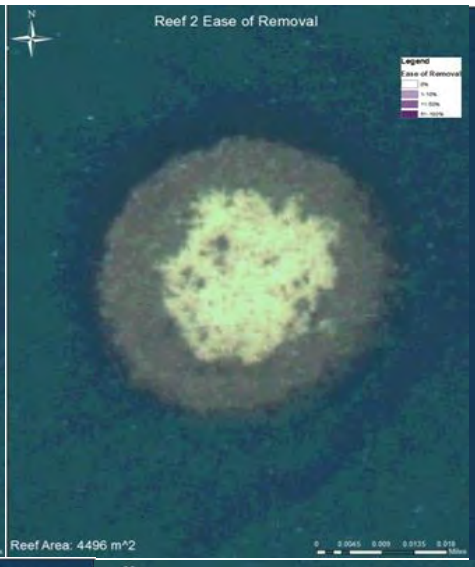
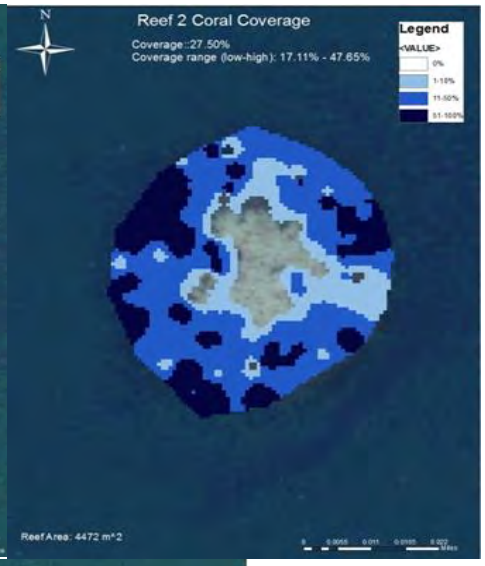
Appendices

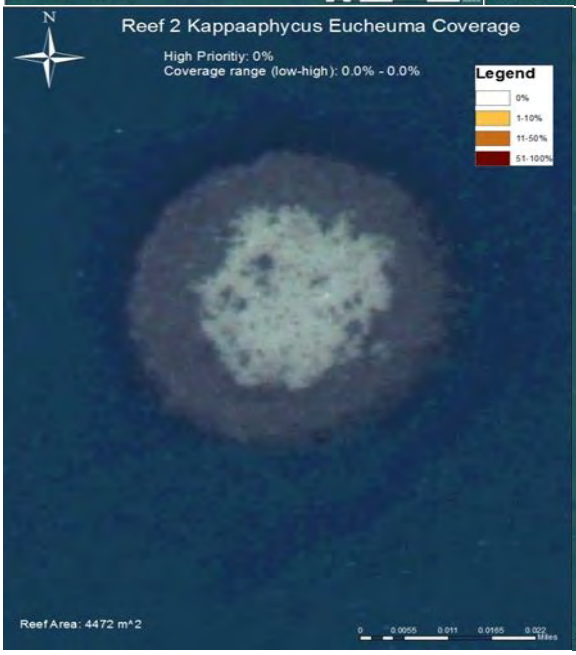
Appendix A: Individual patch reef coverage maps of ease of removal, coral cover, *Gracilaria/Acanthophora* cover, *Eucheuma/Kappaphycus* cover, management priority, and reef flat depth.

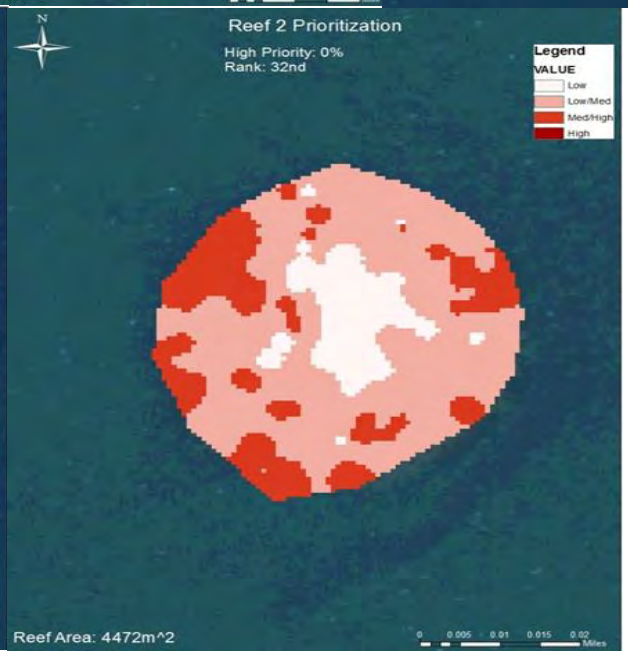
Reef 2

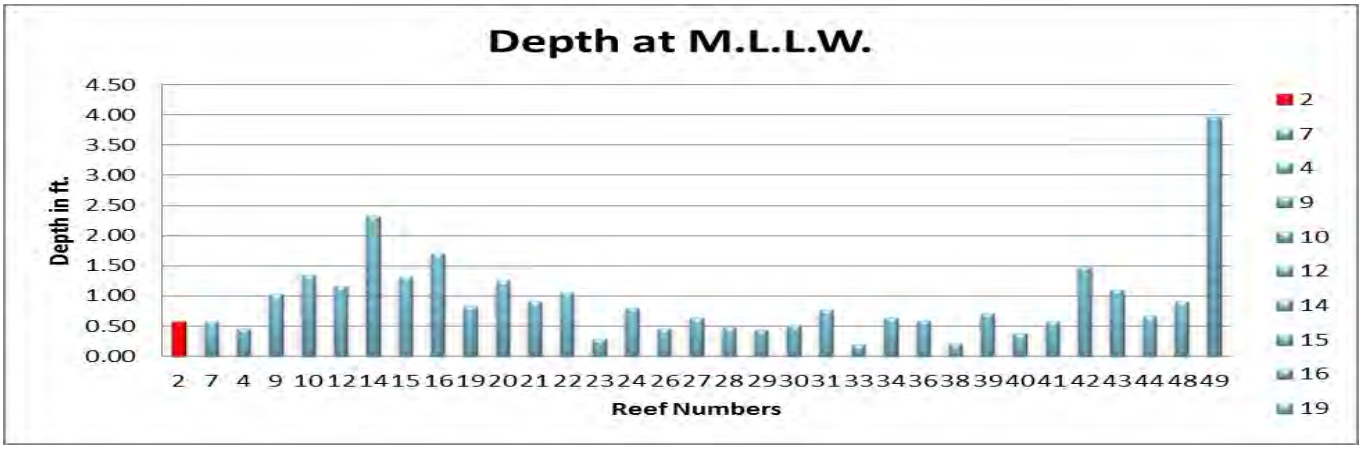












Appendix A: cont'd.

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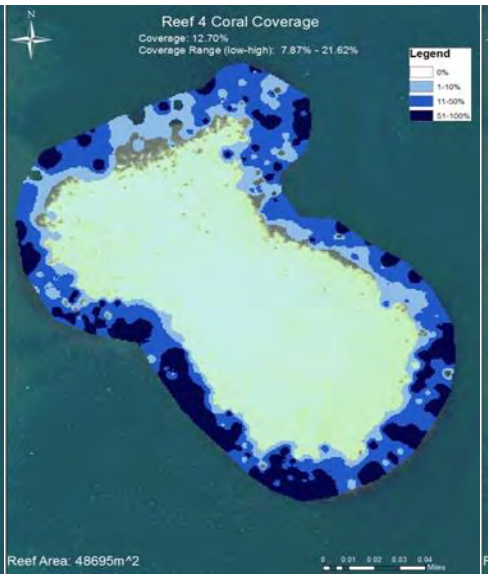
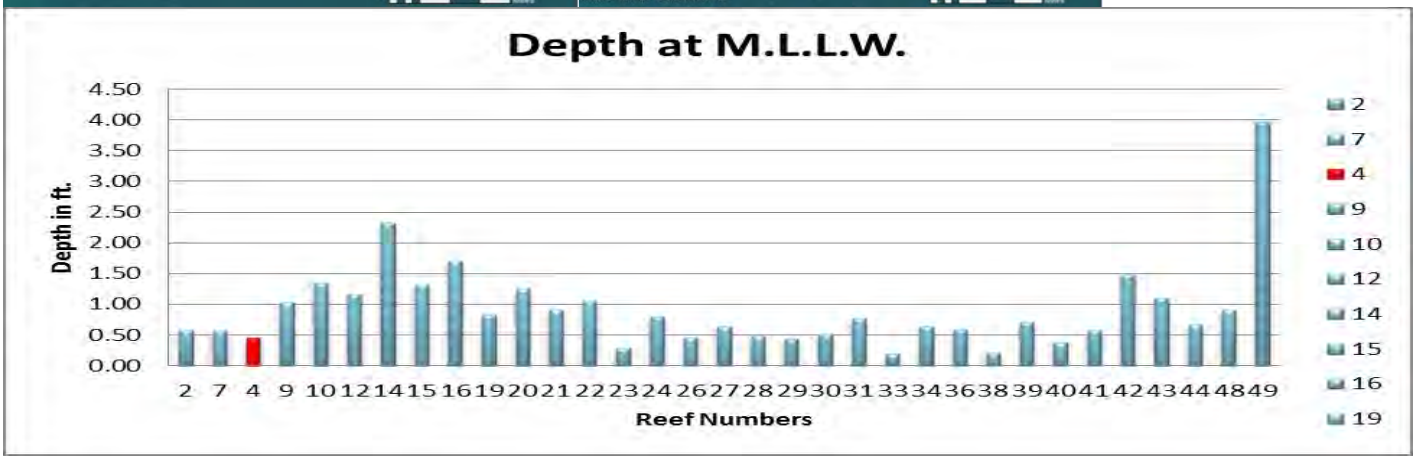
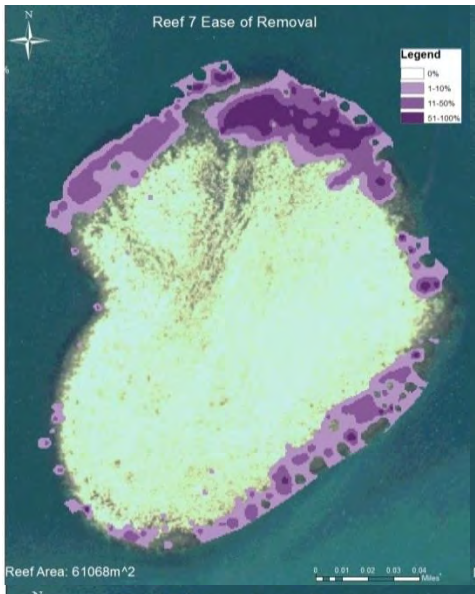
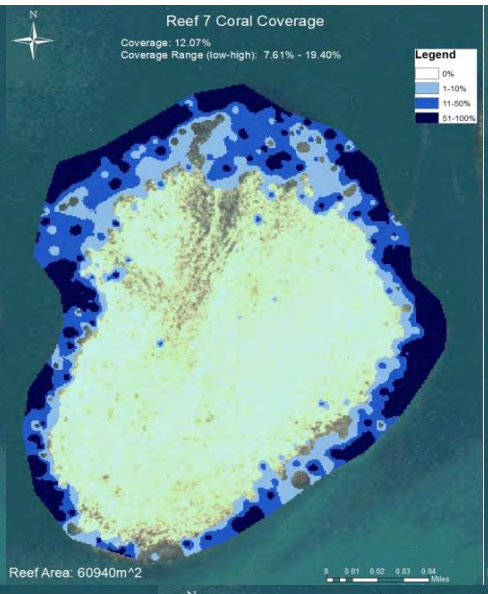


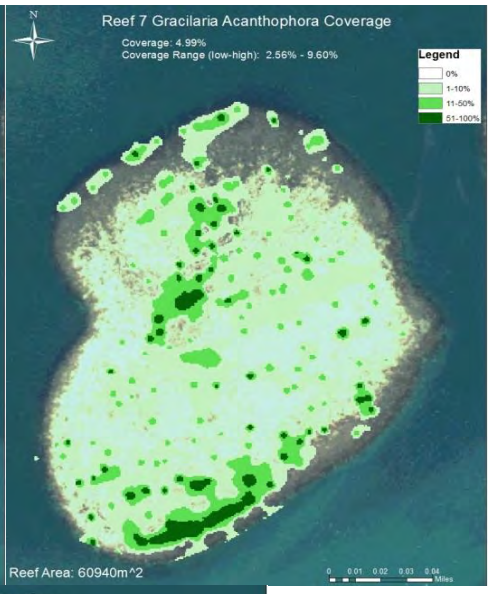


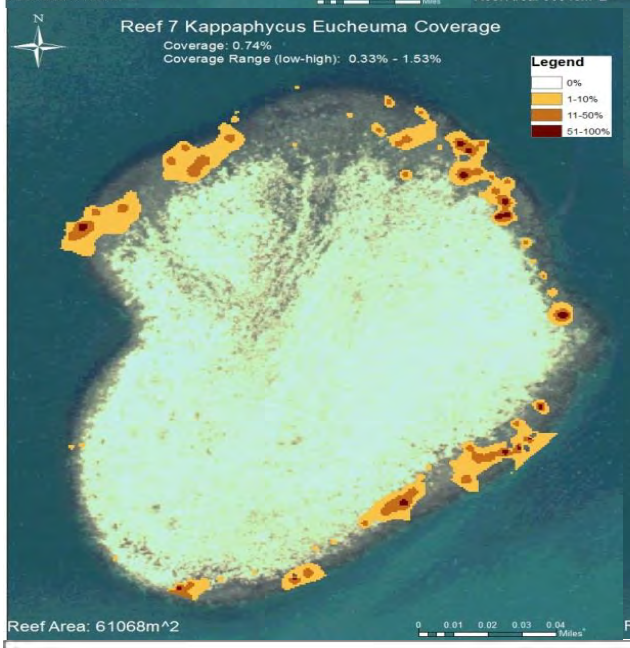
Appendix A: cont'd.

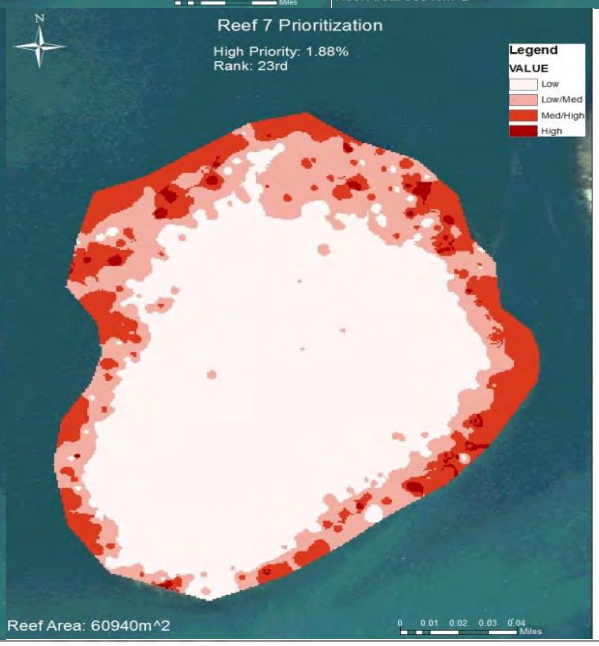
Reef 7

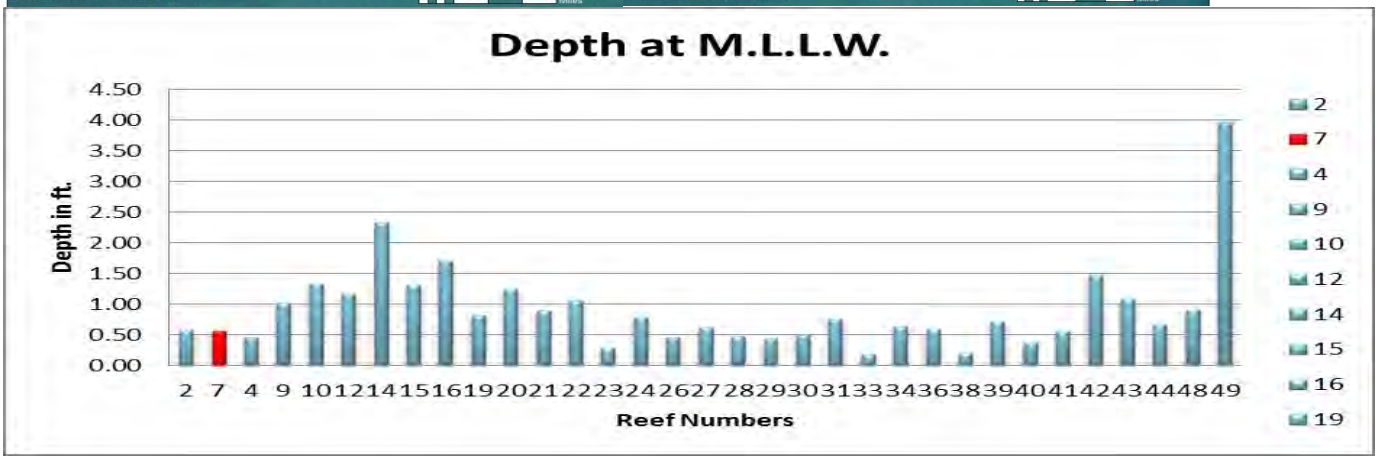












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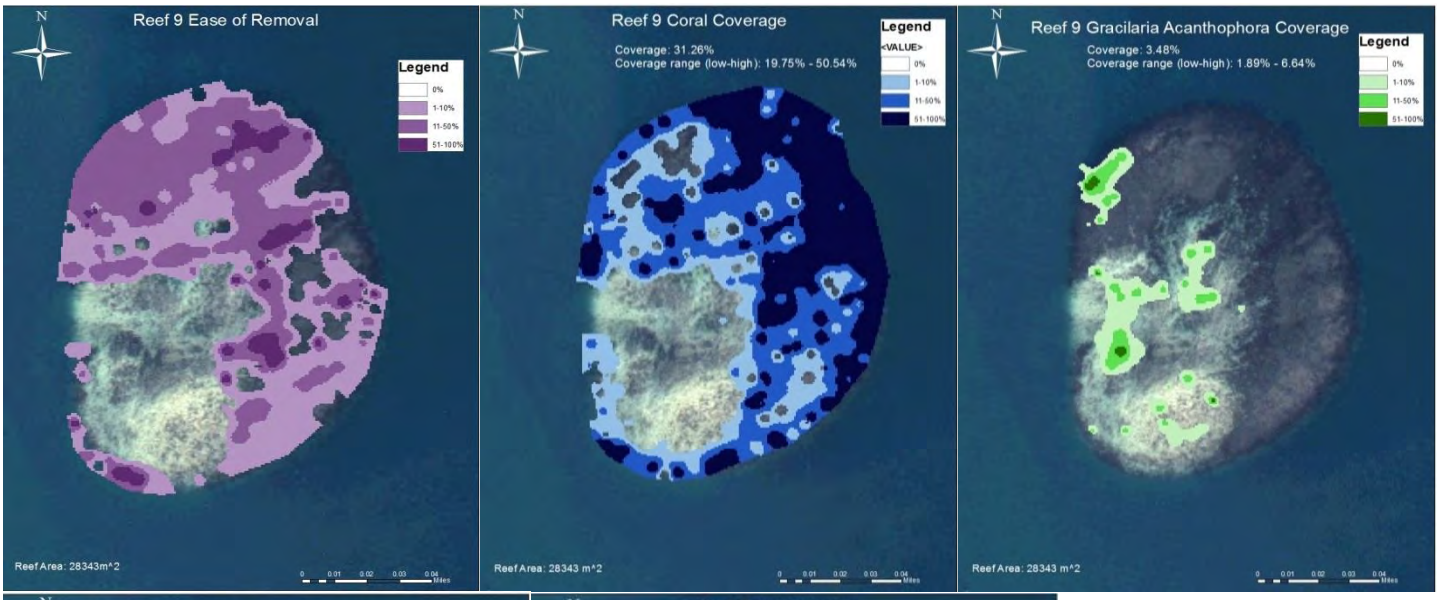
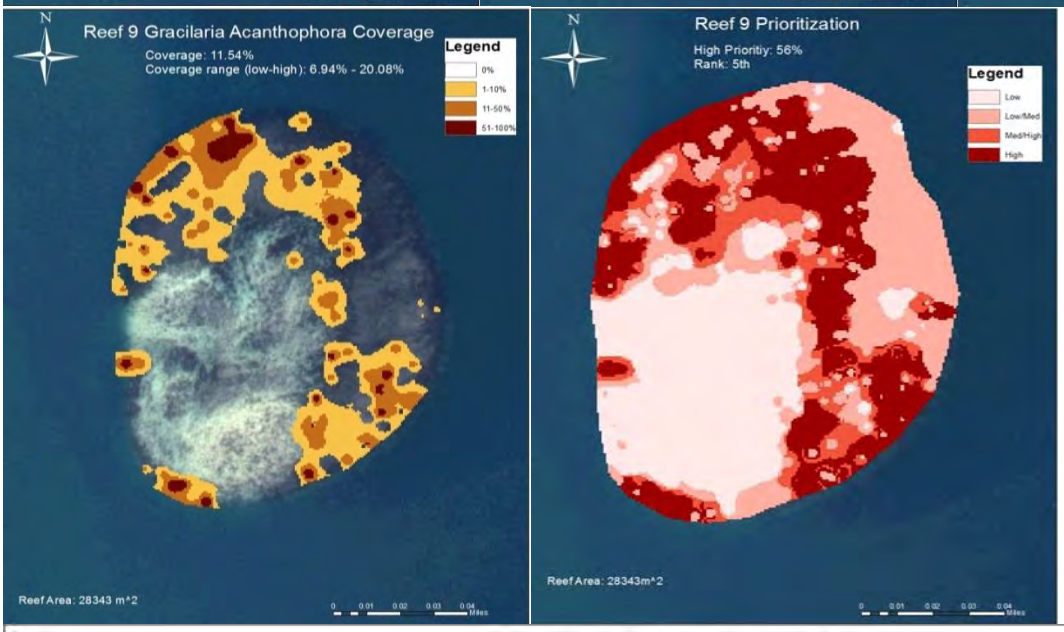
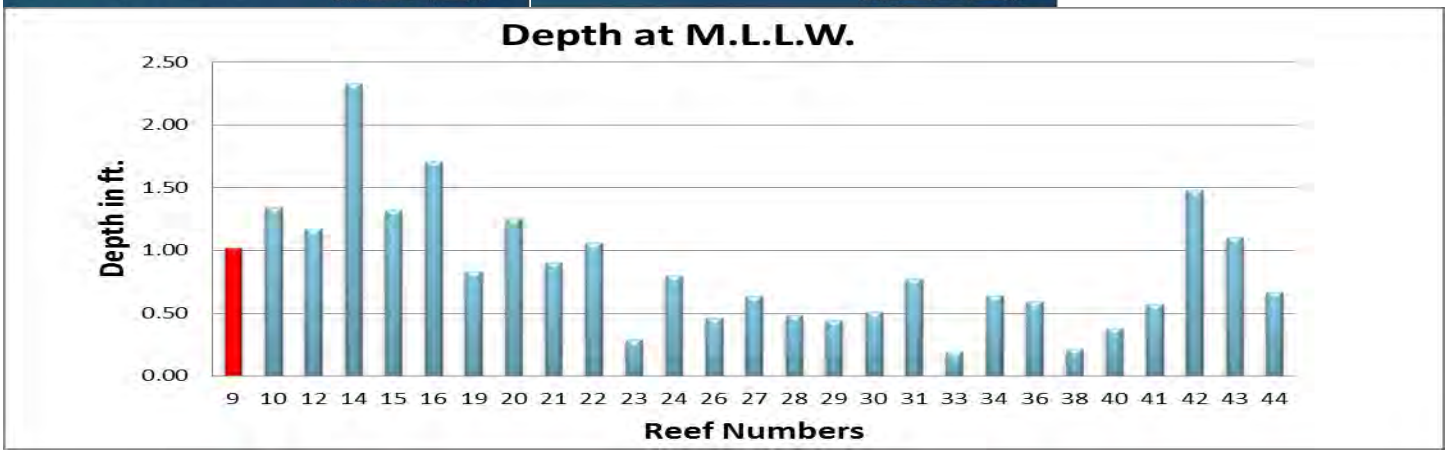
Reef 9







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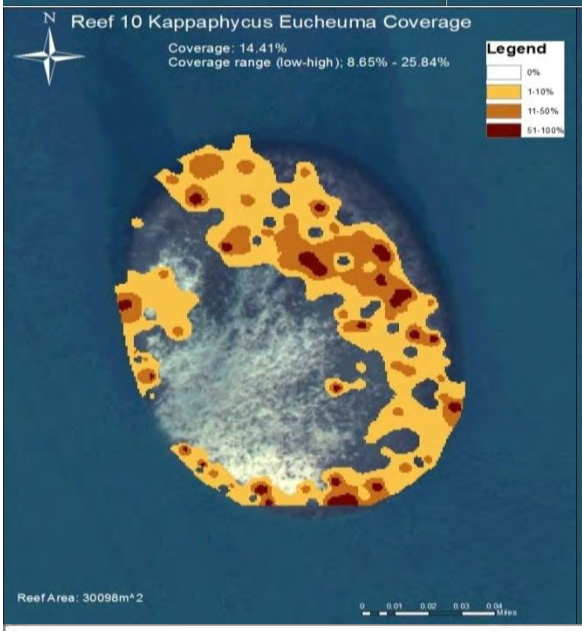
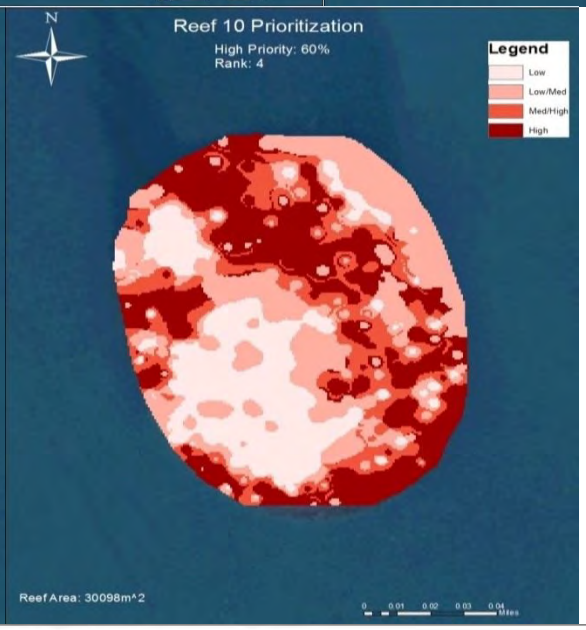
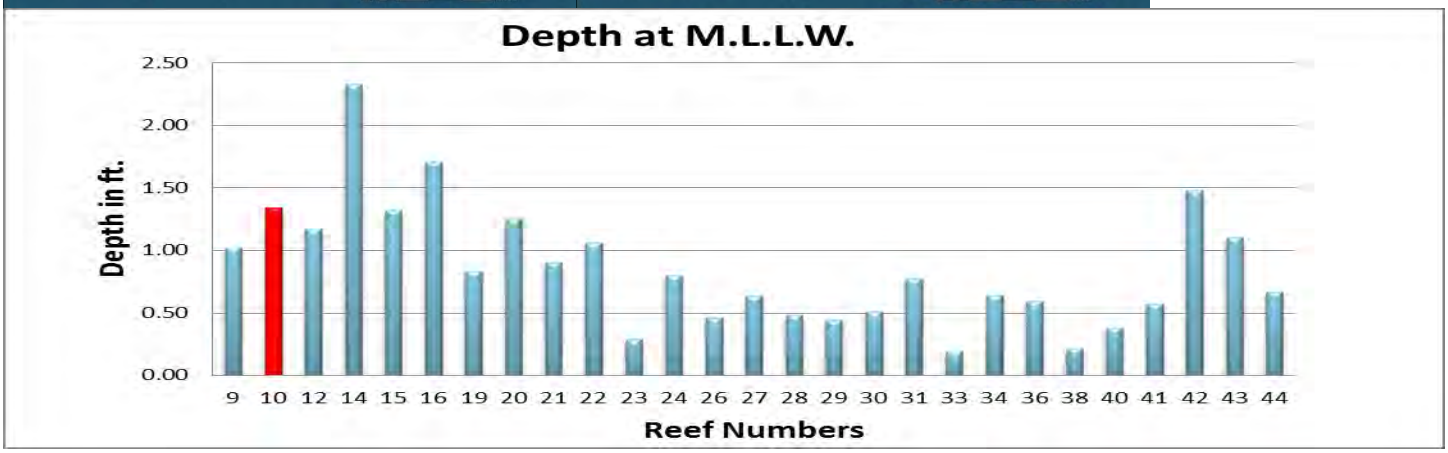
Reef 10







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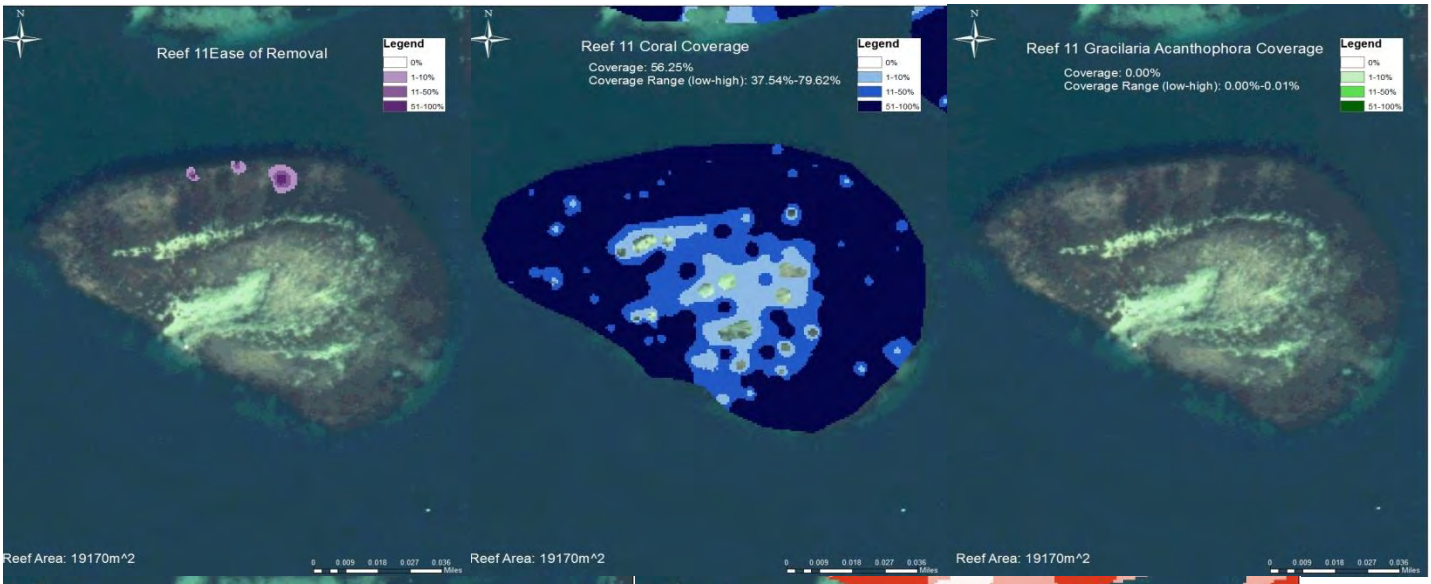

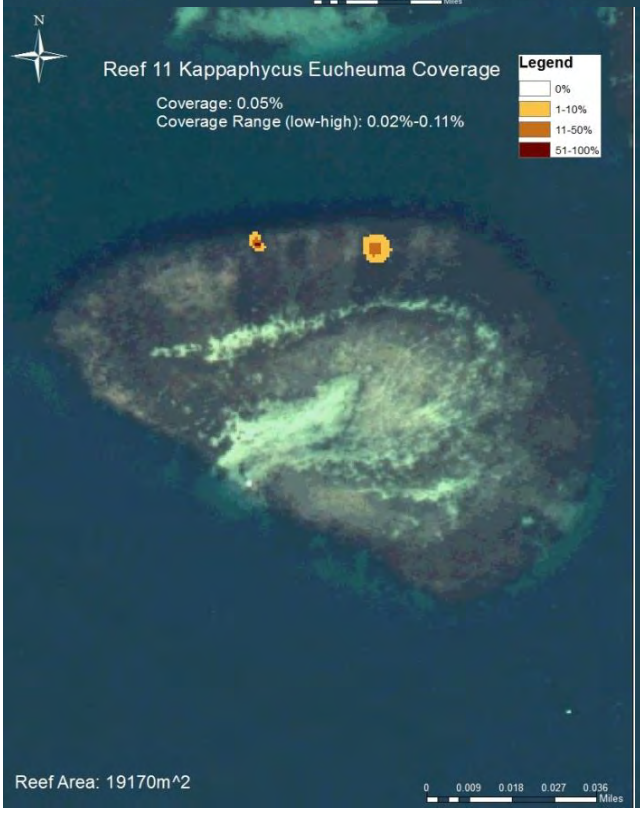

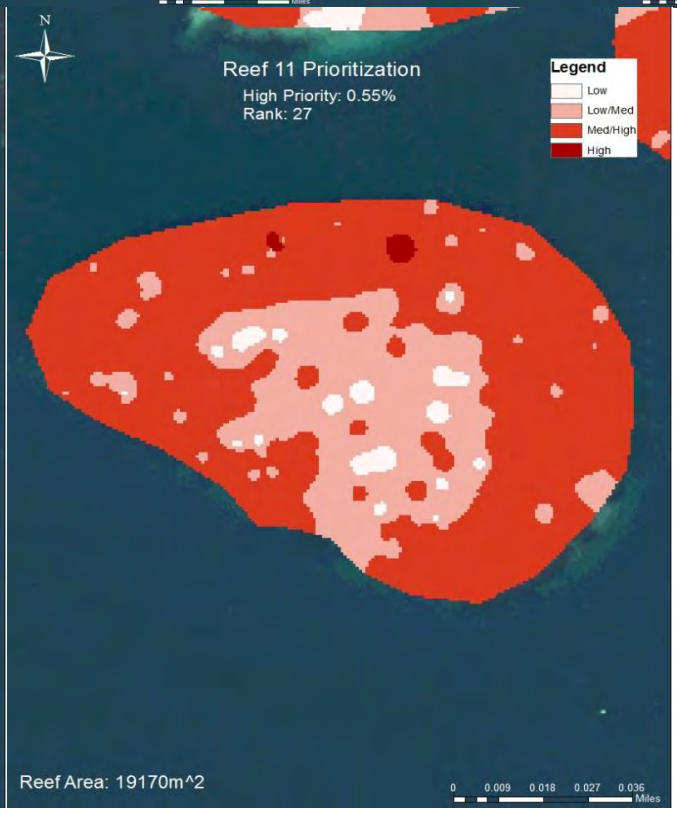

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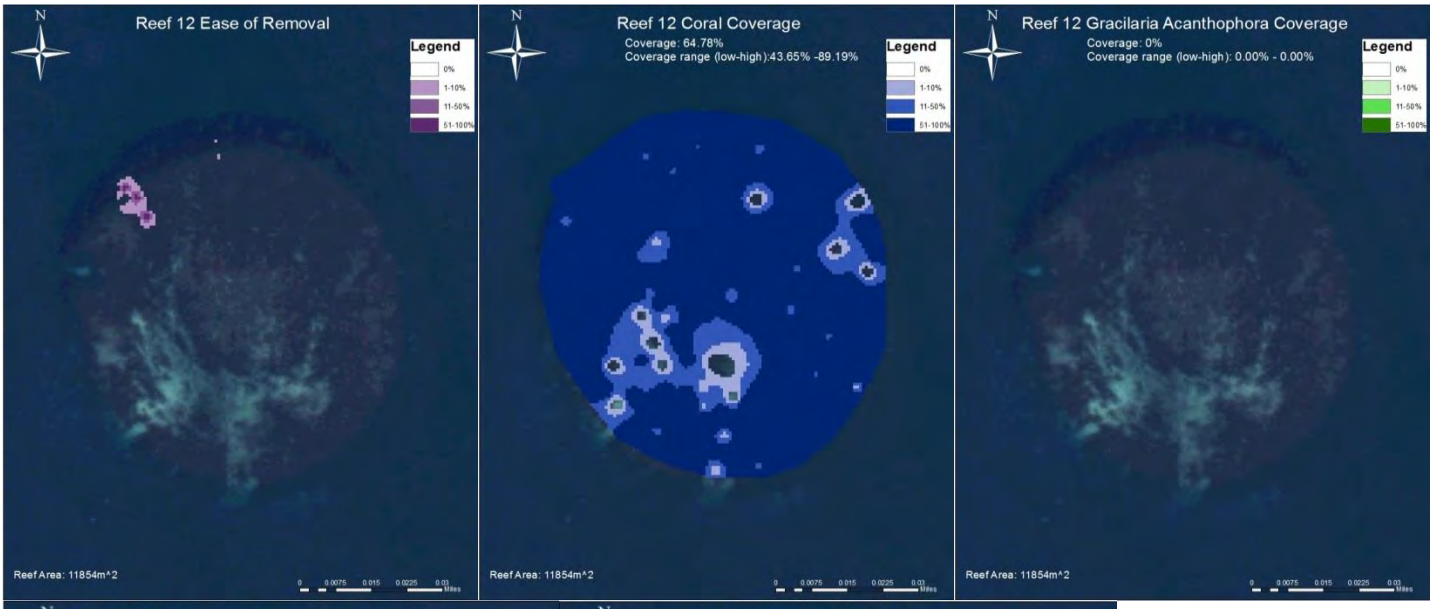
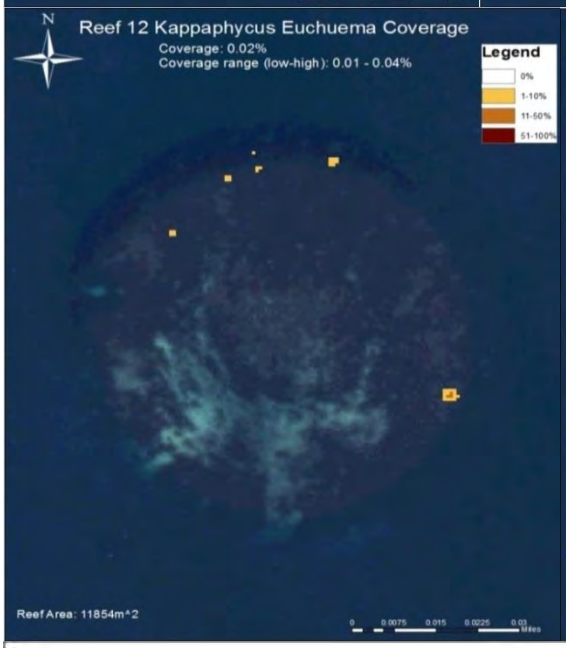
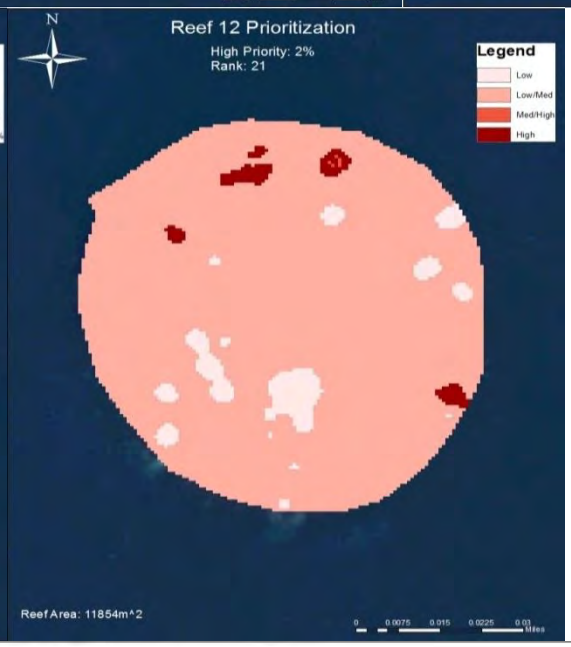
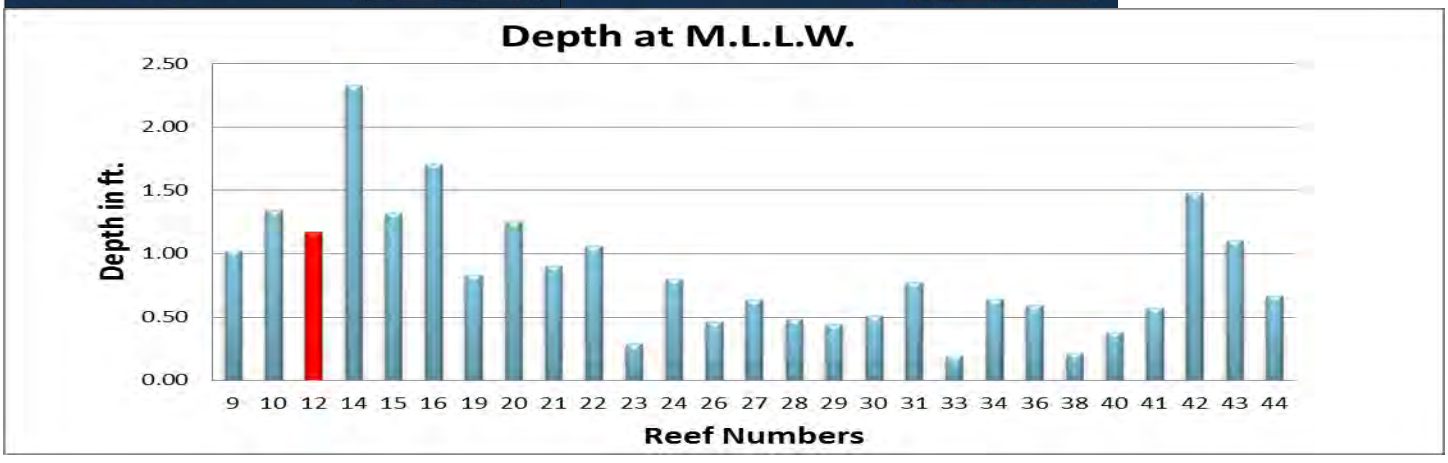


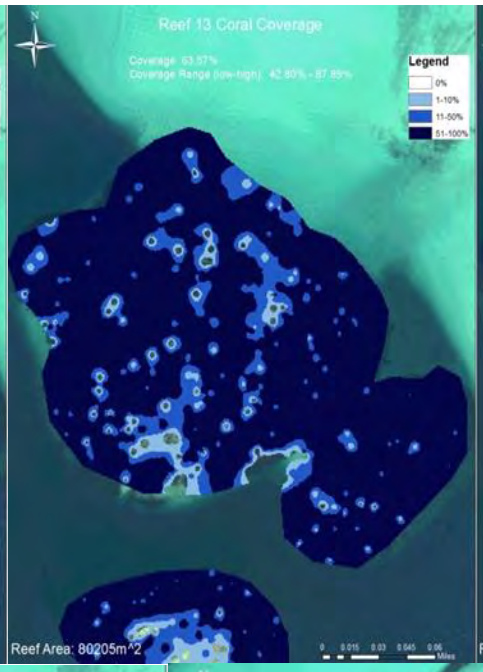


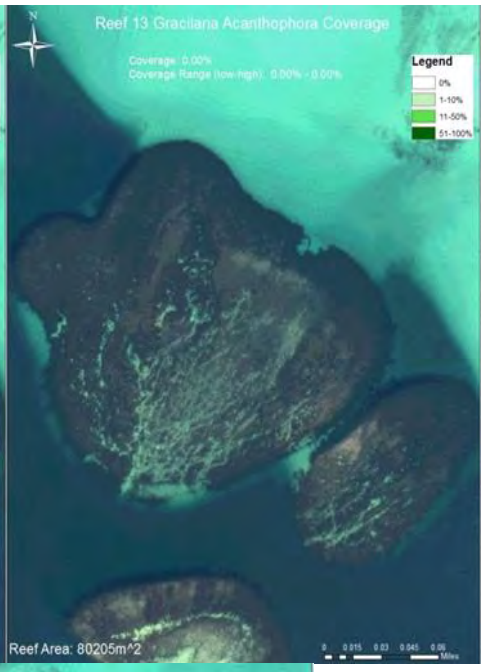


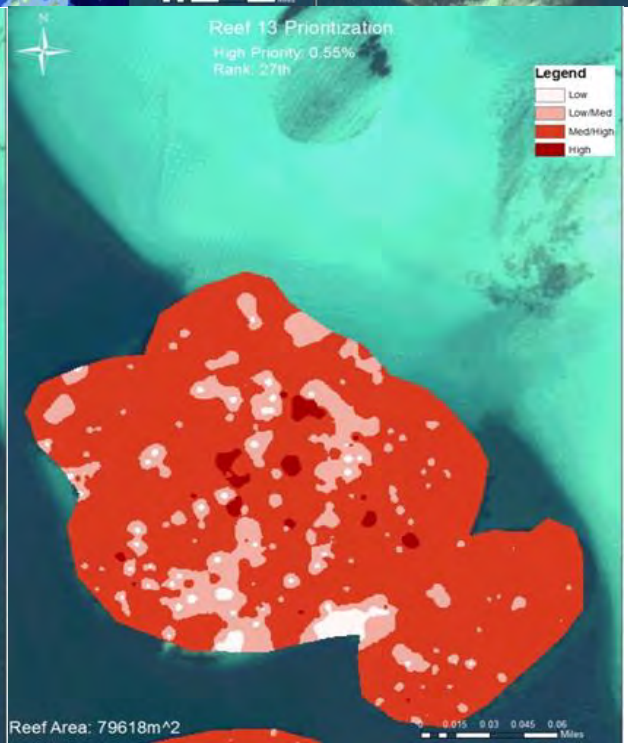


Appendix A: cont'd.

Reef 13

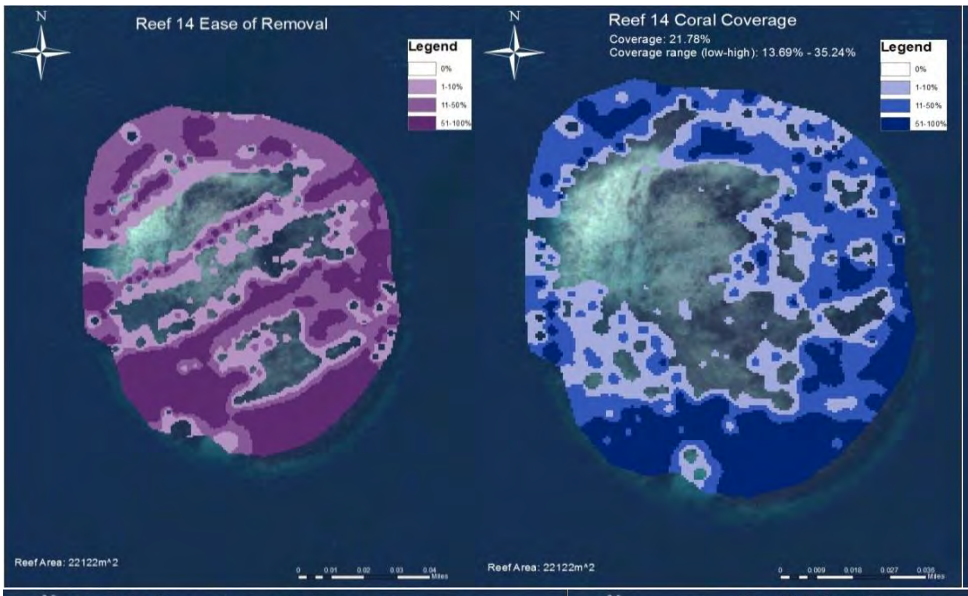


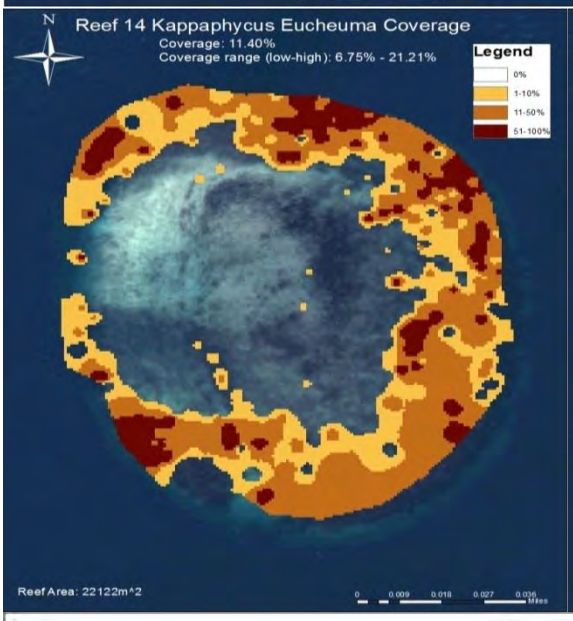


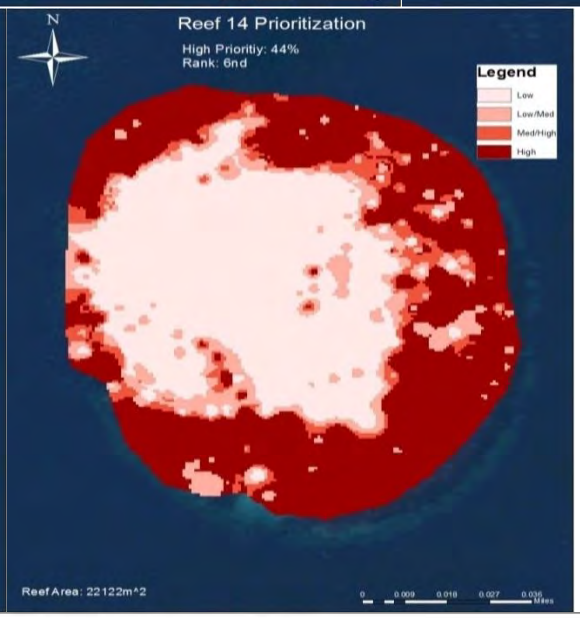


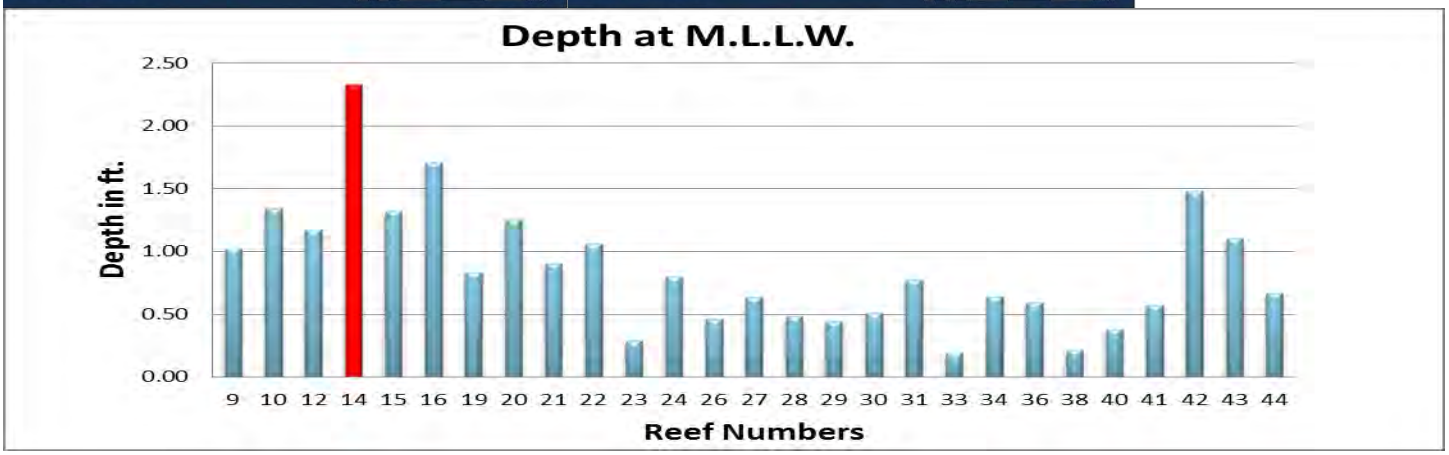
Appendix A: cont'd.

Reef 14



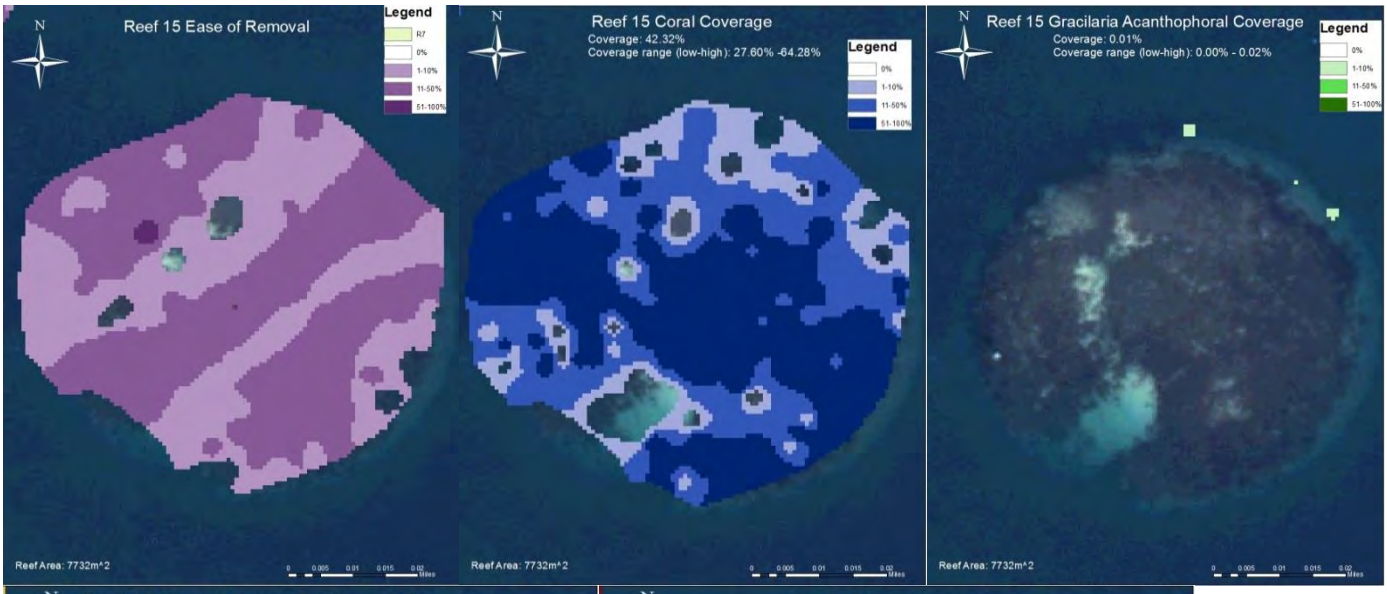


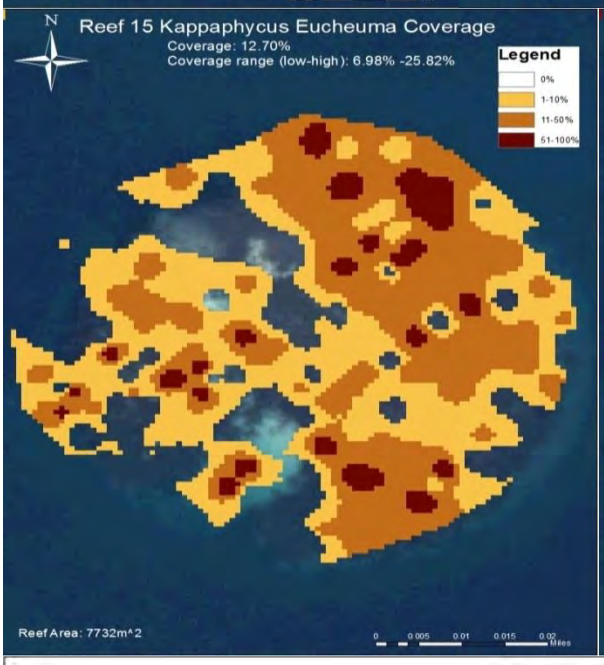


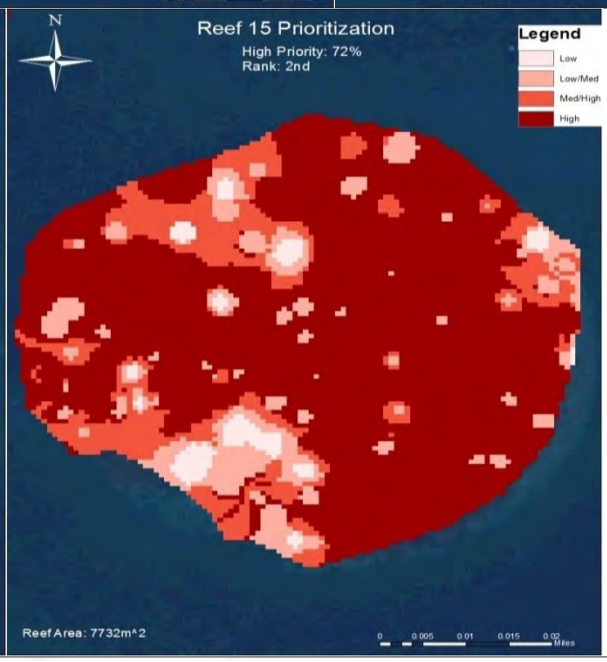


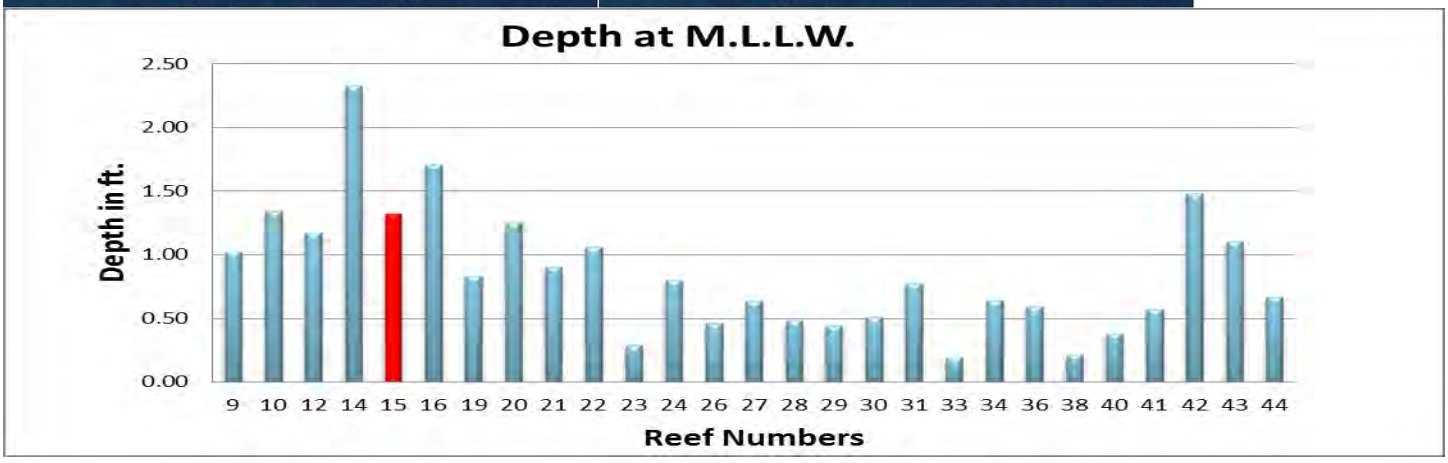
Appendix A: cont'd.

Reef 15



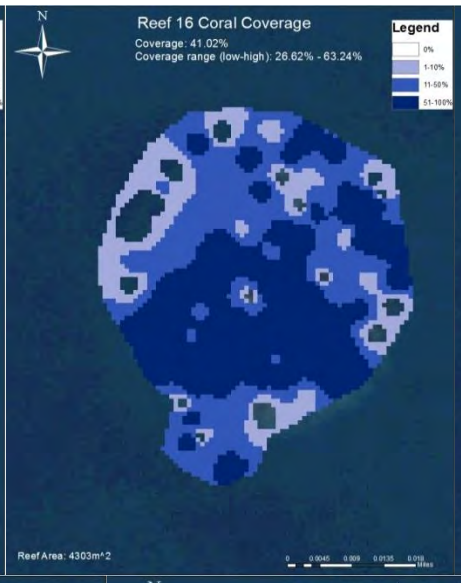


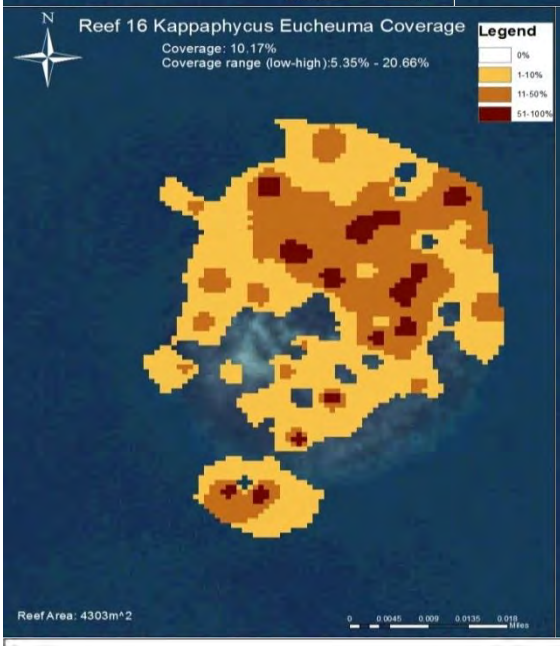


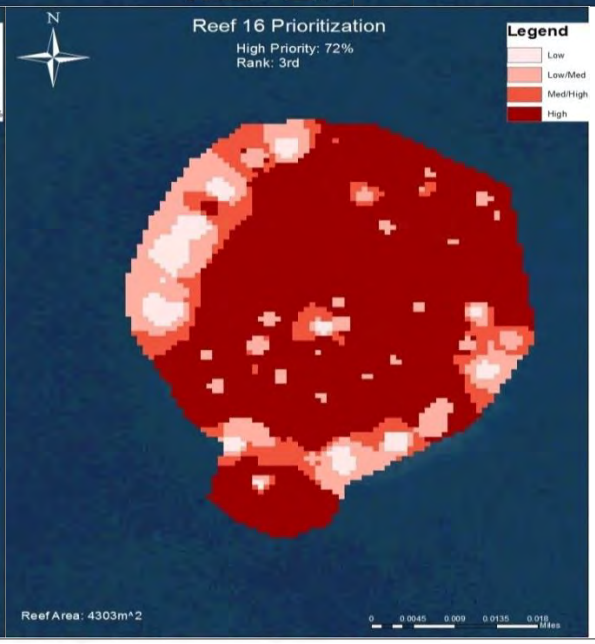


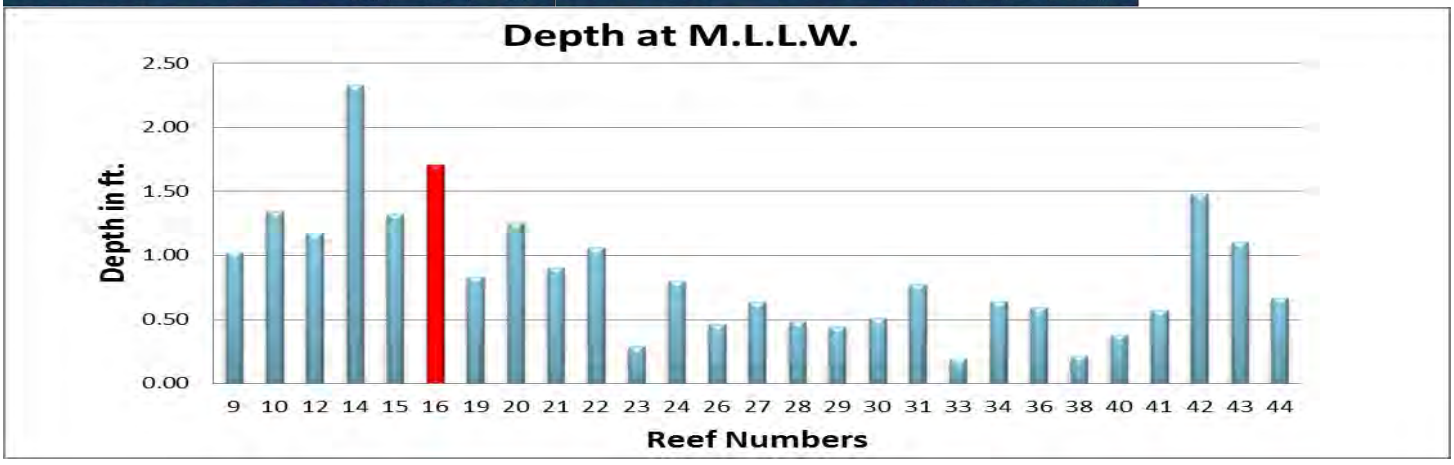
Appendix A: cont'd.

Reef 16



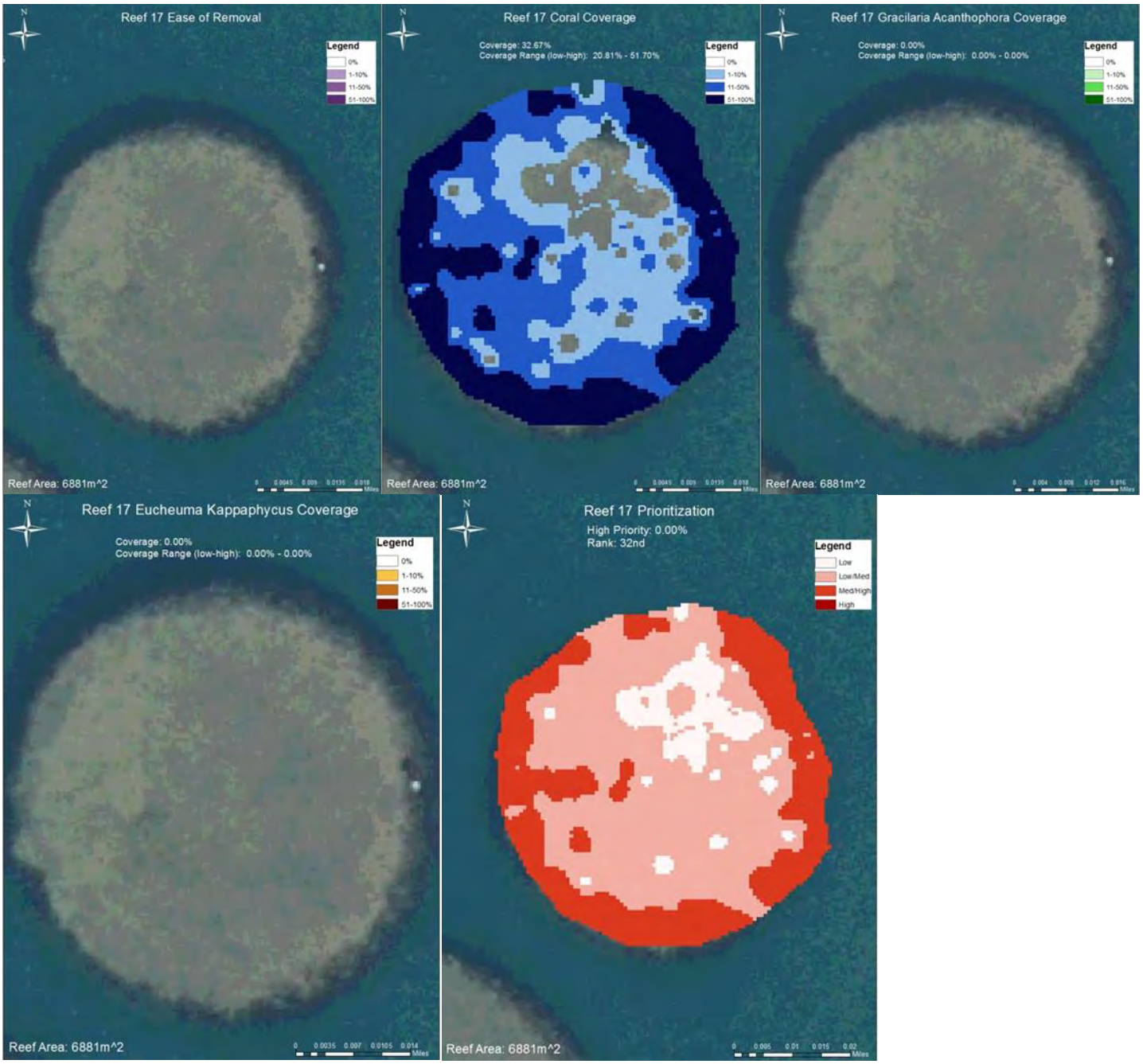






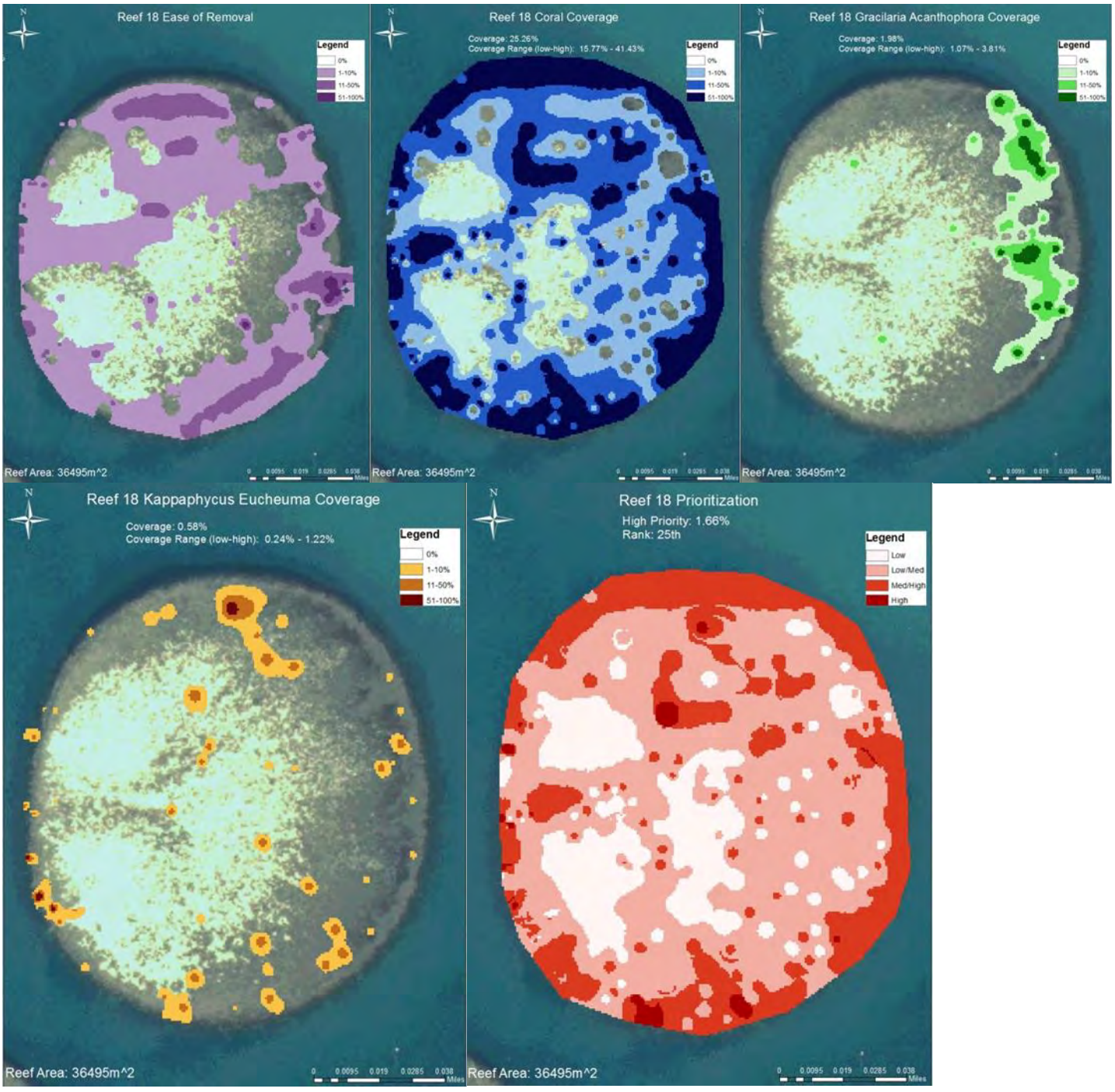
Appendix A: cont'd.

Reef 17



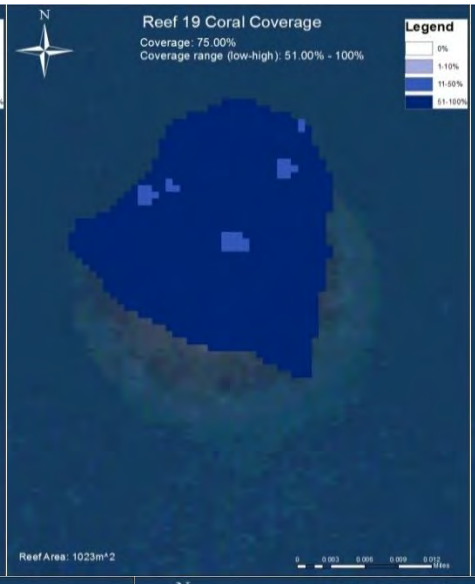
Appendix A: cont'd.

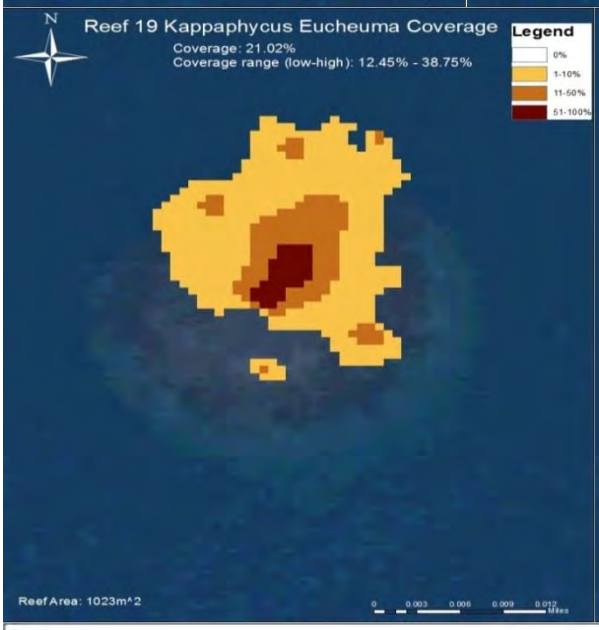
Reef 18

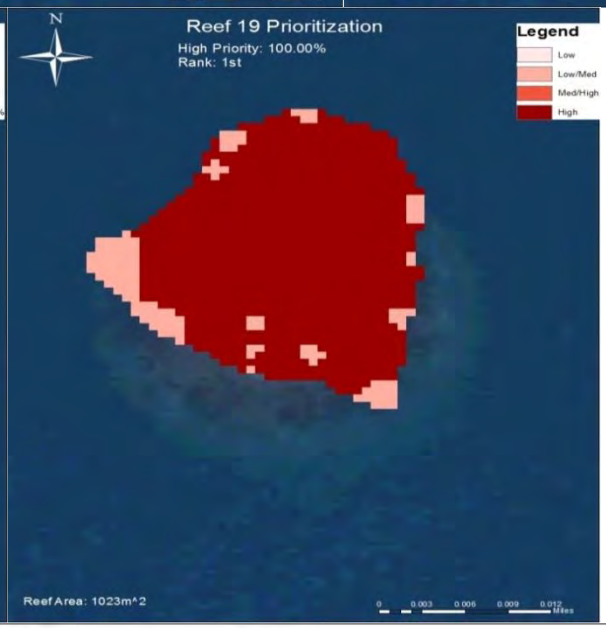


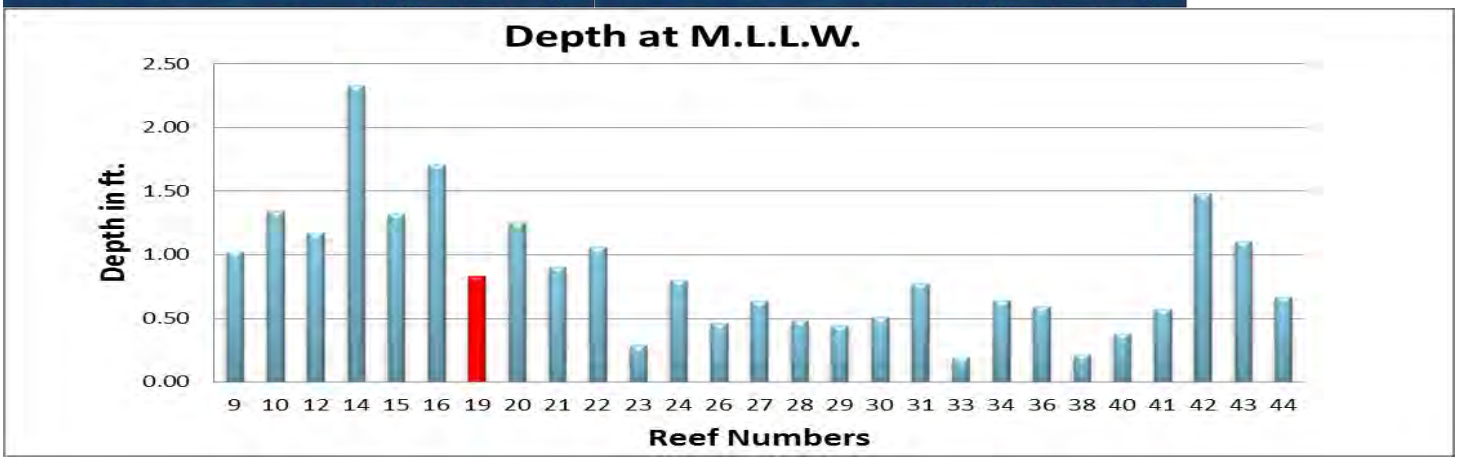
Appendix A

Reef 19



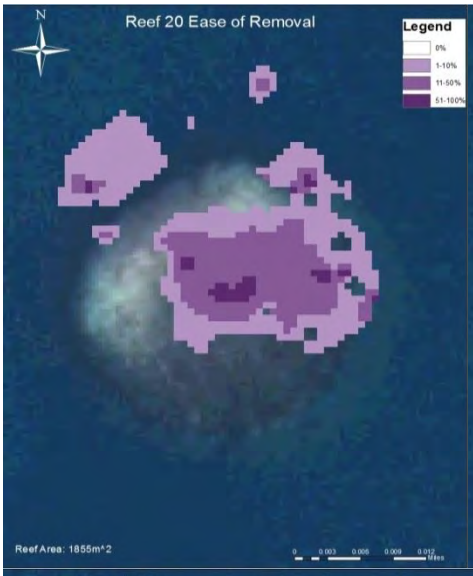


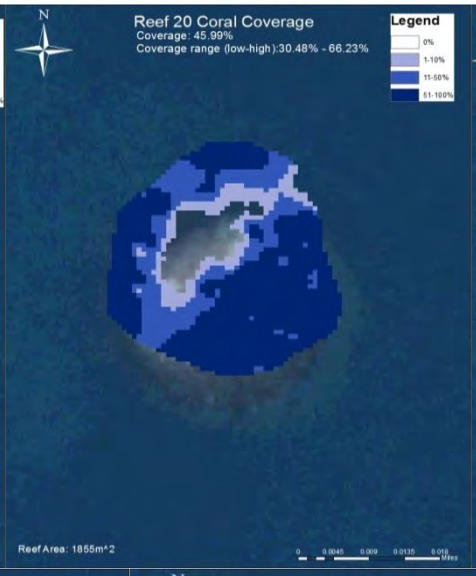


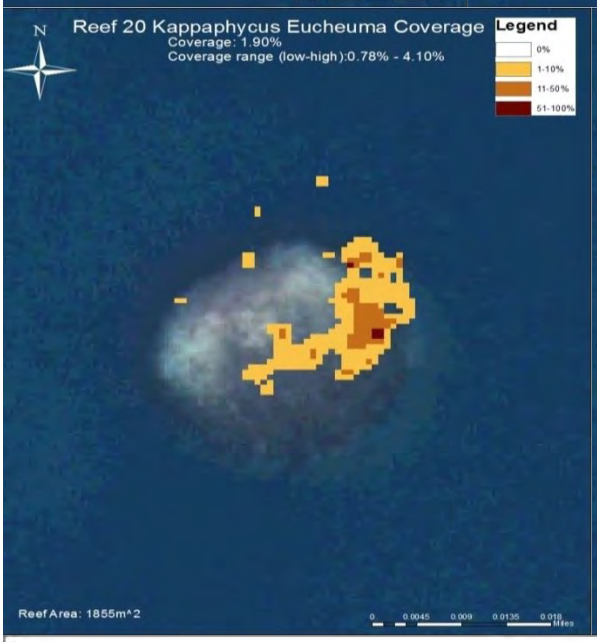


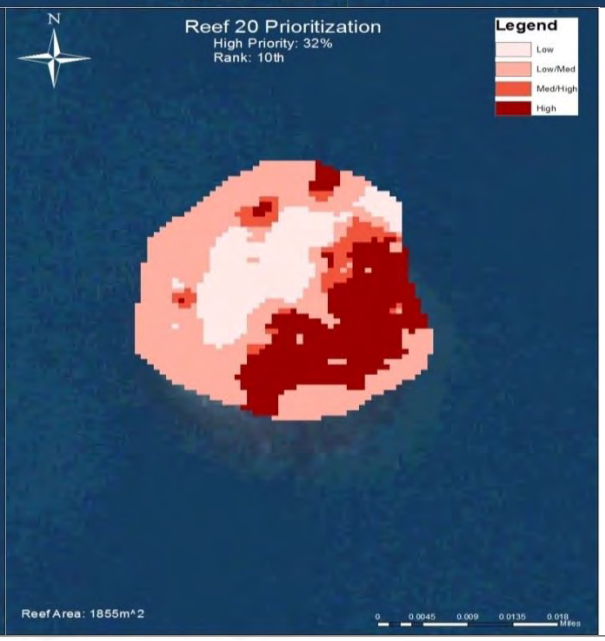
Appendix A: cont'd.

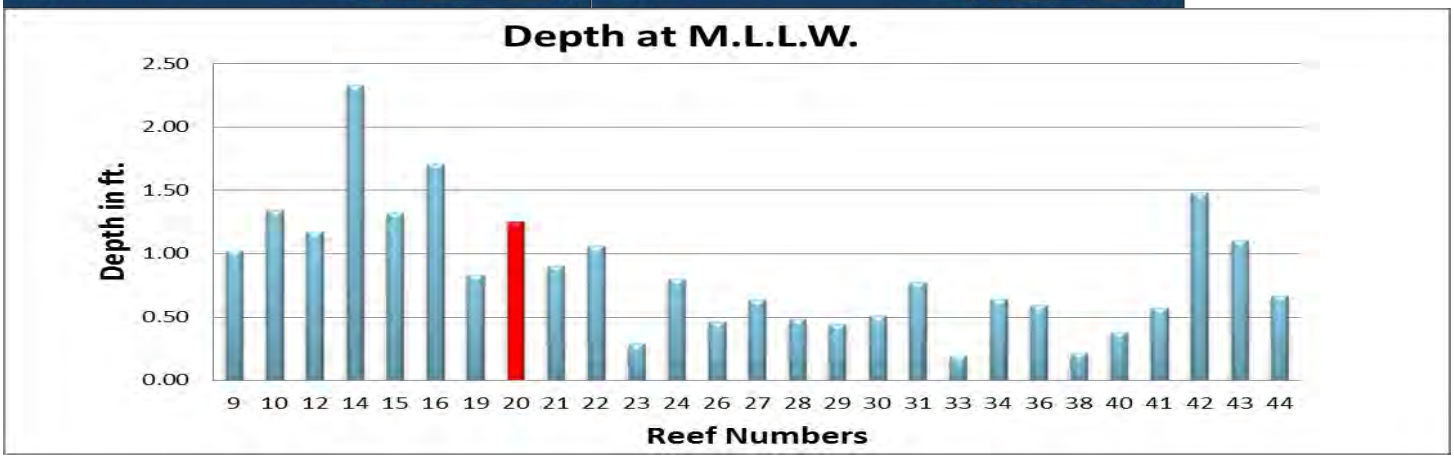
Reef 20





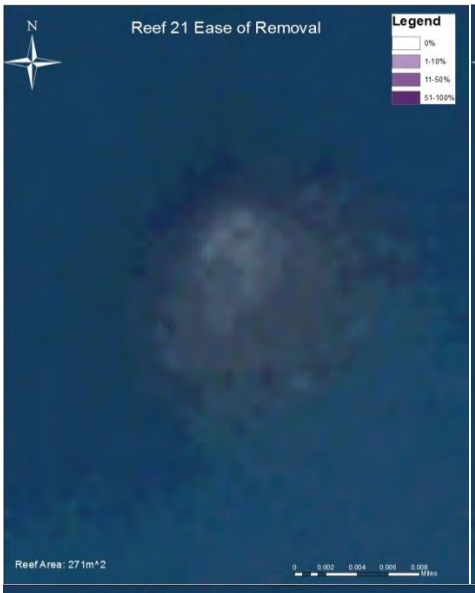


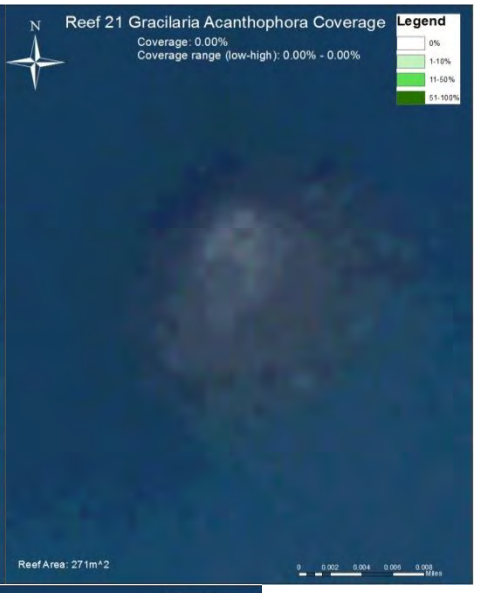


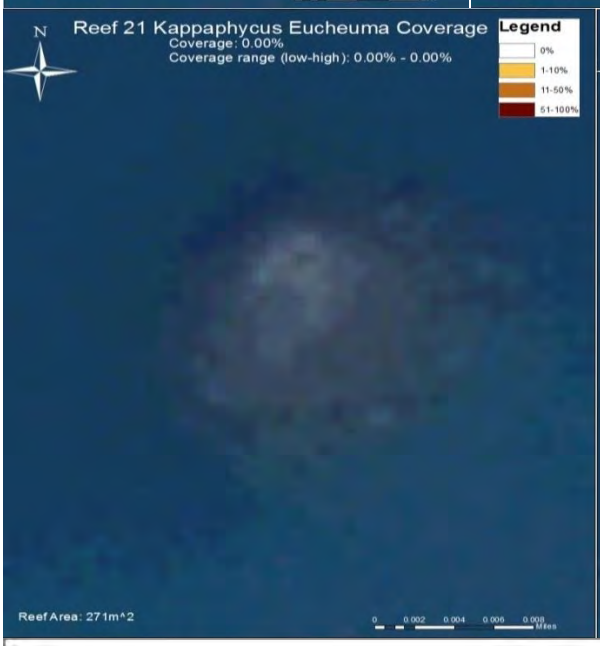


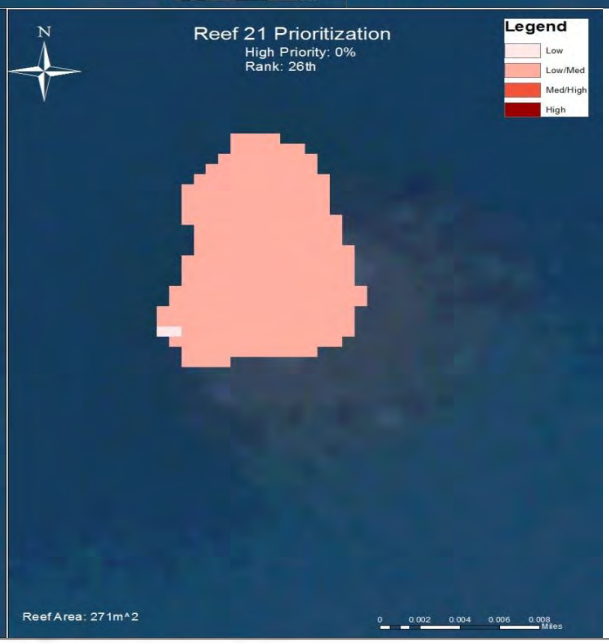
Appendix A: cont'd.

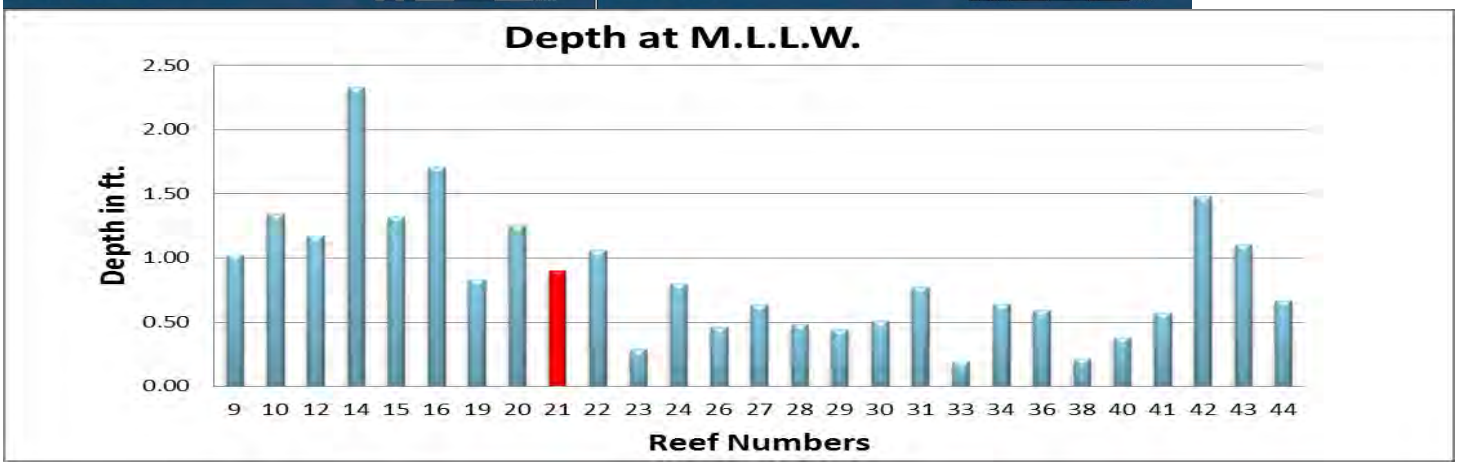
Reef 21





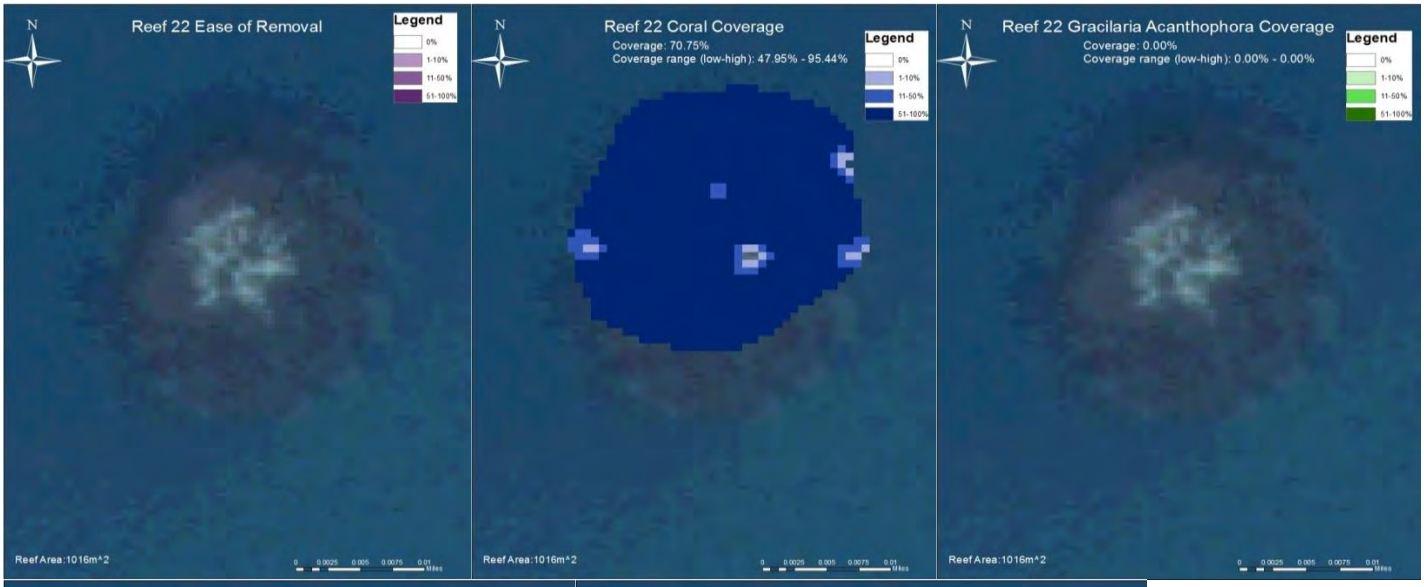


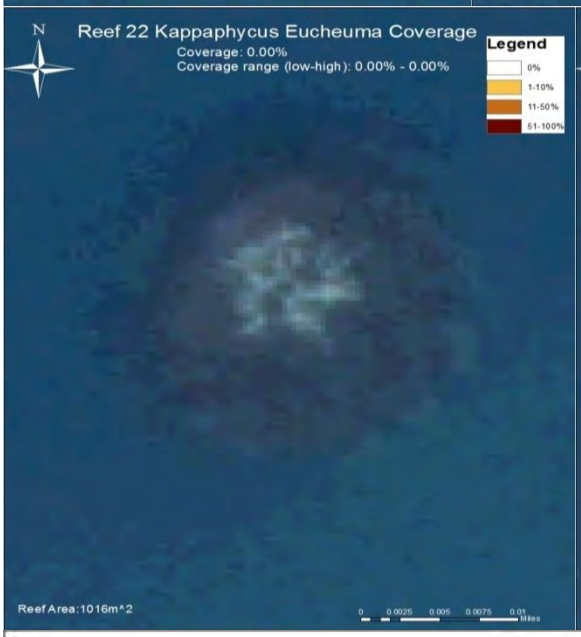


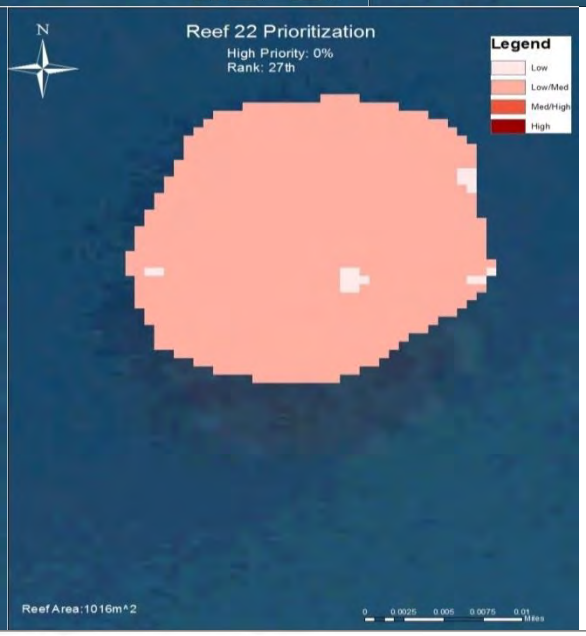


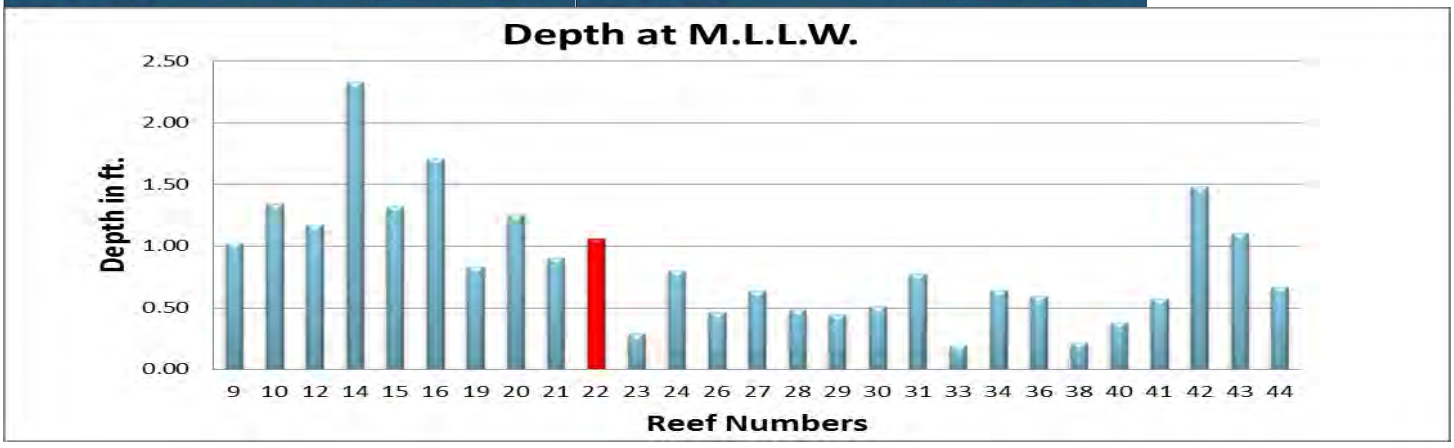
Appendix A: cont'd.

Reef 22



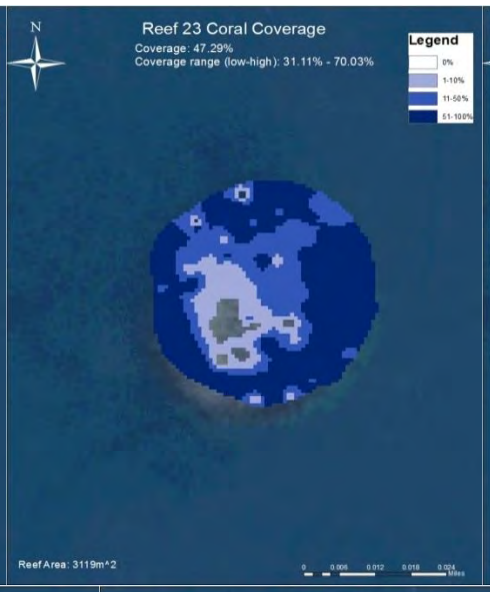


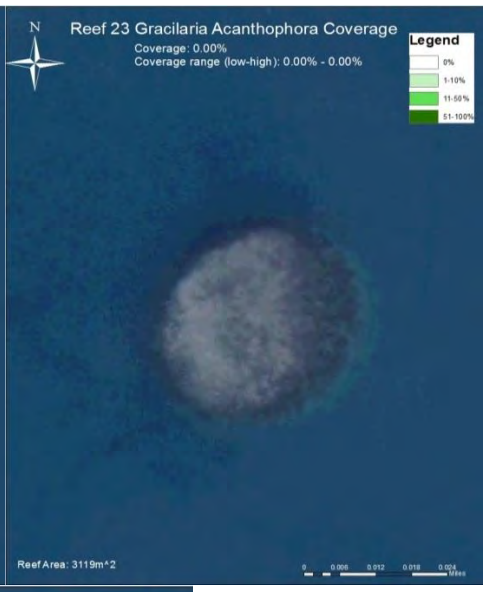


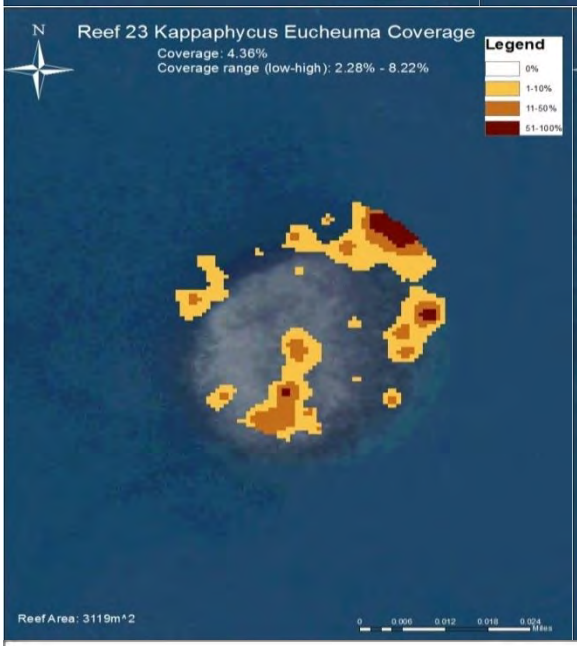


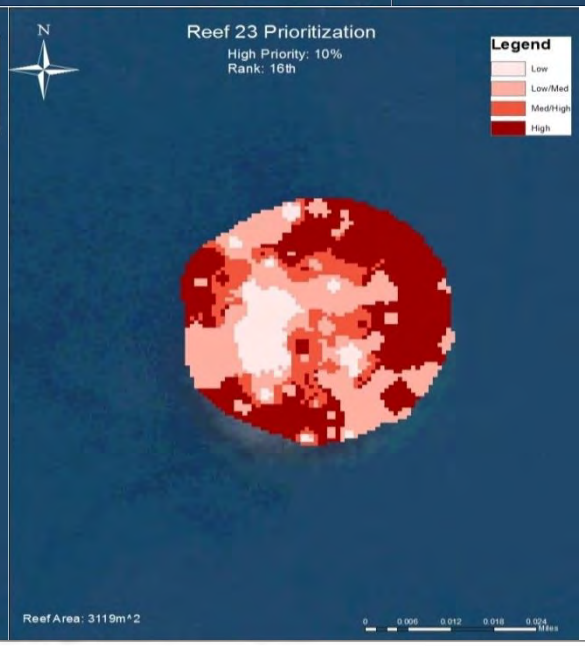
Appendix A: cont'd.

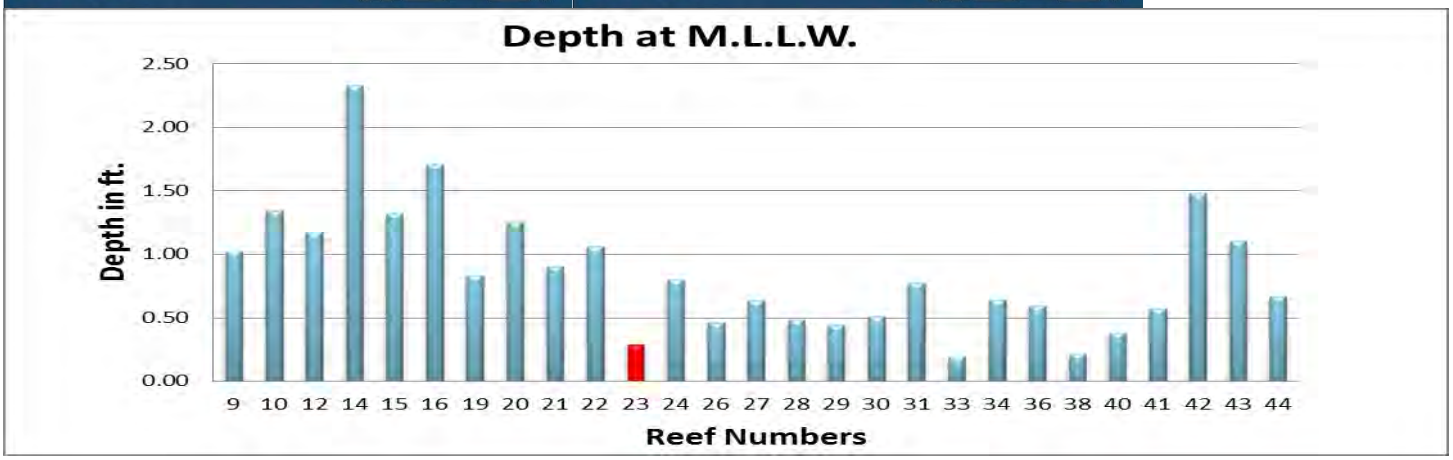
Reef 23





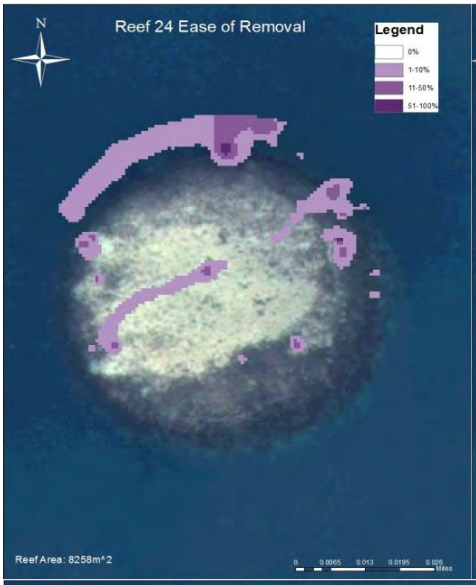


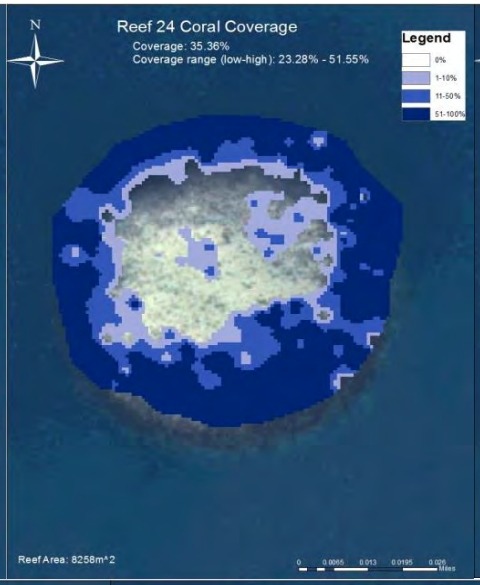


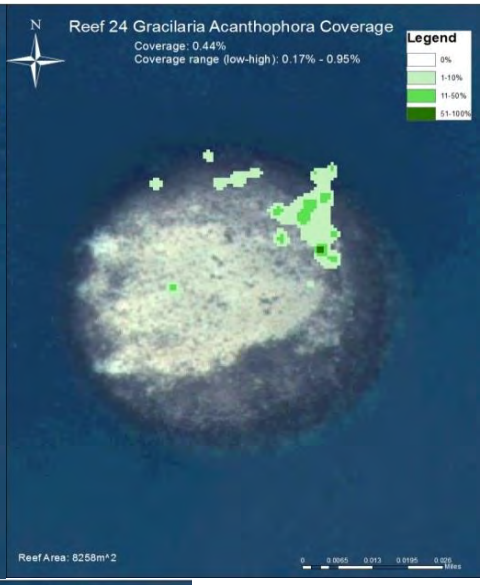


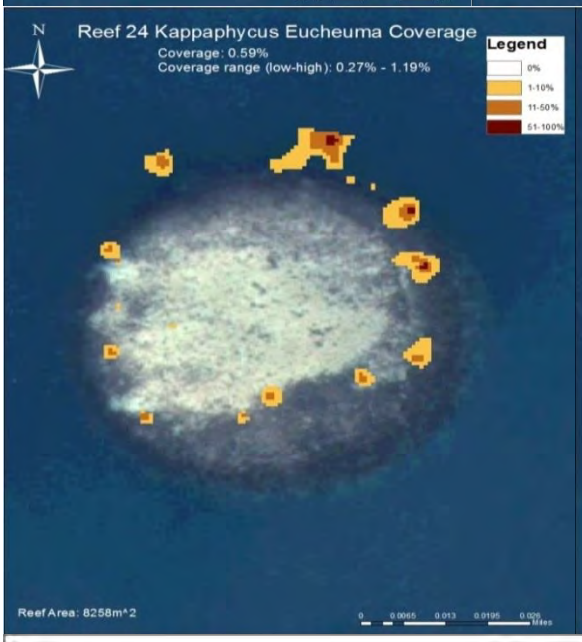
Appendix A: cont'd.

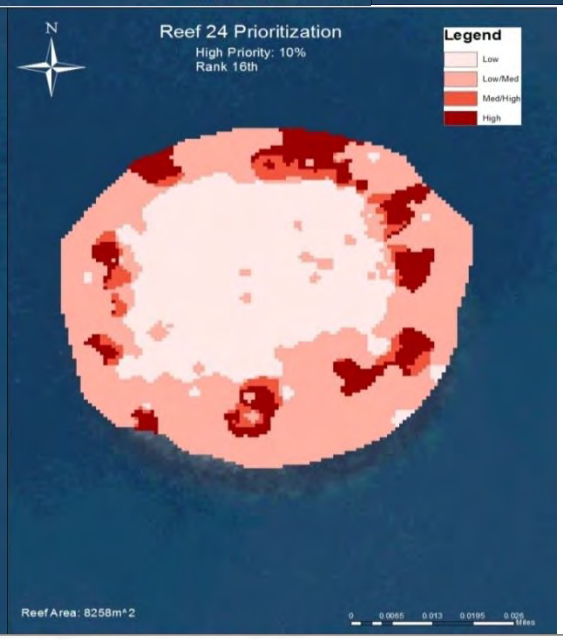
Reef 24

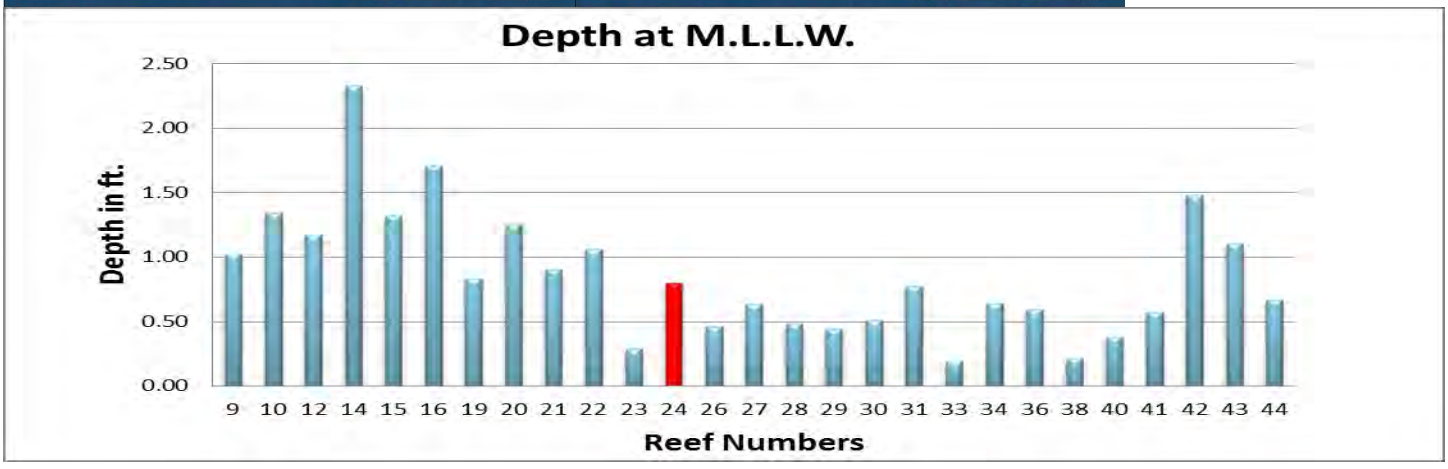






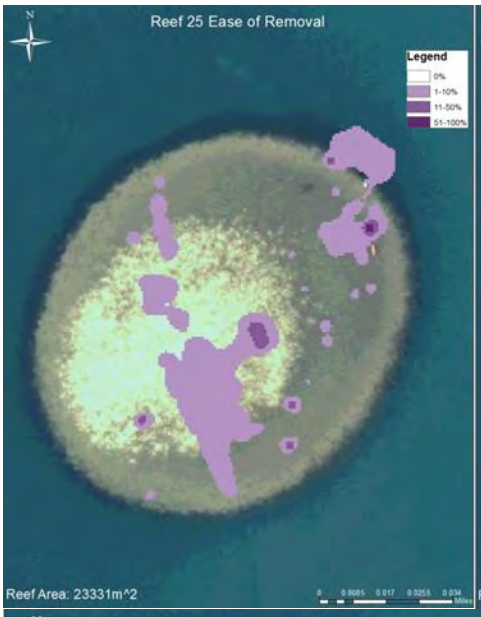


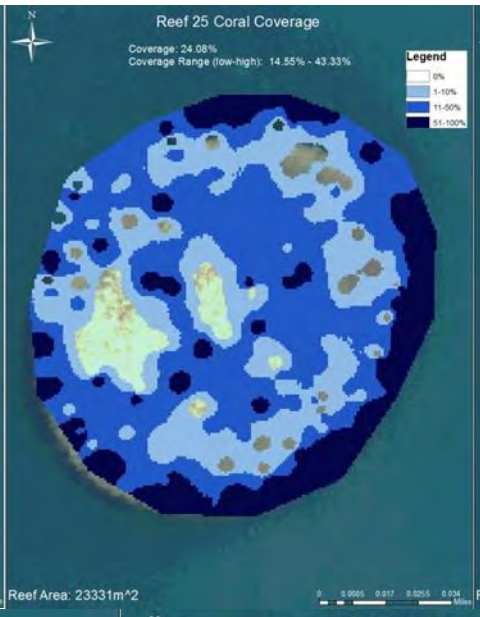


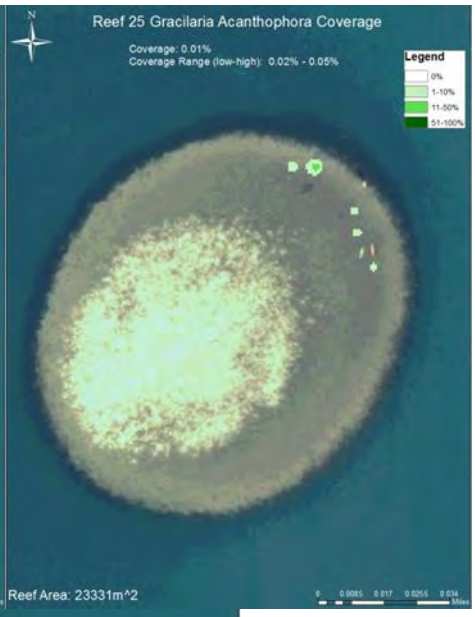


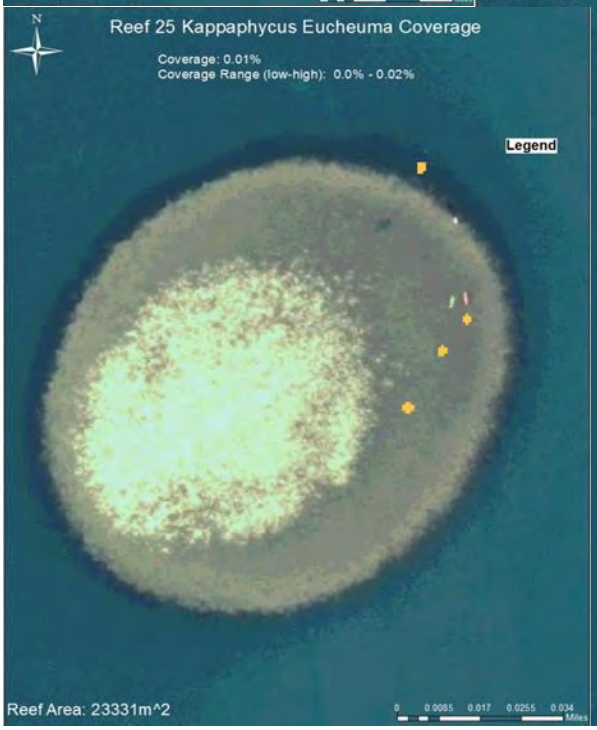
Appendix A: cont'd.

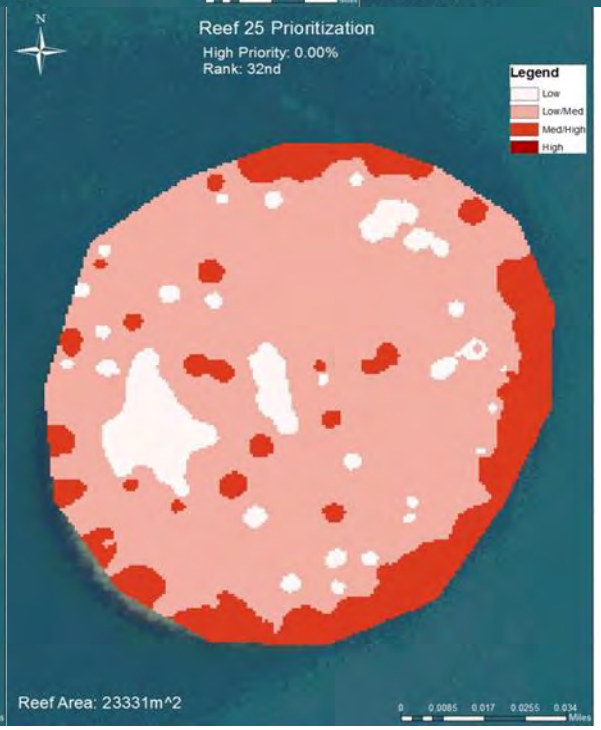
Reef 25





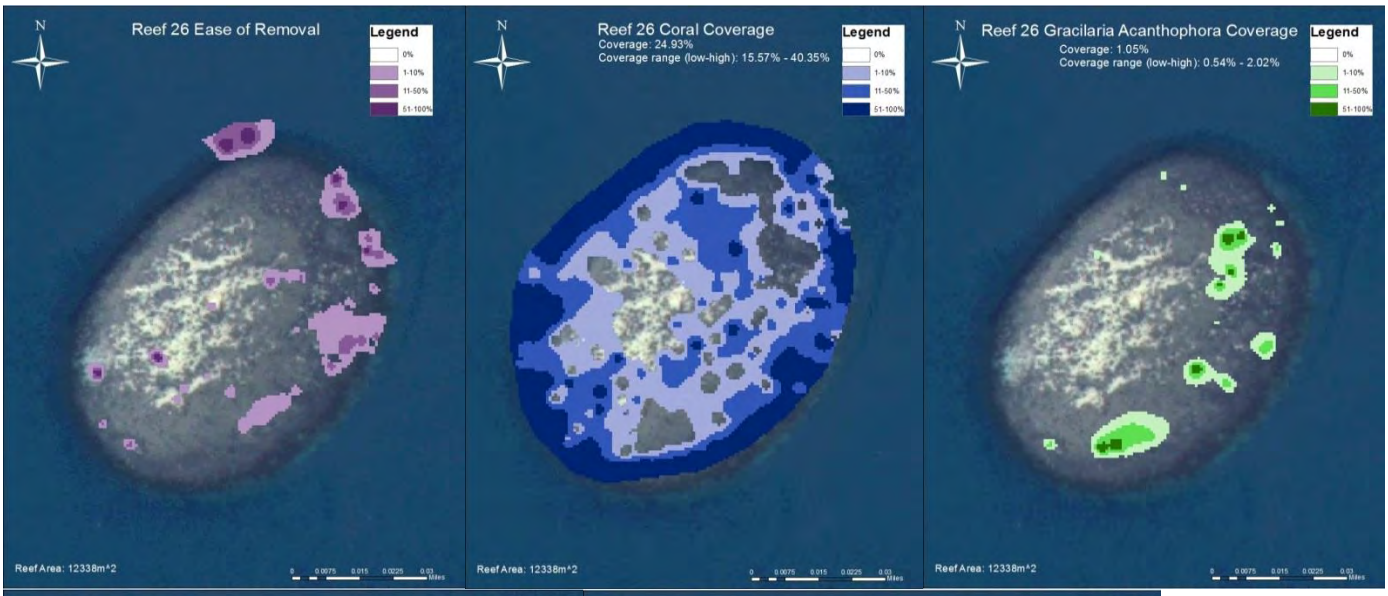


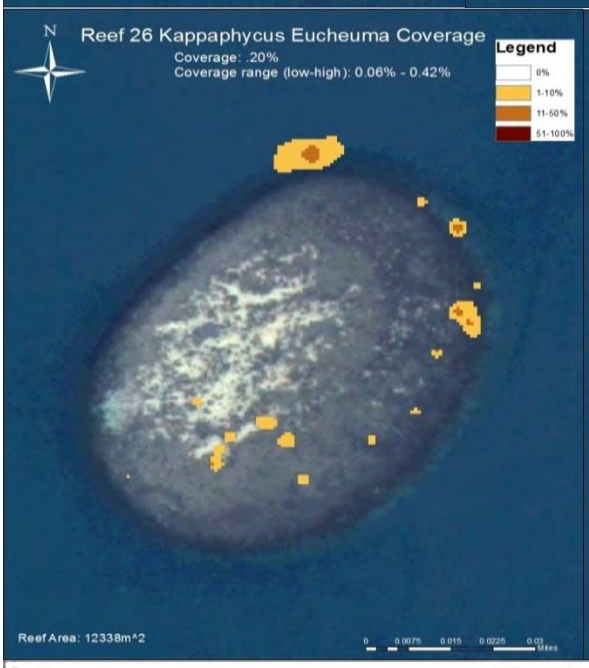


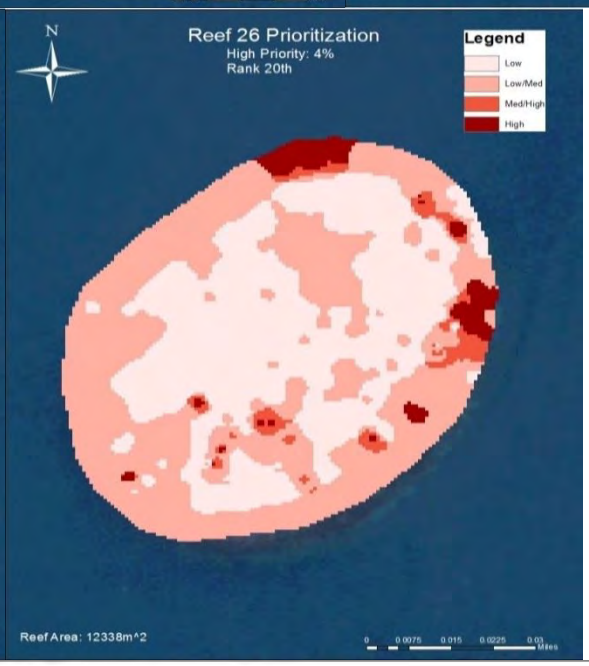


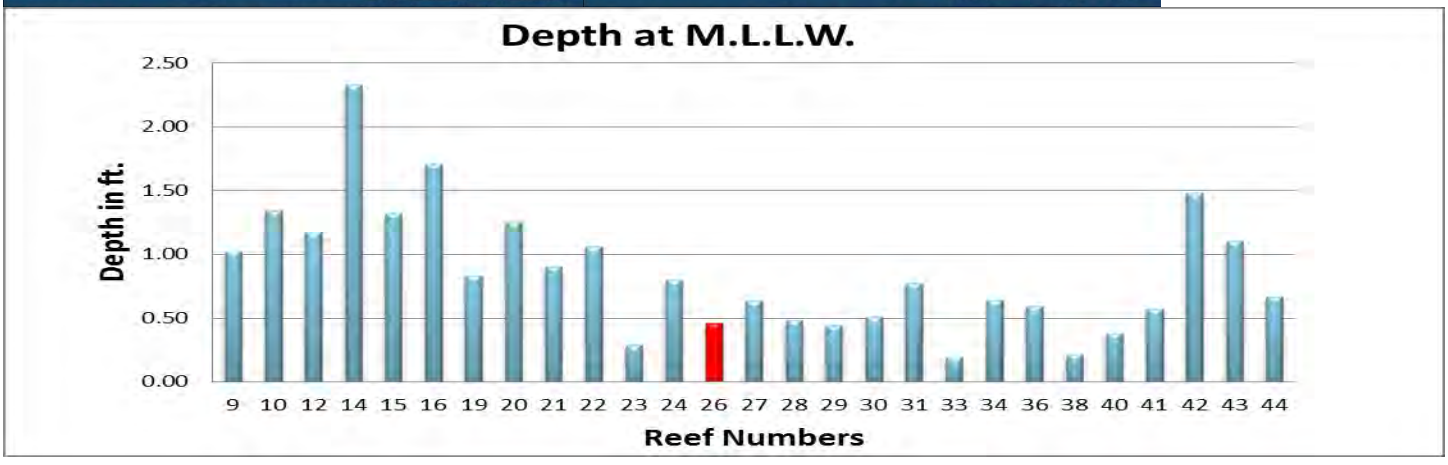
Appendix A: cont'd.

Reef 26



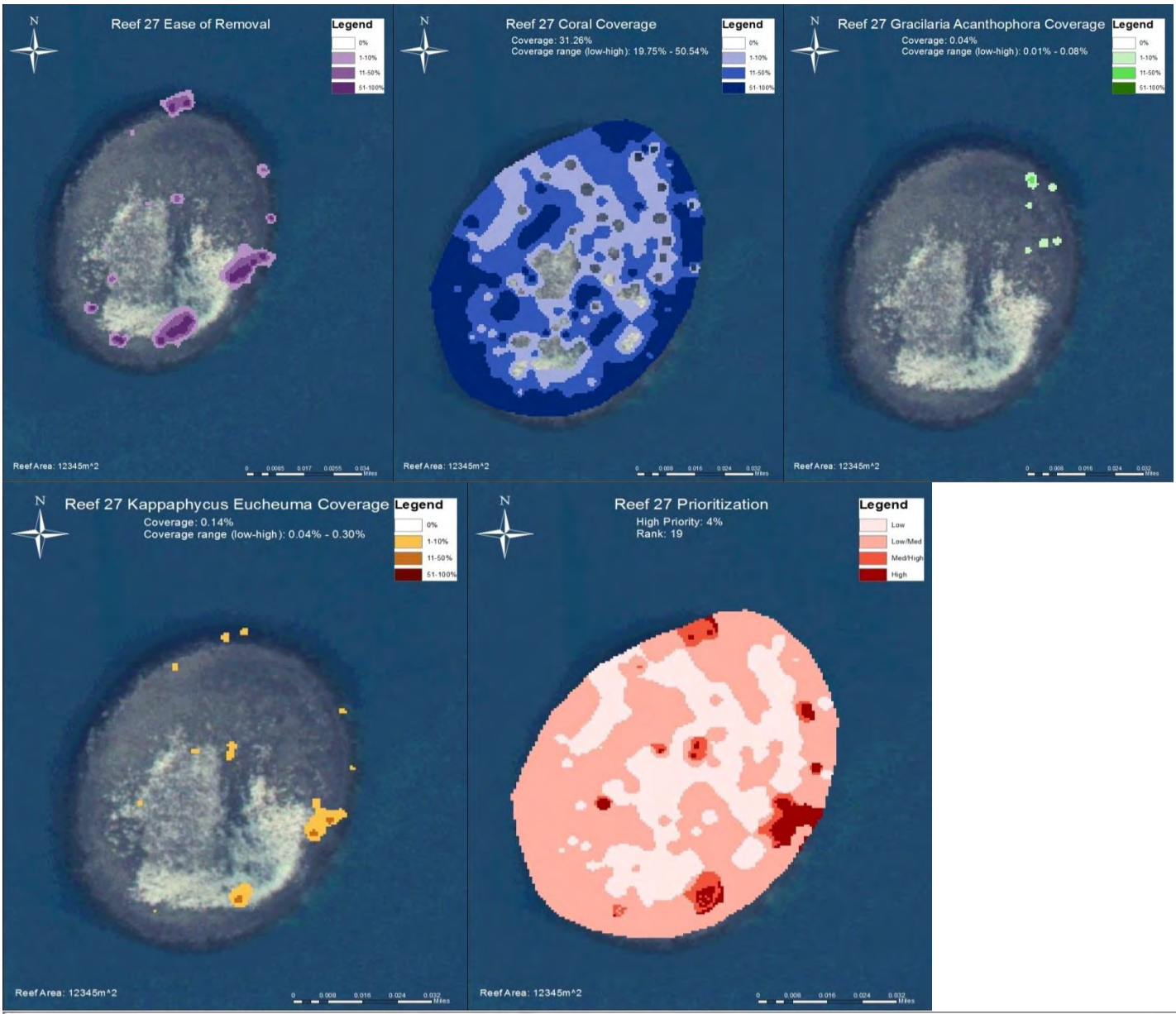


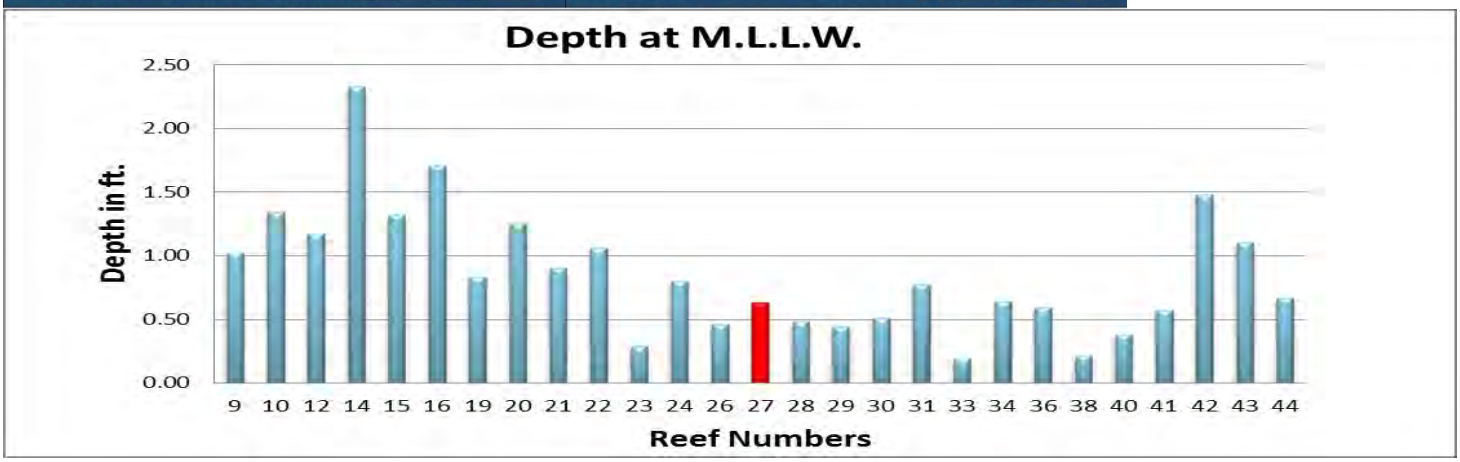




Appendix A: cont'd.

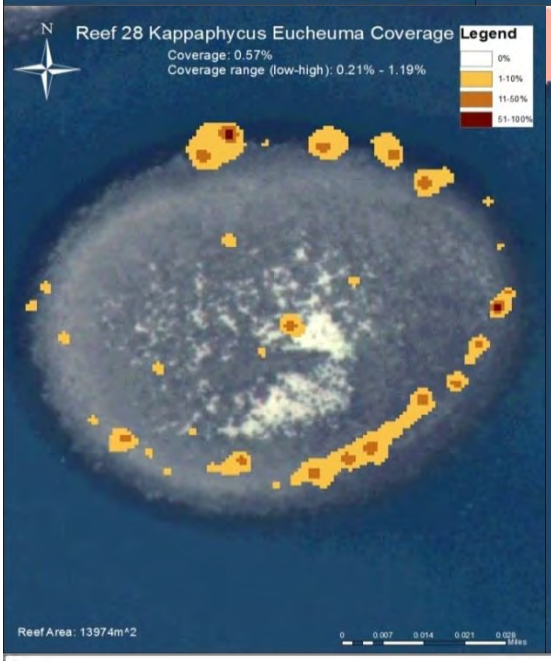
Reef 27

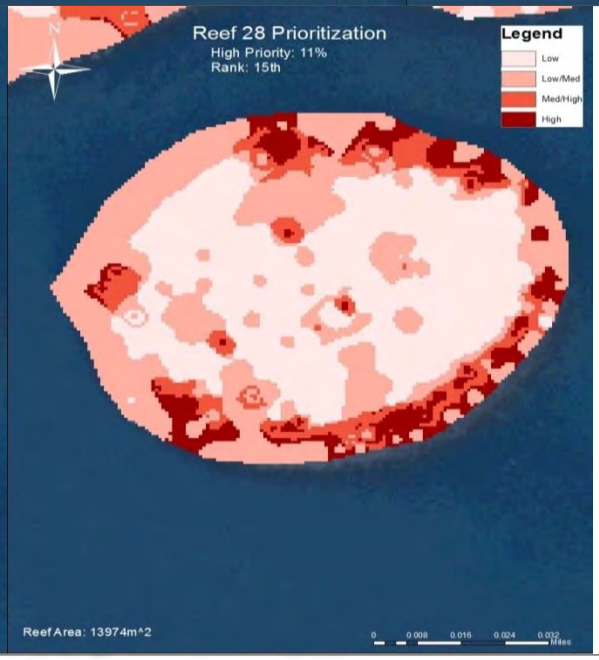


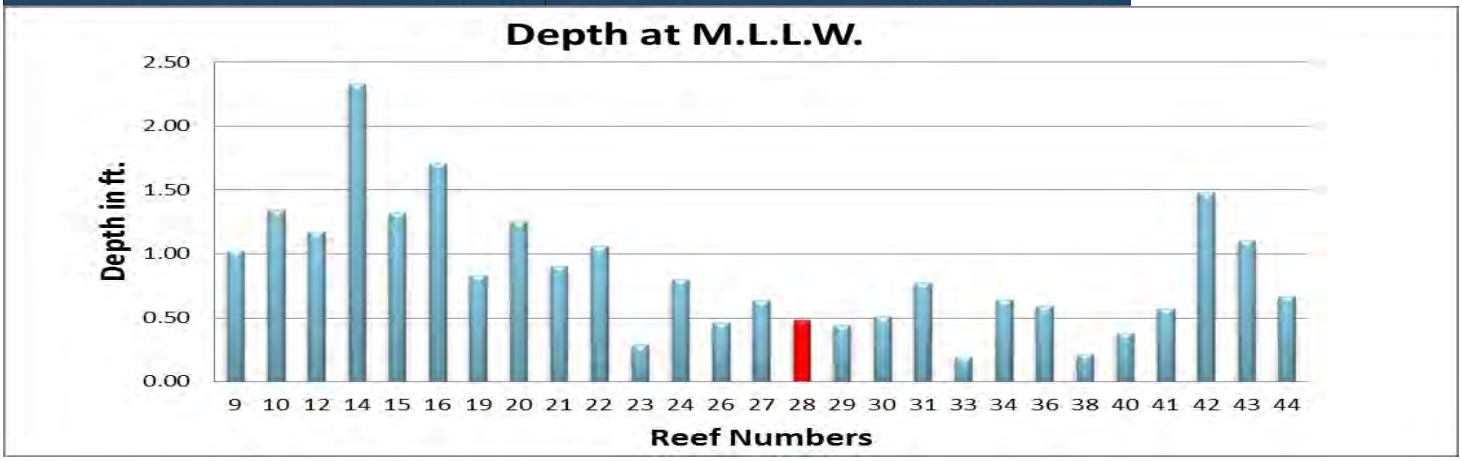


Appendix A: cont'd.

Reef 28

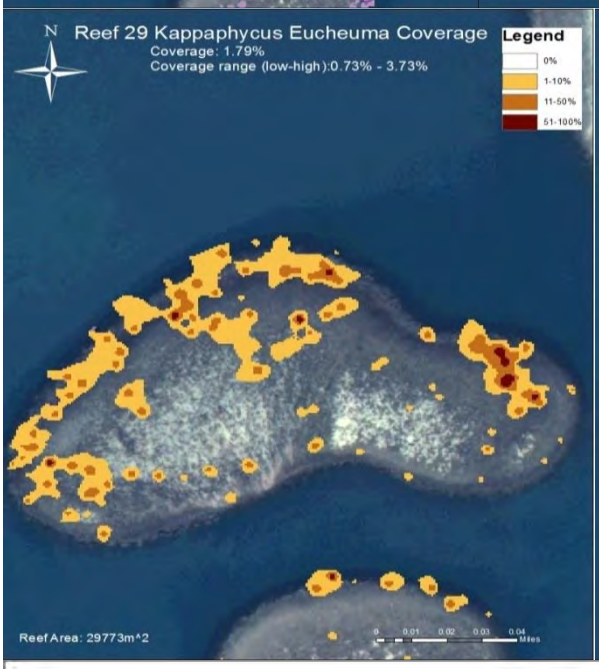


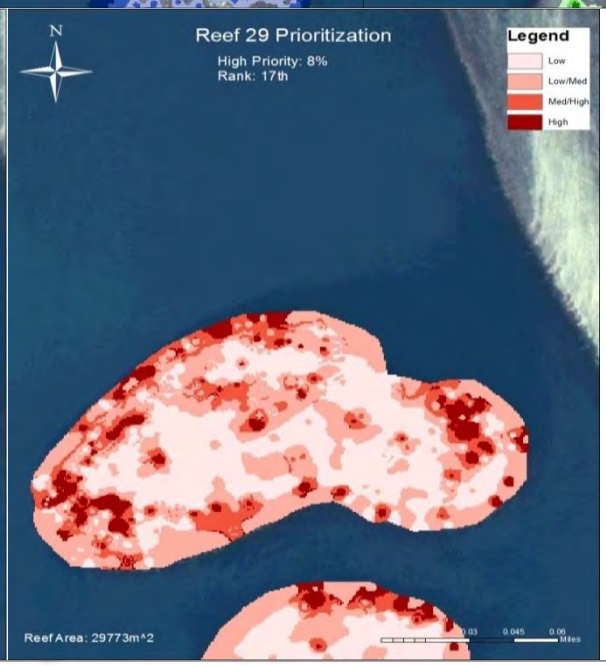


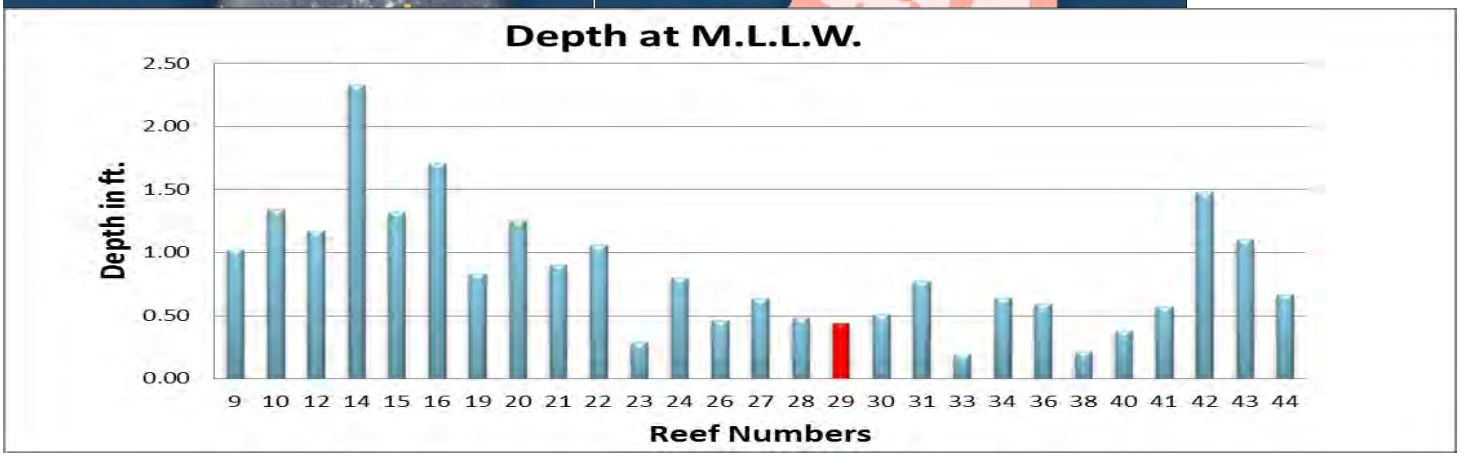


Appendix A: cont'd.

Reef 29

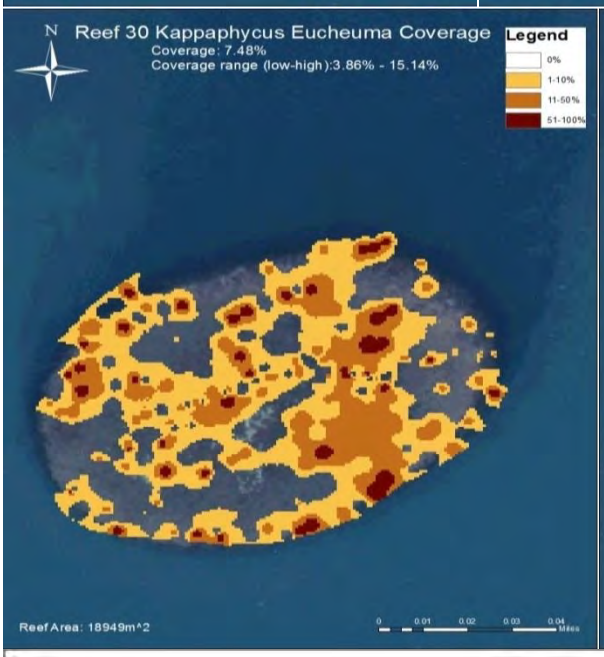


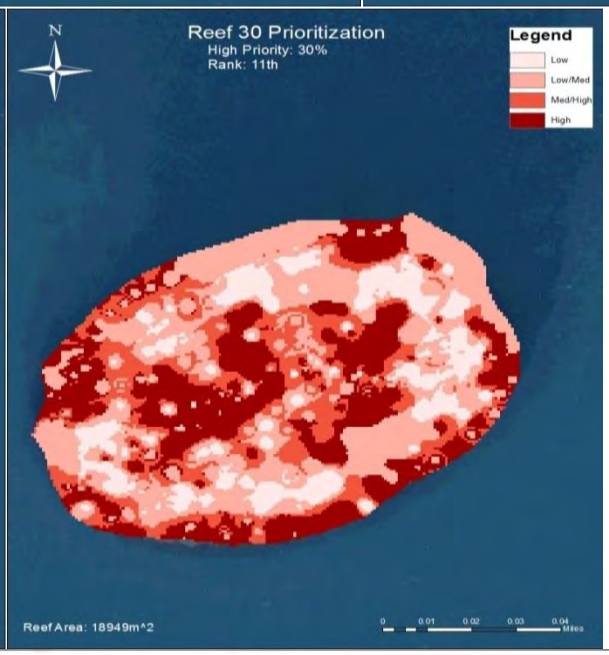


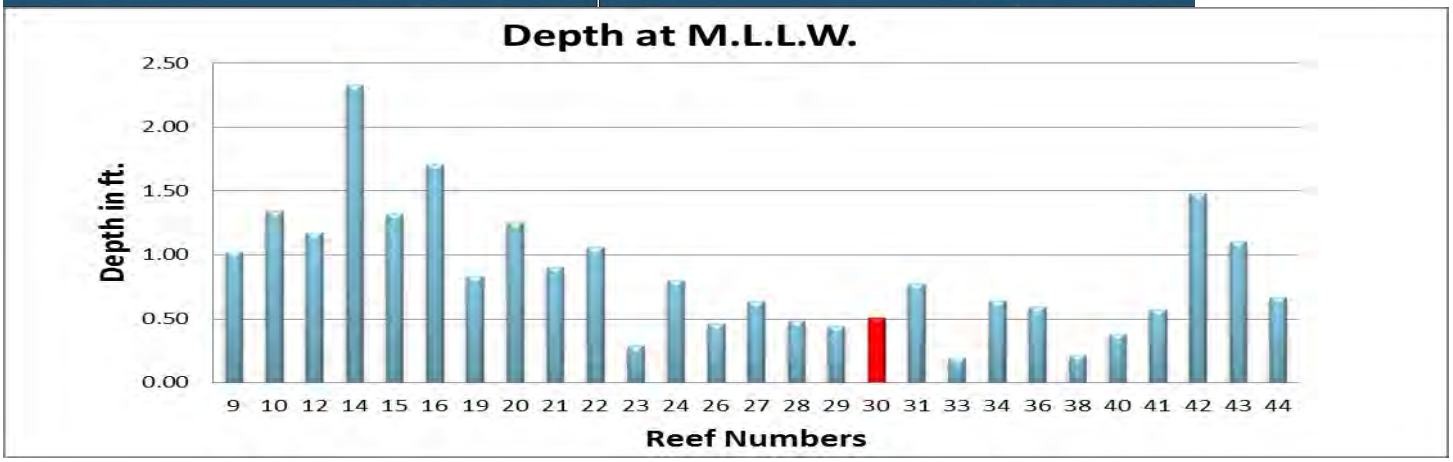


Appendix A: cont'd.

Reef 30

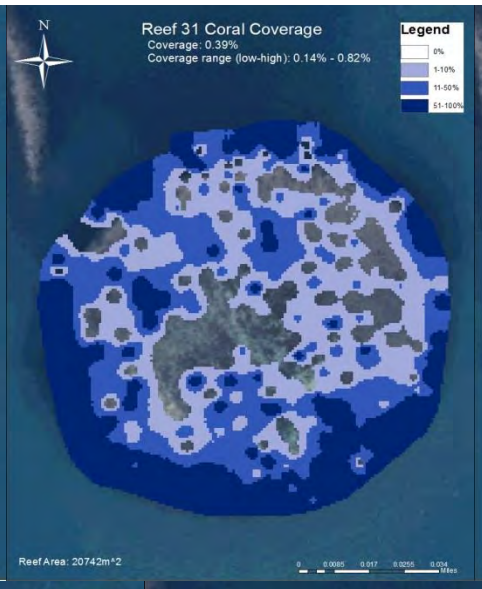


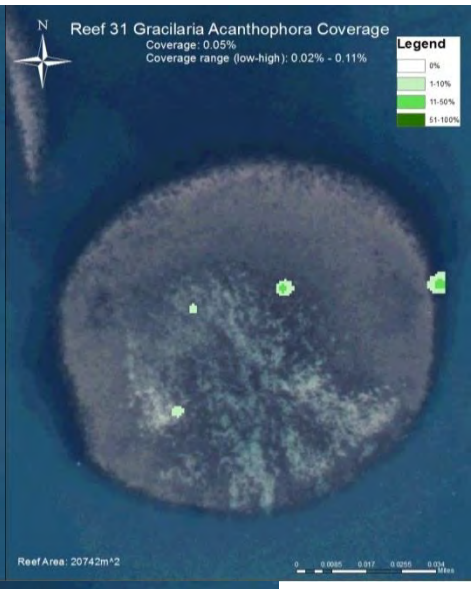


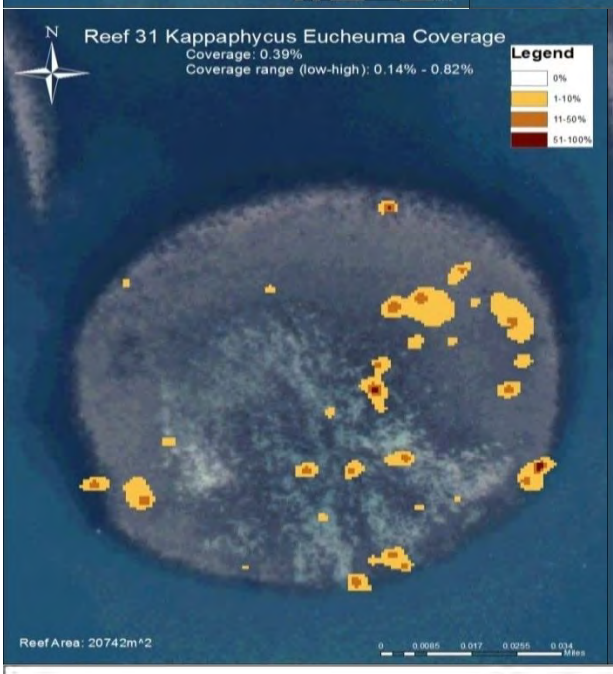


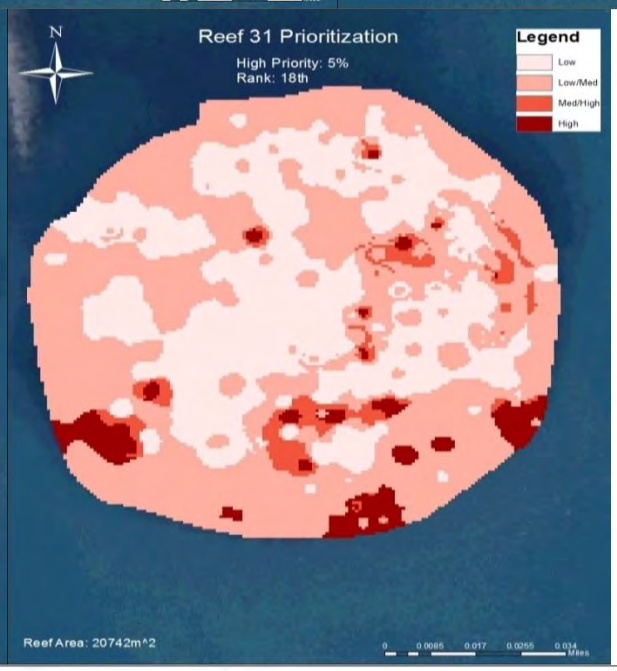
Appendix A: cont'd.

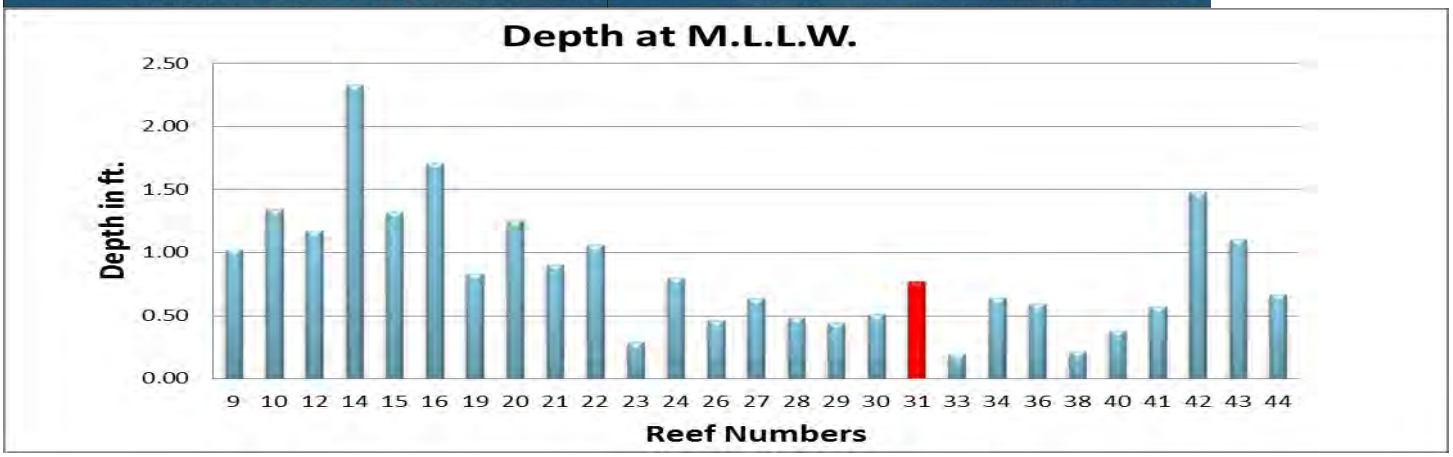
Reef 31





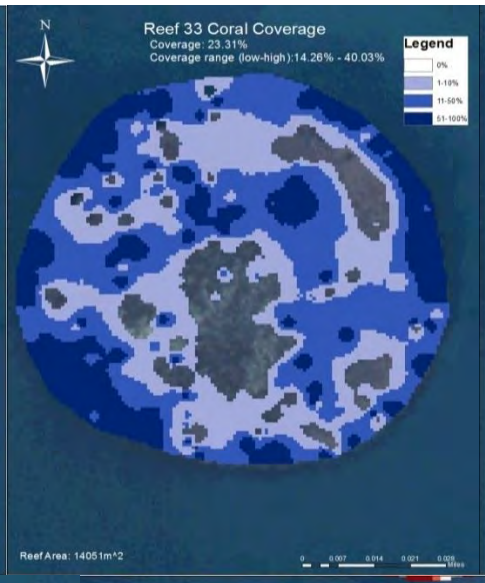


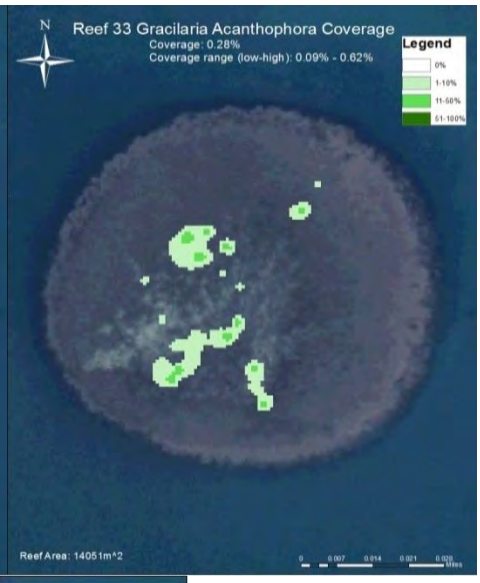


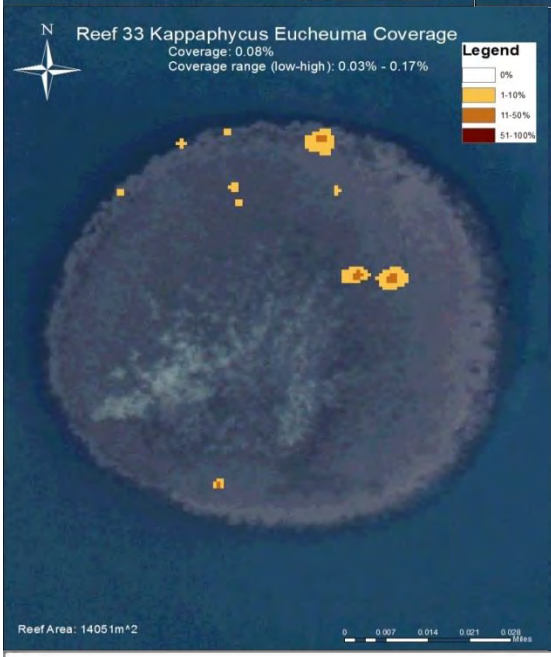


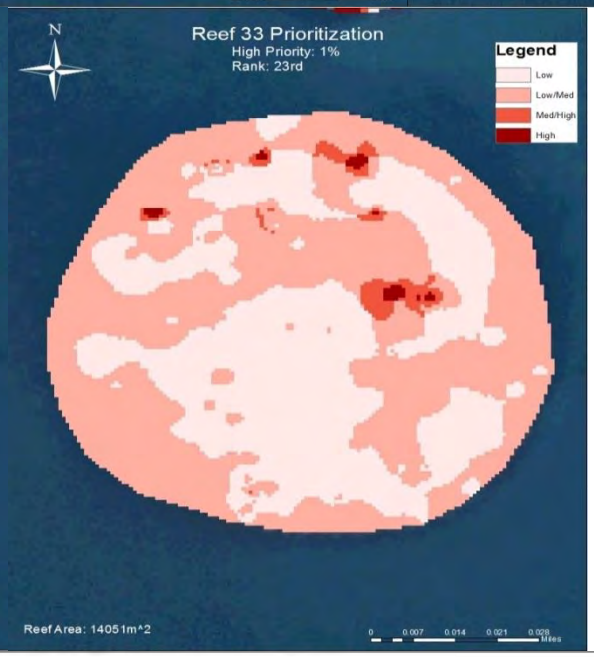
Appendix A: cont'd.

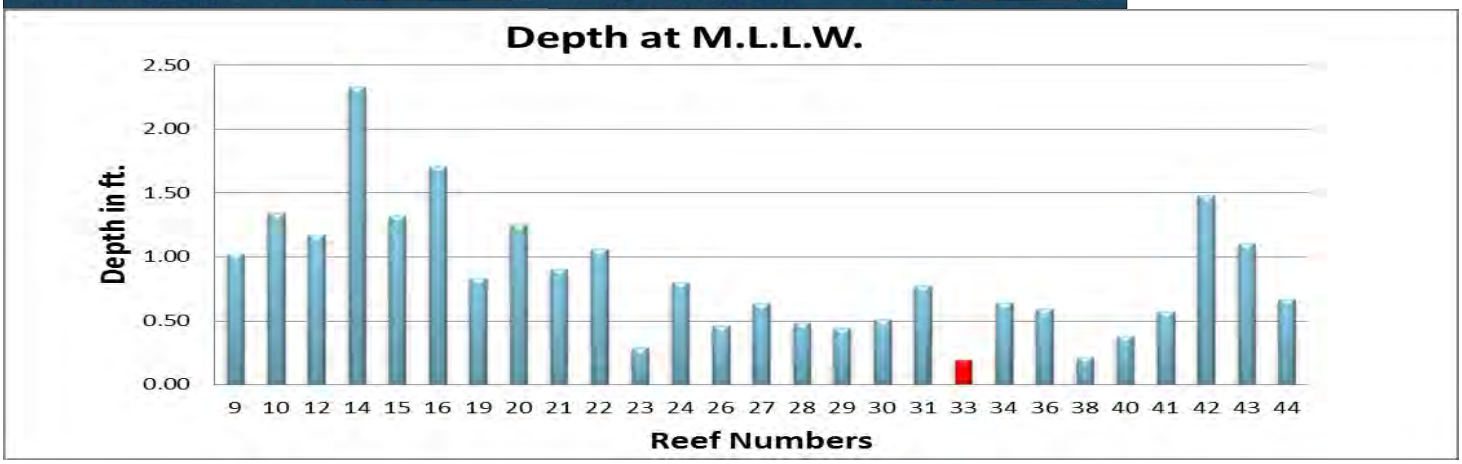
Reef 33





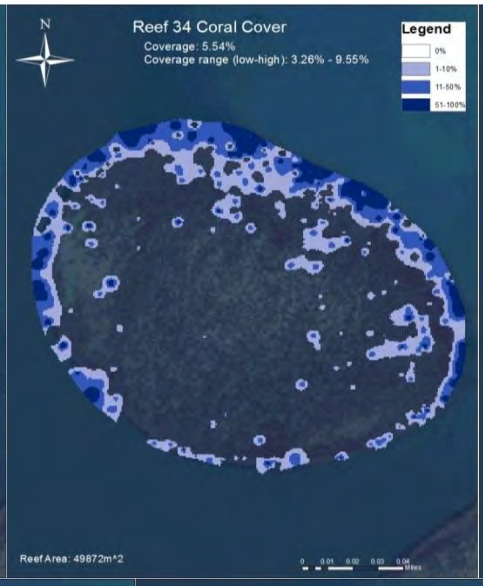


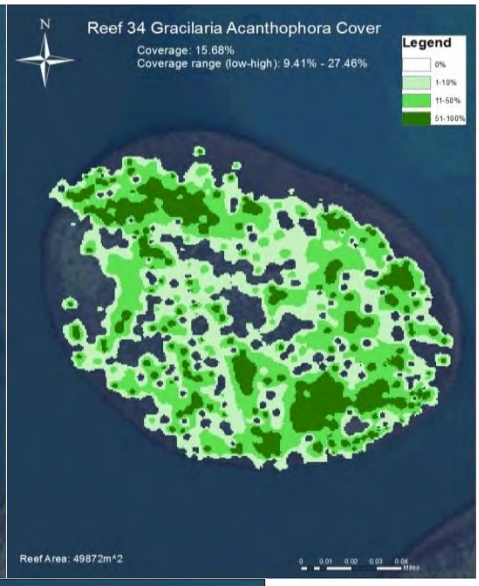


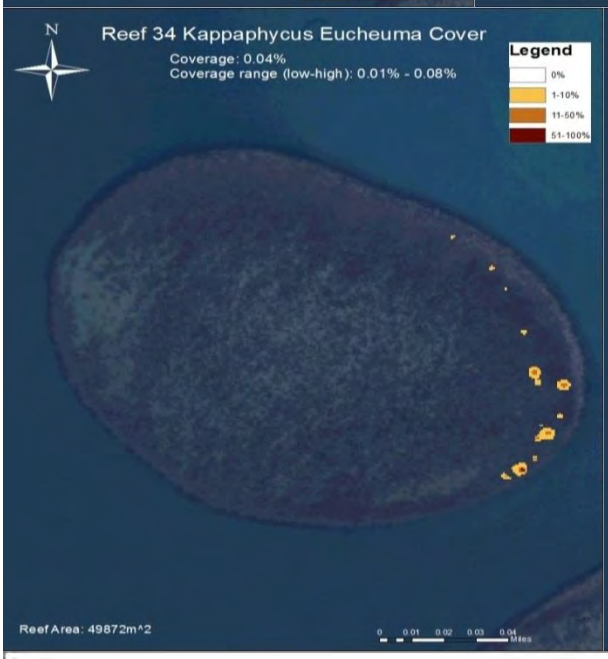


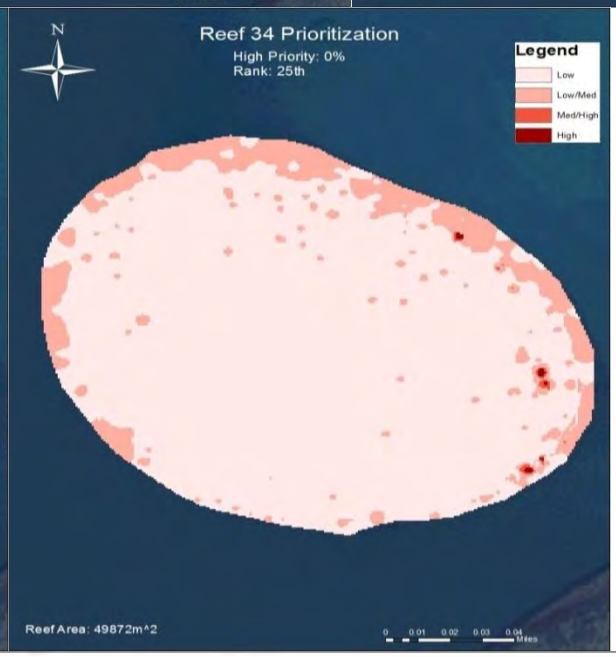
Appendix A: cont'd.

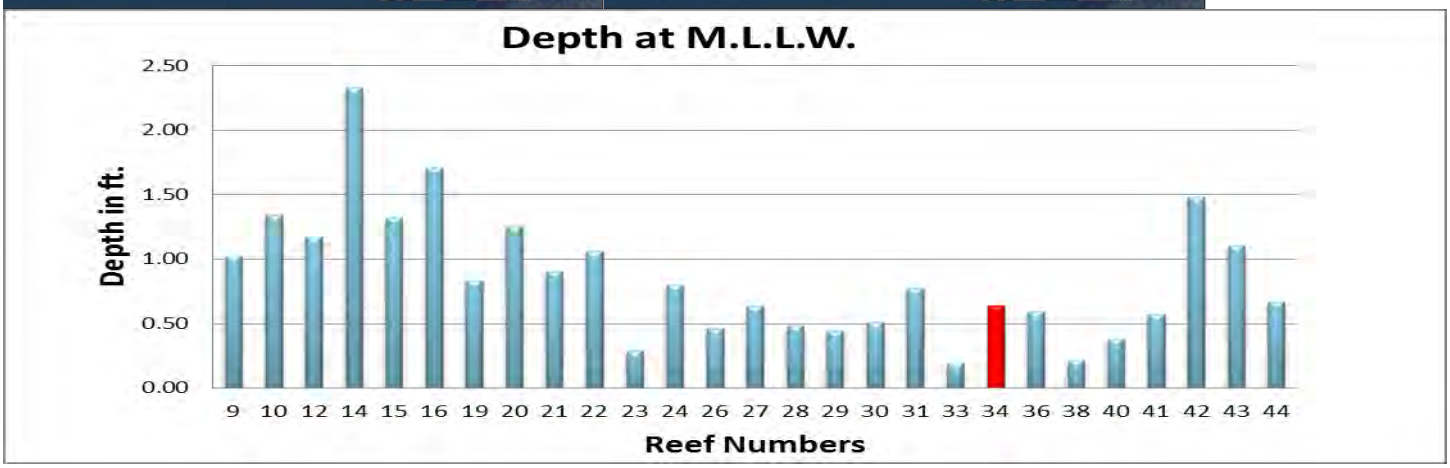
Reef 34





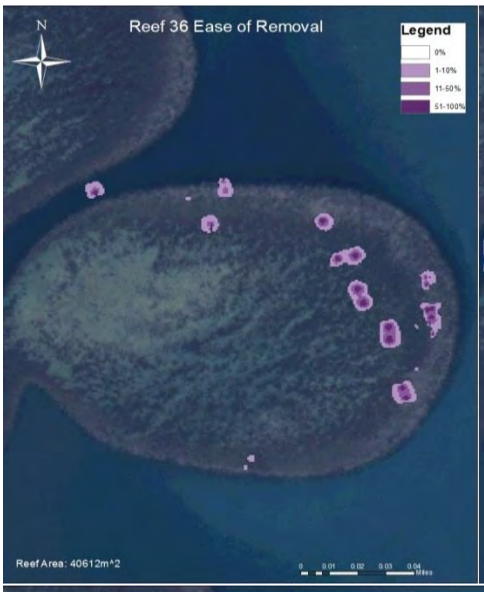


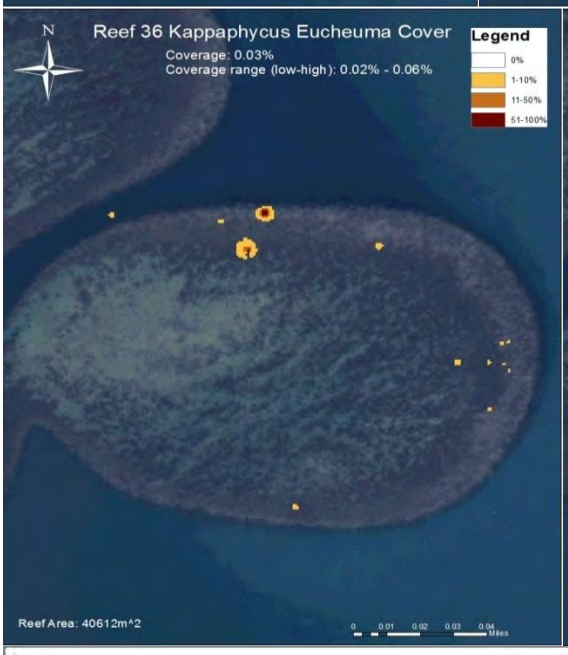


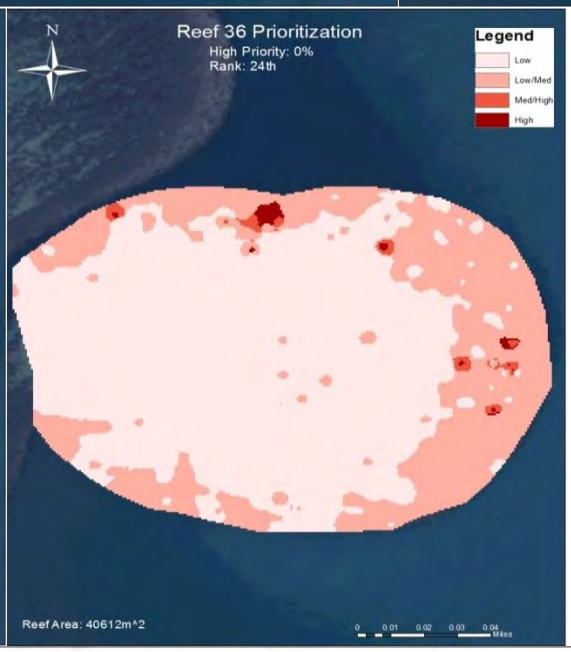


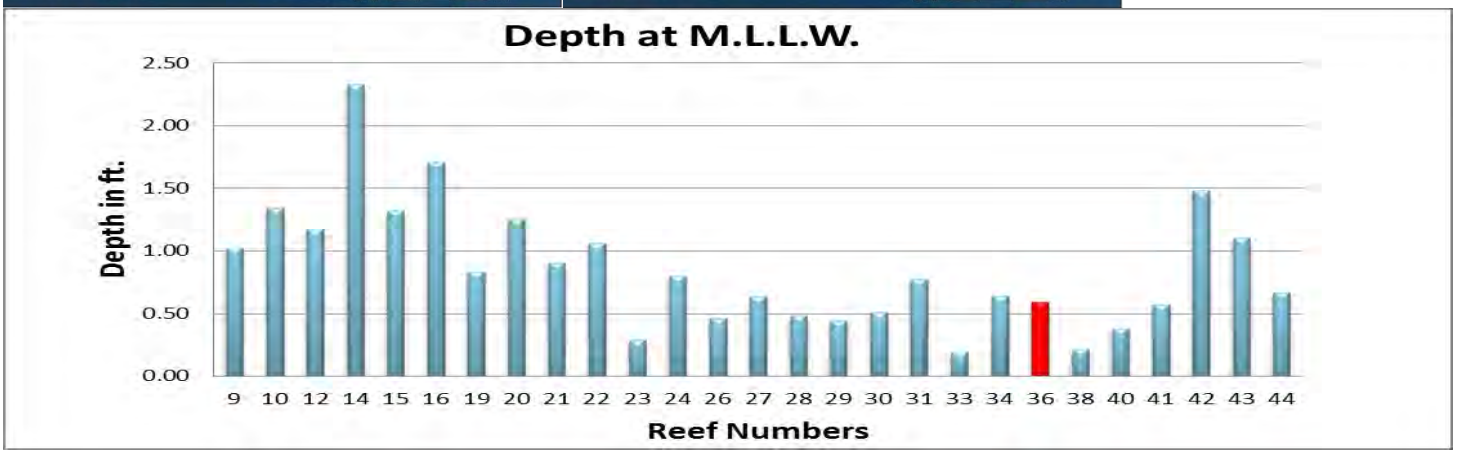
Appendix A: cont'd.

Reef 36



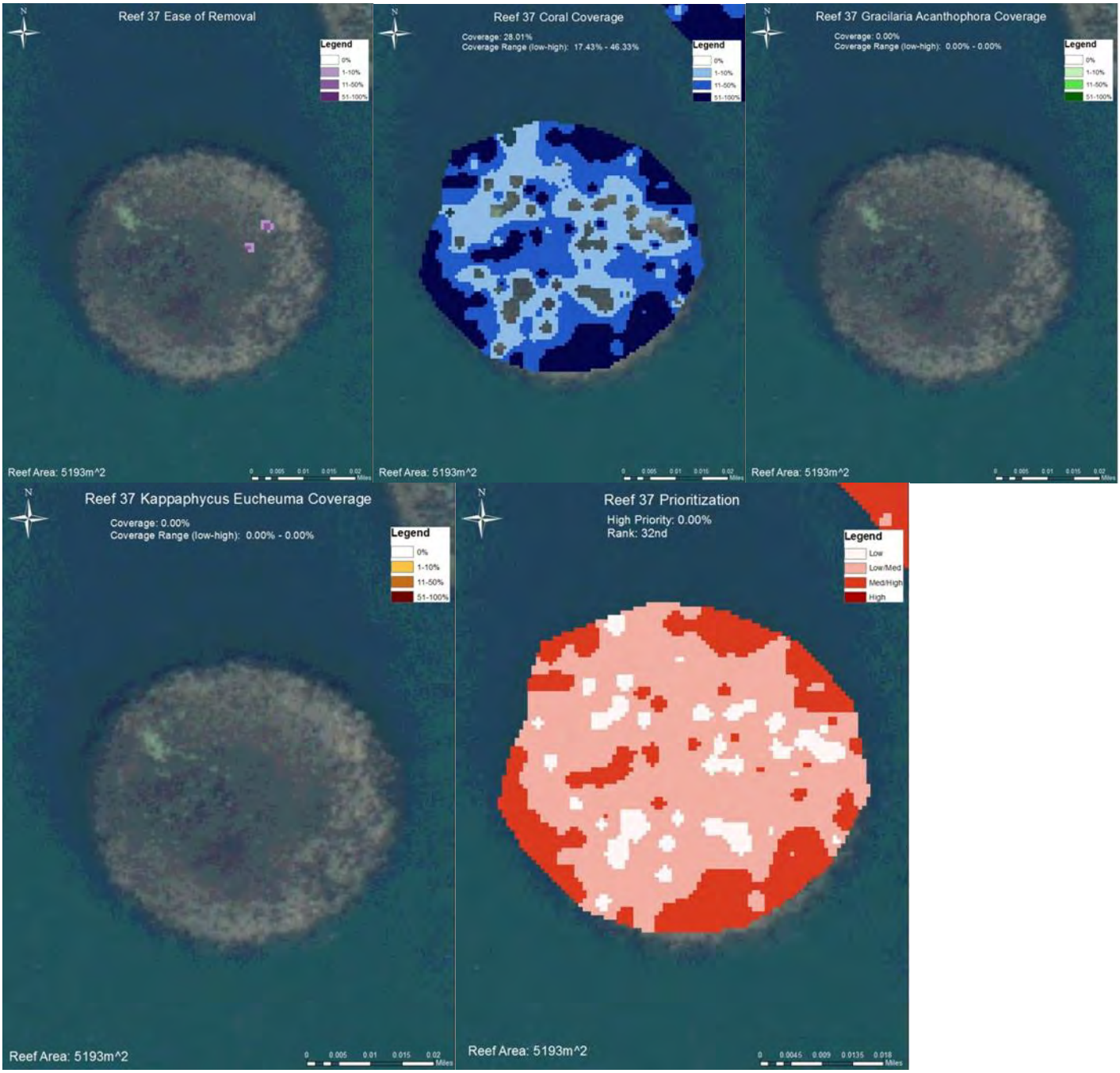






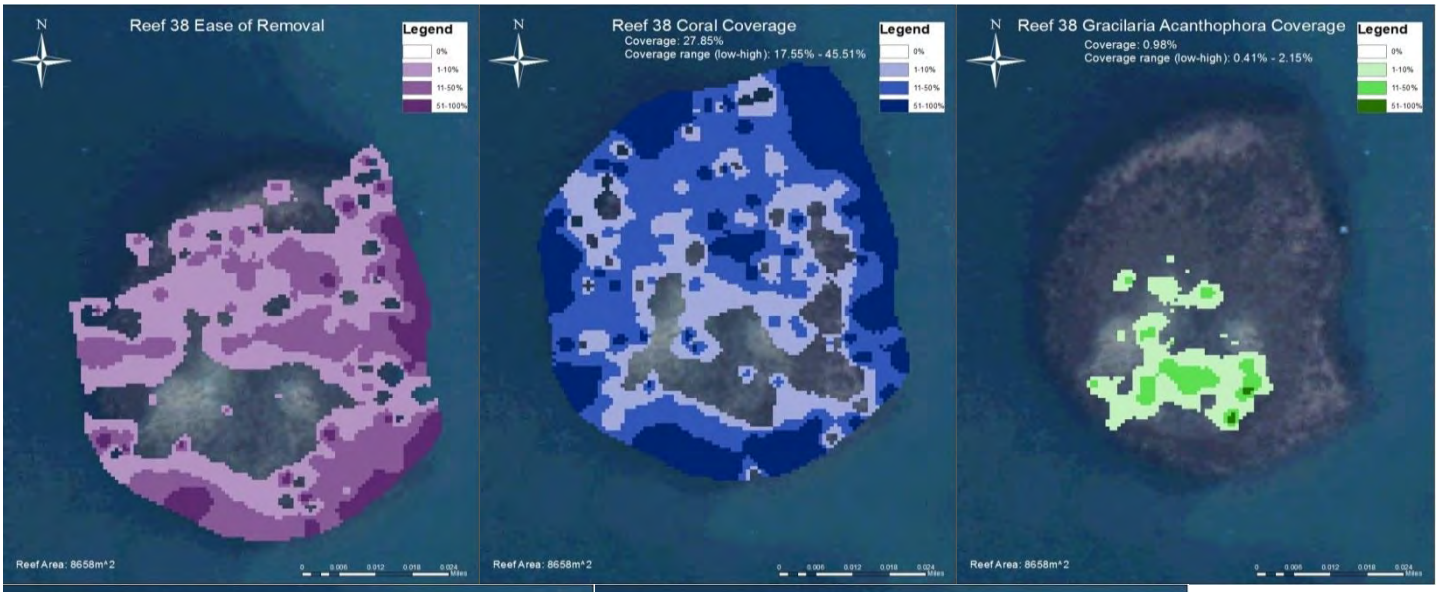
Appendix A: cont'd.

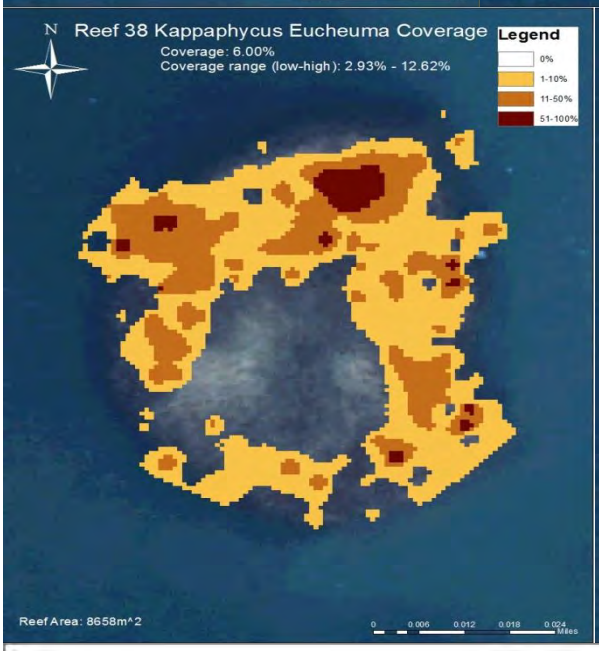
Reef 37

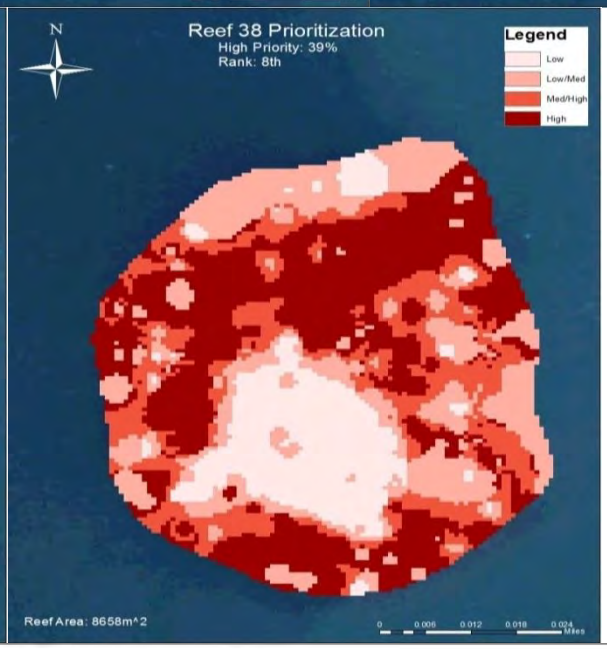


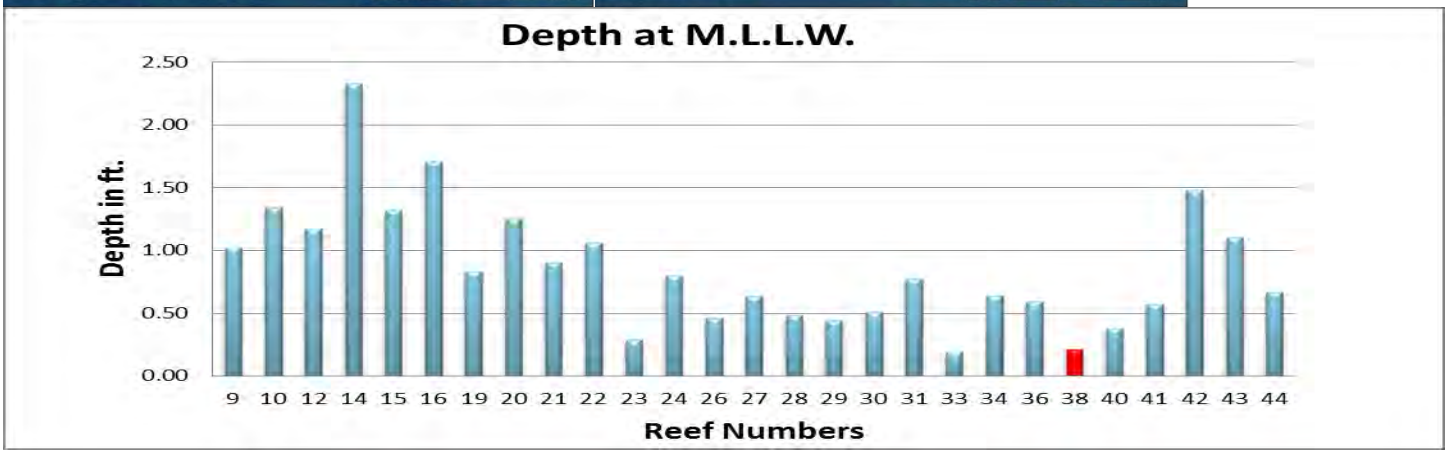
Appendix A: cont'd.

Reef 38



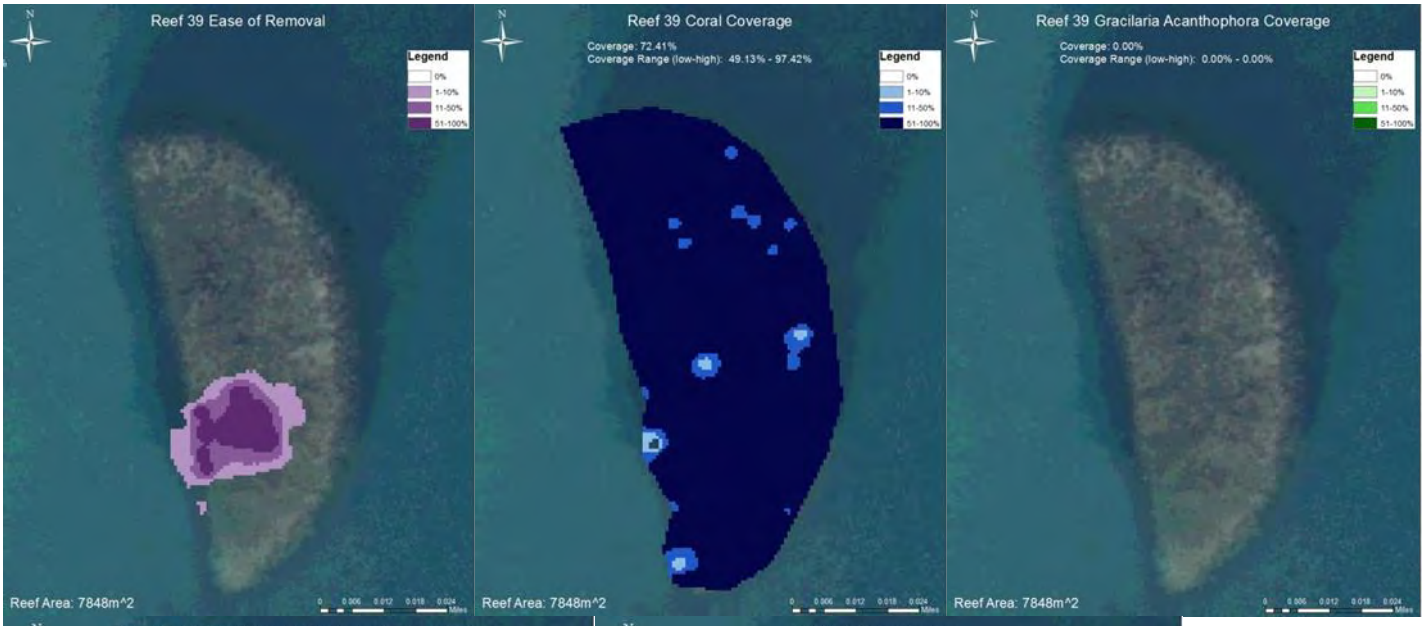


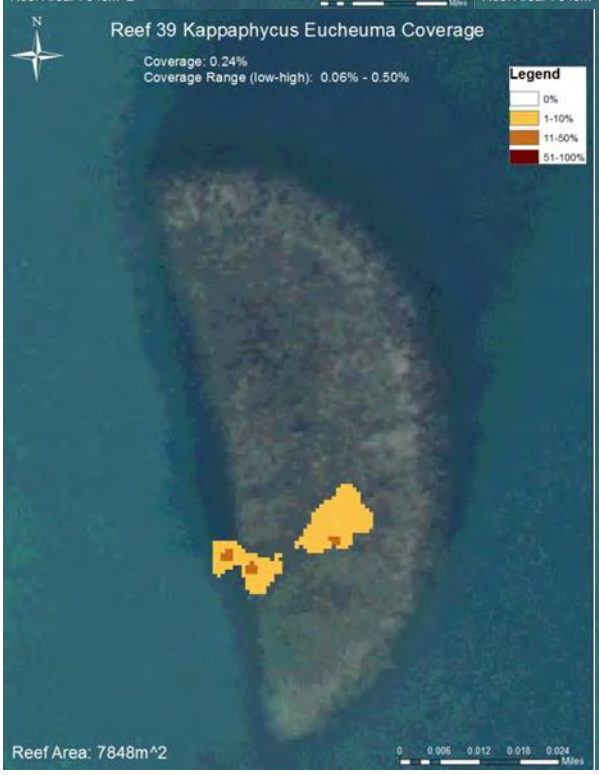




Appendix A: cont'd.

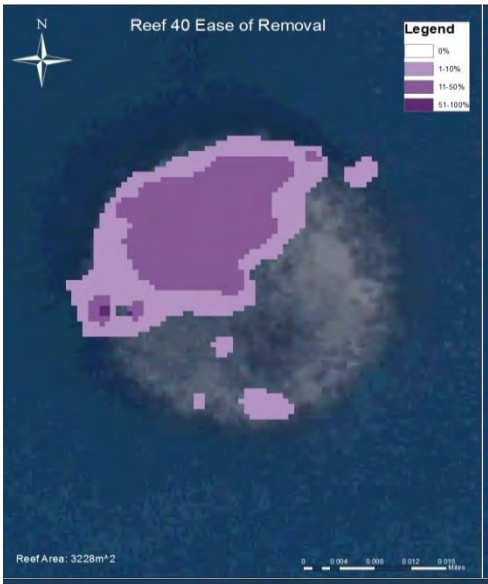
Reef 39

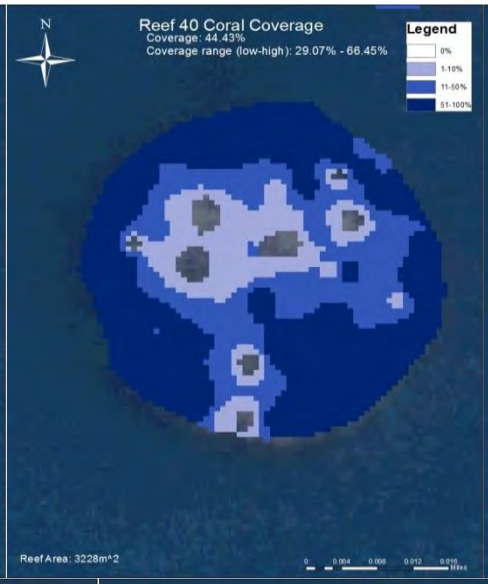


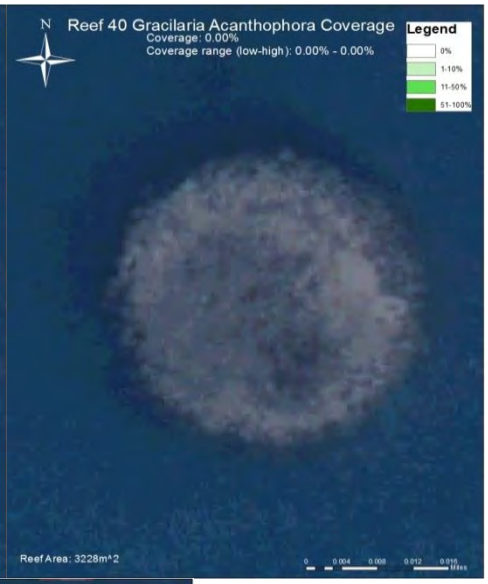


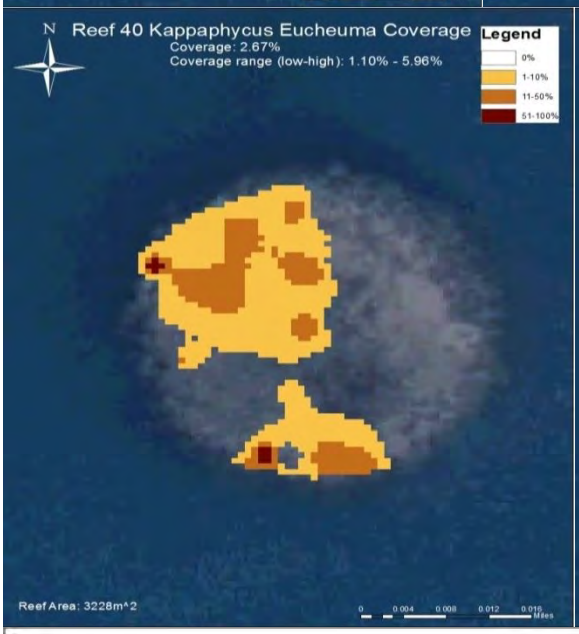
Appendix A: cont'd.

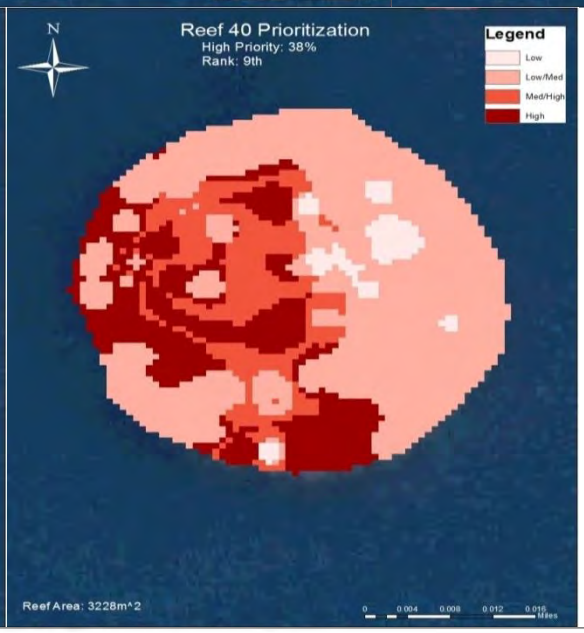
Reef 40

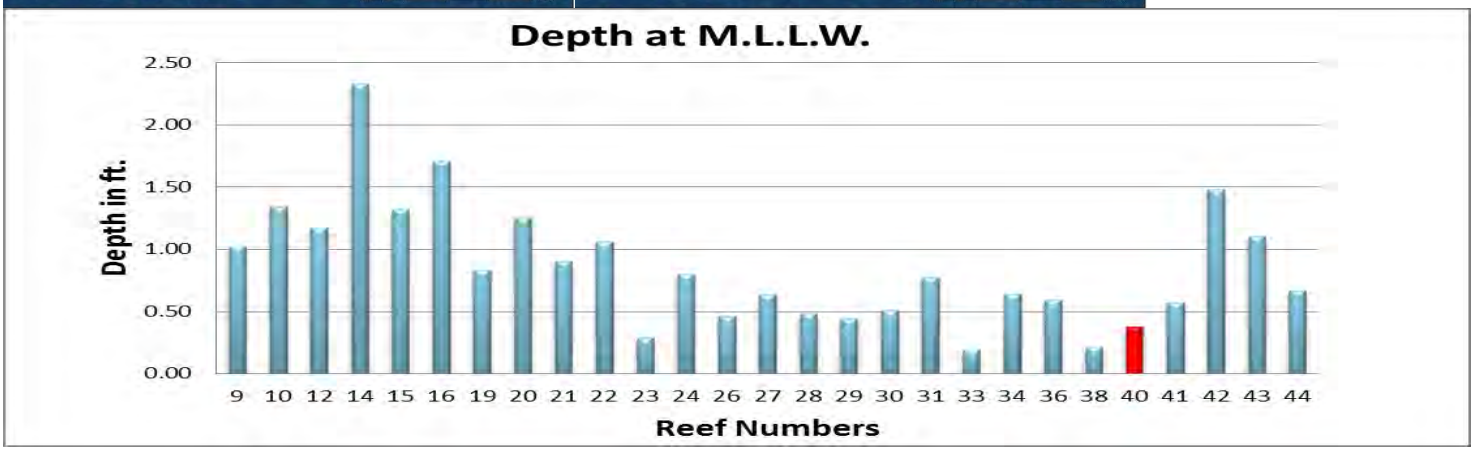






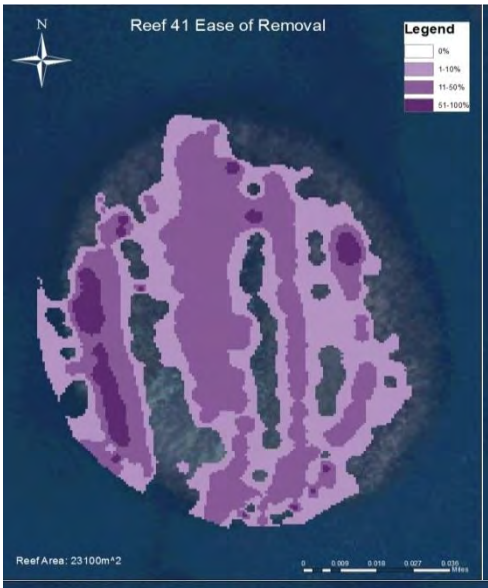


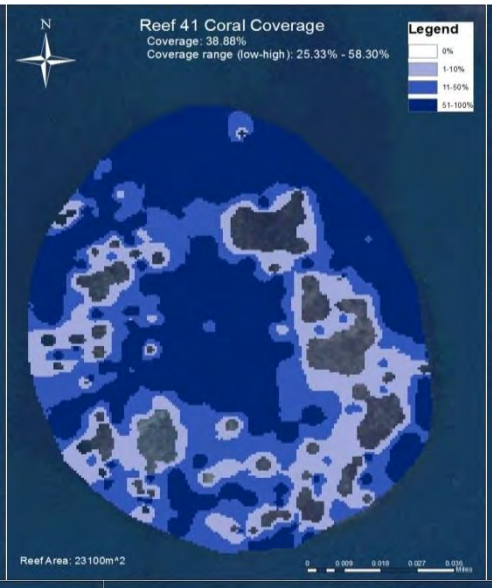


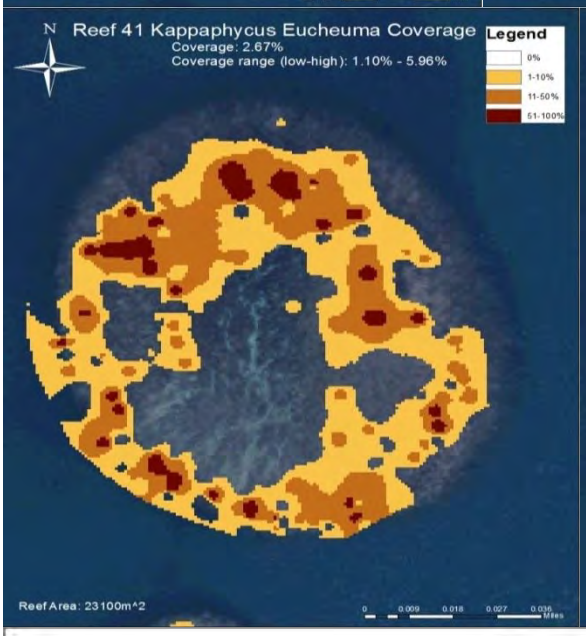


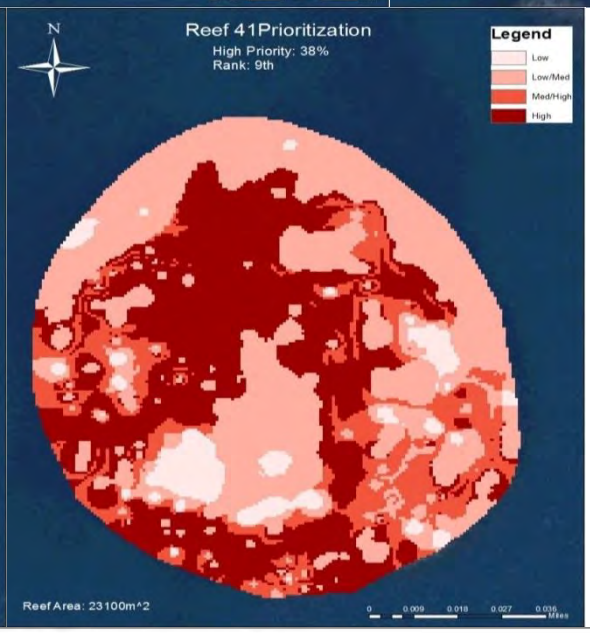
Appendix A: cont'd.

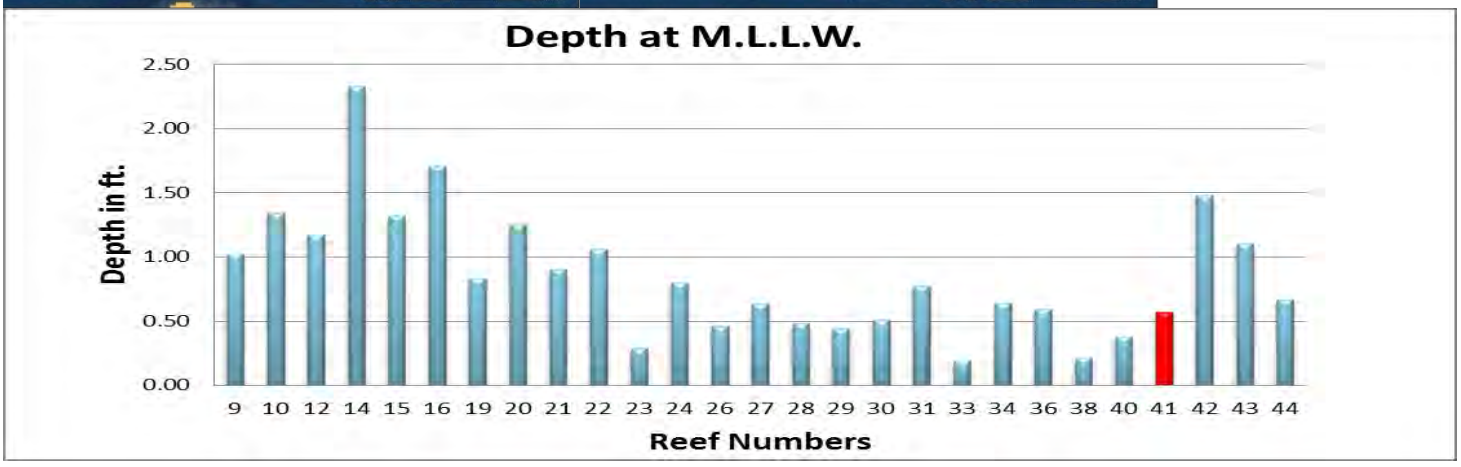
Reef 41





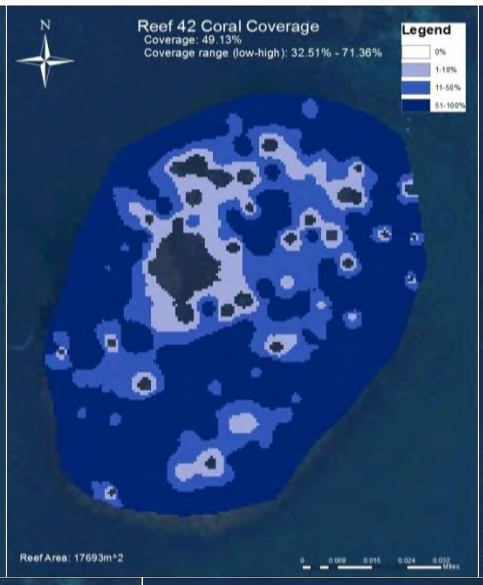


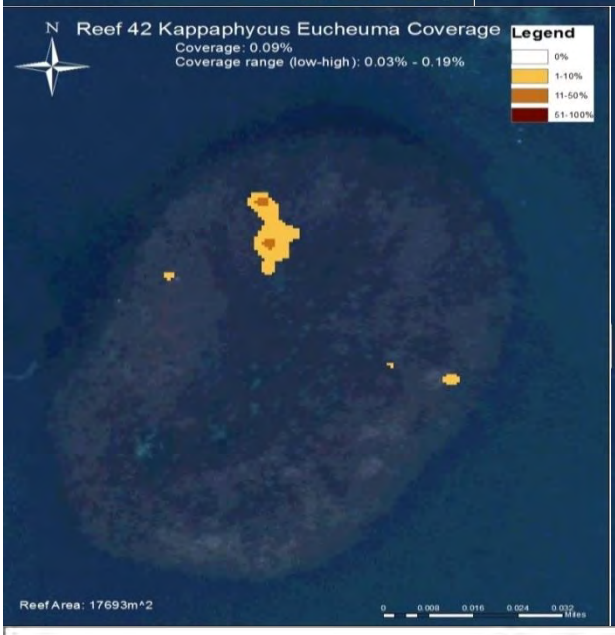


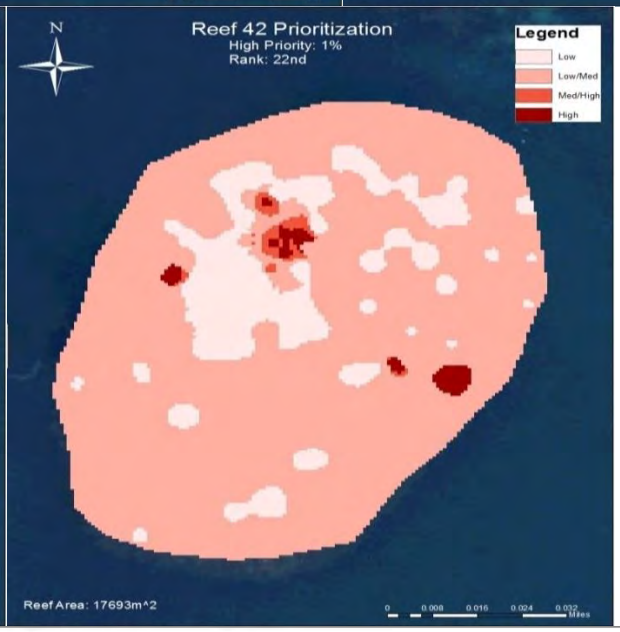


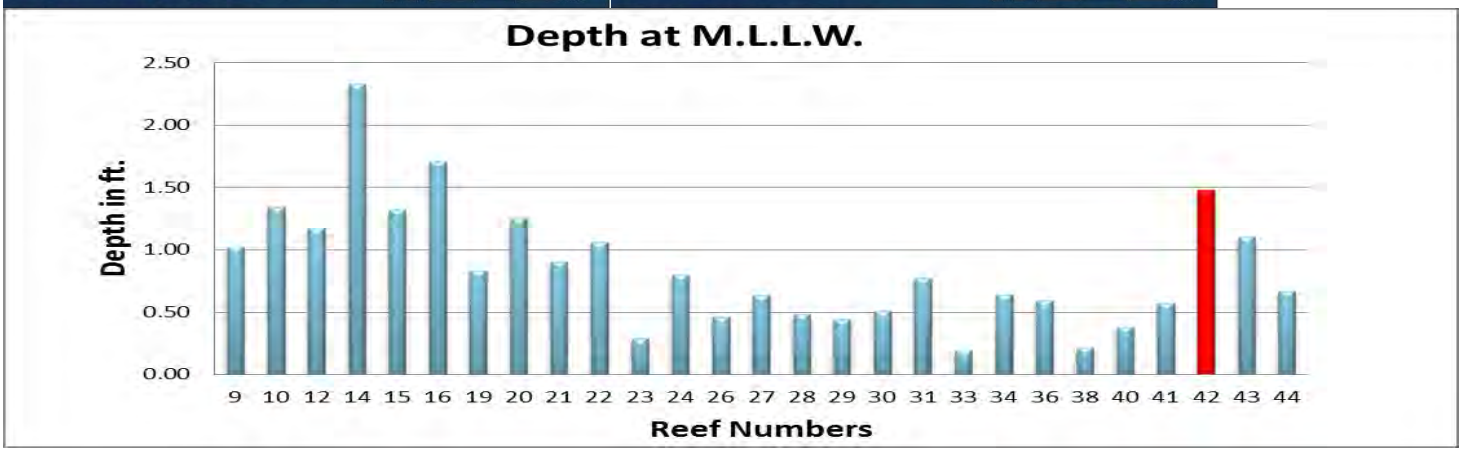
Appendix A: cont'd.

Reef 42



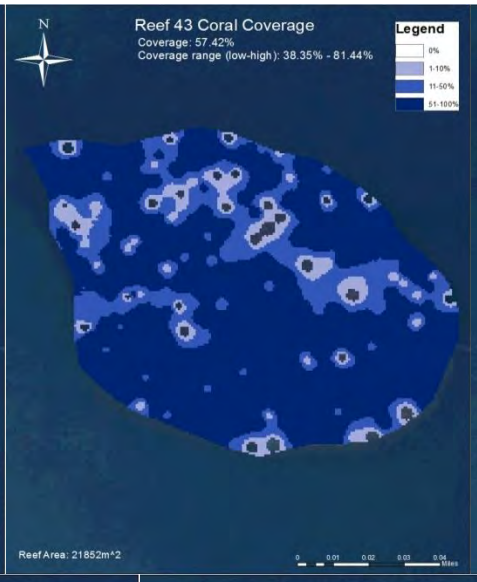


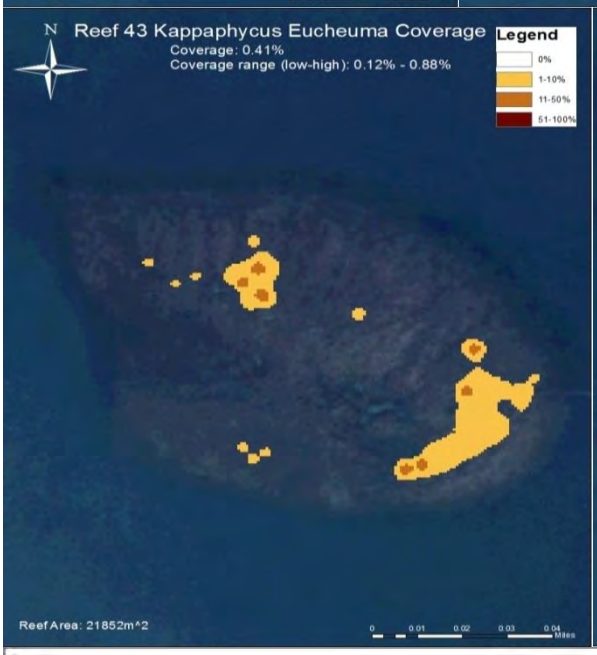


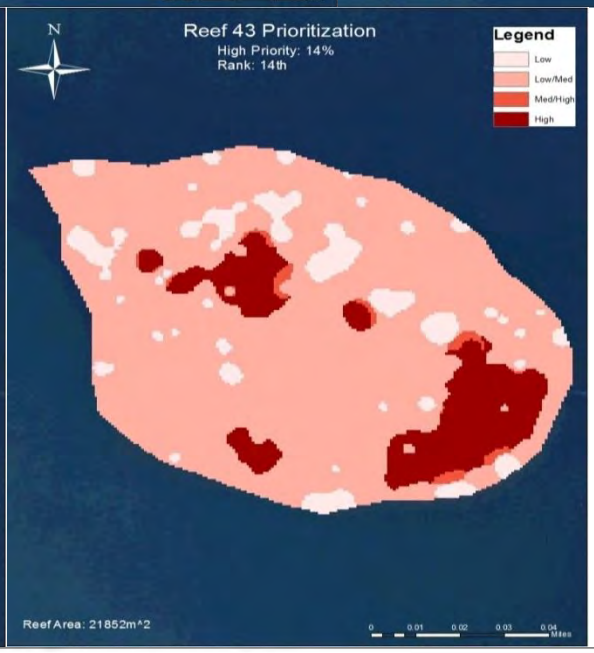


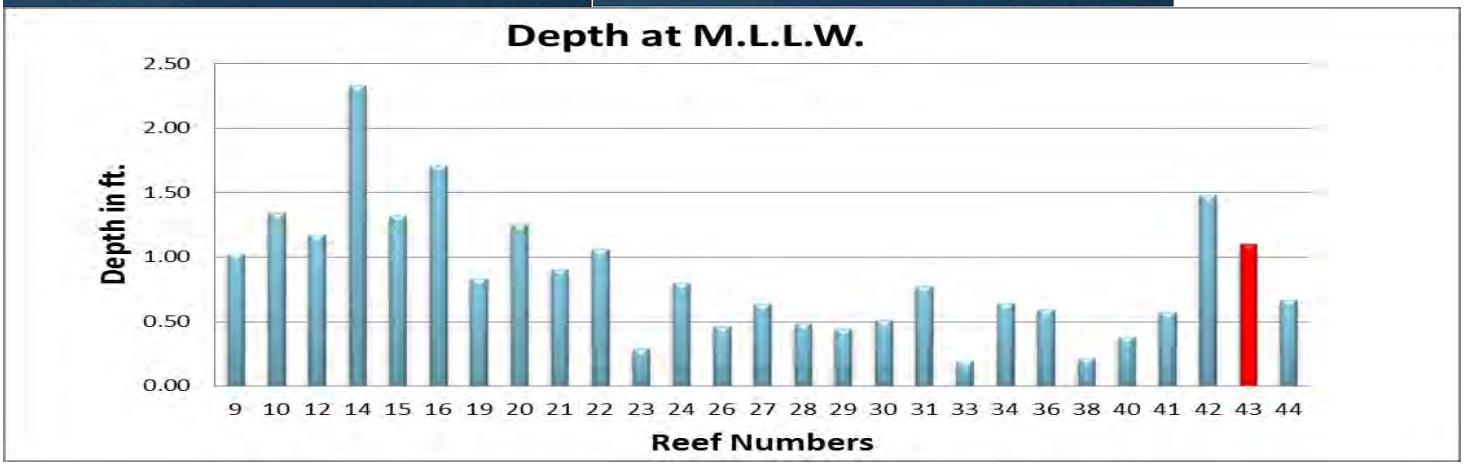
Appendix A: cont'd.

Reef 43



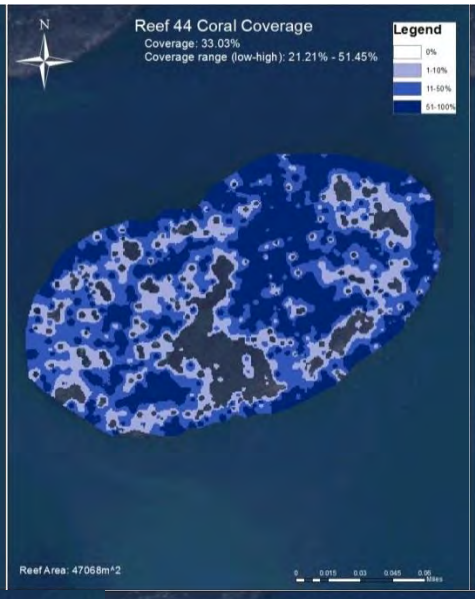


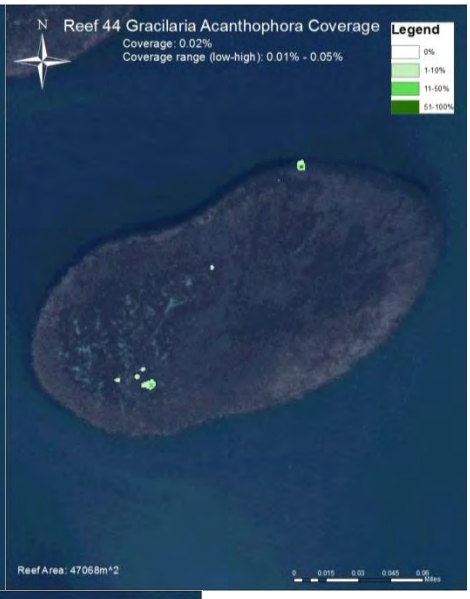


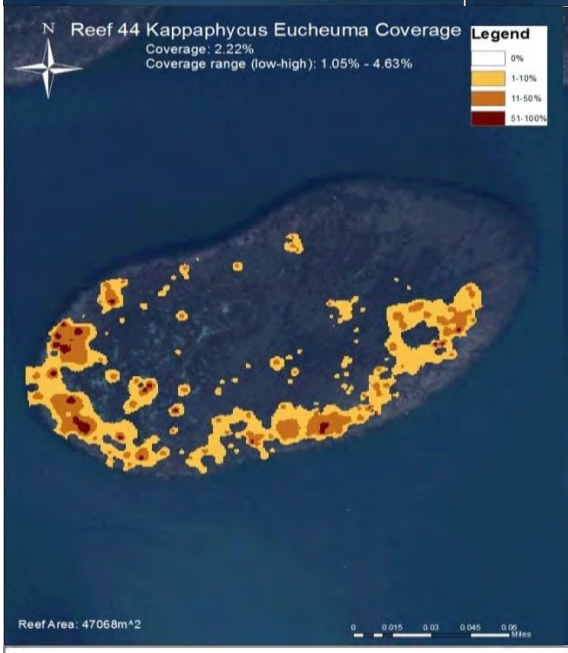


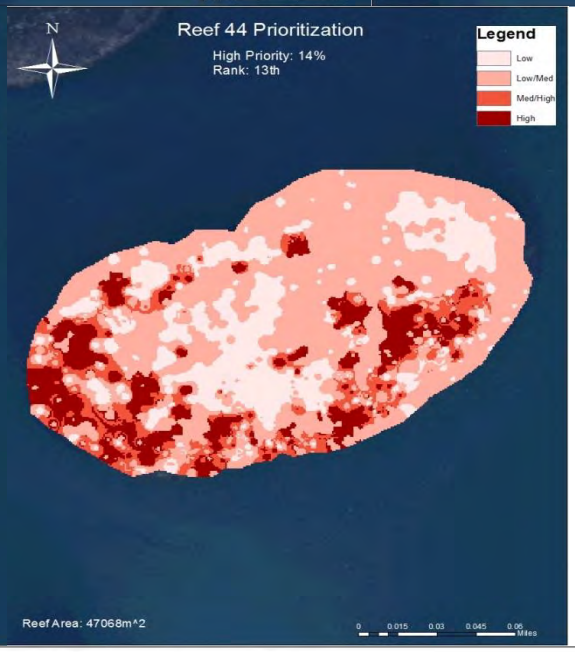
Appendix A: cont'd.

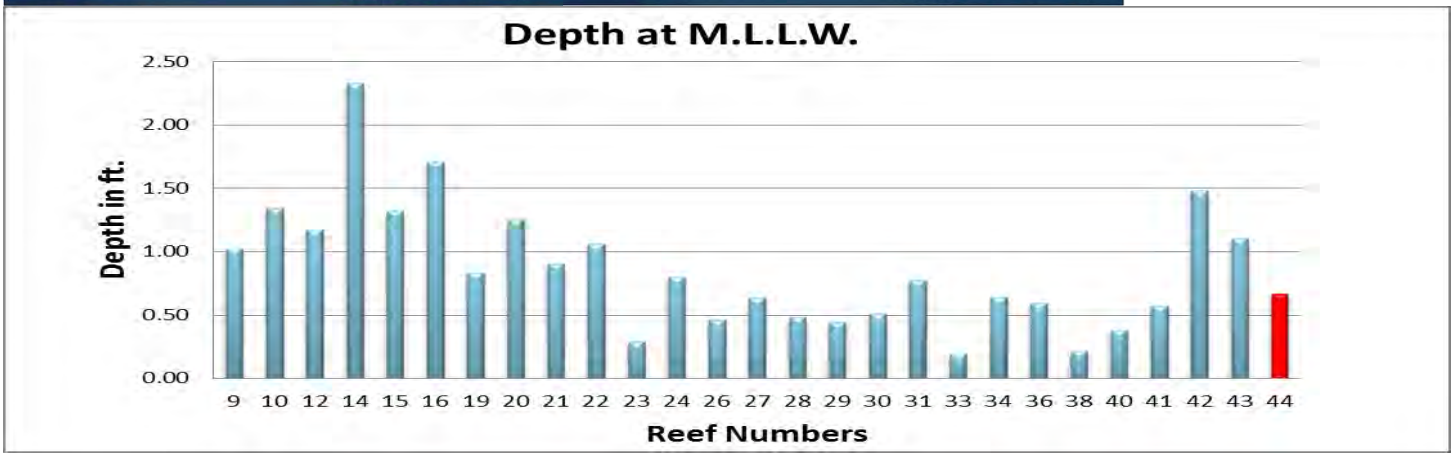
Reef 44





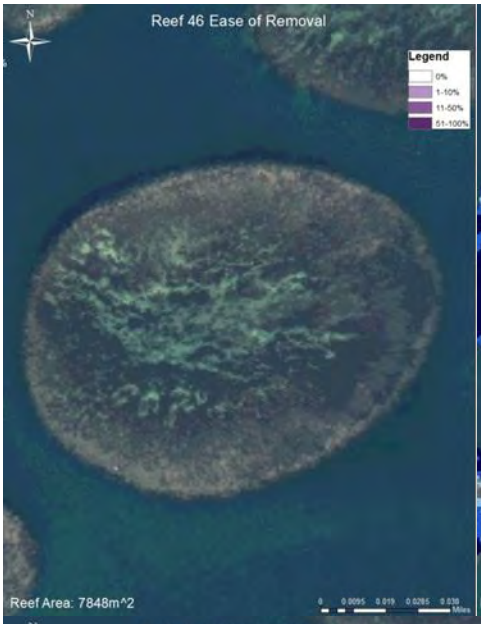


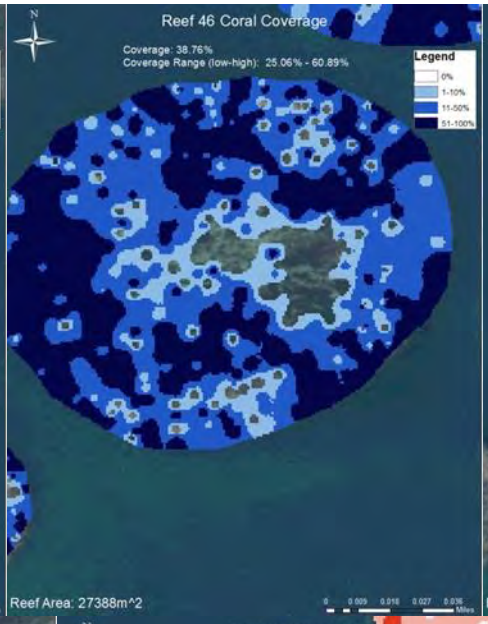


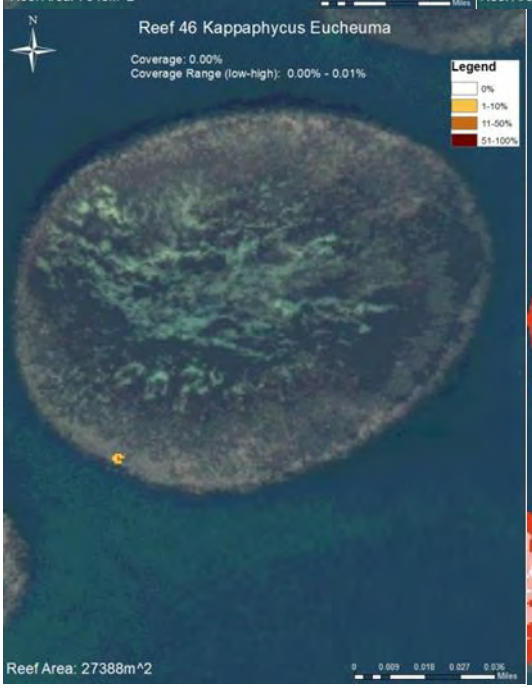


Appendix A: cont'd.

Reef 46

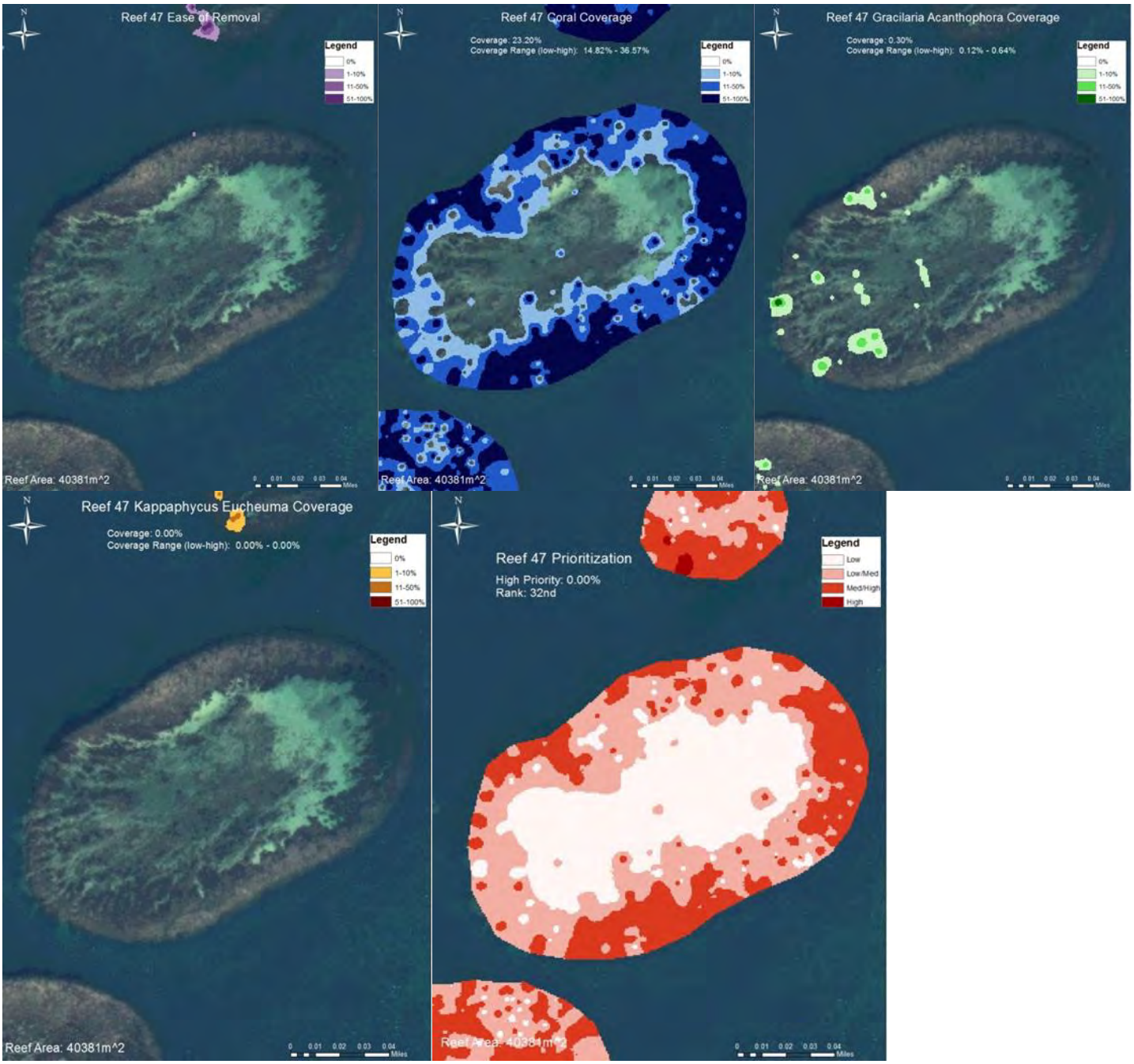






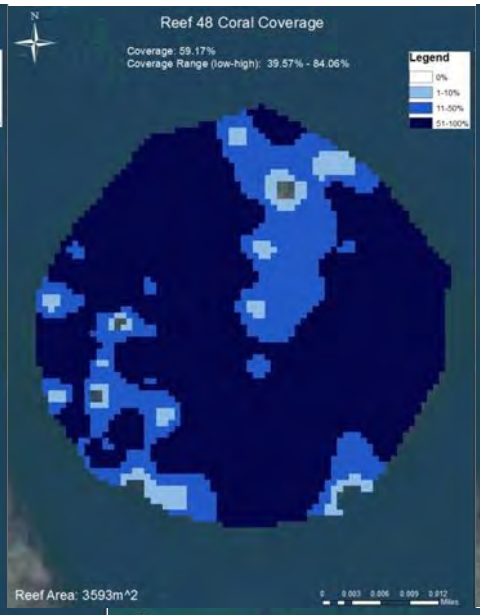
Appendix A: cont'd.

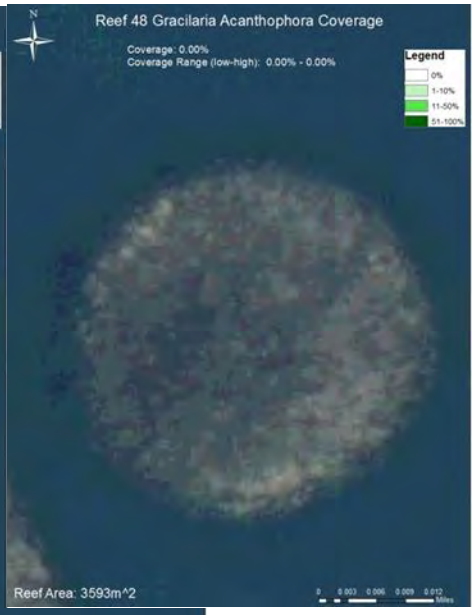
Reef 47

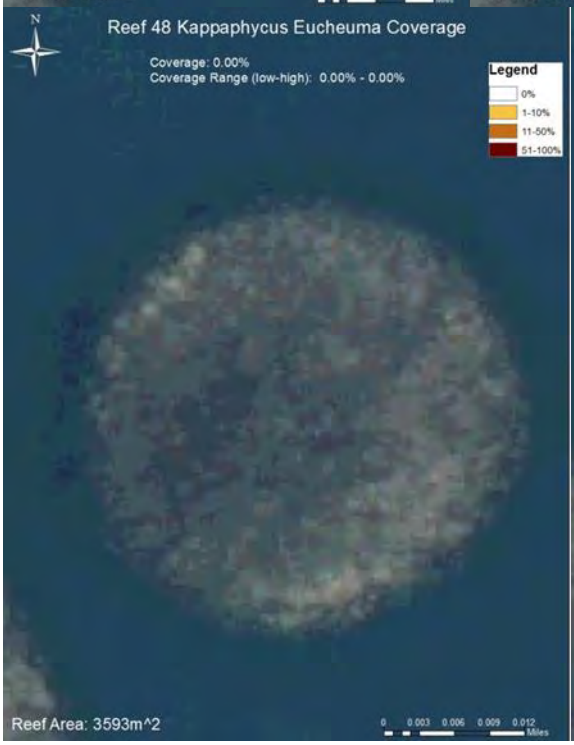


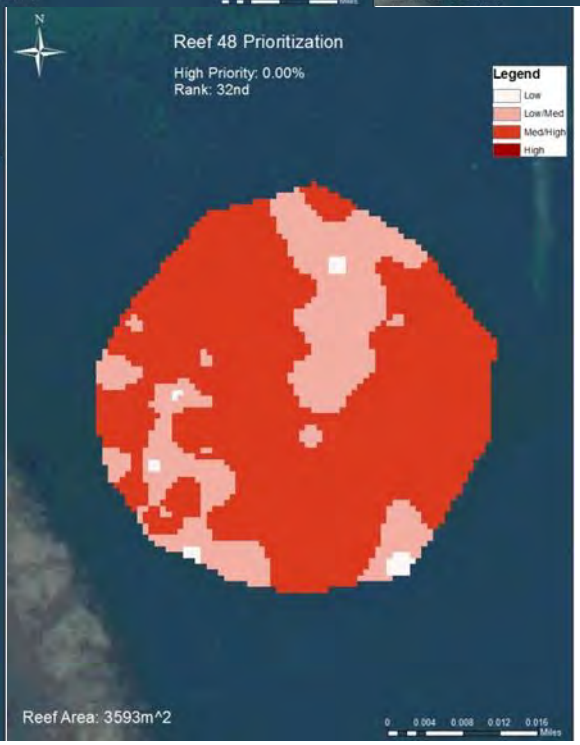
Appendix A: cont'd.

Reef 48



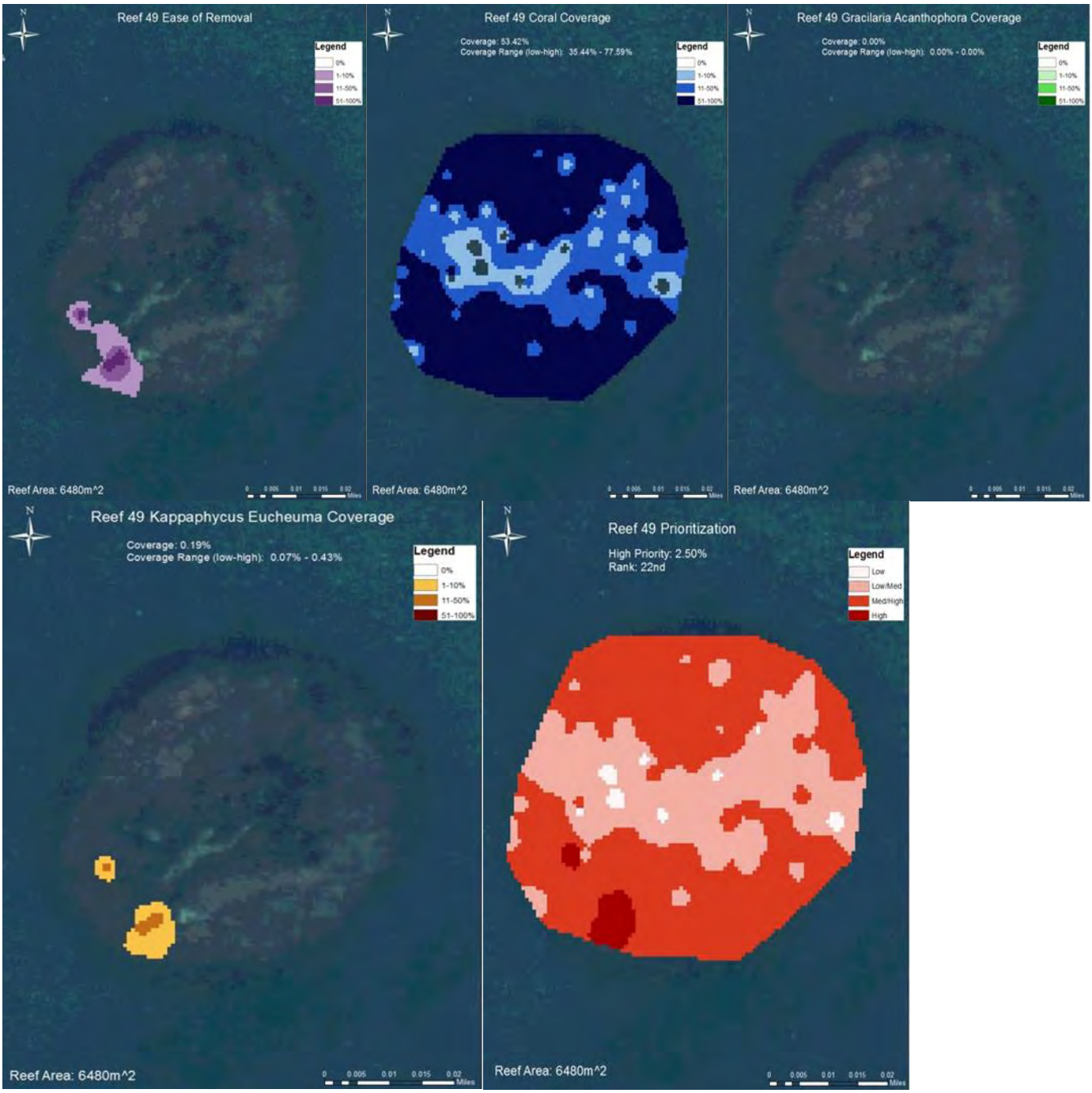




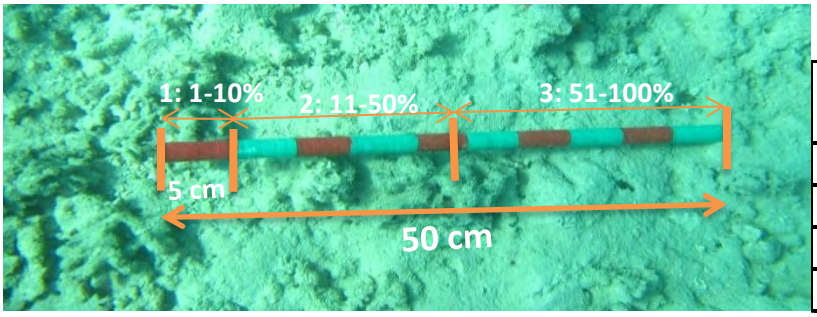


Appendix A: cont'd.

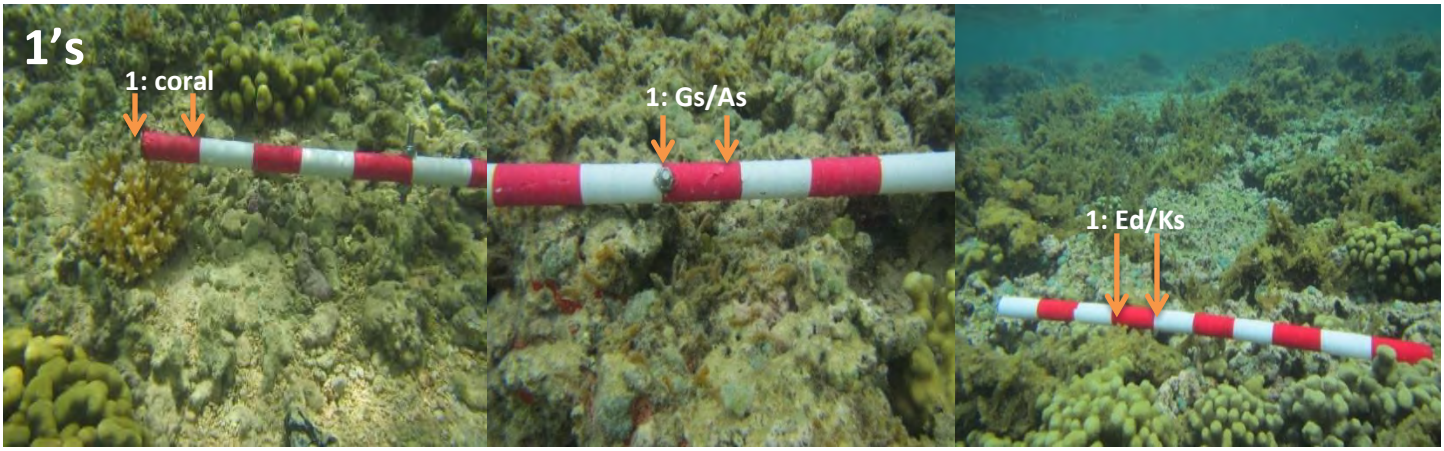
Reef 49

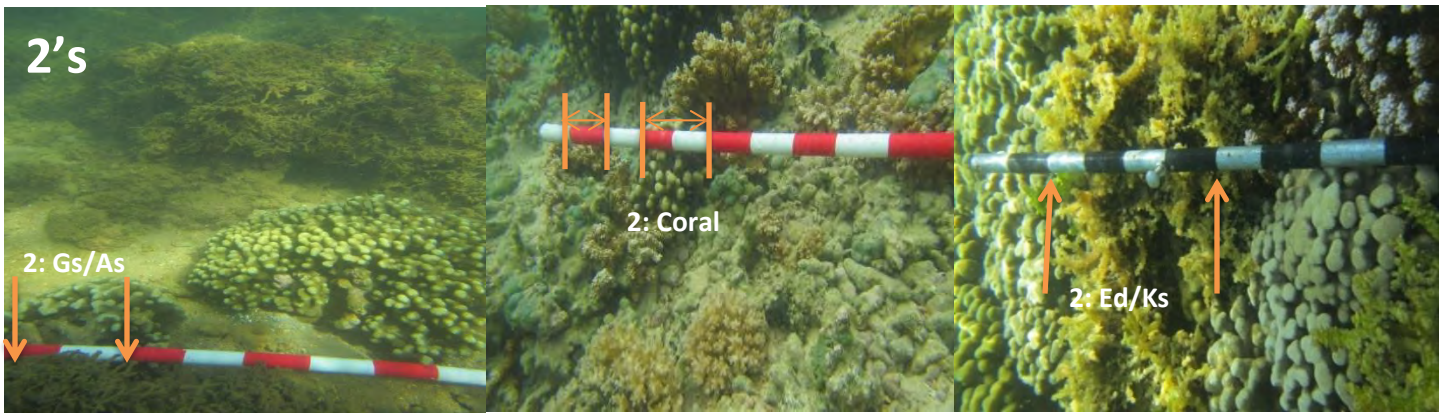


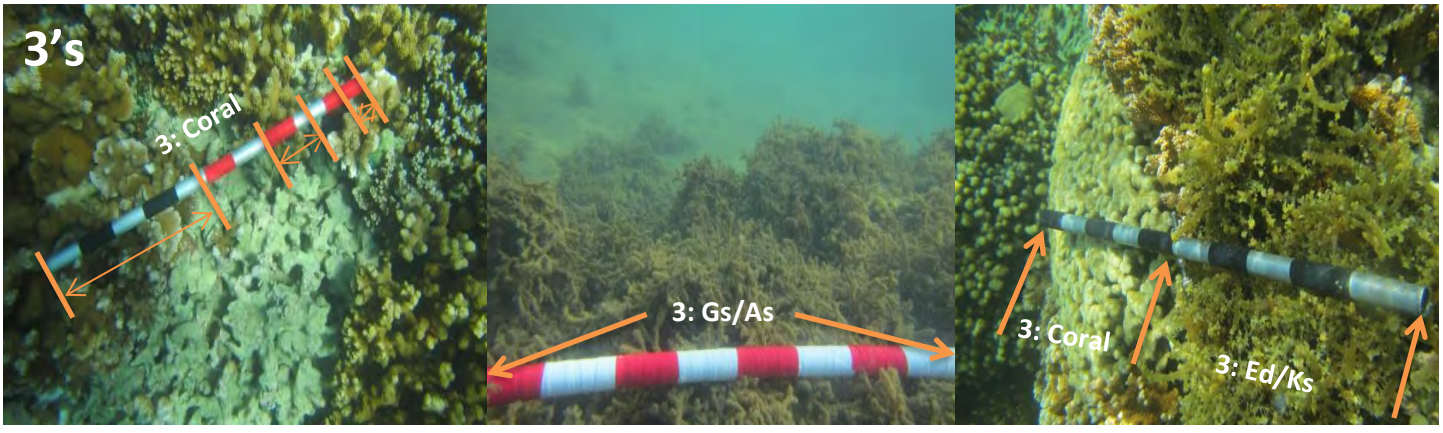
Appendix B: Examples of benthic cover classification system used for the snap-assessment surveys.



Percent cover	Length	Cover Code
0%	0 cm	0
1-10%	0.1-5 cm	1
11-50%	5-25 cm	2
51-100%	25-50 cm	3

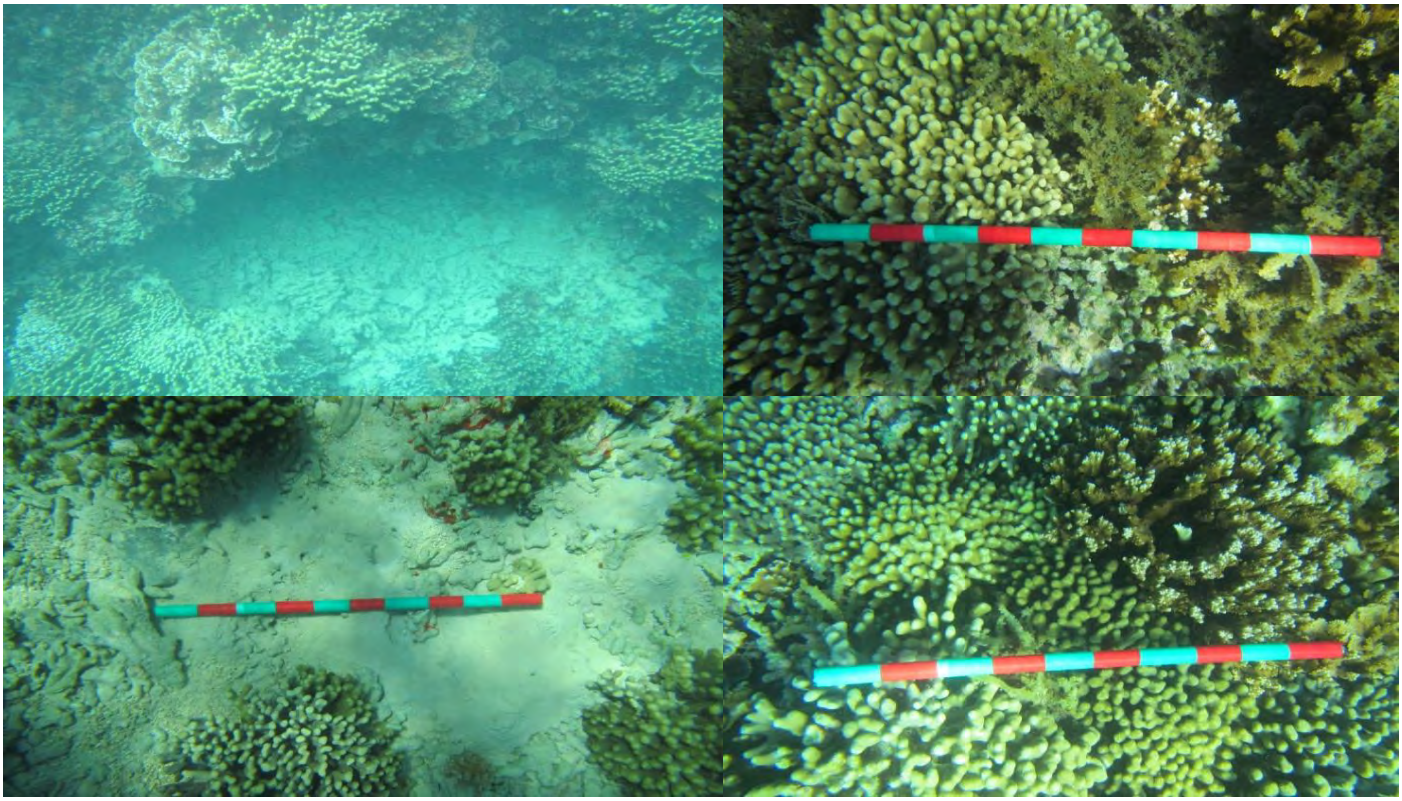






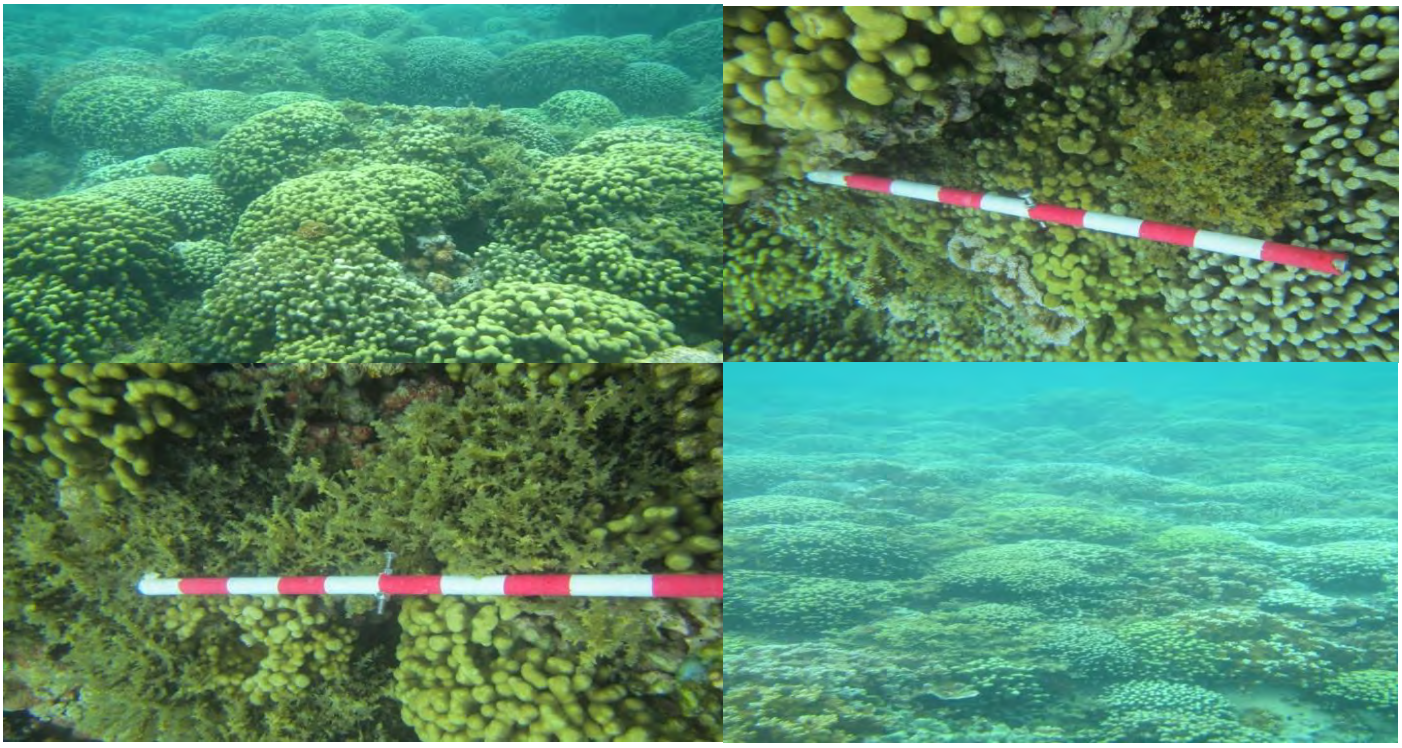
Appendix C: Photo documentation of surveyed reefs.

Reef 15



Photos Taken 02/19/2014

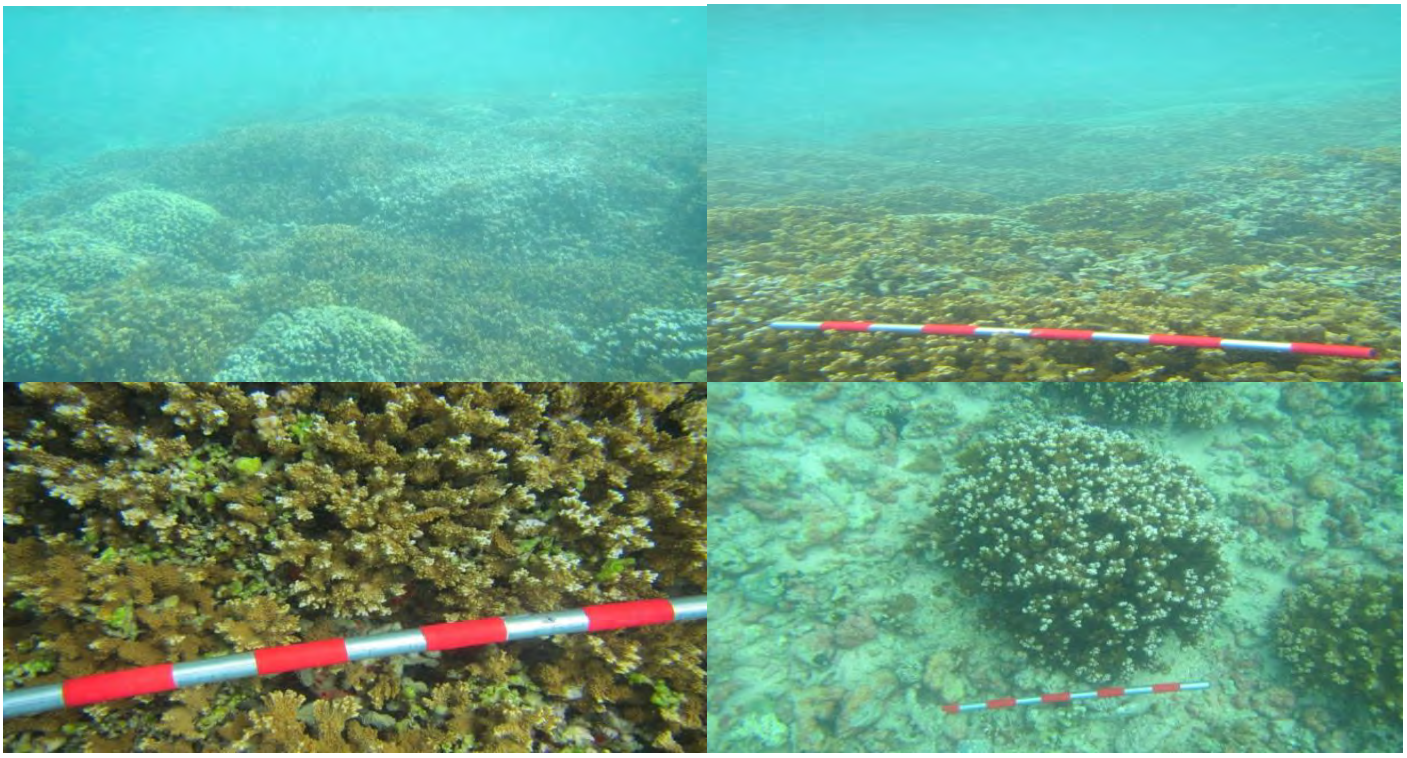
Reef 16



Photos taken 02/19/2014

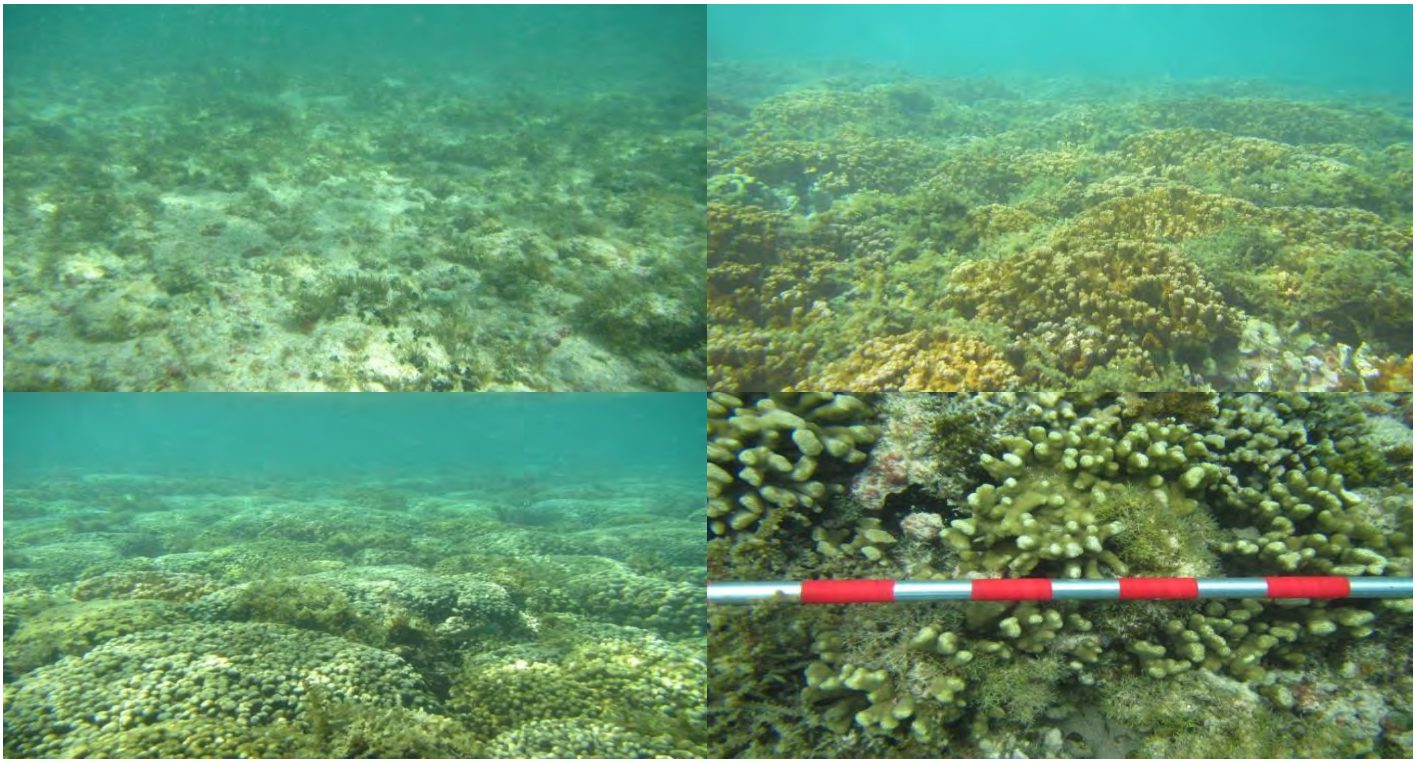
Appendix C: cont'd.

Reef 12



Photos Taken 2/27/2014

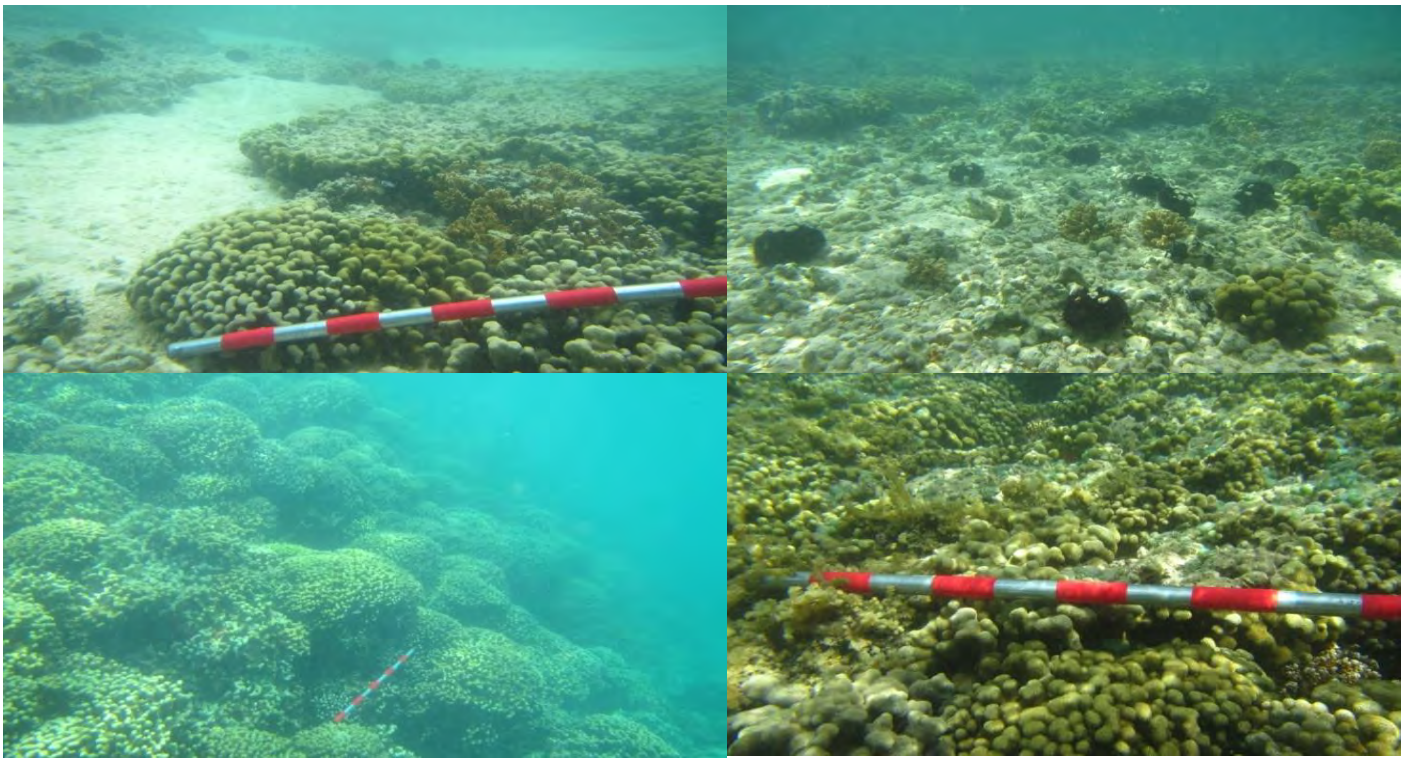
Reef 14



Photos Taken 2/27/2014

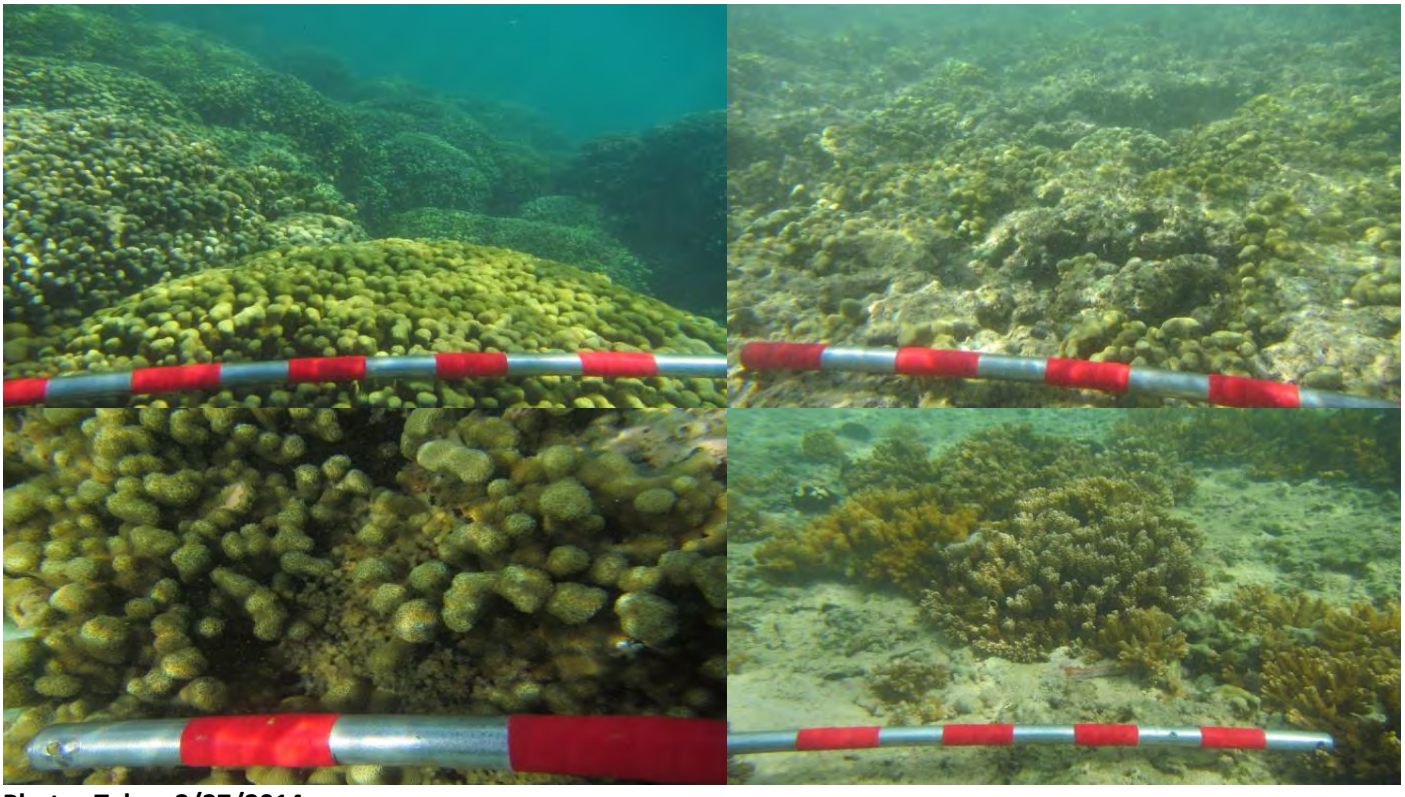
Appendix C: cont'd.

Reef 26



Photos Taken 2/27/2014

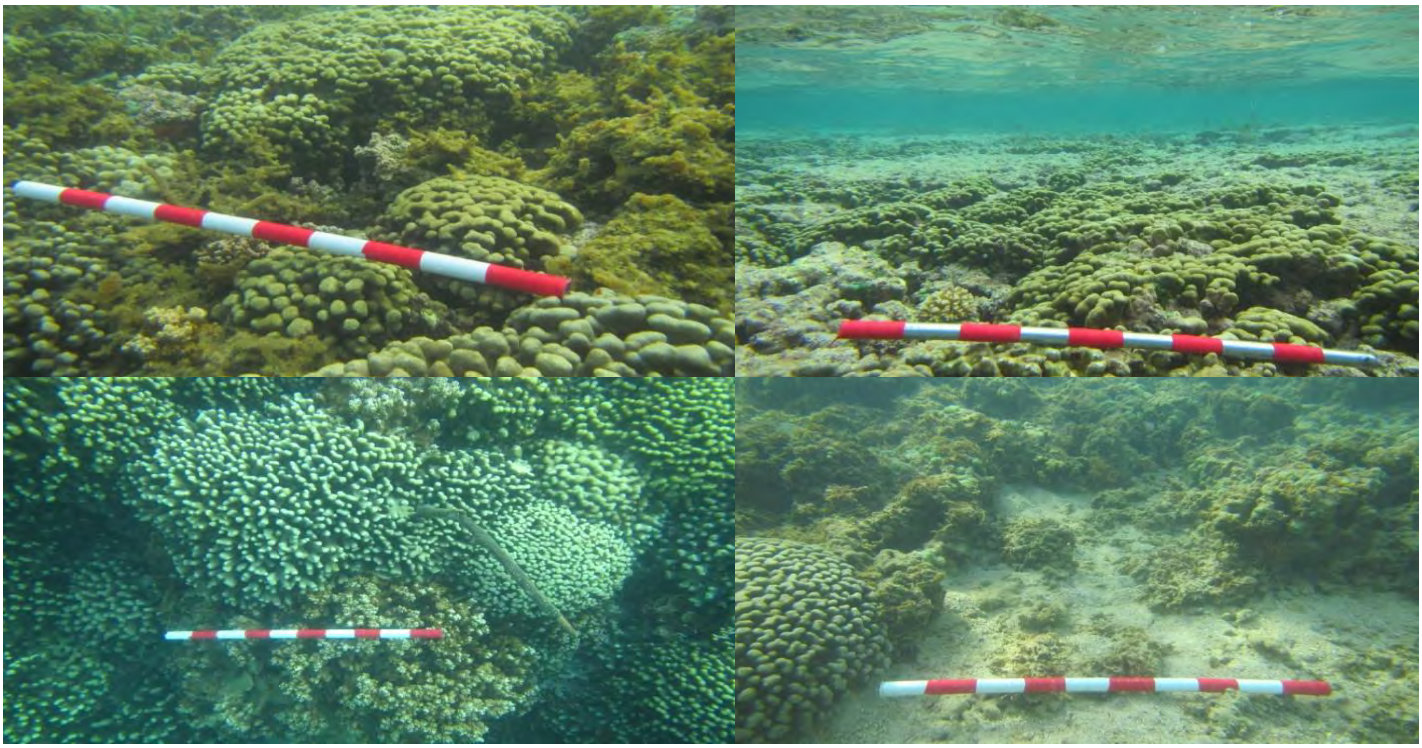
Reef 27



Photos Taken 2/27/2014

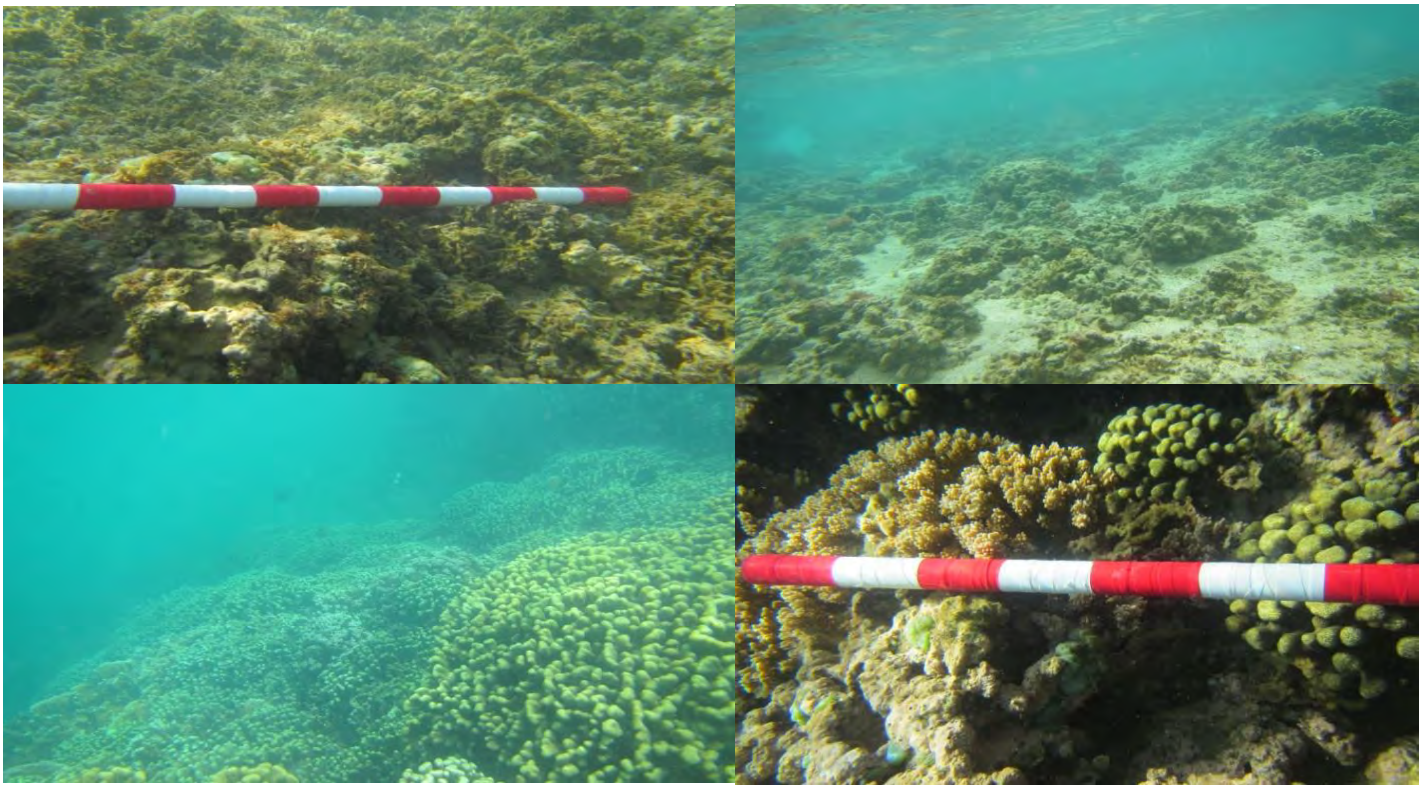
Appendix C: cont'd.

Reef 38



Photos Taken 2/27/2014

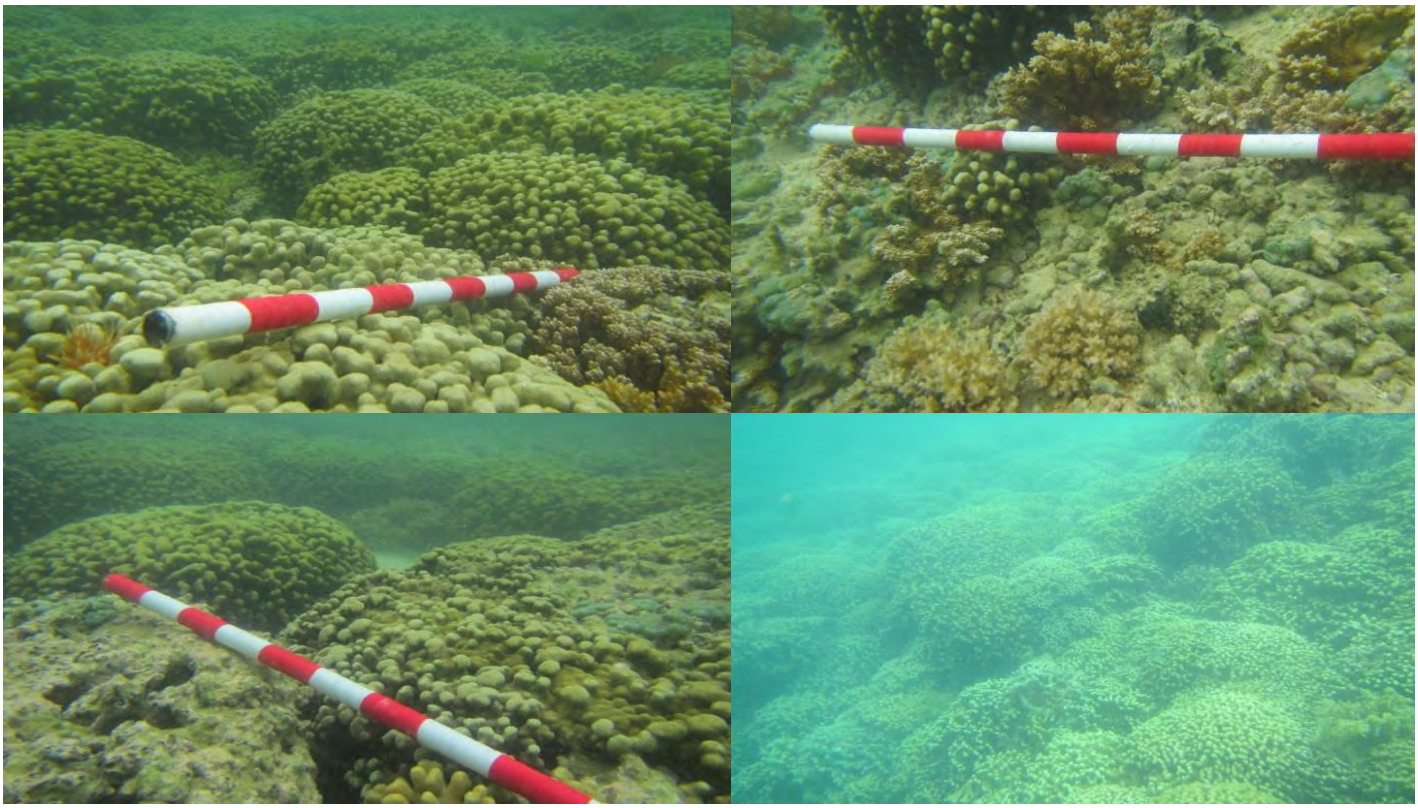
Reef 33



Photos Taken 3/10/2014

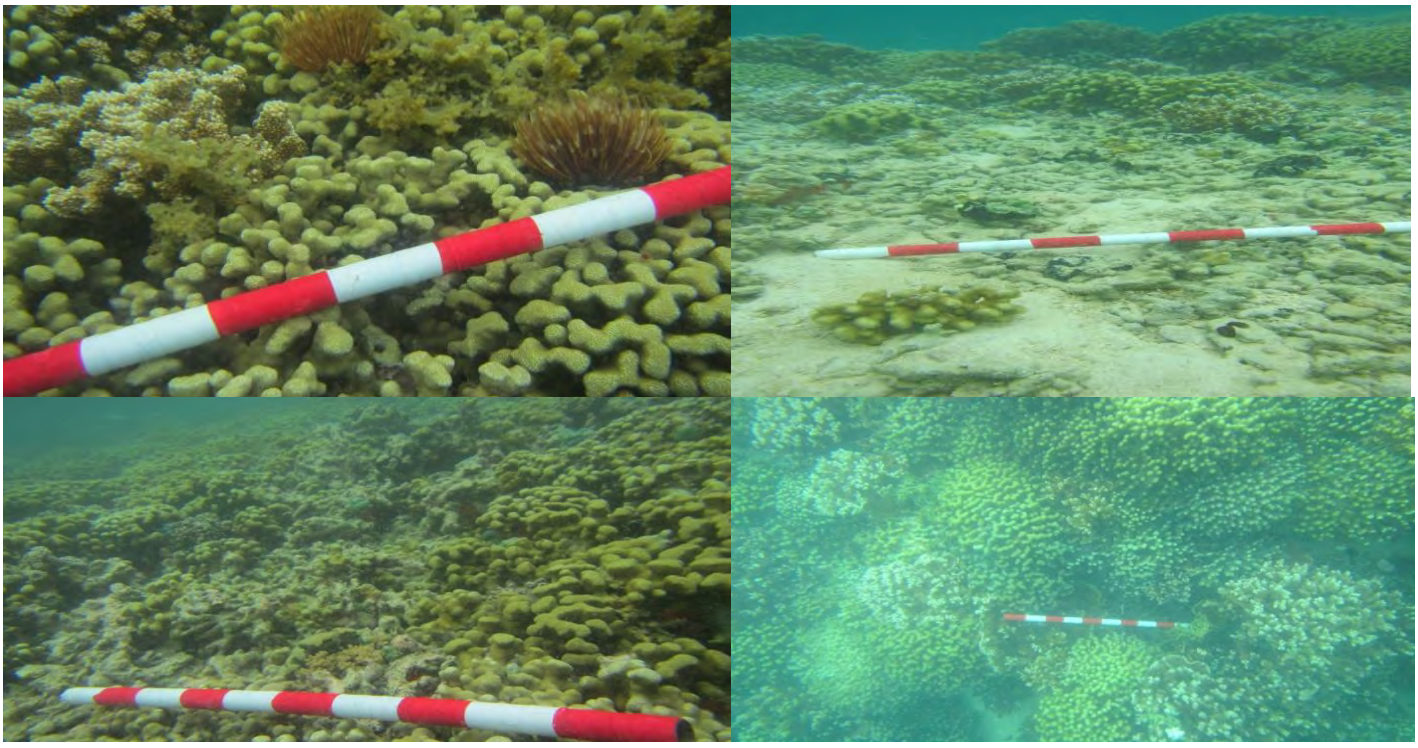
Appendix C: cont'd.

Reef 24



Photos Taken 03/10/2014

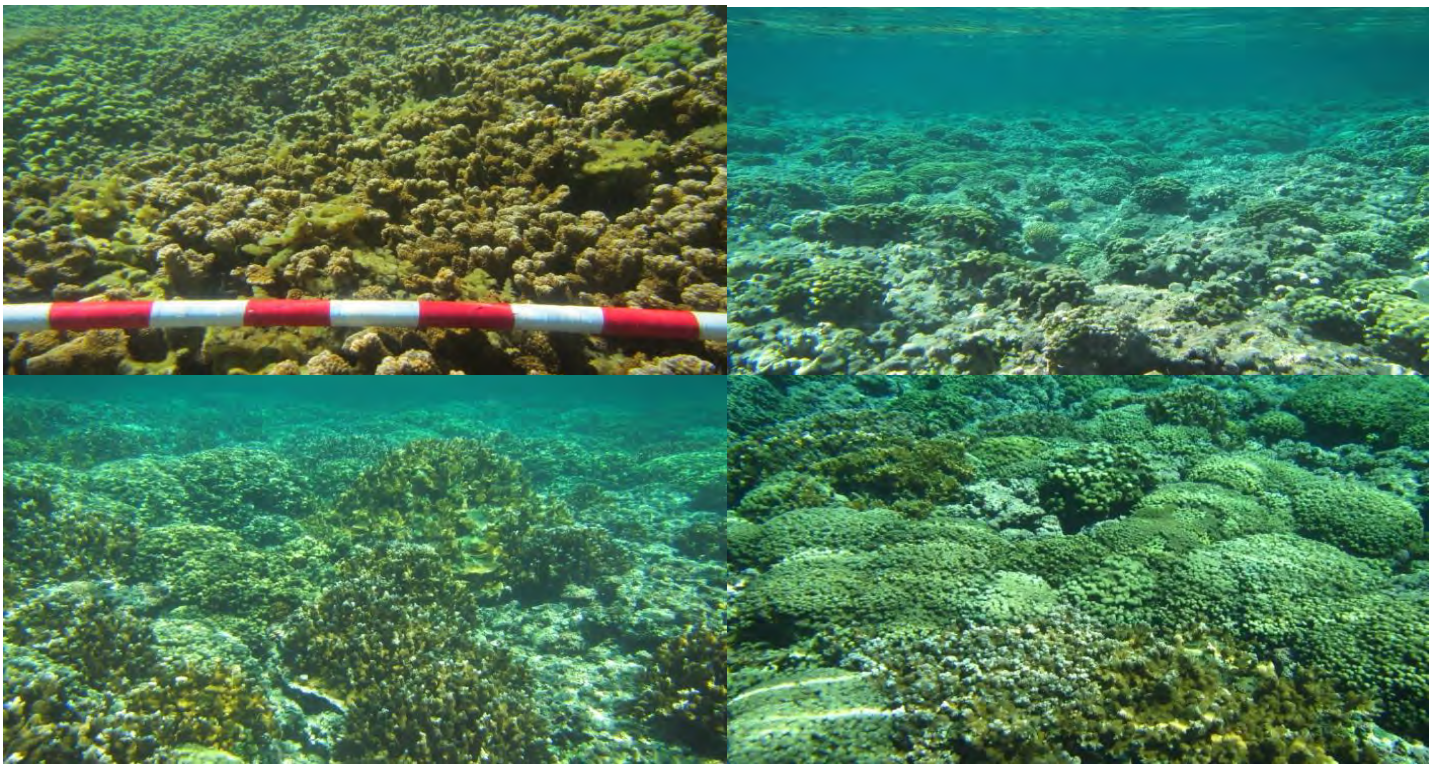
Reef 20



Photos Taken 03/10/2014

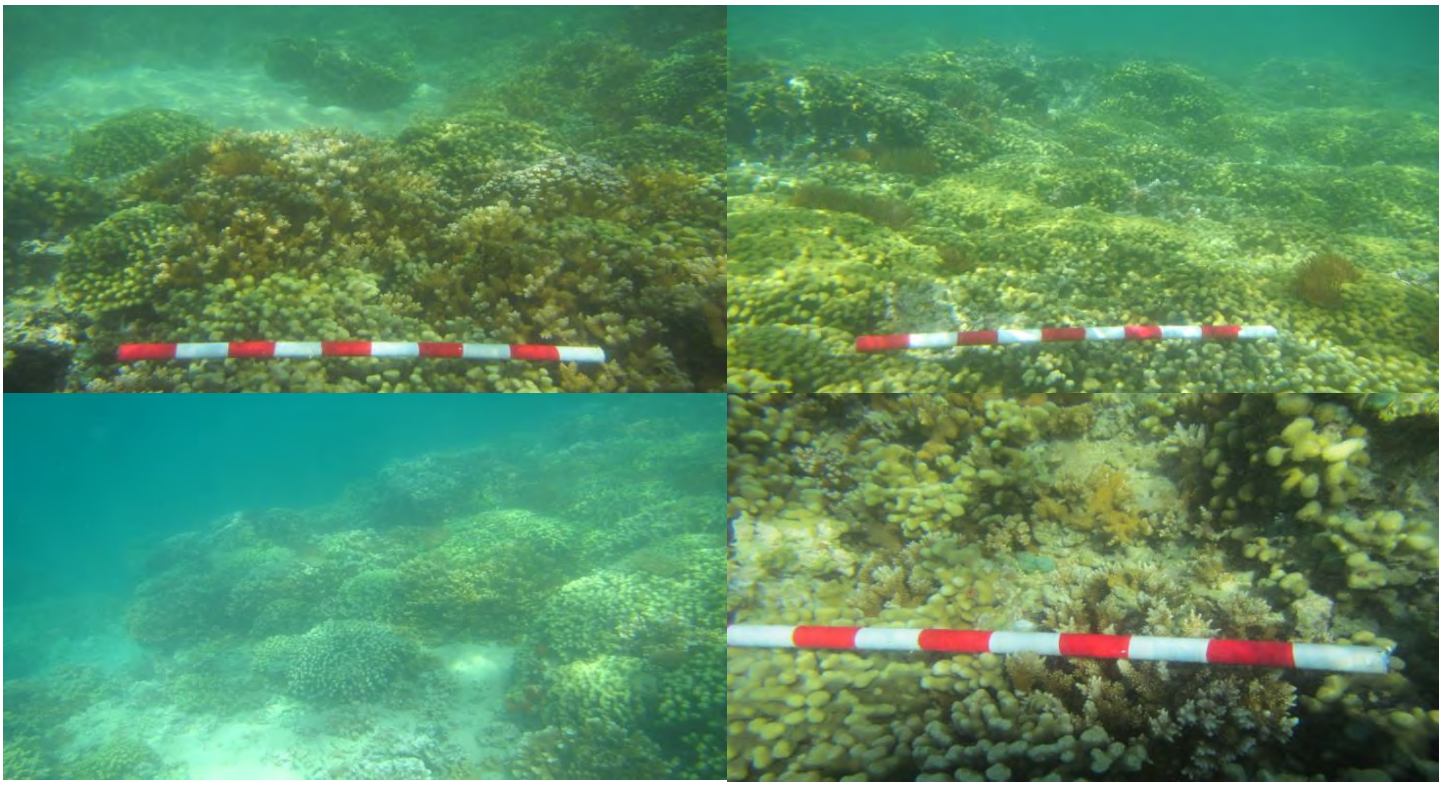
Appendix C: cont'd.

Reef 44



Photos Taken 03/11/2014

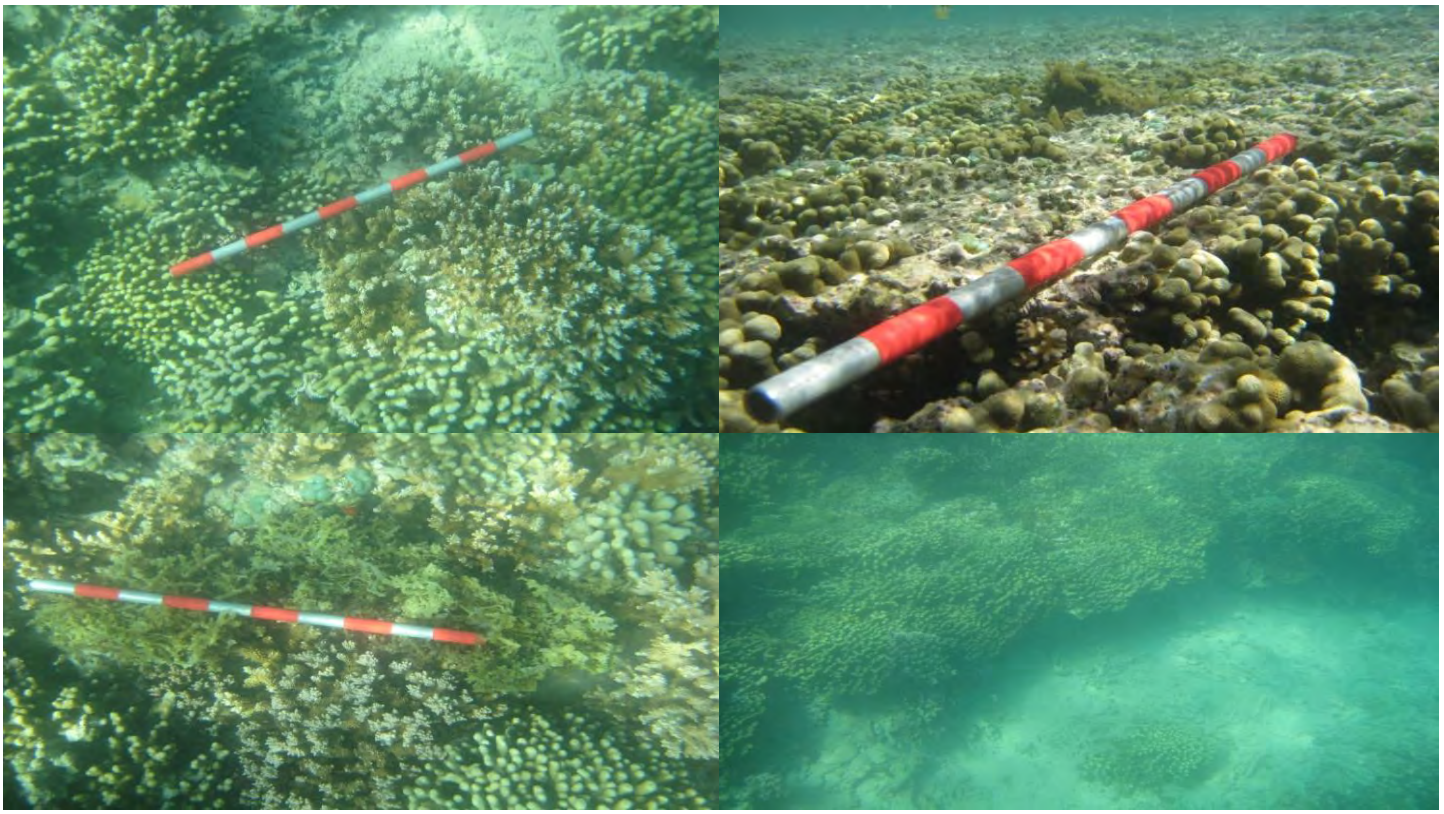
Reef 22



Photos Taken 03/11/2014

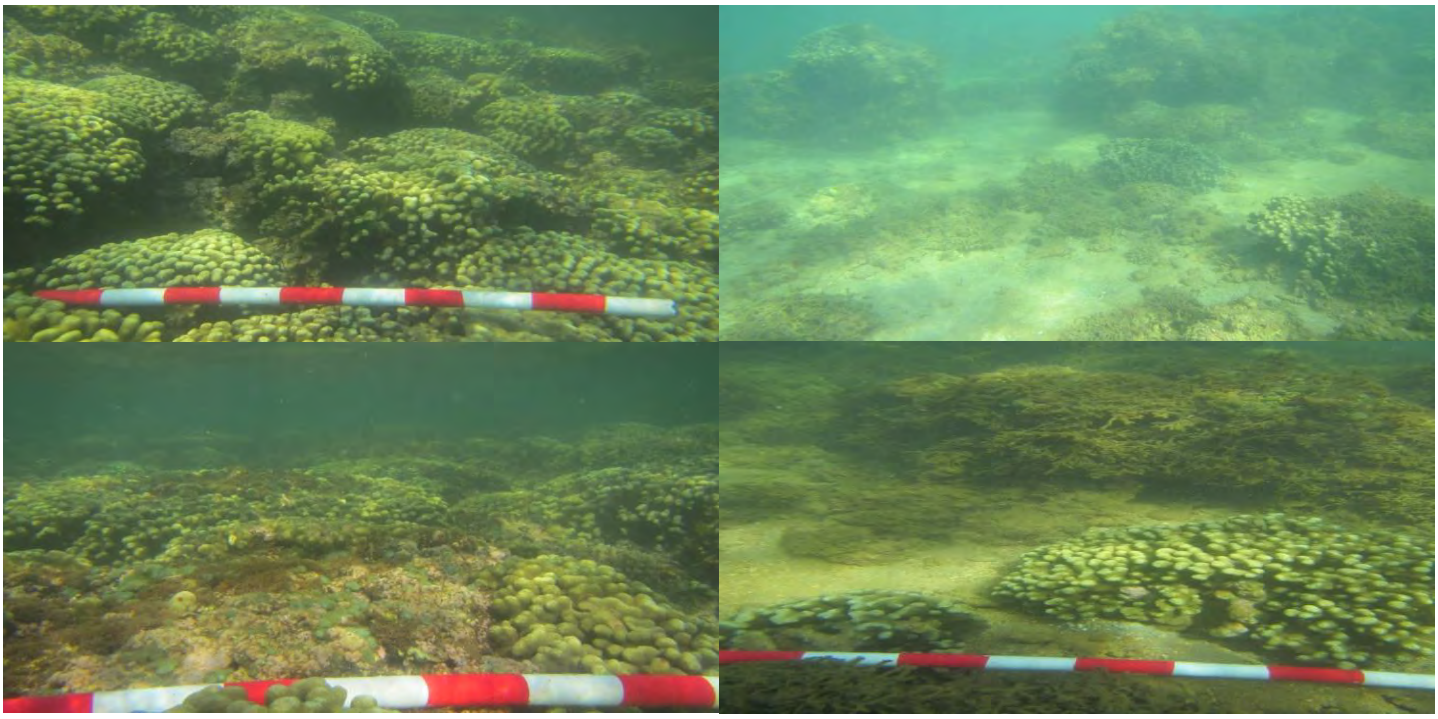
Appendix C: cont'd.

Reef 23



Photos Taken 03/11/2014

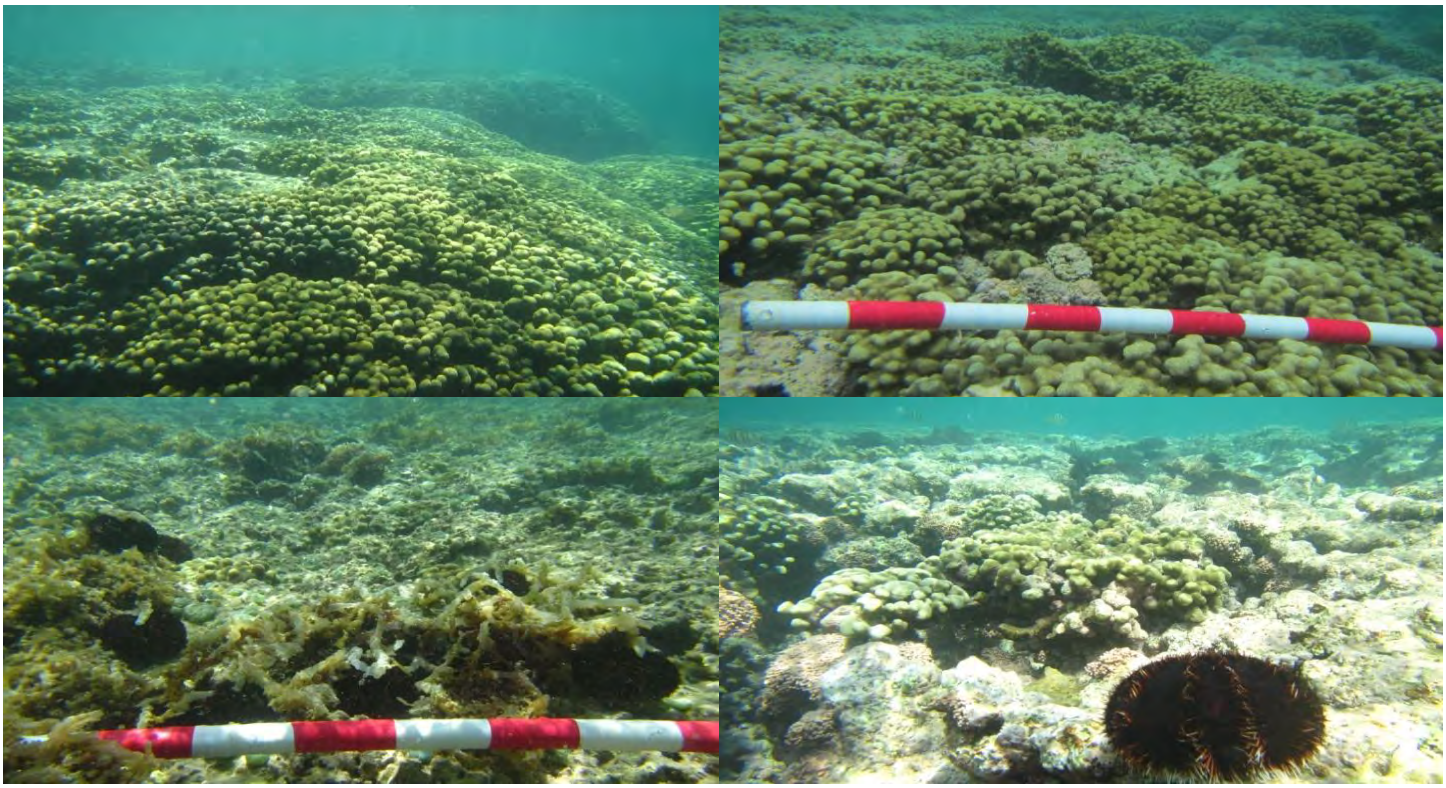
Reef 34



Photos Taken 03/12/2014

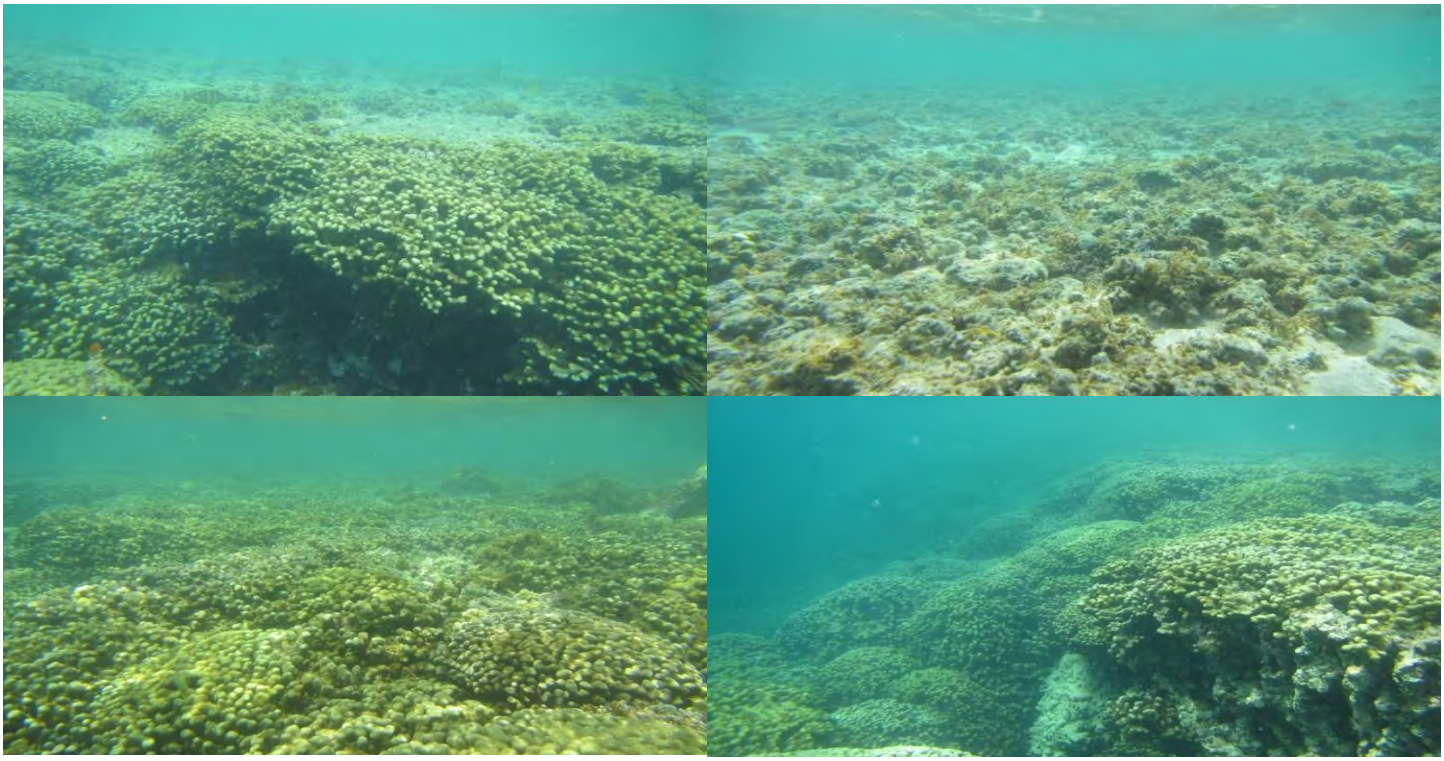
Appendix C: cont'd.

Reef 29



Photos Taken 03/12/2014

Reef 28



Photos Taken 03/12/2014

Appendix C: cont'd.

Reef 30

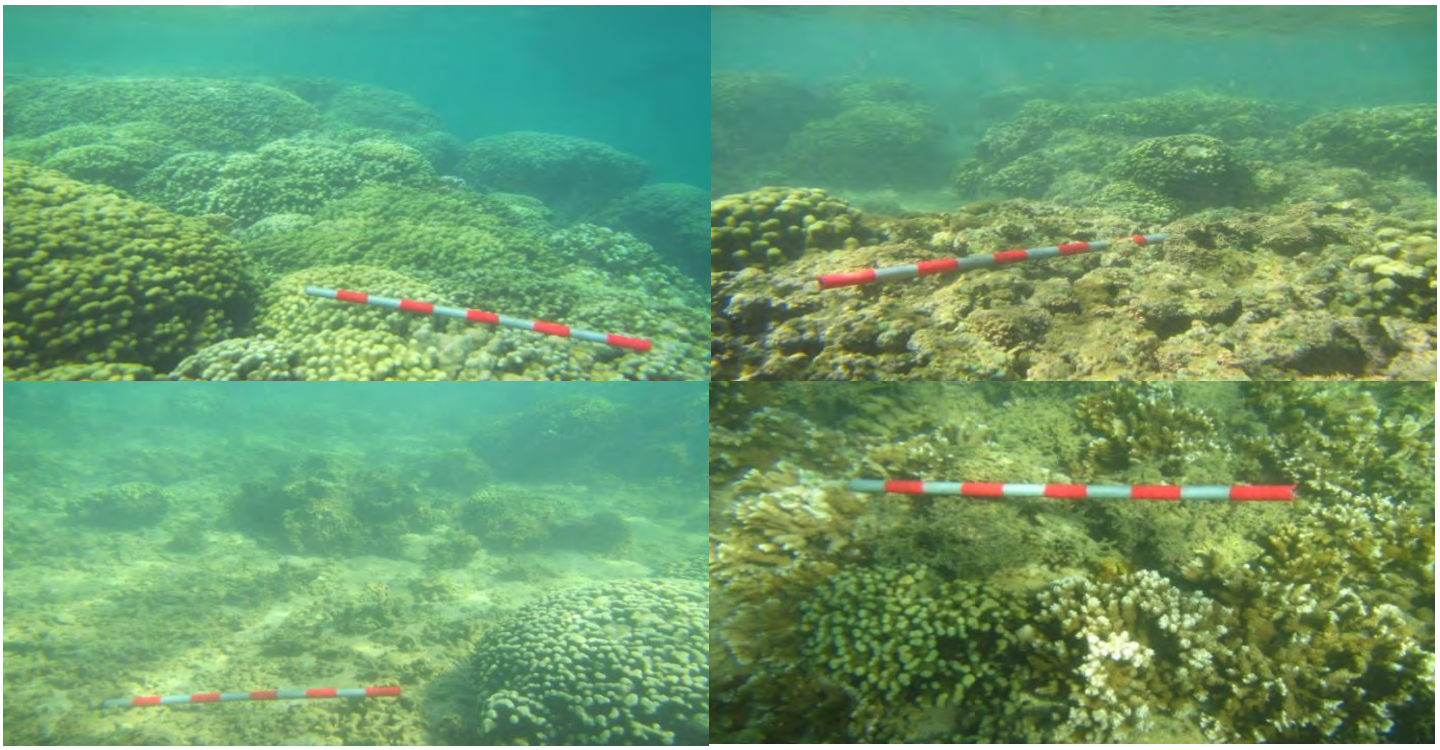
Photos Taken 03/12/2014

Reef 41

Photos Taken 03/13/2014

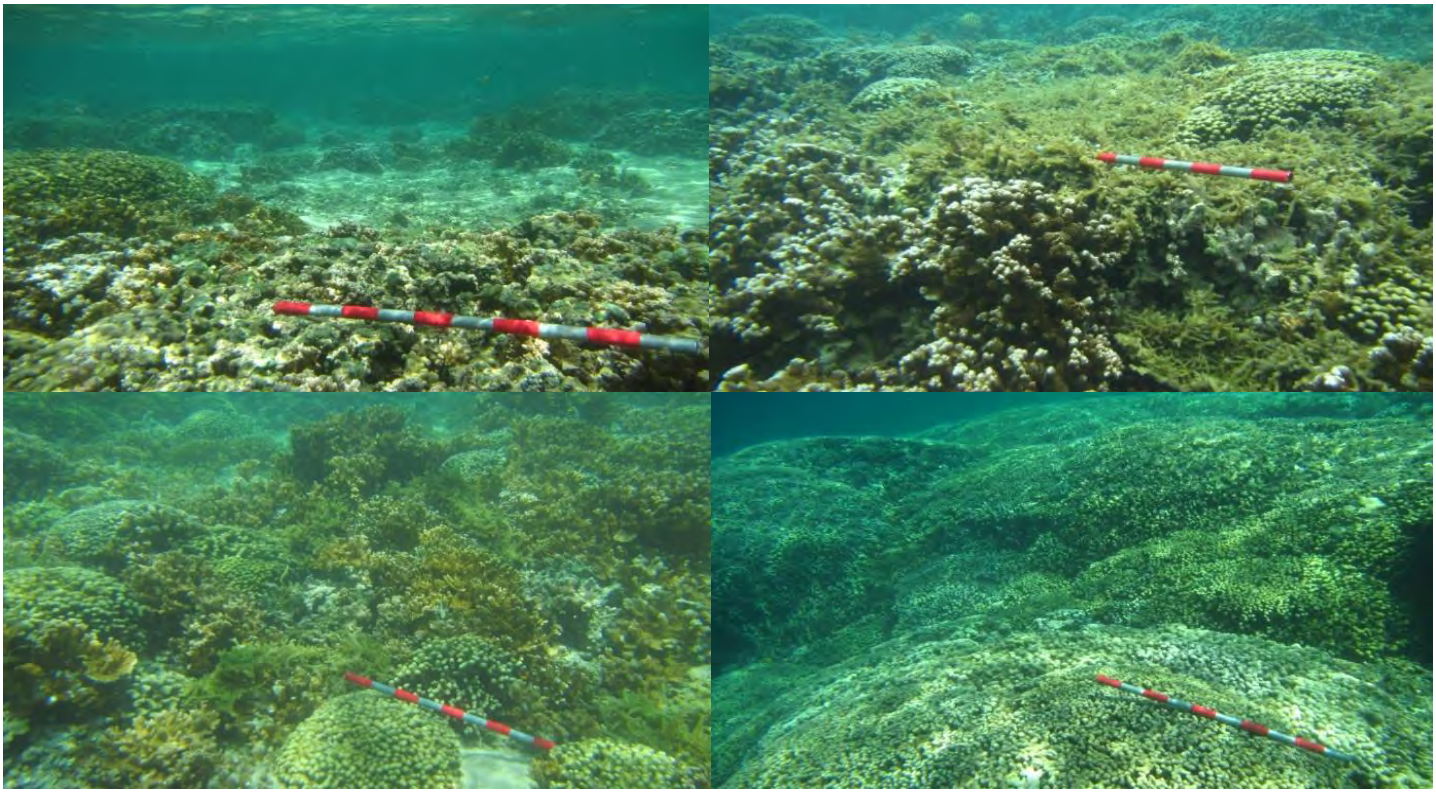
Appendix C: cont'd.

Reef 36



Photos Taken 03/13/2014

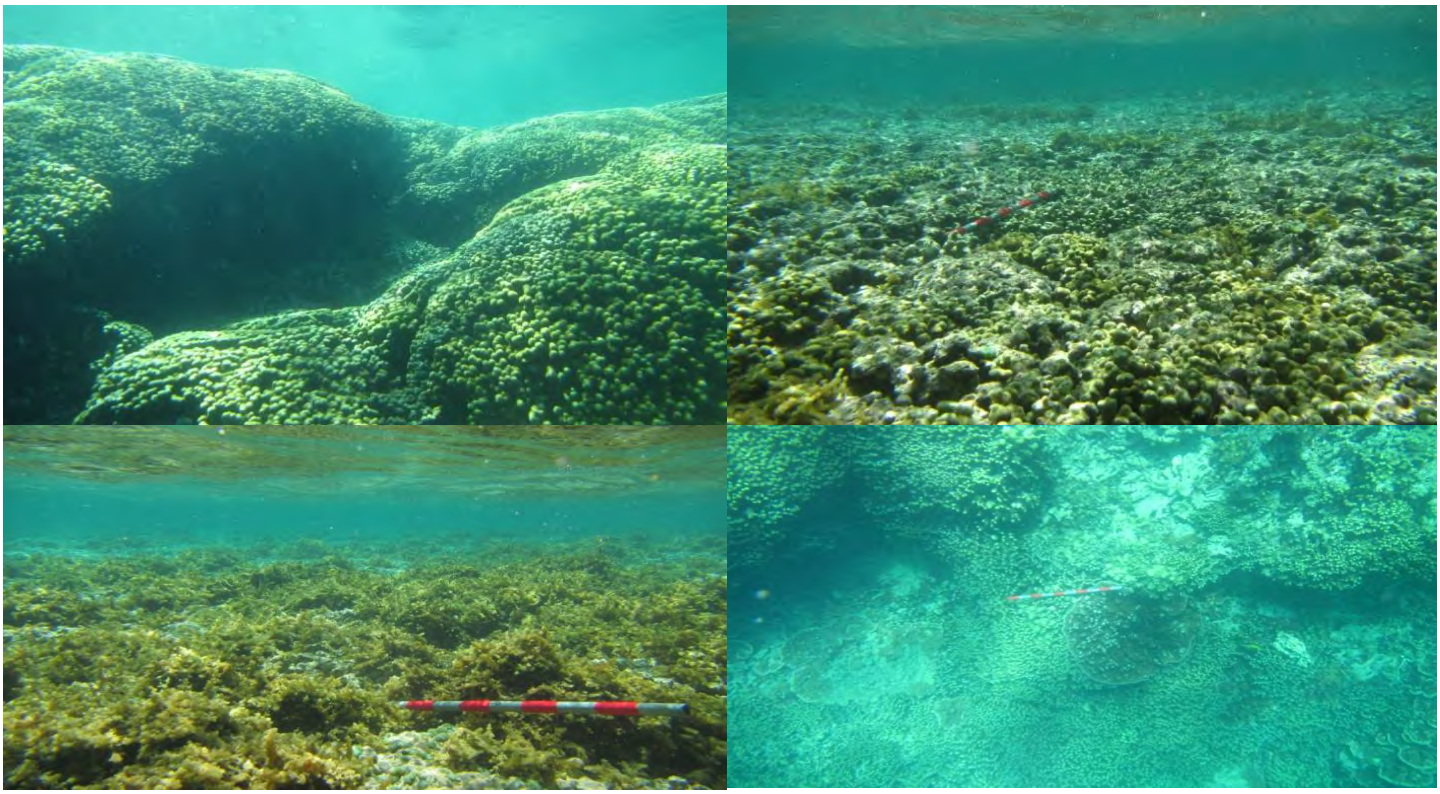
Reef 31



Photos Taken 03/13/2014

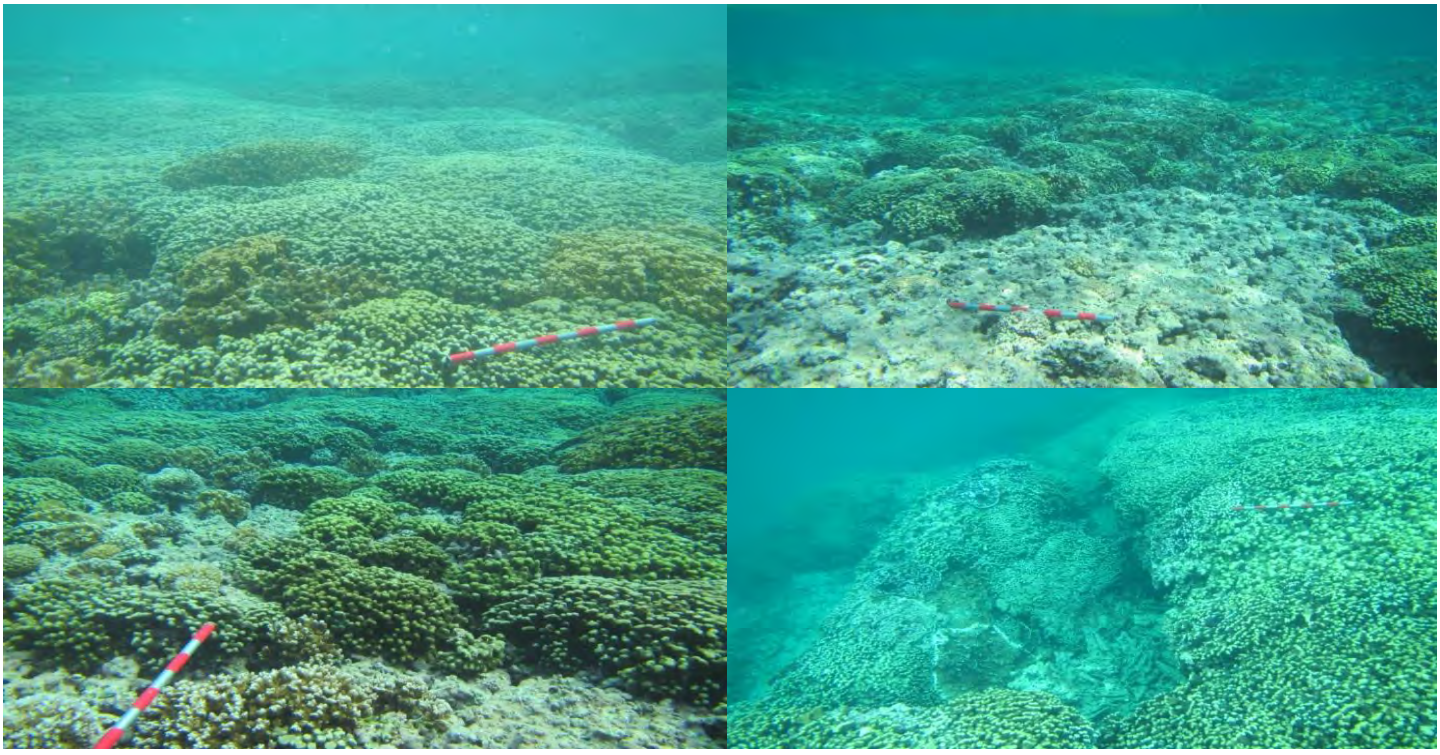
Appendix C: cont'd.

Reef 40



Photos Taken 03/13/2014

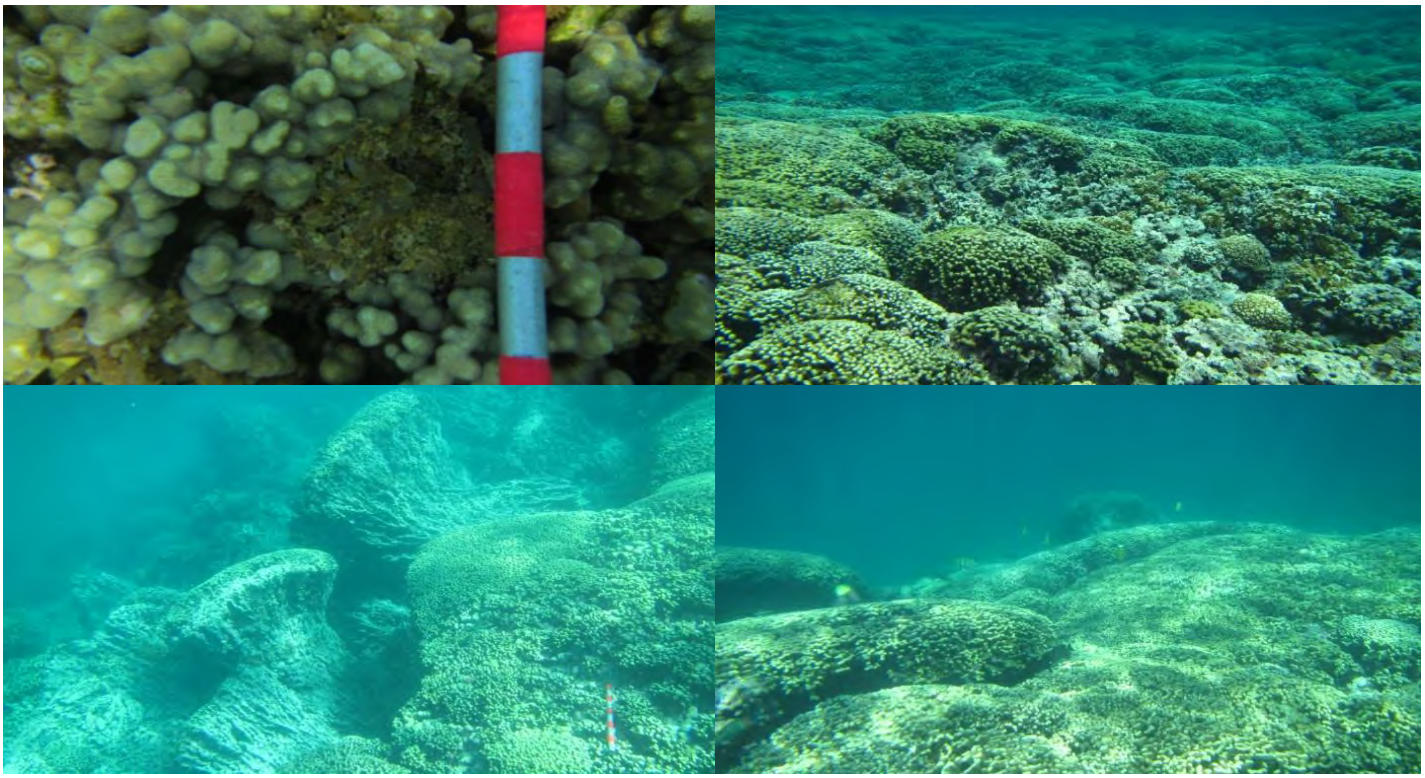
Reef 42



Photos Taken 03/13/2014

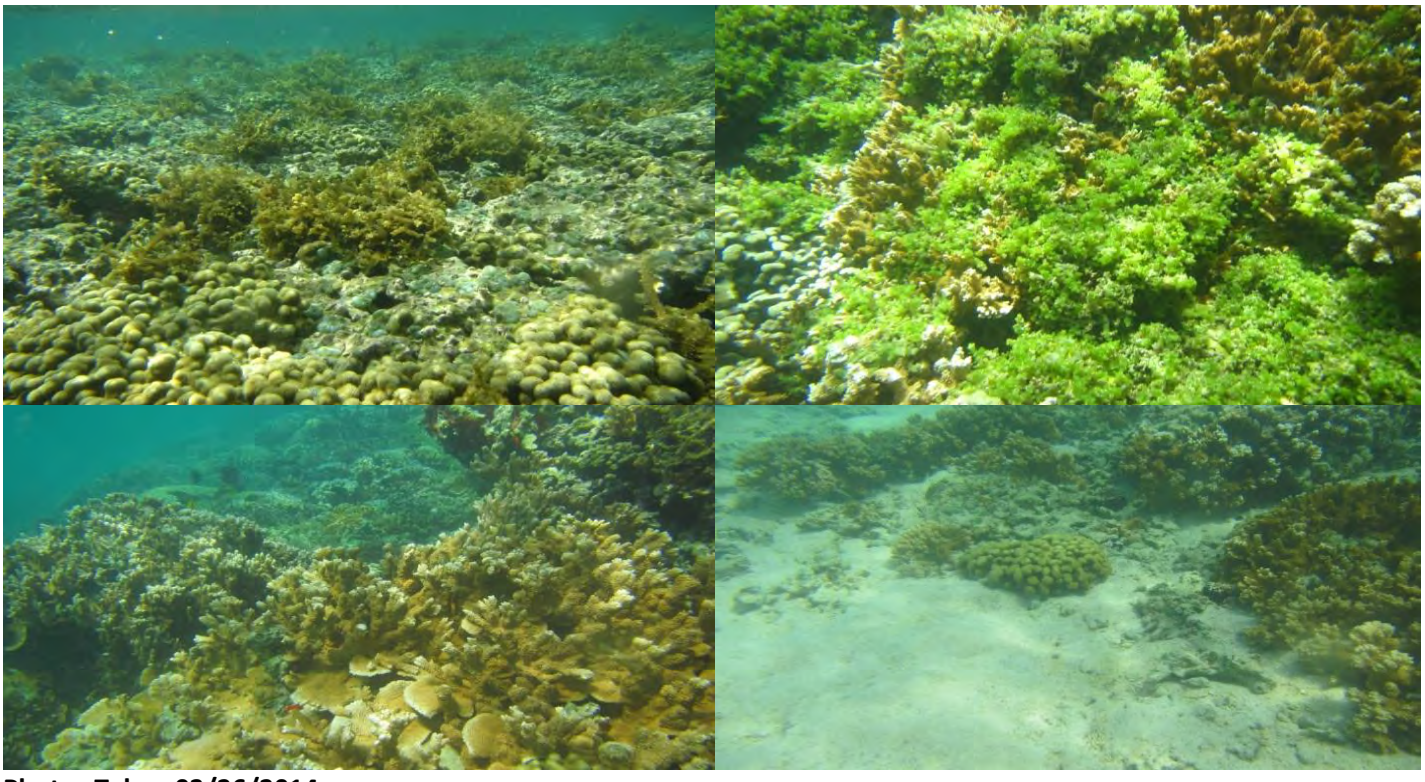
Appendix C: Cont'd.

Reef 43



Photos Taken 03/13/2014

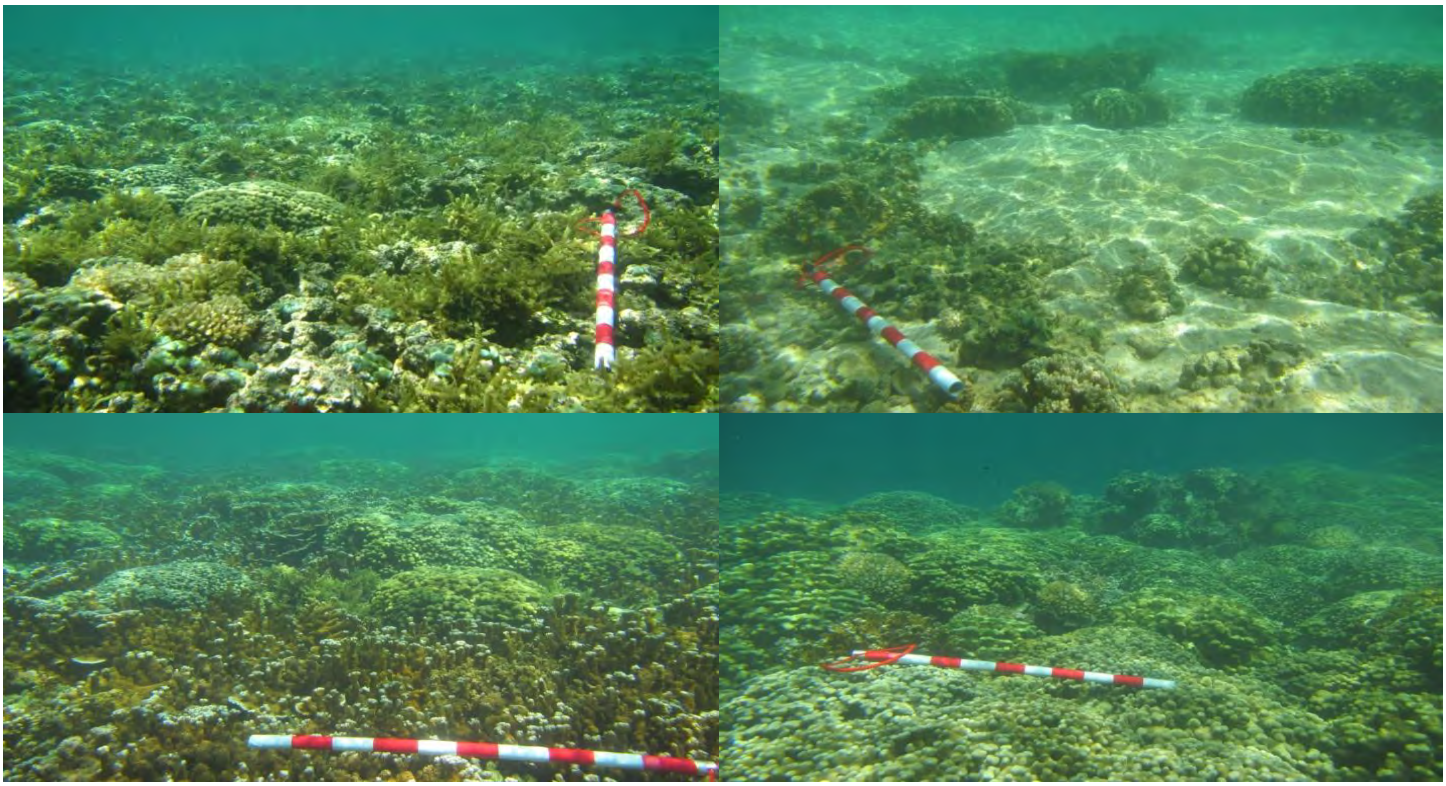
Reef 9



Photos Taken 03/26/2014

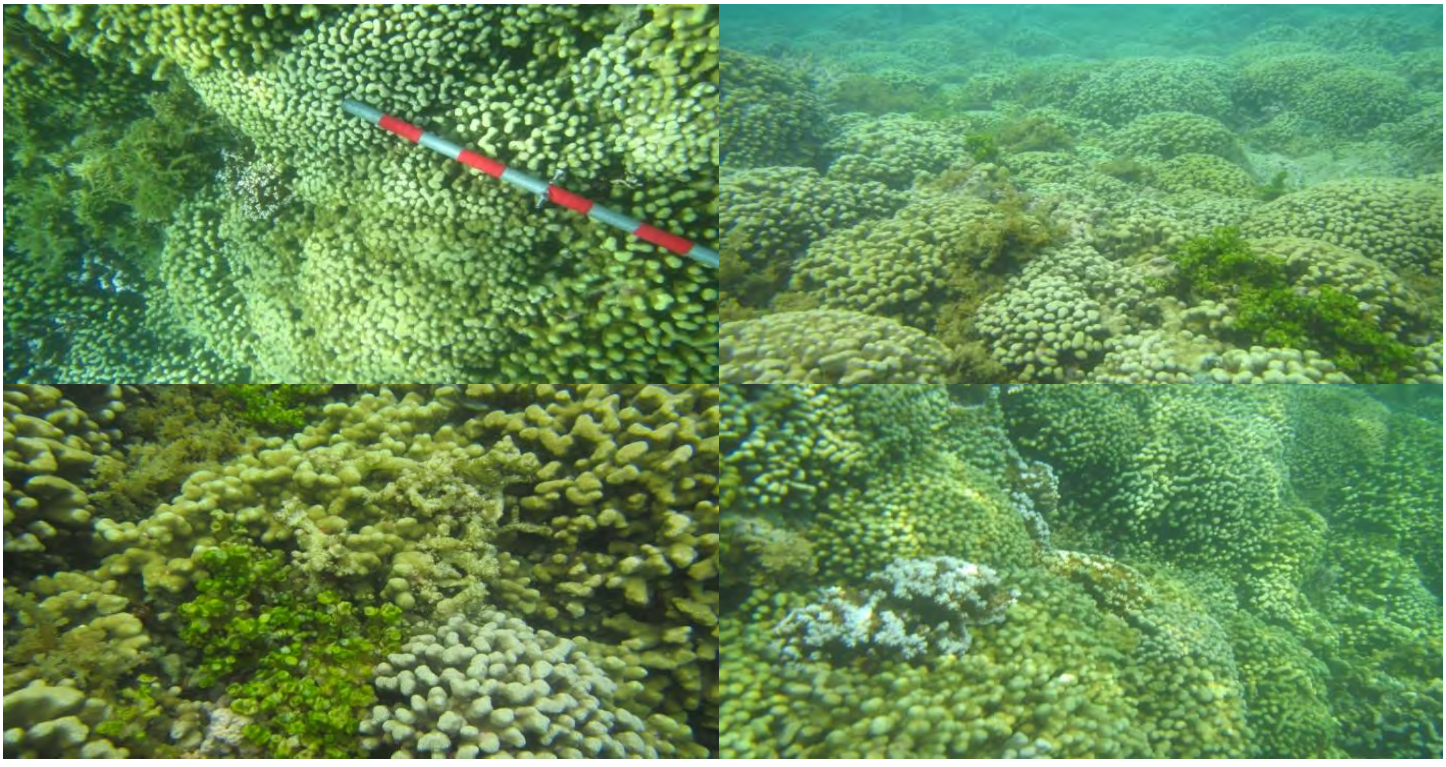
Appendix C: cont'd.

Reef 10



Photos Taken 03/27/2014

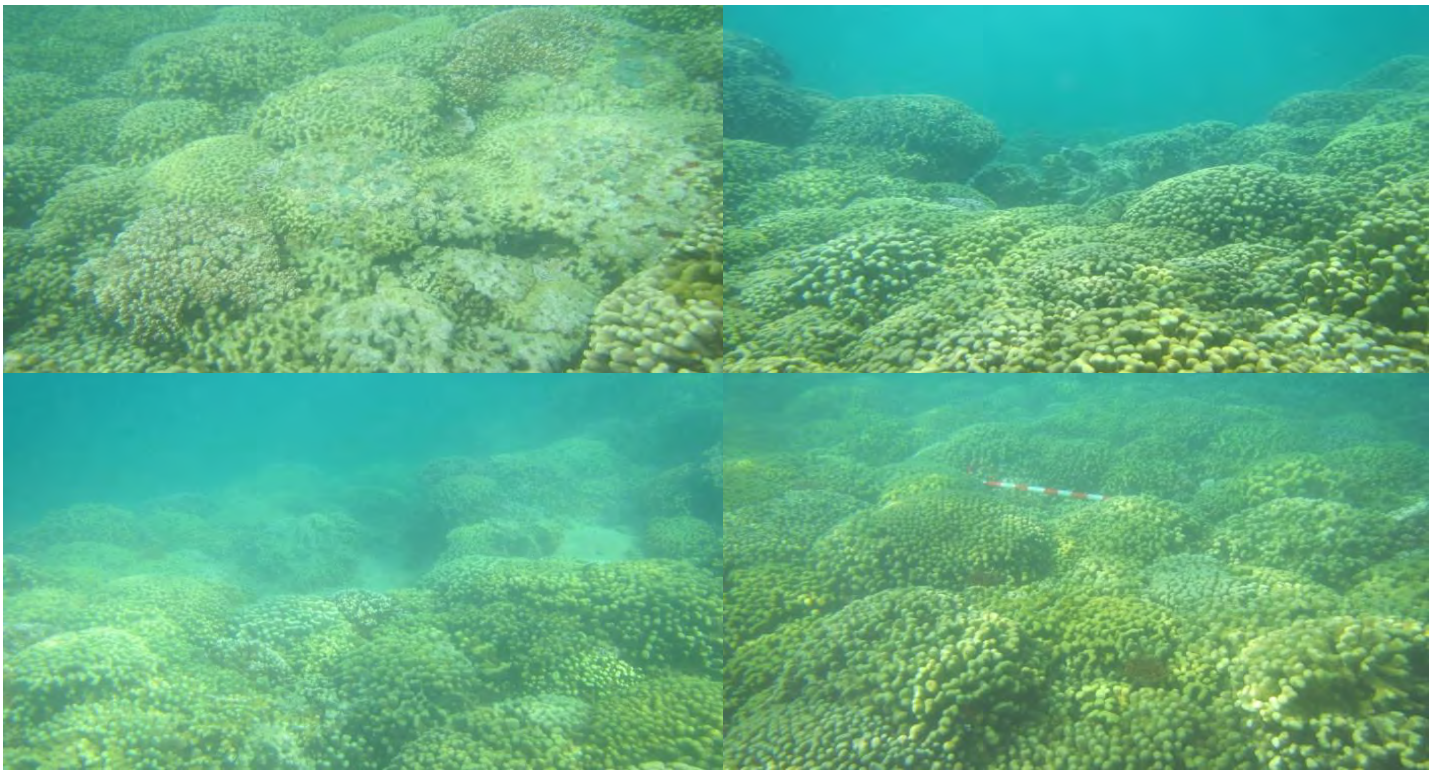
Reef 19



Photos Taken 03/27/2014

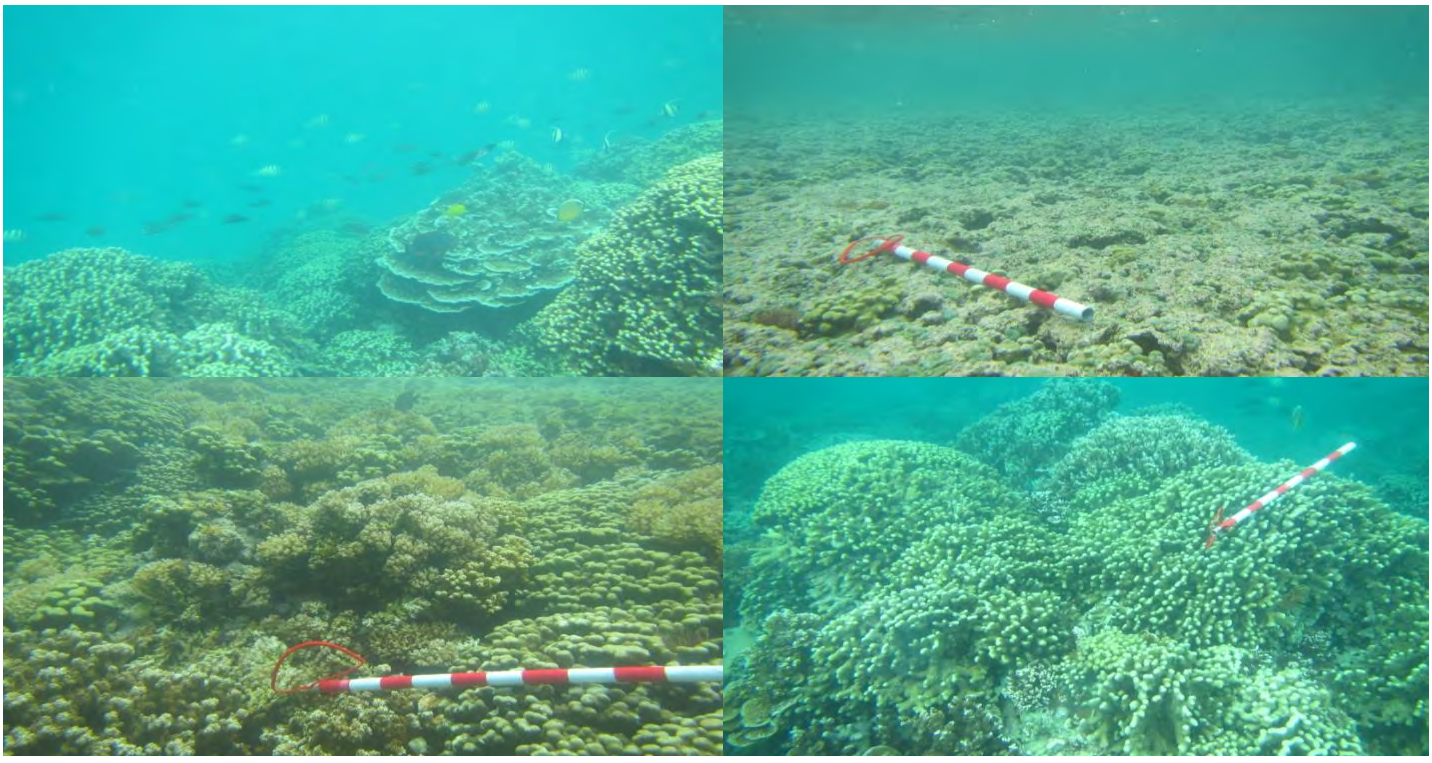
Appendix C: cont'd.

Reef 21



Photos Taken 03/27/2014

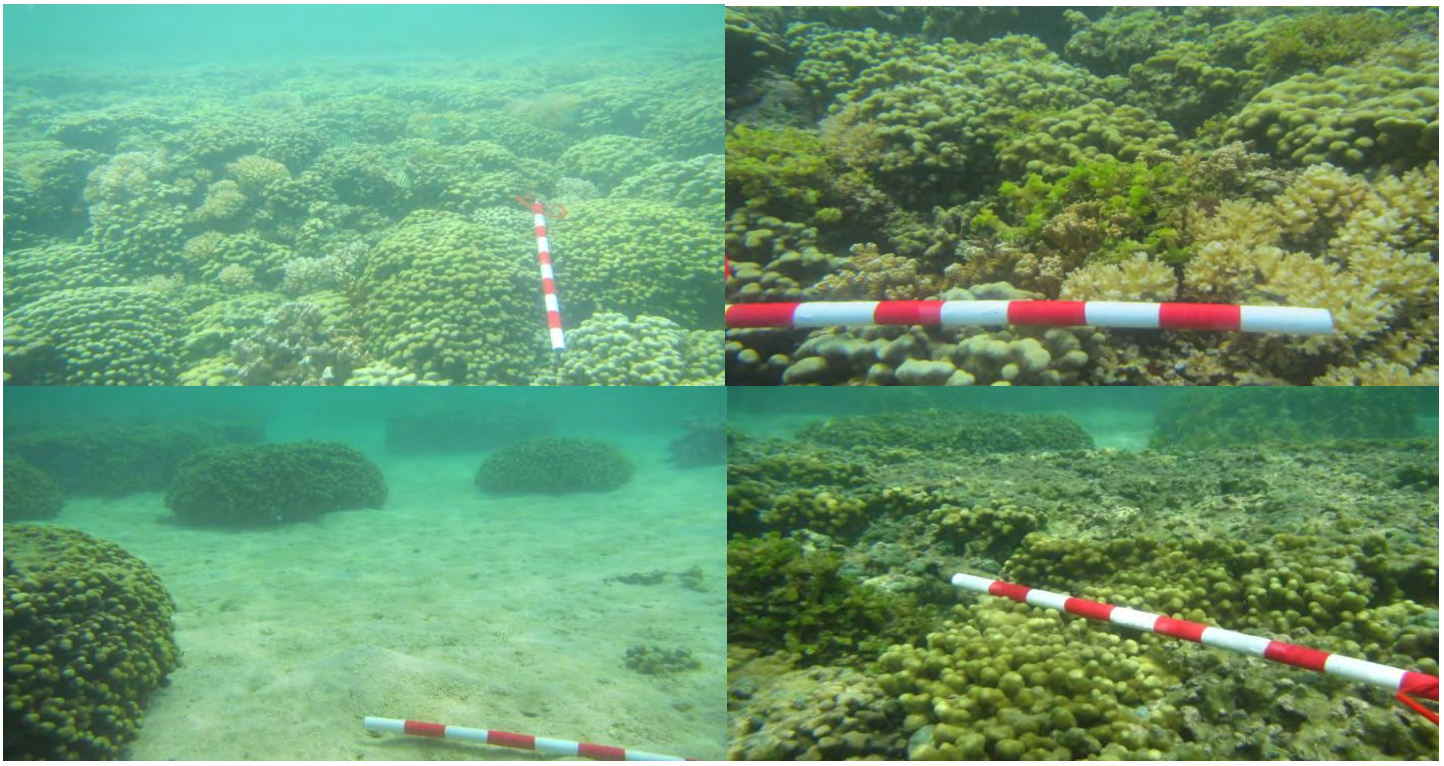
Reef 17



Photos Taken 03/27/2014

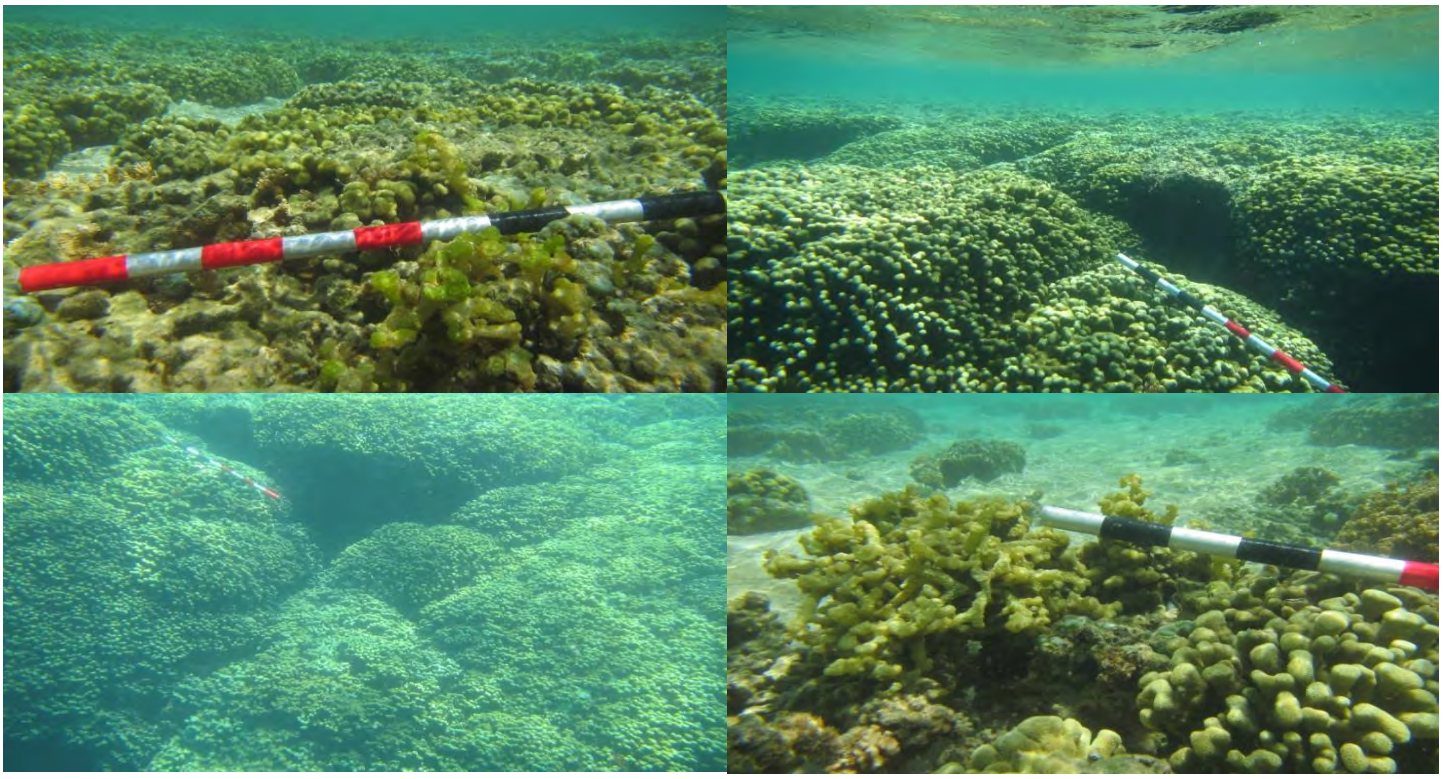
Appendix C: cont'd.

Reef 18



Photos Taken 03/27/2014

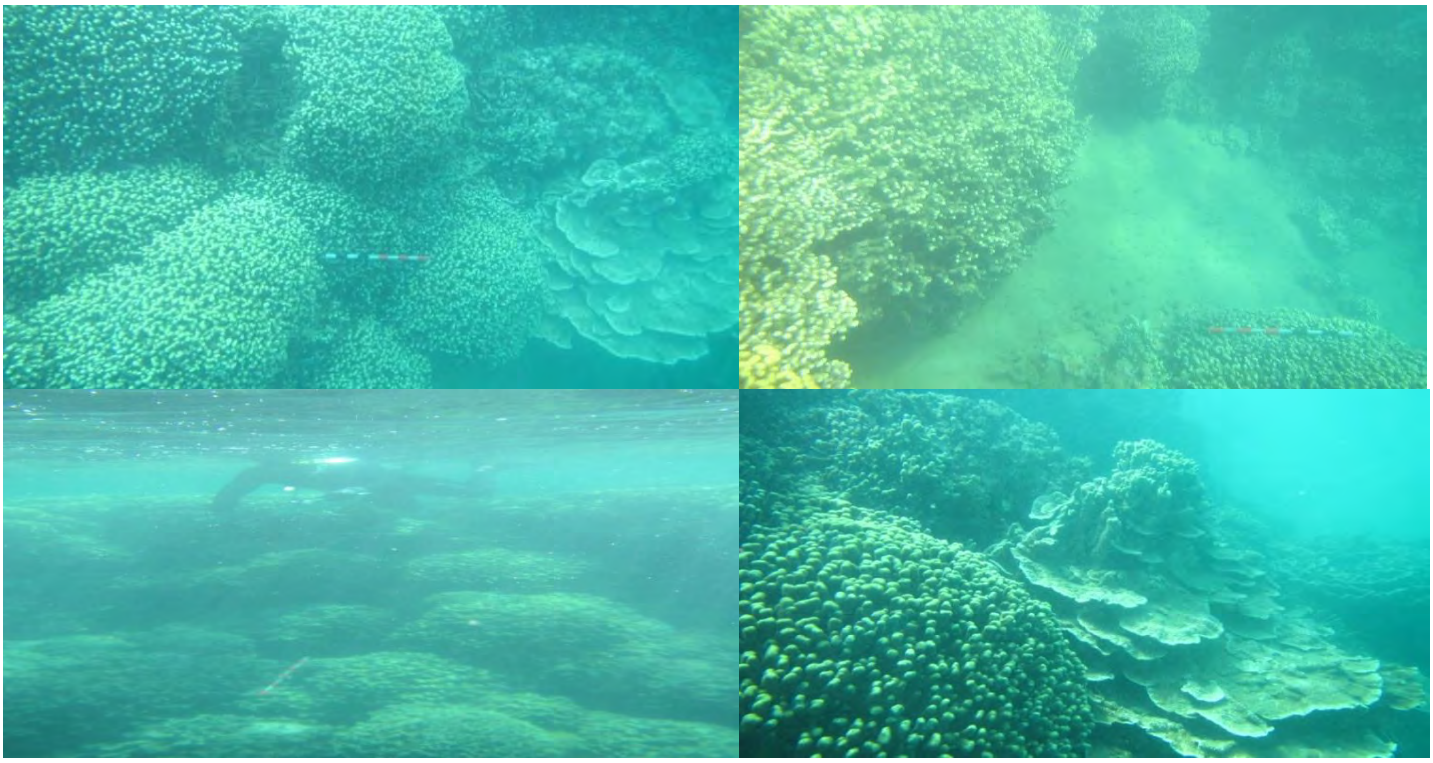
Reef 25



Photos Taken 03/25/2014

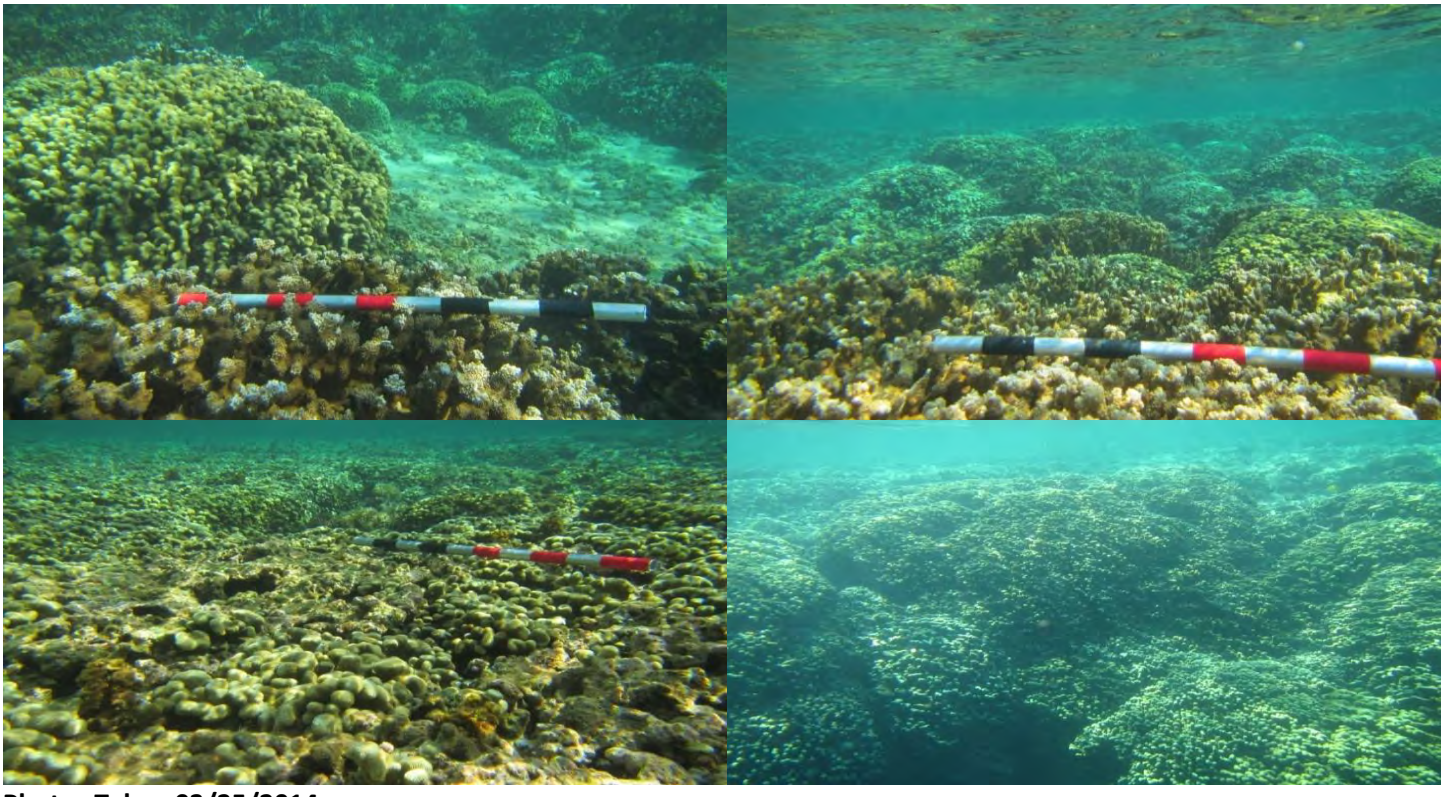
Appendix C: cont'd.

Reef 37



Photos Taken 03/25/2014

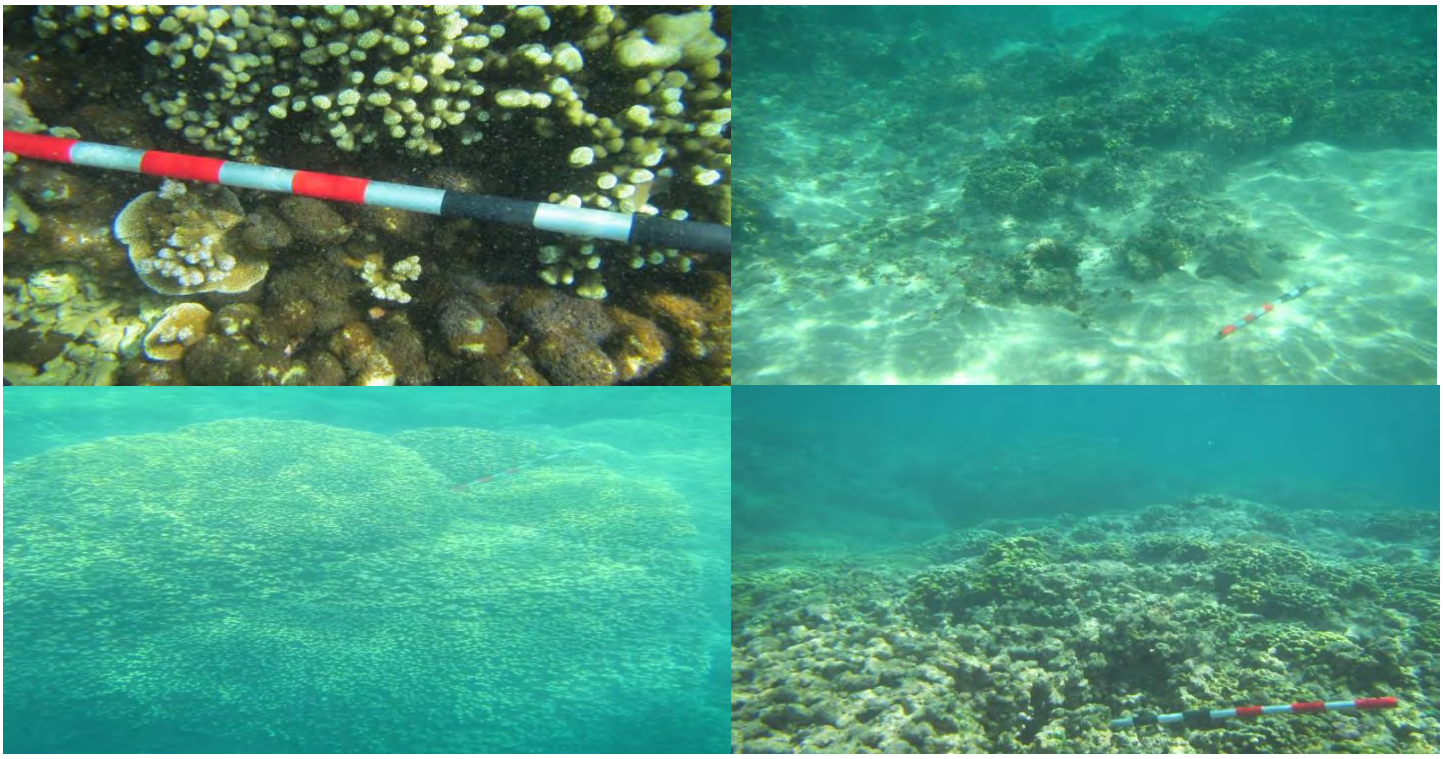
Reef 46



Photos Taken 03/25/2014

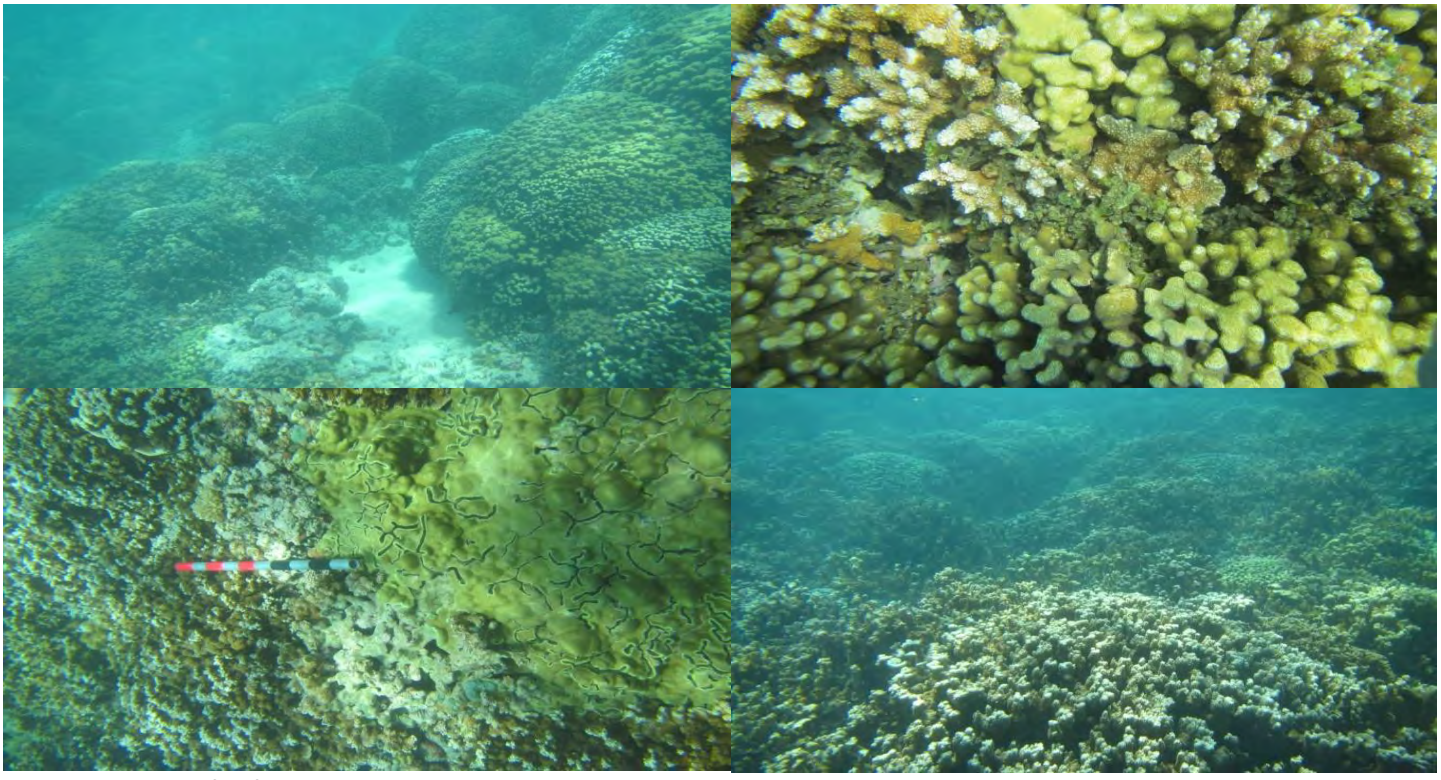
Appendix C: cont'd.

Reef 47



Photos Taken 03/25/2014

Reef 13



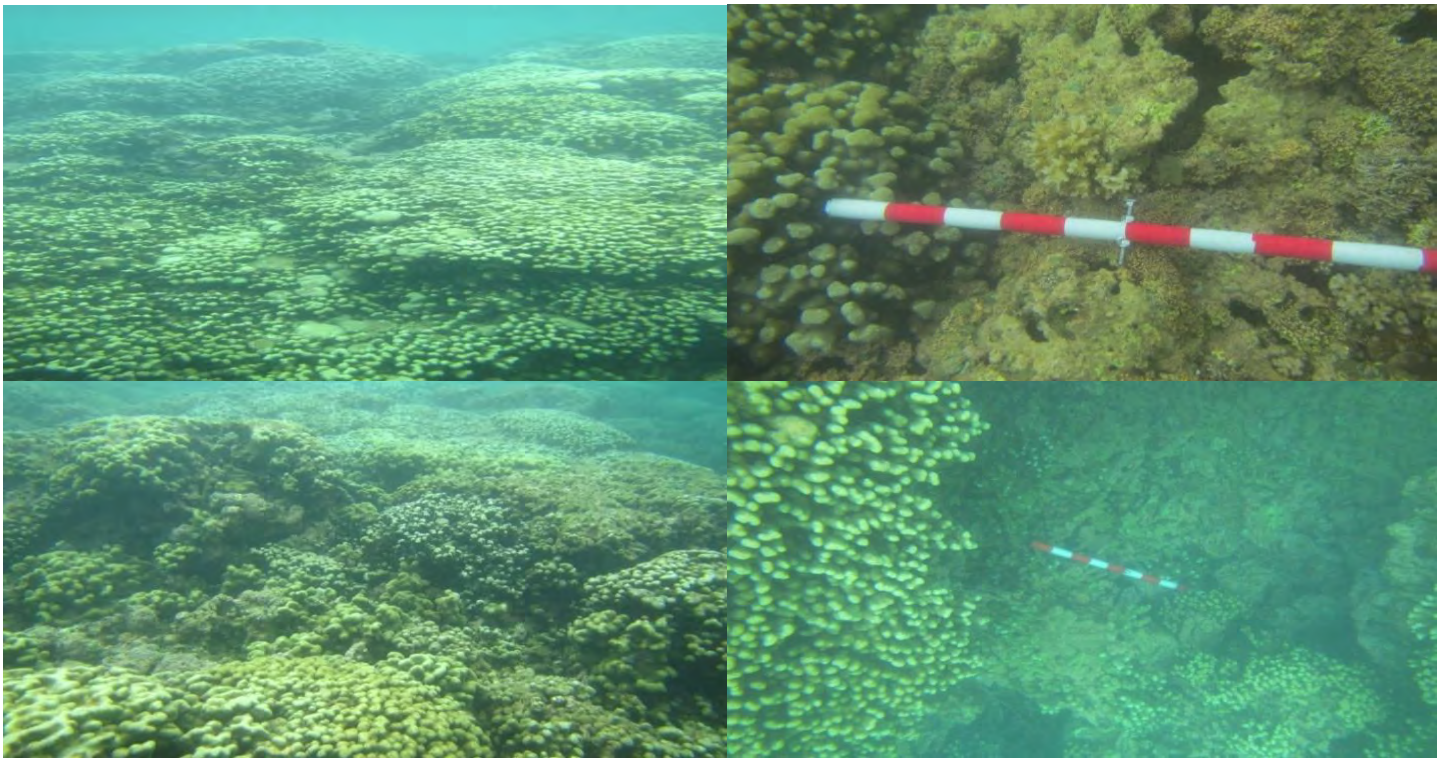
Photos Taken 03/26/2014

Appendix C: cont'd.

Reef 11

Photos Taken 03/26/2014

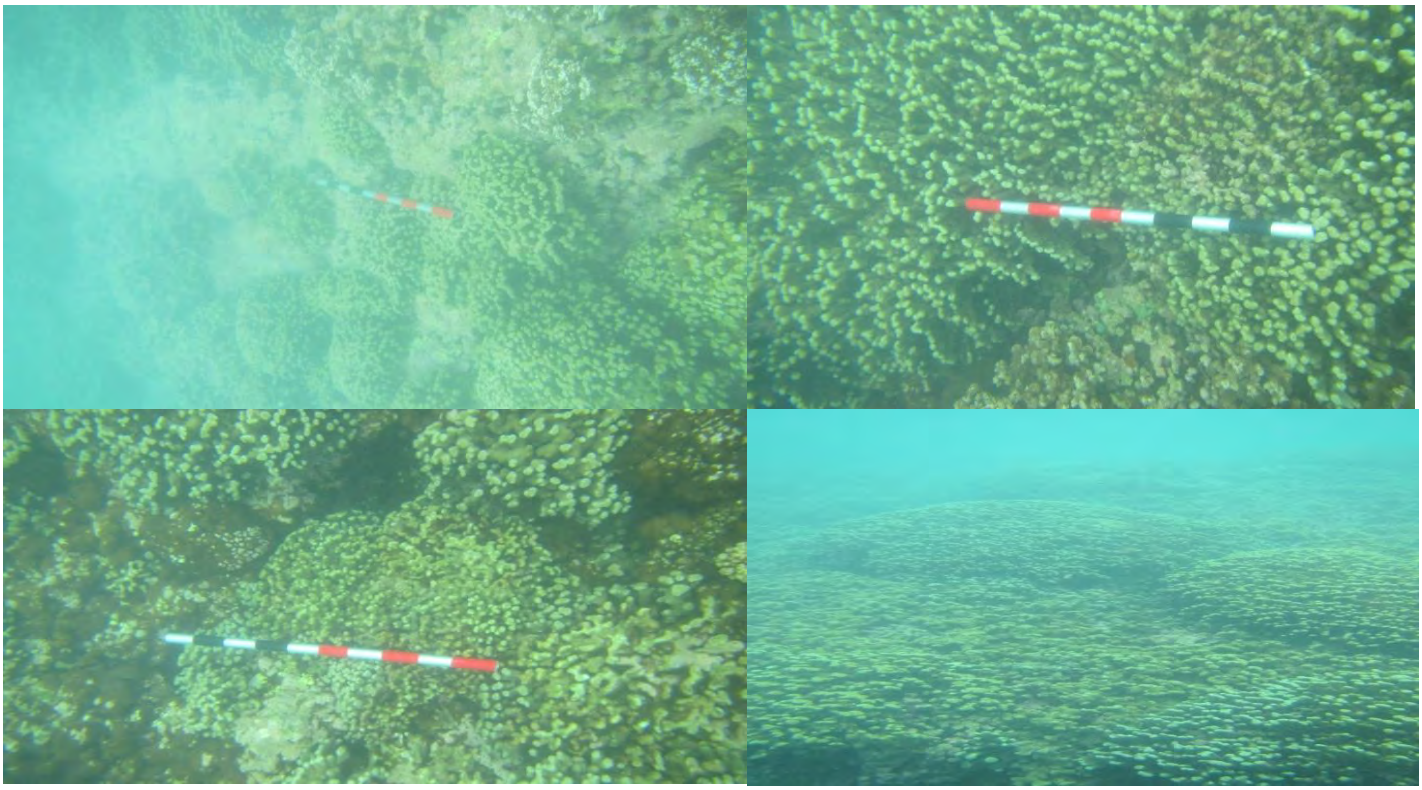
Reef 48



Photos Taken 04/07/2014

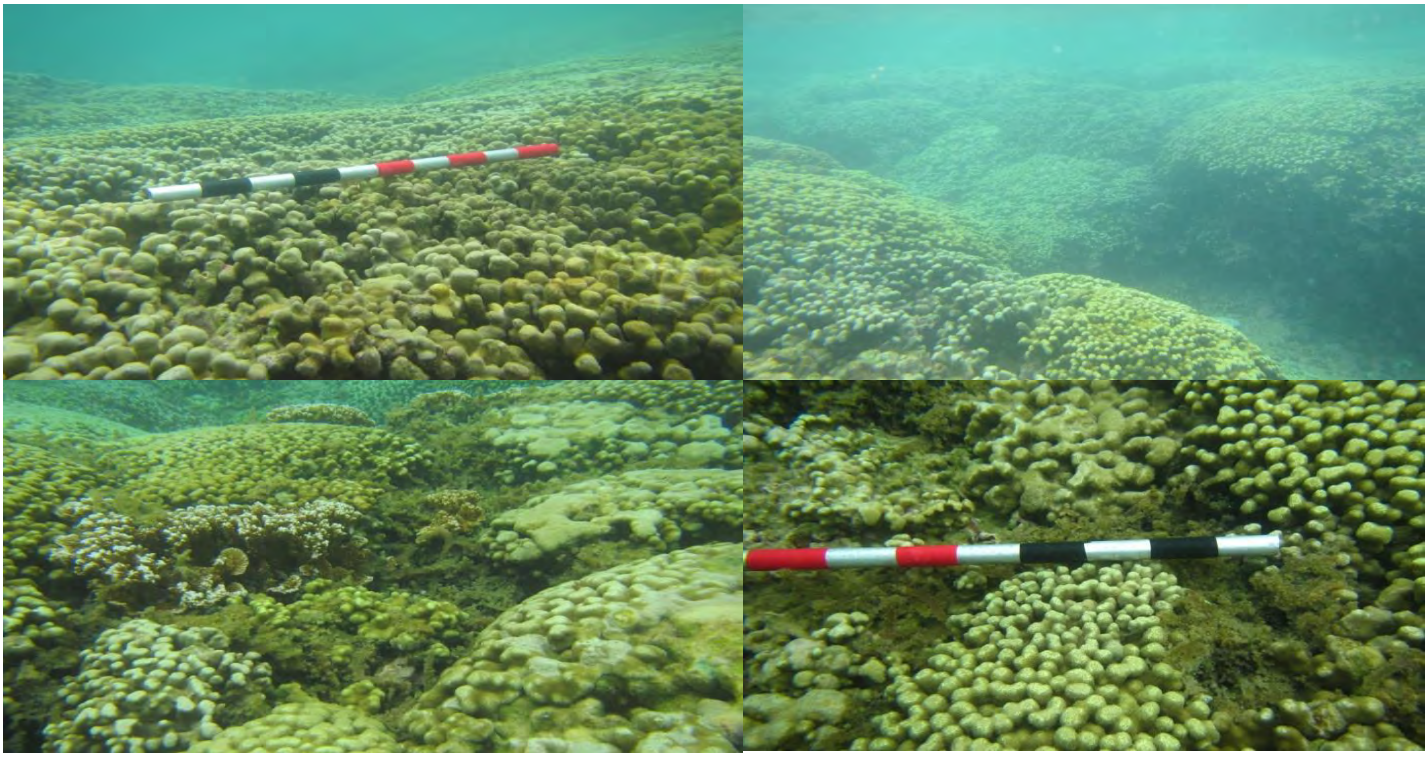
Appendix C: cont'd.

Reef 49



Photos Taken 04/07/2014

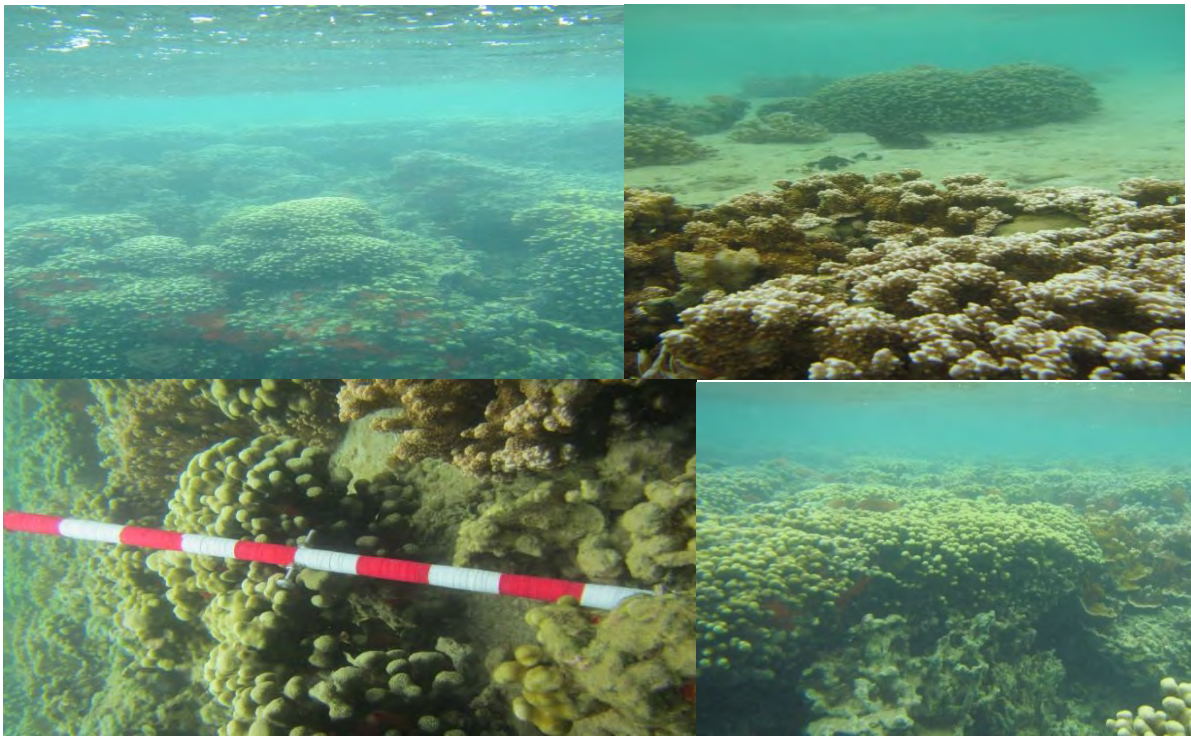
Reef 39



Photos Taken 04/07/2014

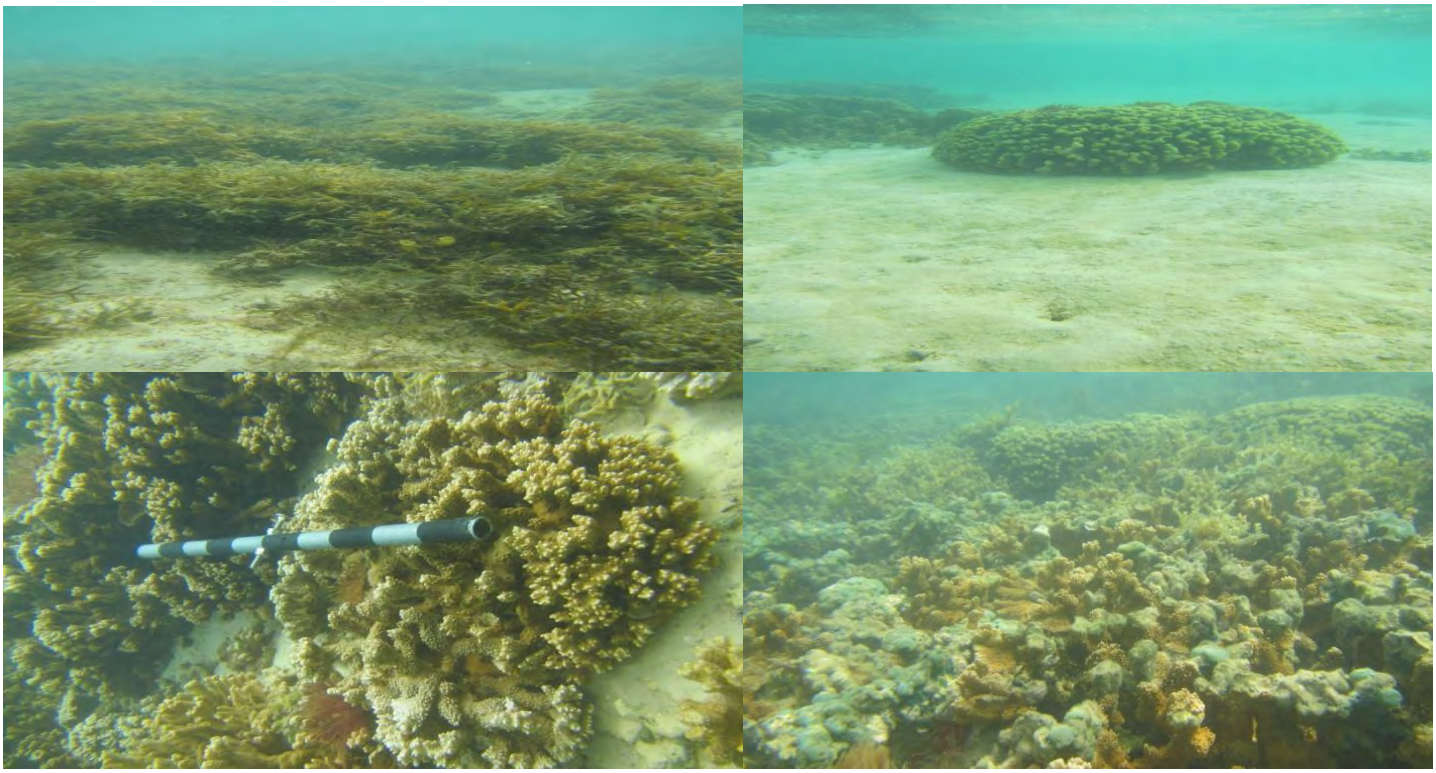
Appendix C: cont'd.

Reef 2



Photos Taken 04/07/2014

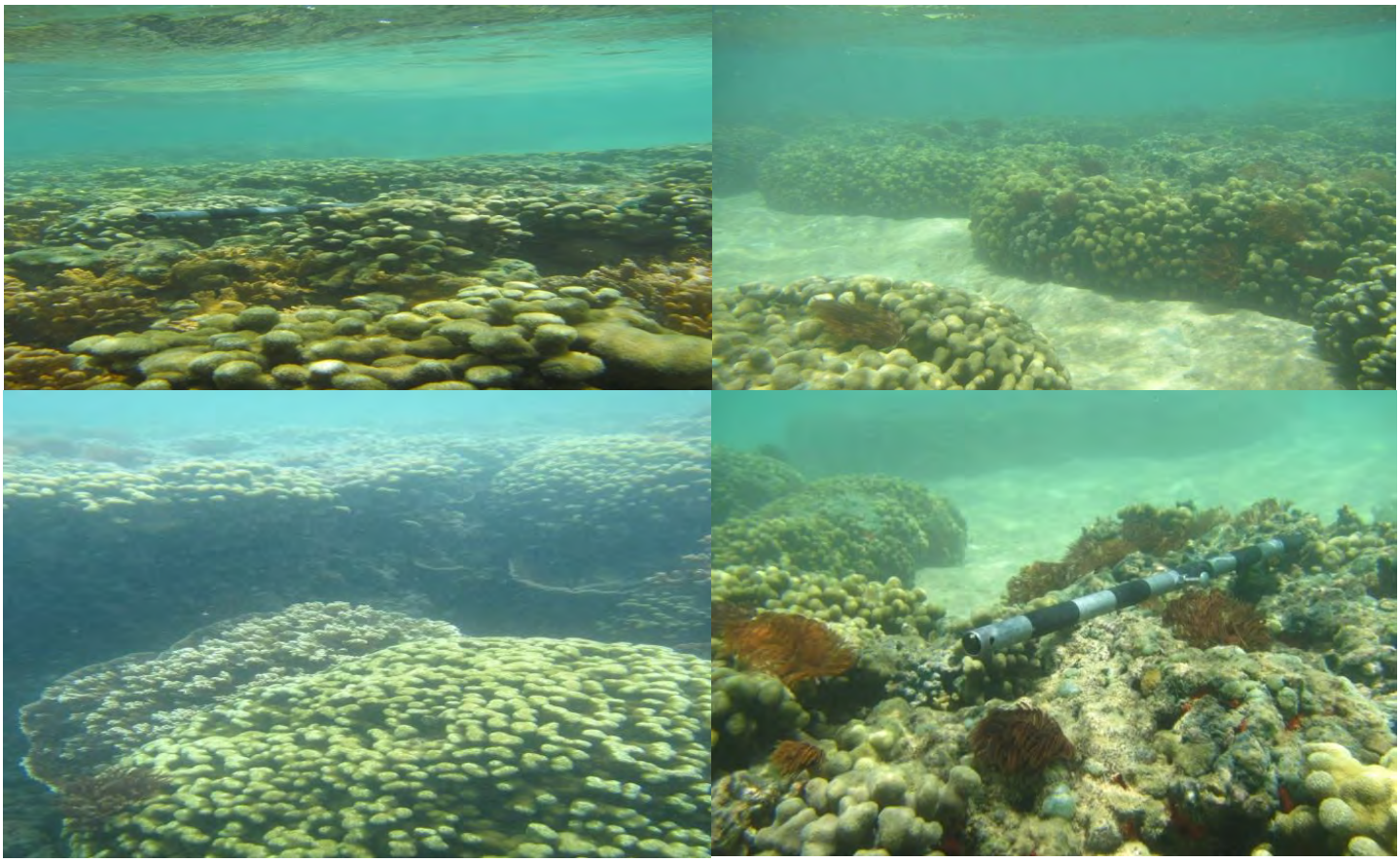
Reef 7



Photos Taken 04/08/2014

Appendix C: cont'd.

Reef 4



Photos Taken 04/08/2014

Appendix D: Kaneohe Bay Snap-Assessment Field Protocol

Kaneohe Bay SNAP Assessment Protocol

Prepared by Brian Neilson

1) Record reef metadata: One surveyor will record metadata for each reef.
    a. Depth profile of reef slope, reef crest, and reef flat (approximately 10 measurements). Comment on any unique features of the reef.
    b. Take photos above and below the water

Reef Metadata

Reef #	Date	Reef depth/habitat/time	Surveyors/GPS #	Photo #	Unique Features/Comments/Overall Assessment

2) Surveyors' grid the reef by lining-up 5-10 m apart and taking a GPS point every 5-10 m (Figure 1). Surveyors will use their GPS to estimate 5-10 m sample spacing. Surveyors will carry a half meter measuring stick to measure a 50 cm linear sample area (Fig. 1). While looking at the GPS (not the reef) surveyors will place the half meter stick, every 5-10 m, take a GPS point, and record the following features The percentages below refer to what percent of the 50 cm stick is composed of live coral or invasive algae (5 cm=10%, 25 cm=50%). Surveyors will estimate what is visible below the stick. If live coral is visible beneath algae it is recorded. Therefore it is possible to have greater than 100% accumulative cover of various benthic types.
    a. Record Live Coral (0-3), 0=No coral, 1=< 10% coral, 2=11-50%, 3=50-100% within the sample area.
    b. Record presence of Large (>160 cm) coral heads within the sample area.
    c. Record Kappaphycus/Eucheuma , Gracilaria /Acanthophora density 0=No invasive algae, 1=1-10% invasive algae, 2=11-50%, 3=51-100% within the sample area.
    d. Record habitat type (reef slope (at the 2 m contour or less), reef crest, reef flat) of each survey point.
    e. Record the ease of removal (1: easy, 2: moderate, 3: difficult). This measurement is a qualitative assessment of the area visible around the surveyor (not limited to the measuring stick). A difficult algae removal site would have multiple algae attachment points, algae is growing in rubble, or growing within coral fingers. An easy algae removal site would have few attachment points growing on solid dead coral substrate and dislodges easily. A moderate algae removal site would have characteristics in between easy and difficult.

Appendix D: cont'd.

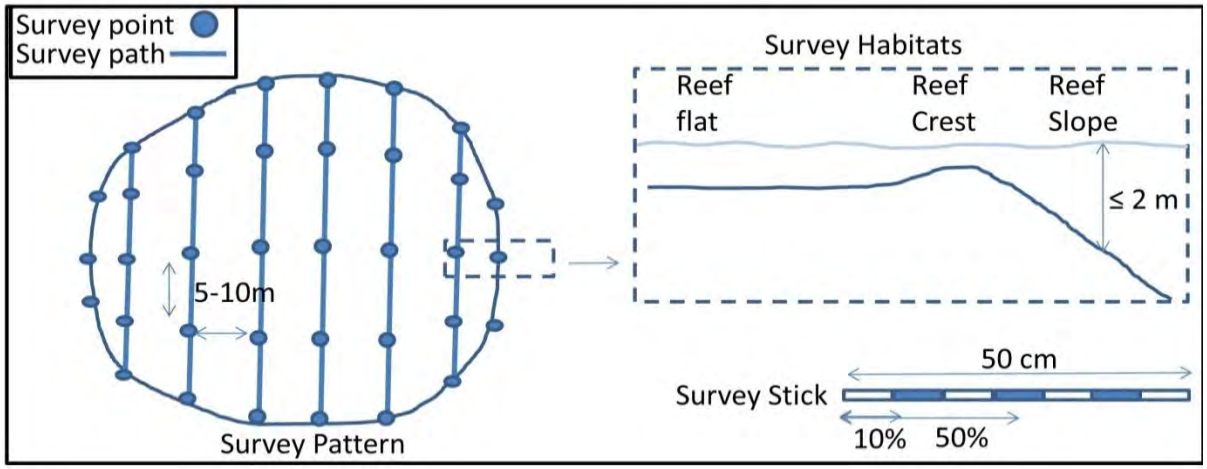


Figure 1: Example survey grid pattern, grid spacing, habitat types, and survey measuring stick.

	Coral(0-3)		Algae(0-3)			
#	Live	>160	Ed/Ks	Gs/As	**S/C/F**	**Ease(0-3)**
21	2	--	1		f	2
22						

Example Data Sheet: Surveyor marked waypoint 21 on the GPS and noted live coral cover of 2=11-50%, Ed/Ks invasive algae density of 1=1- 10%, on a reef flat habitat, and an ease of removal of 2.

Time estimates:

Using the above method an 12,000 m^2 patch reef survey will collect approximately 650 data points and take a six person crew 30-min to complete.

Analysis:

1) Upload gps points and enter field data to Access/ArcGIS database.
2) Create ArcGIS shapefiles of survey points, interpolate data, create coverage maps and estimate live coral cover and invasive algae cover. Estimate removal time and urchin stocking.
3) Set reef flat depth of all surveyed patch reefs at centimeters above mean low tide.
4) Score and rank individual reefs according to defined ranking criteria (e.g. live coral and invasive algae).

Appendix E: Snap-Assessment Data Sheet

Name:			GPS:			Date:			Reef:			Pg__of___	
	Coral(0-3)		Algae(0-3)		S/C/F	Ease(0-3)		Coral(0-3)		Algae(0-3)		S/C/F	Ease(0-3)
#	Live	>160	Ed/Ks	Gs/As			#	Live	>160	Ed/Ks	Gs/As		
1							51						
2							52						
3							53						
4							54						
5							55						
6							56						
7							57						
8							58						
9							59						
10							60						
11							61						
12							62						
13							63						
14							64						
15							65						
16							66						
17							67						
18							68						
19							69						
20							70						
21							71						
22							72						
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41							91						
42							92						
43							93						
44							94						
45							95						
46							96						
47							97						
48							98						
49							99						
50							100						
0:None, **1**:<10%, **2**:11-50%, **3**:>50%. [10%=5 cm, 50%=25 cm] Easy=1, Mod=2, Difficult=3,													
Observed Rare coral species/Comments: Reef													
Observed Rare coral species/Comments: Reef													
Photo Log (Reef/Photo #)													

Appendix F: Snap-Assessment Field Supply List

1) 1x GPS unit per surveyor + 1x backup GPS unit for every 4-5 surveyors
2) 1x GPS dry bag per GPS unit
3) 1-2x extra GPS dry bags in case of leak
4) 2x AA batteries per GPS unit + 1x backup set
5) 1x half meter marked measuring stick (mark every 5cm)
6) 1x underwater camera per reef
7) 1x clipboard per surveyor
8) 2x data sheets per surveyor +extras on hand
9) 1x box of golf pencils
10) 1x bag of rubber bands
11) 1x Desiccant packet per GPS bag