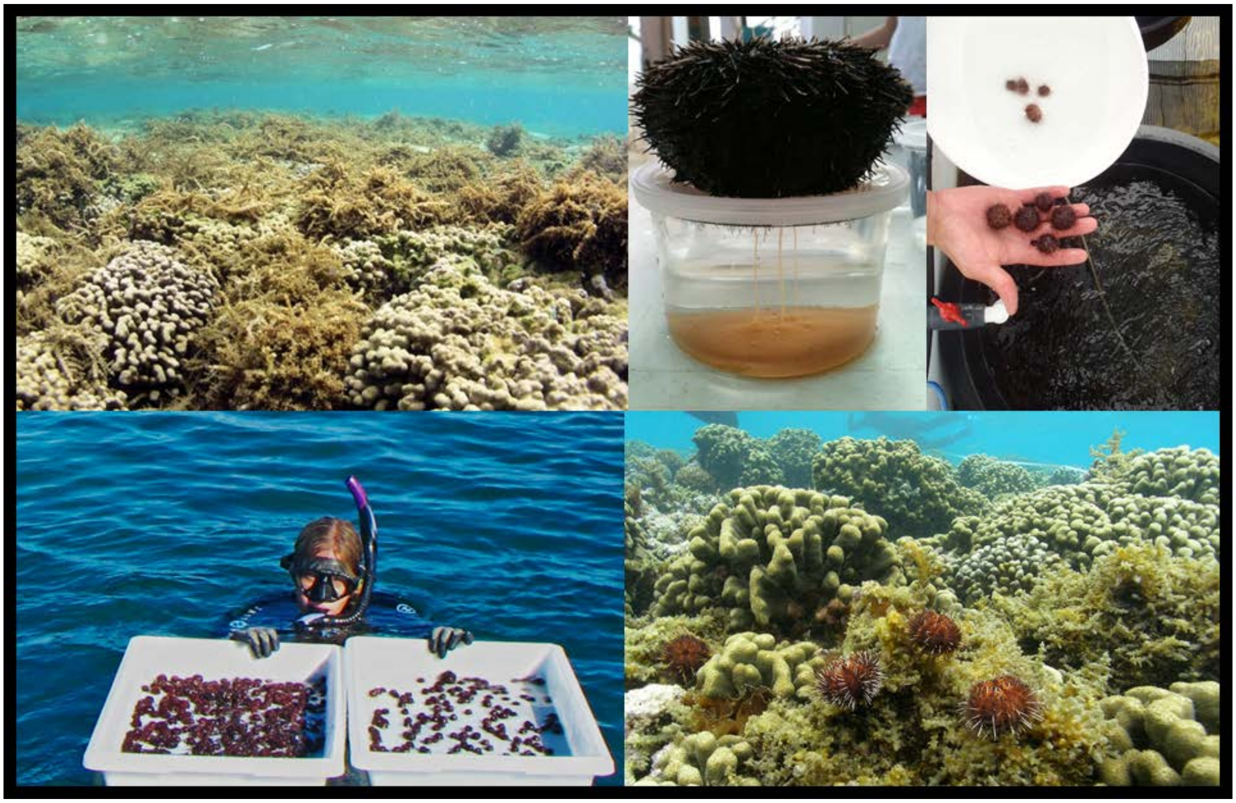
Cape Flattery Settlement Restoration Project: Restoring Reefs in Kāneʻohe Bay



ANNUAL PROGRESS REPORT

Division of Aquatic Resources

Aquatic Invasive Species Team

Jan – Dec 2020

Contents

RESTORATION PLAN ACTIONS IMPLEMENTED

The Division of Aquatic Resources (DAR) continued Cape Flattery Mitigation efforts to combat invasive algae in Kāneʻohe Bay during the January – December 2020 reporting period. Although restricted due to the COVID-19 pandemic, urchin outplanting continued on target reefs prioritized for treatment, annual SNAP and presence/absence surveys were completed on all treatment reefs, and reef markers were installed around the Hawaiʻi Institute of Marine Biology on Coconut Island in Kāneʻohe Bay. Additionally, work has continued on the Heʻeia watershed restoration plans.

As of December 11, 2018, all priority reefs have been stocked with the project's initial target numbers of urchins (*Tripneustes gratilla*). Priority reefs are reevaluated annually and urchin outplanting has progressed to maintenance stocking of reefs based on annual surveys to maintain <5% cover of invasive algae. Work plan progress can be seen in Table 1 and all treatment reefs are highlighted in Figure 1.

The annual monitoring of the Flattery reefs was conducted over eight days between June 15 and July 7, 2020, delayed from March of 2020 due to COVID-19 restrictions. The monitoring was modified from past years as agreed upon in the annual Cape Flattery Trustees meeting on May 13, 2020. The modified monitoring plan consisted of SNAP surveys of ten select reefs with a high cooccurrence of live coral and invasive algae relative to other reefs throughout the bay (Appendix A) and Marker 12, the inception site of this project. The remaining treatment reefs were surveyed for presence or absence of invasive algae to generate a general map of algae coverage on those reefs for continued management. The presence absence surveys produce a lower resolution view of the invasive algae coverage compared to the maps generated from the finer scale SNAP surveys which can be used to calculate percent cover of invasive algae. Data from both survey methods can be used to forecast urchin needs on individual reefs. Results of the monitoring are shown in Table 2, Table 3 and the "Annual Monitoring" section beginning on page 9.

Table 1: Work plan progress.

Action	Who is responsible	Timeframe	Progress	Accomplishments	Notes
Conduct baseline monitoring surveys	Monitoring Coordinator, Project Technicians	March – May 2016	Complete	Priority reef assessment completed 4/2016; Marker 12 assessment completed 5/2016	
Prioritize reef restoration efforts	DAR Aquatic Biologist, Trustees	March 2016 - November 2016	Complete	Prioritization complete	
Outplant native sea urchins to restoration area	Project Technicians, DAR Urchin Hatchery	April 2016 - end of project	In progress	Since the last reporting period, 23,1000 urchins have been released on treatment reefs	Initial targets reached for all reefs. Targets updated annually based on survey data.
Annual reporting to the Cape Flattery trustee council	Monitoring Coordinator, DAR Aquatic Biologist	Annual through end of project	In progress	Ninth progress report submitted	Reporting frequency changed from biannual to annual at 2020 Flattery Trustees meeting.
Follow-up monitoring of coral and algae conducted annually	Monitoring Coordinator, Project Technicians	March through end of project	In progress	Annual monitoring for restoration reefs completed in June 2020	Monitoring delayed due to pandemic. Updated monitoring plan approved at 2020 Flattery Trustees meeting.
Maintenance of outplanted urchins	Monitoring Coordinator, Project Technicians	August 2018-end of project	In progress	Urchins added to previously stocked reefs as needed and available	
Identification of and continuation on future priority reefs	DAR Aquatic Biologist, Trustees	January 2017-end of project	In progress	Reefs 14, 16, 26, 27, 29, and three fringing reef areas added in 2017	Reefs are re-prioritized based on annual algae surveys

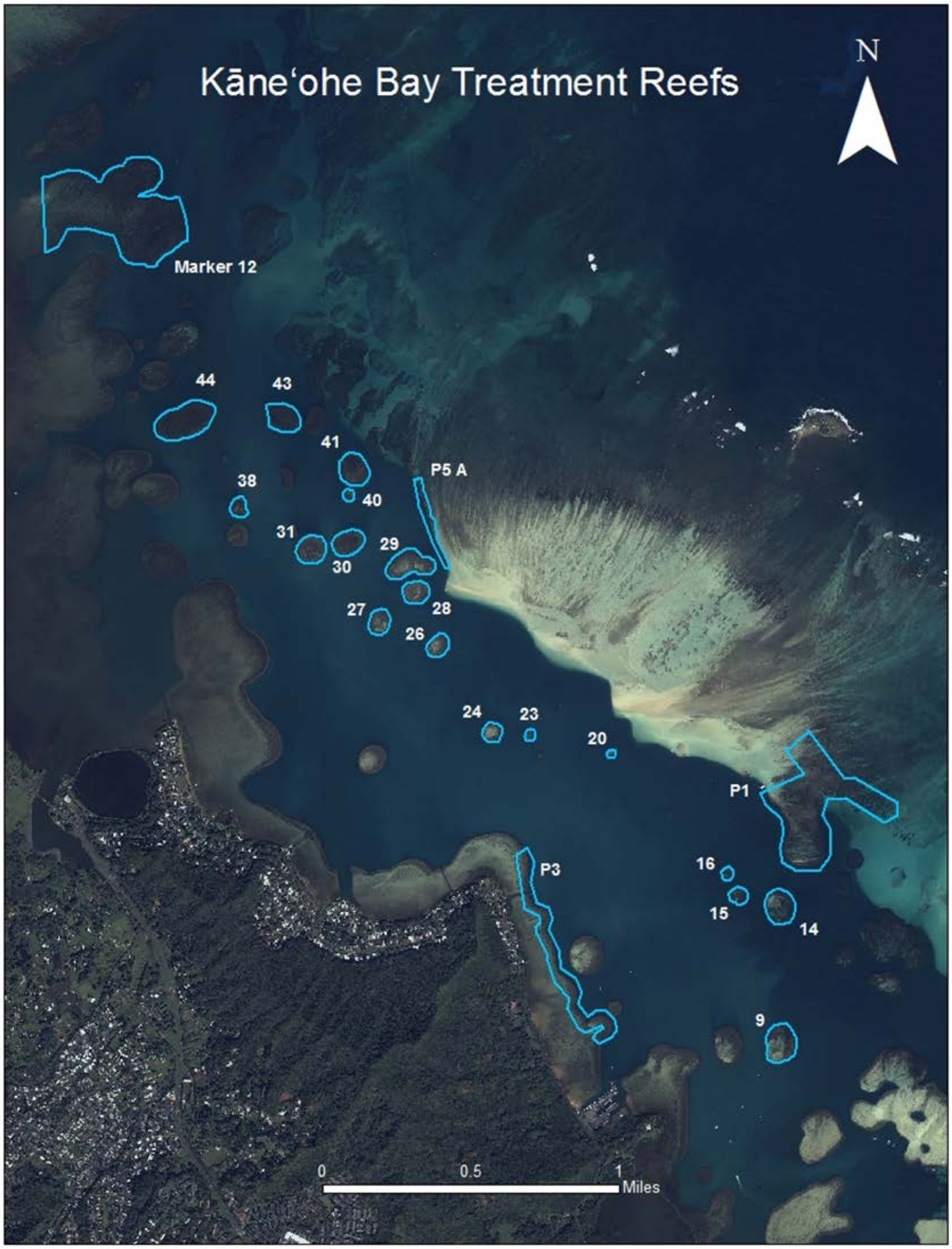


Figure 1: Treatment reefs in Kāne'ohe Bay.

Table 2: Reef characteristics and progress from SNAP Surveys in Kāne'ohe Bay.

2019 SNAP Survey (March)					2020 SNAP Survey (June)				
Reef	Area Surveyed (m^2)	Area of Coral (m^2)	Area of *Eucheuma/ Kappaphycus* (m^2)	Area of *Gracilaria/ Acanthophora* (m^2)	Area Surveyed (m^2)	Area of Coral (m^2)	Area of *Eucheuma/ Kappaphycus* (m^2)	Area of *Gracilaria/ Acanthophora* (m^2)	Target number of urchins needed for ongoing maintenance stocking
Marker 12	281,389	176,505	3,088	48,988	278,942	163,407	3,788	50,564	0
9	29,578	25,633	1,505	490	29,198	26,257	1,135	1,166	0
14*	24,835	18,465	3,486	3,286	24,835	20,220	3,519	4,099	4,555
15	7,789	7,597	3,023	0	7,778	7,773	841	0	905
16*	3,789	3,371	328	8	3,793	3,781	165	0	0
20	2,441	2,438	106	23	2,440	2,432	13	0	0
23	3,700	3,540	790	0	3,709	3,680	1,729	0	3,088
30	19,383	18,343	1,936	0	19,398	18,419	444	0	0
40	3,309	3,272	775	0	3,313	3,208	661	0	991
41	24,834	23,689	8,522	56	24,832	19,970	5,194	188	7,905
TOTALS	401,047	282,853	23,559	52,851	398,238	269,147	17,489	56,017	17,444

**2019 SNAP survey for Reefs 14 and 16 occurred in August 2019.*

Table 3: Area of Eucheuma / Kappaphycus mapped in Presence / Absence Surveys in Kāne'ohe Bay.

2020 Presence / Absence Survey			
Reef	**Area Surveyed (m^2)**	**Area of *Eucheuma/ Kappaphycus* (m^2)**	**Target number of urchins needed for ongoing maintenance stocking**
24	12,155	403	0
26	11,911	1,738	2,285
27	12,958	917	539
28	16,541	122	0
29	29,816	728	0
31	22,233	245	0
38	9,707	3,187	5,404
43	24,833	4,215	5,947
44	50,115	15,875	26,739
P1	224,680	5,930	0
P3	92,860	0	0
P5	19,755	799	0
TOTALS	417,128	34,159	40,914

URCHIN HATCHERY

During the period from January – December 2020, Flattery staff conducted seven urchin spawning events, resulting in 211 wild urchins being spawned as well as additional urchins spawned from resident AFRC broodstock. 33,655 liters of phytoplankton were produced to feed urchin larvae, and 1,209.25 kg of macroalgae were produced to feed juvenile urchins. In total, 9,774,000 larvae were produced and moved into settlement tanks. Of these 334,945 spat, or post-larval urchins, were counted and moved into grow-out tank. 23,100 urchins grew to transplantation size (~10mm) and were released onto treatment reefs during this reporting period (Table 4).

Over three days from October 20 - 22, Flattery staff counted settled urchins from the September 8, 2020 spawn, totaling 206,915 urchin spat. This is the largest settlement event recorded by the urchin hatchery to date. Approximately 90% survival is expected through outplanting. These urchins will be outplanted from January through March 2021. Until now the largest number of urchins released in a calendar year was 112,043. At present, 2021 is projected to yield greater numbers.

Table 4: DAR Urchin Hatchery metrics for January – December 2020.

	Food production		**Urchin production**			
Date	**Phytoplankton produced (l) (for urchin larvae)**	**Macroalgae produced (kg) (for urchin juveniles)**	**Broodstock urchins**	**Number of larvae moved into settlement phase (x1000)**	**Number of spat moved into grow-out phase**	**Number of hatchery urchins outplanted**
Jan 2020	4,163	127	27	0	0	12,400
Feb 2020	3,345	80	30	142	4,019	0
Mar 2020	2,845	66	0	1,970	0	3,750
Apr 2020	1,670	123	30	0	22,969	0
May 2020	4,185	111	0	1,160	0	0
Jun 2020	4,100	82	30	510	17,666	0
Jul 2020	4,194	100	30	0	4,903	1,400
Aug 2020	504	116	0	52	2,449	0
Sep 2020	4,805	94.25	30	0	0	0
Oct 2020	3,179	214	34	3,420	206,915	2,300
Nov 2020	592	86	0	2520	0	1,900
Dec 2020	73	127	0	0	76,024	1,350
Totals	33,655	1,209.25	211	9,774	334,945	23,100

URCHIN OUTPLANTING

In total, 23,100 urchins were outplanted onto priority reefs during this period. An additional 31,006 urchins were produced by the hatchery and outplanted to the Waikīkī MLCD as mitigation for the Kapalama Container Terminal Expansion Project. While the goal is to share resources evenly between the projects, urchin outplantings on Kāneʻohe Bay patch reefs were not possible for much of the reporting period due to safety protocols limiting boat operations due to the COVID-19 pandemic.

Since the February 2017 completion of primary reefs, work has progressed on additional reefs, resulting in target numbers of urchins outplanted being reached on all treatment reefs on December 11, 2018. Control reefs were converted to treatment reefs and targeted for outplanting. Additional maintenance outplanting occurred on the treatment reefs nearing the 5% algal cover threshold and will continue throughout the project duration. Current target numbers of urchins required for maintenance stocking to keep algae below the 5% cover target can be seen in Table 3 and Table 4. Note that target numbers for urchin outplantings in Table 4 is based on presence absence data from which actual percent cover of algae can not be extrapolated skewing projections higher than needed. Table 5 shows the urchin releases that have occurred from January - December 2020, including the number and destination of the urchins and the hours contributed by Flattery and DAR civil service staff.

Table 5: Urchin outplants for January - December 2020.

Date	Urchin source	Reef Number	Number of Urchins Released	Area treated (m^2)	Work Hours	Flattery team members	DAR team members	Total Hours
1/10/20	Hatchery	P5	6,000	3,000	4	3	3	24
1/17/20	Hatchery	R15, R16, R26	4,800	2,400	4	2	2	16
1/22/20	Hatchery	R14	1,600	800	4	1	2	12
3/13/20	Hatchery	R9, R14	2,500	1,250	4	1	3	16
3/18/20	Hatchery	P1	1,250	625	3	2	1	9
7/30/20	Hatchery	R23	1,400	700	4	2	1	12
10/5/20	Hatchery	R23	2,300	1,150	5	2	2	20
11/5/20	Hatchery	R40	1,900	950	5	2	3	25
12/10/20	Hatchery	R26	1,350	675	4	2	1	12
Totals			23,100	11,550	37	17	18	146

ANNUAL MONITORING

The annual monitoring of the Flattery treatment reefs was conducted over eight days between June 15 and July 7. Monitoring was not conducted in March as in past years due to COVID-19 restrictions. The monitoring was modified from past years as agreed upon in the annual Cape Flattery Trustees meeting on May 13, 2020. The modified monitoring plan (Appendix A) consisted of SNAP surveys of ten select reefs with a high cooccurrence of live coral and invasive algae relative to other reefs throughout the bay. The remaining treatment reefs were surveyed for presence or absence of invasive algae to generate a general map of algae coverage on those reefs. The presence absence surveys produce a lower resolution view of the invasive algae coverage compared to the maps generated from the finer scale SNAP surveys which can be used to calculate percent cover of invasive algae. Data from both survey methods can be used to forecast urchin needs on individual reefs however, only the maps generated from the SNAP surveys can produce an accurate percent cover for the reefs.

Maps showing interpolated coral and invasive algae coverage of each reef monitored using the SNAP survey methodology can be found in Appendix B. Additionally, maps were generated for the reefs surveyed using the presence / absence methodology and are included in Appendix C.

It should be noted that the following numbers are interpolations across the whole patch reef area. High densities of algae cover can be found in smaller areas across individual reefs and algae coverage is not evenly distributed across the reefs.

Coral Coverage

Coral distributions were variable throughout the survey area. Coral cover ranged from 2,432 m^2 to 163,407 m^2 (Figure 2). This is because the areal extent of each reef surveyed is highly varied. The total area of the SNAP surveyed restoration area covered by coral was estimated at 269,147 m^2. Coral area data was not collected for the reefs surveyed using the presence / absence methodology.

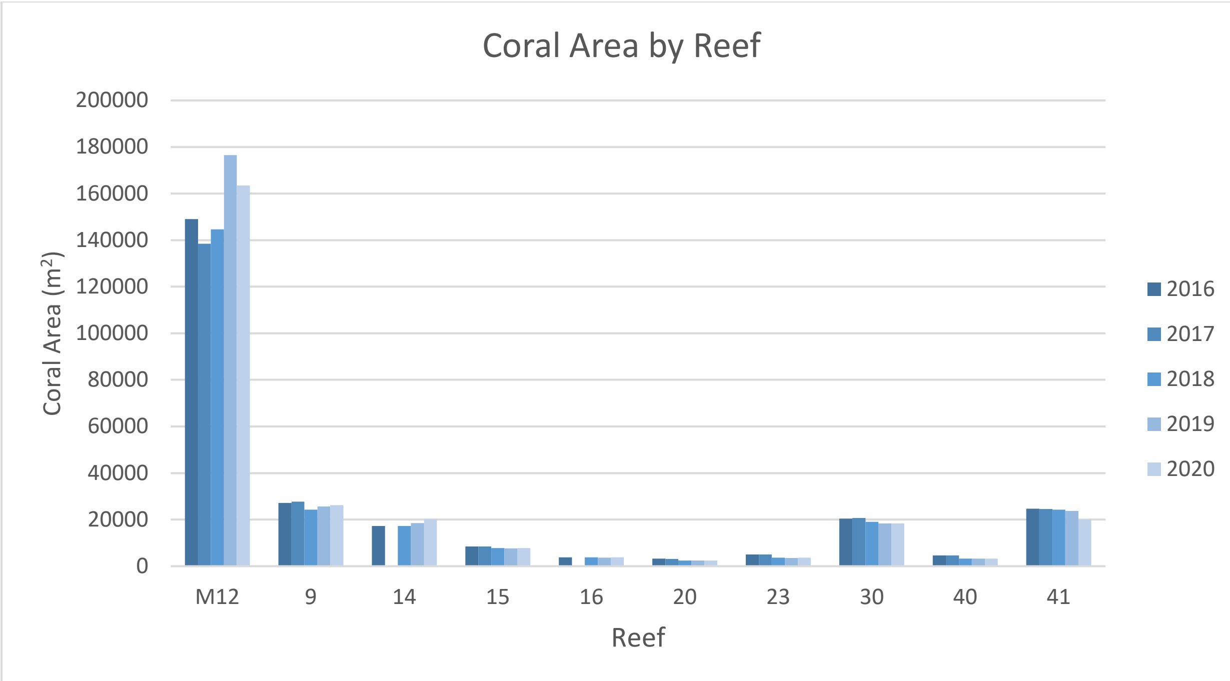


Figure 2: Coral cover (m²) by reef.

Kappaphycus/Eucheuma

The total area of *Kappaphycus/Eucheuma* decreased between 2019 and 2020 on seven of the ten reefs surveyed using the SNAP survey methodology. *Kappaphycus/Eucheuma* area ranged from 13 m^2 to 5,194 m^2 (Figure 3). Only reef 23 (9.93%) showed interpolated algae densities above the target of 5% cover. The remaining nine reefs showed algae coverage ranging from 0.03% to 1.78%. Post survey urchin outplantings were prioritized for reef 23 and the target was reached for that reef in October.

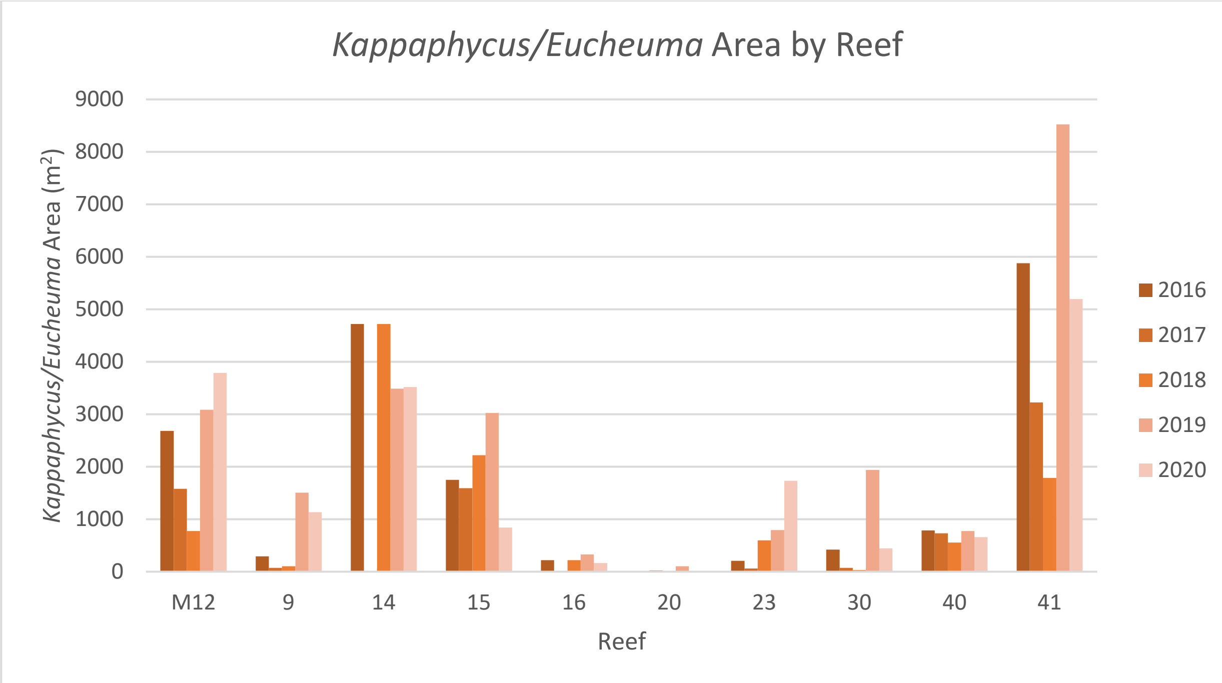


Figure 3: Kappaphycus/Eucheuma cover (m²) by reef.

Gracilaria/Acanthophora

An increase in *Gracilaria/Acanthophora* was noted on four of the ten reefs surveyed using the SNAP methodology (Figure 4) though areal coverage remained relatively low and the remaining six reefs had no *Gracilaria/Acanthophora* present. *Gracilaria/Acanthophora* is typically seen in higher densities in the fringing reef areas and is generally found in more rubbly, sandy areas with lower coral cover. For this reason, *Gracilaria/Acanthophora* areas are currently not directly targeted for urchin outplanting. We will continue monitoring these invasive algae to determine if the areas should be targeted for biocontrol in the future.

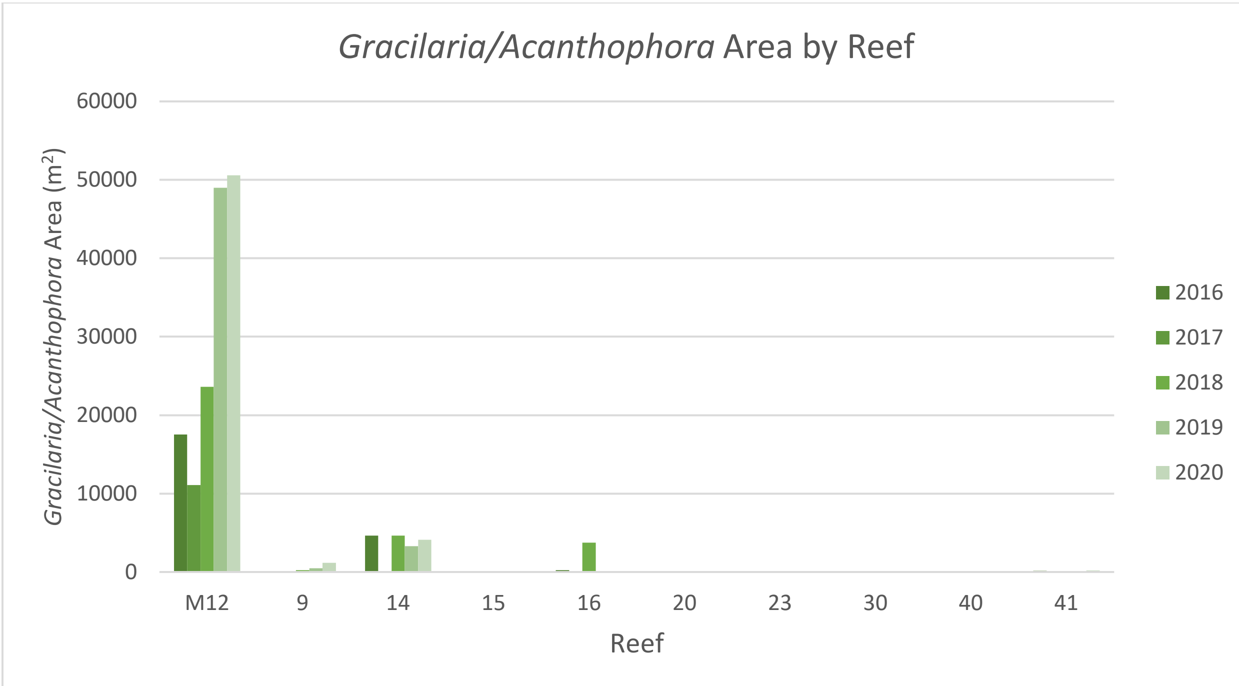


Figure 4: Gracilaria/Acanthophora cover (m²) by reef.

CORAL REATTACHMENT PILOT STUDY

Photos of the coral reattachment plots are normally taken each May. Due to the COVID-19 pandemic, the photos were not collected during this reporting period. However, past years photomosaics of the plots are currently being processed. Photomosaics can be analyzed to determine coral growth rates and coverage within the plots. Other metrics such as coral volume, linear rugosity, or surface complexity may be calculated based on need or available resources.

HE‘EIA WATERSHED RESTORATION

Table 6. below provides a summary of the objectives and tasks outlined in the He'eia Restoration Proposal towards enhancing coral recovery through watershed restoration with the following sections summarizing work completed during the January – December 2020 time period.

Table 6: He'eia restoration objectives progress.

Objective	Timeframe	Completed Tasks/Notes
Hydrologic Modeling Flood Scenarios	Jan-Mar 2019	Conducted a flood frequency, channel morphology, and flood pathway analysis throughout He'eia wetland.
Watershed Analysis	Feb-Apr 2019	Examined the broader landscape to identify sediment sources and sediment delivery mechanisms. USGS (John Stock) sediment source site visit and analysis.
He'eia Partnership Workshop	July 23, 2019	Presented hydraulic model results and design considerations and alternatives to Kako'o Oiwi and partners. Participated in partner discussion on landscape level wetland and cultural restoration vision.
Flood model presentation to Paepae o He'eia	July 25, 2019	Presented flood model and design considerations and alternatives specific to fishpond.
Wetland and Channel Design Recommendations	Jul-Aug 2019	Development of a range of design plan scenarios. Appropriate scale of retention areas. Stable channel widths to accommodate a range of flood flows. Configuration of roads to reduce flood impacts and delivery of sediment.
Conservation Action Plan (TNC)	Feb-Mar 2020	Provided flow model input to inform decision process and guide implementation. Contributed to writeup of hydrology, aquatic biota monitoring, wetland design sections.
Heavy Equipment Implementation guidance	Apr-Jun 2019	Provided guidance on heavy equipment methods for mangrove removal in wetlands.
Regulatory and Environmental Policy Guidance	Sep 2019-present	Assisted in permitting process for regulatory compliance. SAP permit assistance for aquatic sampling and planned future invasive fish removal.
Aquatic Biota Data Collection and Analysis	June 2019-present	Watershed wide (estuary to USGS gage) aquatic biota sampling as part of project effectiveness monitoring, long-term monitoring, and planned future invasive fish removal program. Bi-annual
Baseflow Hydraulic Modeling	Jan-Mar 2020	Examined potential effects to aquatic biota from reductions in baseflow and effects to the natural hydrologic function.
Restoration Implementation by Technician/Restoration Specialist	Jun 2019-present	Constructed sediment retainment areas, removed flow barriers, and reestablished natural channel flow paths and waterways. Planted native vegetation and continued maintenance of restored areas. Guided restoration tours to stakeholders and visitors.

Mangrove Removal & Wetland Restoration

This task addresses the He‘eia project objectives to *decrease sediment and nutrient loads to He‘eia reef* and *reduce freshwater pulses in He‘eia stream during storm events* by removal of invasive mangrove and creation of additional flow paths that increase sediment collection areas and increase retention and filtering of sediment and nutrients.

From Jan-Sep 2020, mangrove removal in the Kako’o Oiwi managed wetland has continued with a 4 acre area remaining from original stand of over 12 acres (see photo). This section has increased the extent of the brackish water estuary upstream up to 800 feet from the bridge. This remaining stand is planned to be fully removed by the end of 2020. Previously cleared areas continue to be maintained to allow streamflow passage and establishment of native vegetation.

During this time period, DAR participated in planning and design meetings, including the TNC Conservation Action Plan, which guided ground operations incorporating elements aimed at reducing sediment transport. Because roads can disrupt natural stream flow paths and be avenues for sediment transport, reducing the number of roads and their placement location were discussed at length. DAR provided flow model input to inform the decision process and guide the ground implementation.

Figure 5. Blue area is where previous mangrove stand has been cleared and begun to be replanted and maintained with native vegetation. Red area is the remaining stand of approximately 4 acres that will be removed by the beginning of 2021.

He‘eia Stream Baseflow Assessment

This task addresses the objective to *reduce invasive plant growth leading to decreased wetland area and capacity to retain sediment and nutrients*.

The He‘eia restoration project employs an adaptive management component where modifications or additions are required to meet project objectives. It was previously not known the extent to which water withdrawals affected He‘eia stream baseflows and flow inundation characteristics which in turn can affect sediment delivery dynamics. A new threat was identified as the reduction of normal average baseflows from a Board of Water Supply water withdrawal tunnel dug in 1940. This tunnel drained the high-elevation groundwater dike compartments (small aquifers) which produced springs that supplied the baseflow to He‘eia Stream. As a result, median baseflows were permanently reduced by more than half the normal baseflow or by approximately 1.0 mgd.

Subsequently, the restoration strategy was expanded to include effects from reduced natural baseflows due to water withdrawals from the development tunnel. The reduced normal baseflow limit aquatic biota habitat and encourages invasive plant growth and establishment. Reductions in the natural baseflow levels from water withdrawals have increased growth of invasive vegetation and limit aquatic biota habitat. Baseflows area an important component to maintain sufficient freshwater to stream and estuary biota for survival, especially during dry periods. Disruption to baseflow, mainly reductions in quantity, can encourage invasive plant growth particularly in areas previously inundated by water. This can further disrupt natural ecosystem processes by limiting water dispersion or wetland area that retain sediment and nutrients or cause migration barriers for aquatic biota.

DAR worked with USFS to develop a model examining average baseflow conditions pre and post water withdrawal tunnel development. The model (Figure 6) identifies area reductions in surface water and their extent. These areas coincided with proliferation of invasive grass and plant growth such as California grass (*Brachiaria mutica*) and Hau (*Hibiscus tiliaceus*) which have led to changes in channel location, streamflow characteristics, and sediment delivery dynamics. The model quantifies the amount of channel habitat reduced at baseflow conditions from flow reductions caused by tunnel construction.

Model results were shared with He'eia partners towards goal of better informed management decisions in an adaptive management framework. Additional work is being collaboratively developed towards incorporation restoration of baseflows into the greater watershed restoration plan.

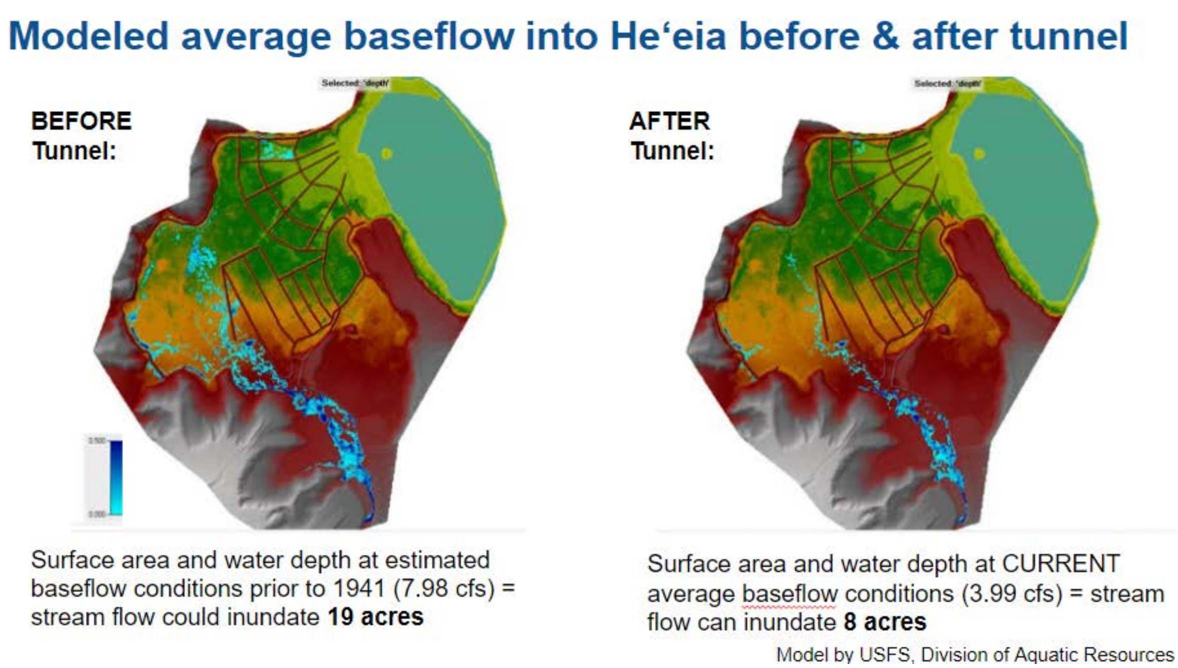


Figure 6. Surface water model (2D Hec-Ras) showing extent and location of water surface inundation during baseflow conditions pre and post Board of Water Supply development tunnel condition.

Aquatic Biota Monitoring

This task addresses the objective to *monitor project effectiveness and change as a result of restoration activities and Protect against spread of invasive fish and vegetation to estuary and reef.*

An aquatic fish survey was completed in June/July 2020. This is the third survey since they began in 2019. The sampling took place from the estuary up to just below the headwaters of Heʻeia stream. Stream flows were at their lowest level since surveys began. One observation worth mentioning is that native O'opu nakea appeared to congregate in deeper pools, potentially using the deeper pools as refuge from a reduction in habitat availability elsewhere from low flows. Participants in the planning and data collection included NERR, Kako'o Oiwi, TNC, and DAR staff.

Plans to remove nonnative invasive fish in Heʻeia estuary and wetlands began in early 2020 and are currently being developed. DAR is assisting in the process of amending the Special Activities Permit (SAP), held by the NERR, to include an invasive fish removal methodology. Additional spot sampling is currently being discussed to accommodate effects of reductions in baseflows associated with the development tunnel as well as potential effects from climate change. These additional sampling periods would occur during extreme low flows or when water is withdrawn from tunnel and time periods of king tides.

Estuaries are key habitats connecting the reef system with upstream freshwater system and serve as nursery habitat and refuge for a number of aquatic species. Estuary sampling conducted during this time period showed increases in abundance of native estuarine species such as Aholehole (*Kuhlia xenura*) and Ama'ama (*Mugil cephalus*). Adjustments and additional surveys are being developed that will collect physical data on the lower stream channel and estuary regarding sediment characteristics as they directly relate to sediment delivery dynamics to the adjacent reef system.

Table 7. Heʻeia estuary sampling data collected June and July 2020.

Species	Common name	Total catch	Native	Non-native
Kuhlia xenura	Hawaiian flagtail/Āholehole	162	×	
Mulloidichthys flavolineatus	Yellowstripe goatfish/Weke ʻā (adults)/ʻOama (juveniles)	94	×	
Mugil cephalus	Striped mullet/ʻAmaʻama	96	×	
Osteomugil engeli	Kanda mullet	50		×
Tilapia complex	Tilapia	46		×
Caranx ignobilis	Giant trevally/Ulua aukea	10	×	
Atherinomorus insularum	Hawaiian silverside/ʻIao	10	×	
Acanthurus triostegus	Convict surgeonfish/Manini	9	×	
Naso unicornis	Bluespine unicornfish/Kala	5	×	
Acanthurus nigrofuscus	Brown surgeonfish/Lavender tang/Māʻiʻiʻi	3	×	
Caranx melampygus	Bluefin trevally/ʻŌmilu	3	×	
Poecilia sp.	Mollies/Guppies	3		×
Eleotris sandwicensis	Sandwich island sleeper/Oʻopu akupa	2	×	
Lutjanus fulvus	Blacktail snapper/Flametail snapper/Toʻau	2		×
Pterygoplichthys multiradiatus	Long-fin armored catfish/Orinoco sailfin catfish	2		×
Rhinecanthus rectangulus	Reef triggerfish/Picasso triggerfish/Humu humu nukunuku apuaʻa	2	×	
Saurida nebulosa	Nebulous lizardfish/Clouded lizardfish/ʻUlae	2	×	
Bothus pantherinus	Panther flounder/Leopard flounder/Pākiʻi	1	×	
Echidna nebulosa	Snowflake moray/Starry moray/Puhi kāpā	1	×	
Upeneus arge	Bandtail goatfish/Finstripe goatfish/Nightmare goatfish/Weke pueo	1	×	

USFWS Coastal Wetland Grant submission

To address continued funding needs for the next phase of project implementation and maintenance of existing restored areas, DAR submitted a coastal wetland grant through USFWS in July 2020 to support additional wetland restoration work in the previous mangrove stand removal area and upstream open water areas inundated by California grass and other non-native vegetation. If acquired, this would fund an additional fifteen acres of restored wetlands within a two year grant cycle with a long-term (20 years) commitment to maintain restored wetland area.

OTHER PROGRESS

22 reef markers were placed around Coconut Island in partnership with the Hawaiʻi Institute of Marine Biology to clearly mark the regulated fishing areas within the Hawaiʻi Marine Laboratory Refuge. Reef markers previously placed throughout Kāneʻohe Bay continue to be maintained on patch reefs determined to be likely grounding areas by vessels in Kāneʻohe Bay.

David Cohen and Wesley Dukes both presented at the World Aquaculture Society – Aquaculture America conference in February 2020. David Cohen's presentation, "Sea Urchin Hatchery Update: Improved Survivorship, Pest Reduction and Community Involvement", and Wesley Dukes' presentation, "Sea Urchin Biocontrol of Invasive Macroalgae: Aquaculture Innovation for Successful Reef Restoration", together highlighted the entire process from spawn to outplant of DAR's sea urchin biocontrol method. David Cohen chaired, organized, and moderated the Sea Urchin session for the conference and Wesley Dukes moderated the Coral Restoration session.

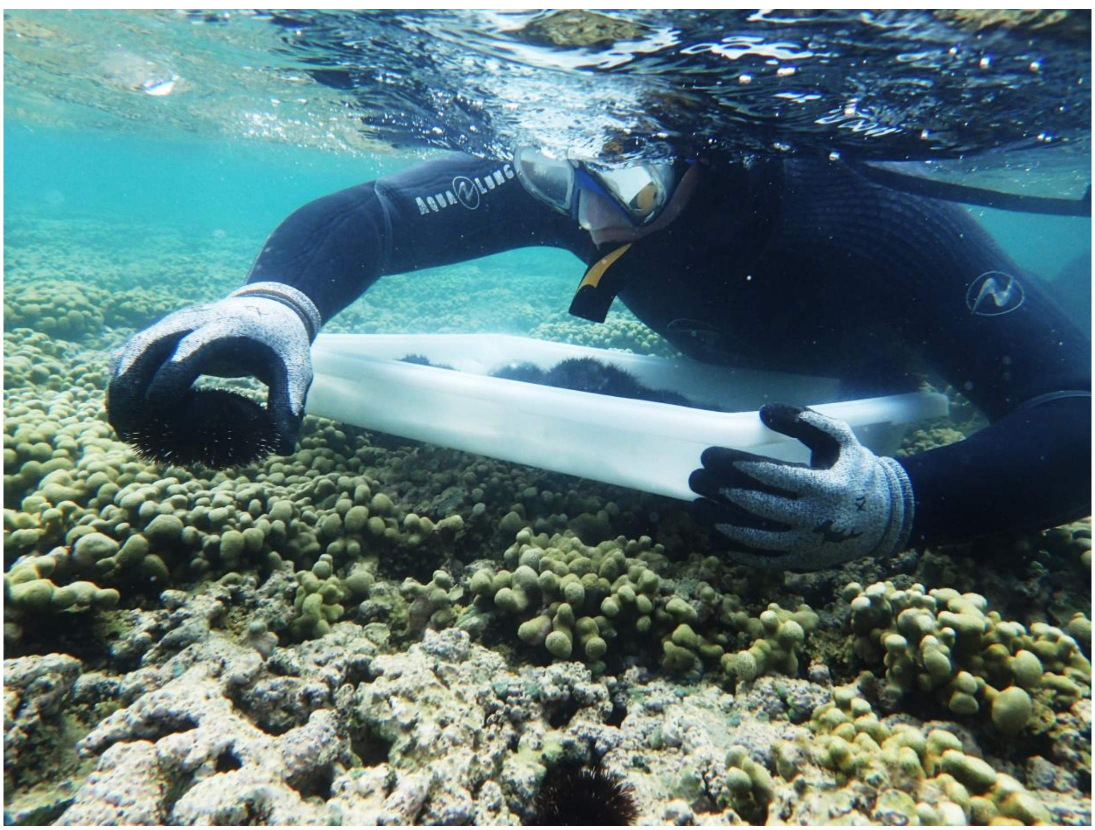
Wesley Dukes also presented at the 2020 Hawaiʻi Conservation Conference with a presentation titled "Coral Reef Restoration using Native Sea Urchins (*Tripneustes gratilla*) for Biocontrol of Invasive Macroalgae".

Finally, DLNR issued a press release titled "Coral Reef Restoration using Native Sea Urchins (*Tripneustes gratilla*) for Biocontrol of Invasive Macroalgae" in August 2021. The press release generated stories that were run in local newspapers and on television.

APPENDIX A

Cape Flattery Settlement Restoration Project: Restoring Reefs in Kāneʻohe Bay

MONITORING PLAN



Division of Aquatic Resources
Aquatic Invasive Species Program
Updated June 2020

Contents

Project Funding

This monitoring plan is part of restoration work outlined in the settlement to offset the impacts to coral damaged by the Cape Flattery ship grounding event.

Goals and Objectives of Project

1. To aid in the <u>regrowth</u> and <u>colonization</u> of coral colonies and other native coral reef organisms on select reef areas in Kāne'ohe Bay
2. To protect unaffected coral reef habitat in Kāne'ohe Bay

Restoration Objectives

1. Clear and maintain over 25 acres of invasive algae to levels <u>less than 5% cover</u>
2. Protect against the spread of invasive algae to unaffected reef areas

Project Site Description

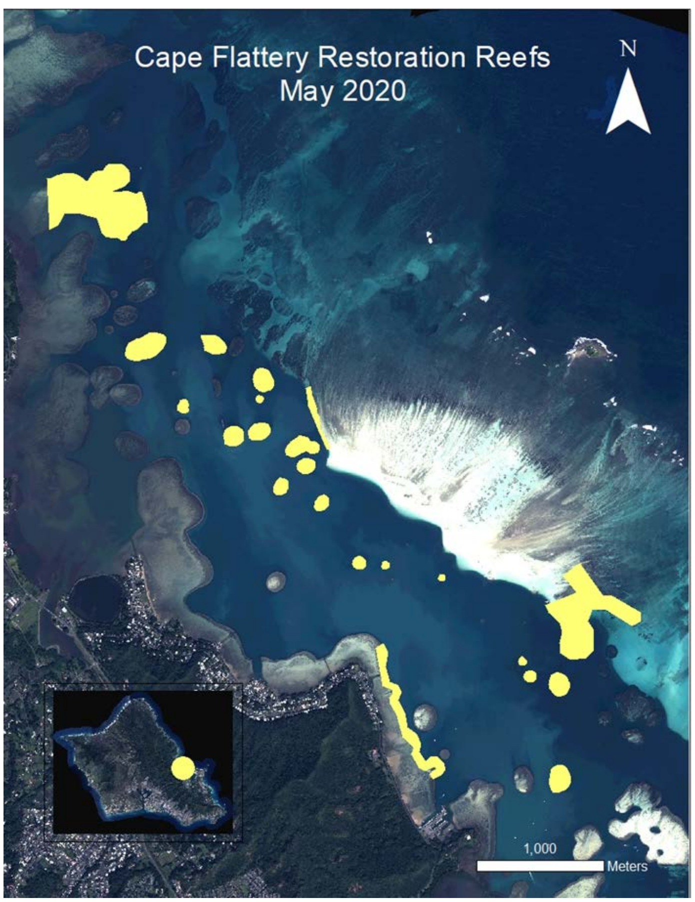


Figure 2 Restoration area located in Kāne'ohe Bay, O'ahu

Restoration Area

This restoration effort is currently focused on 19 distinct reefs and 3 fringing reef areas within Kāne'ohe Bay, O'ahu (Figure 1). Reefs in Kāne'ohe Bay have abundant coral reef habitat but are heavily affected by four species of invasive algae (*Eucheuma* spp., *Kappaphycus* spp., *Gracilaria salicornia, and Acanthophora spicifera*) that are overgrowing and killing coral colonies. *Eucheuma* spp. and *Kappaphycus* spp. are the primary target of this restoration effort. Hereafter "invasive algae" will refer to the target species, *Kappaphycus* spp. and *Eucheuma* spp. Kāne'ohe Bay has a diverse array of coral species including *Montipora capitata, Montipora patula, Montipora flabellata, Porites compressa, Porites lobata, Pocillopora damicornis, Pocillopora meandrina, Fungia scutaria,* and *Pavona varians.*

Eleven reefs were initially selected for restoration based on their size, percent cover of live coral, and percent cover of invasive algae as determined in 2014 baseline assessments[1]. Marker 12 Reef, patch reefs 20, 23, 24, 28, 30, 31, 38, 40, 41, 43, and 44 are considered ecologically suitable restoration sites because there is an identifiable threat of invasive algae and there are established methodologies for restoring these areas. An additional eleven reefs (reefs 9, 14, 15, 16, 26, 27, 29, and 3 fringing reef areas) were added in 2016 after algae density on the initial reefs were reduced to below the target 5% cover. Additional reefs may be added as restoration progresses. Removing invasive algae allows corals to regrow where partial mortality has occurred and allows for potential recolonization of previously occupied habitats.

Restoration Site Selection

The current restoration site covers a total of 917,428 square meters (227 acres). The area known as Marker 12 is the priority site as deemed by the project trustees. Prioritization within the list of patch reefs was accomplished by giving priority to reefs with the highest co-occurrence of coral cover and invasive algae cover. Consideration was also given to the size of the reefs as smaller reefs historically have a high rate of restoration success as well location within the northern portion of Kāneʻohe Bay.

Marker 12 became the priority because of several factors including high coral cover, high density of invasive algae, proximity to unaffected coral reefs, and the importance of reducing the northern spread of invasive algae outside of the Bay. Outside of Marker 12, small patch reefs are preferred because it is achievable to stock these areas even in the case of limited urchin supply. The northern area of Kāneʻohe Bay is of particular interest because there are ongoing restoration activities in the central region and to prevent spread of the algae outside of Kāneʻohe Bay as invasive algae has demonstrated a south to north pattern of spread and proliferation[2,3].

The restoration strategy was altered following a dramatic shift in the invasive algae abundance in Kāneʻohe Bay in 2015 – 2016. This shift in algae cover also caused a re-thinking of the method and location of the restoration activities as well as the monitoring metrics. Previously, a work plan had been devised only for Marker 12 using a combination of the Super Sucker, an underwater vacuum that divers use to remove invasive algae from the reef and native sea urchins. The current low algae cover and patchiness has made the Super Sucker an ineffective tool and it was determined that the effort would be more efficient applying the urchins to the remaining algal patches. The project was expanded to additional reef locations to maintain the restoration acreage goal and take advantage of the low algae cover. If the algae levels were to increase to the point where the Super Sucker is deemed an appropriate tool; monitoring metrics will be added to this plan (Appendix 1).

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[1] University of Hawaii, Social Science Research Institute (SSRI). 2014. SNAP-Assessment Report. Prepared for Department of Land and Natural Resources, Division of Aquatic Resources. Honolulu, HI: Neilson, B., G. Gewecke, B. Stubbs, K. Tejchma.
[2] Rodgers S and Cox E. 1999. The distribution of the introduced rhodophytes *Kappaphycus alvarizii, Kappaphycus striatum* and *Gracilaria salicornia* in relation to various physical and biological factors in Kaneohe Bay, Oahu, Hawai'i. Pacific Science 53: 232-241.
[3] Conklin E and Smith C. 2005. Abundance and spread of the invasive red algae, *Kappaphycus spp*, in Kaneohe Bay, Hawai'i and an experimental assessment of management options. Biological Invasions 7: 1029-1039.

Restoration Methods

DLNR now solely uses a native biocontrol method of outplanting hatchery-raised native sea urchins (*Tripneustes gratilla*) to reduce the levels of invasive algae and restore target reefs, initiated in 2016. Urchins are collected from the wild and spawned and raised in the DAR sea urchin hatchery. The urchins graze on invasive algae and prevent it from growing back over time. The urchins are particularly effective in certain areas, for example in areas where algae grow deeply within coral fingers or areas with large amounts of loose rubble where other methods such as the Super Sucker prove ineffective. Previously established biocontrol procedures will be followed in the collection, culture, and release of sea-urchins to minimize the risk of disease transmission. A preliminary snapshot (SNAP) assessment was performed on the restoration reefs to determine invasive algae and coral percent cover as well as hotspots of invasive algae in 2016. These hotspots were prioritized within the ranked reefs for treatment with sea urchins. Annual monitoring will determine priority areas for future urchin outplanting.

Monitoring Metrics and Methods

This project will be monitored in a multi-tiered approach, tracking three metrics to show progress and demonstrate completion of goals. Tracking the completion of management plan actions ensures that the promised tasks have been fulfilled. Monitoring of algal and coral cover will document how patterns of algae change over time throughout the broader treatment area and identify hotspots of algae for treatment and finer-scale monitoring. Lastly, monitoring the presence of the target species (sea urchins) deployed to the restoration area will ensure that the required density of urchins (2 urchins per square meter) has been achieved within the affected area. Total number of urchins outplanted on each reef is reevaluated based on annual survey data and annual projections are made based on total urchins needed to keep the algae percent cover below the targeted 5%.

Management plan actions implemented

A management plan tracker will be used to document the accomplishment of milestones outlined in the *Reef Restoration Work Plan for Kāne'ohe Bay, O'ahu*. Progress will be tracked in a table (Table 1) that indicates the team member responsible for each action, the timeframe for the action, progress that has been made, and notes. Other metrics for the advancement of the monitoring plan include number of staff hired to the project and number of work hours per team member.

Table 1 Management plan tracker for the Reef Restoration Work Plan for Kāne'ohe Bay, O'ahu

Action	Who is responsible	Timeframe	Progress	Accomplishments	Notes
Conduct baseline monitoring surveys.					
Prioritize reef restoration efforts					

Outplant native sea urchins to restoration area.					
Bi-annual reporting to the Cape Flattery trustee council					
Follow-up monitoring of coral and algae conducted annually					
Maintenance of outplanted urchins					
Identification of and continuation on future priority reefs					

Algae and Coral Percent Cover

The project will measure changes in algae and live coral cover in the restoration area. Metrics for changes in benthic habitat will be the percent cover, density, and distribution of invasive algae and coral.

From 2016 full in-depth SNAP monitoring was conducted for all the reefs highlighted in Figure 1. In 2020, the monitoring plan was adapted to increase efficiency of monitoring team efforts on the managed reefs- totaling an area of over 227 acres. The 2020 adapted monitoring plan identified select reefs to conduct in-depth reef mapping surveys, while conducting rapid spot-check mapping surveys for additional restoration reefs and is detailed in the next section.

SNAP and Presence / Absence Assessment

A map of invasive algae and coral cover will be created annually by conducting a snapshot, or SNAP survey. The maps will be used to pinpoint hotspots of invasive algae that will be prioritized for treatment. We will also track changes in the density and distribution of algae and coral after the restoration activities. The SNAP assessment will be conducted on a yearly basis on ten treatment reefs (reefs 9, 14, 15, 16, 20, 23, 30, 40, 41, and Marker 12). The reefs were selected based on 2019 survey data comparing interpolated coral cover w/ interpolated algae cover as well as spatial distribution of reefs throughout the bay (figure 2). M12 was chosen due to it being the original Flattery restoration site and R9 and R16 were selected since it has been monitored for a long duration as part of past monitoring. Surveys on the remaining restoration reefs will be abbreviated, only noting presence / absence of algae. The abbreviated surveys will enable us to generate invasive algae distribution maps for forecasting urchin outplantings while minimizing field and processing time. Reefs selected for SNAP surveys may change based on the SNAP and rapid presence absence survey data.

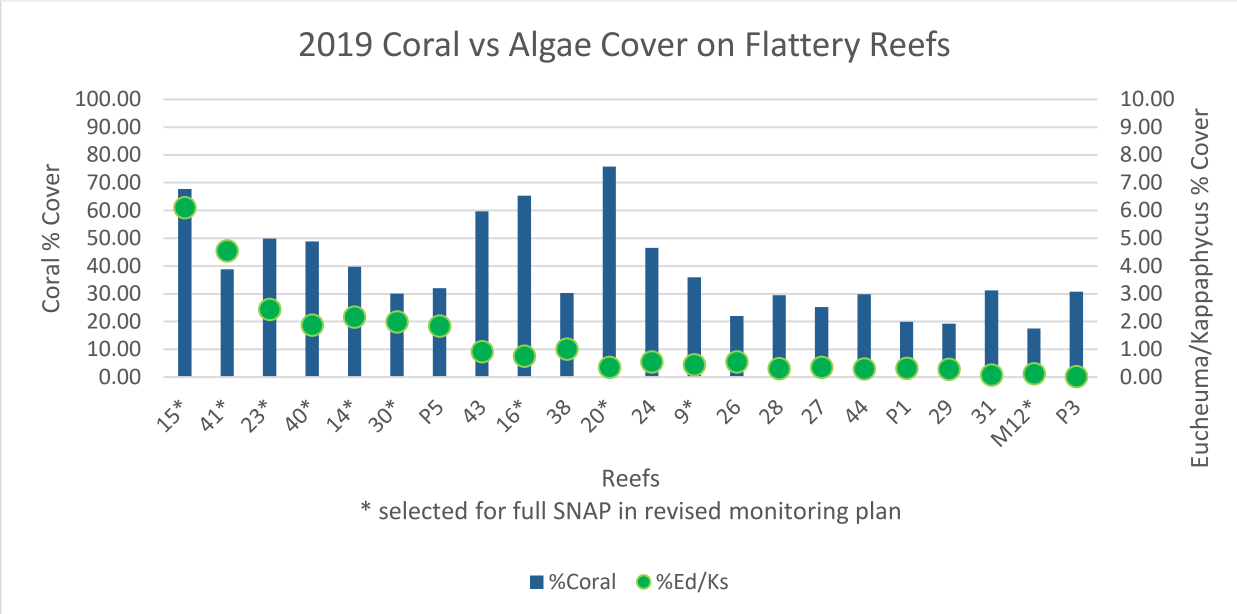


Figure 2 2019 Coral and Algae Cover on restoration reefs: This data was used to identify reefs selected for a full SNAP Survey.

SNAP Survey Methods

Surveyors, spaced approximately 5-10 m apart, swim transects across the reef and randomly place a 0.5 meter measuring stick (SNAP stick) every 5-10 meters (Figure 3). Surveyors swim multiple passes across the reef to sample the reef's flat, crest and slope to depths of ≤ 3 meters. Surveyors make every attempt to avoid bias by haphazardly selecting survey points by tossing the stick at regular intervals and not looking at the reef bottom when tossing the survey stick on a point.

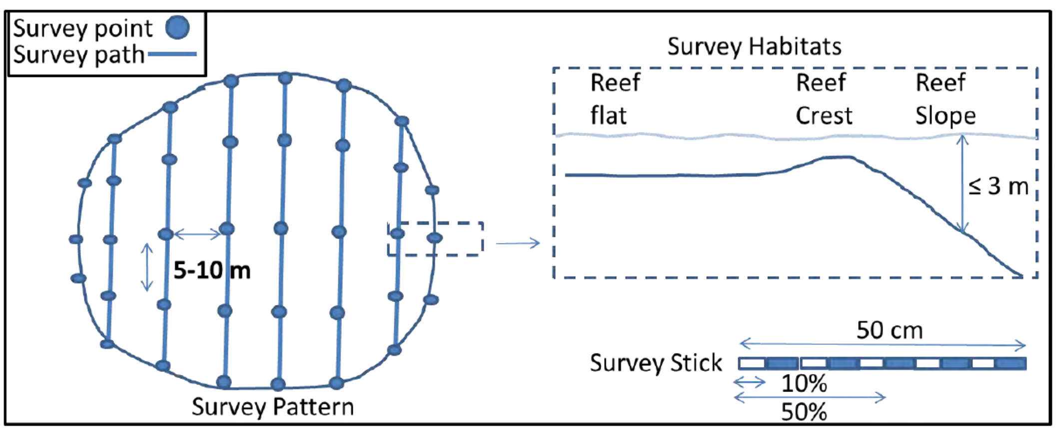


Figure 3 SNAP assessment protocol for measuring density and distribution of live coral and invasive algae

At each survey point, a waypoint is 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 SNAP 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 SNAP stick is partitioned into ten, 5 cm increments. Coral and algae data is categorized into five separate cover classes accumulated across the stick (Table 3).

Table 2 Cover classification for the SNAP assessment

Percent Cover	Cover Code
0%	0
1-10%	1
11-50%	2
51-75%	3
76 – 100%	4

Presence / Absence Survey Methods

This will be an abbreviated SNAP survey involving only a GPS and point taking at algae presence. Surveyors, spaced approximately 5-10 m apart, swim transects across the reef. If invasive algae is present, a GPS point is taken at the location. If the surveyor is swimming over a large area of algae, a point is taken approximately every 10 meters that algae is present. No GPS points are taken if algae is not present. Surveyors swim multiple passes across the reef to monitor the reef's flat, crest and slope to depths of ≤ 3 meters.

Data Management and Mapping

GPS latitude and longitude locations are downloaded and associated survey data entered into a series of spreadsheets. The resulting dataset is checked for errors and exported to an ArcGIS geodatabase. Coral, *Eucheuma/Kappaphycus*, and *Gracilaria/Acanthophora* are mapped using ArcGIS software for each reef. Interpolated raster coverage maps of the reef are 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. Presence / absence data is mapped by aggregating GPS points taken where *Eucheuma/Kappaphycus* is present and creating a polygon for the area. An estimated areal coverage can be determined from these maps.

Number and Density of Target Species

The project will also track the number of sea urchins that have been raised in the DAR urchin hatchery and released to the treatment area. From the urchin hatchery process, the project will track both food production and urchin production (Table 4). Food production includes both the liters phytoplankton grown for urchin larvae and kilograms of macroalgae grown for juvenile urchins. Three phases of the urchin grow-out process will be tracked: number of urchins spawned, number of the resulting larvae moved into the settlement phase to grow out into juvenile urchins, and number of urchins originating from the hatchery that are released in the restoration area. Details regarding the transplantation of urchins including the area treated, number of urchins transplanted, work hours, and number of team members for each release (Table 5). The target density is 2 uchin/m^2 of affected area.

Table 3 Urchin hatchery monitoring metrics

	food production		urchin production		
Date	phytoplankton produced (L)	macroalgae produced (Kg)	urchins spawned	larvae moved into settlement/grow out phase	hatchery urchins outplanted
Totals					

Table 4 Urchin release tracker

Date	Urchin source	Reef Number	Number of Urchins Released	Area treated (m^2)	Work Hours	Number of team members	Total Hours
Totals							

Monitoring Frequency and Schedule

Monitoring Frequency:

	Frequency	
Monitoring Metric	Measurements	Reporting
1. Management plan actions implemented	Monthly	Annual
2. Algae and Coral Cover	Annual	Annual
3. Presence of target species	Annual	Used for urchin outplant locations

Monitoring Schedule:

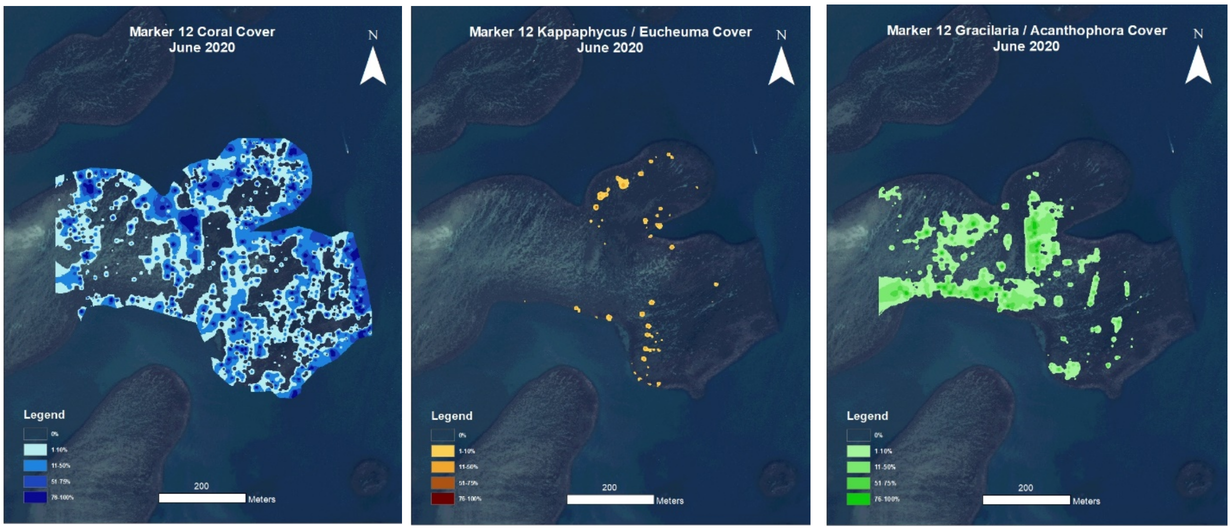
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Management plan actions implemented										Report		
Algae and coral percent cover			X							Report		
Number and density of target species	X	X	X	X	X	X	X	X	X	Report	X	X

Data Sharing Plan

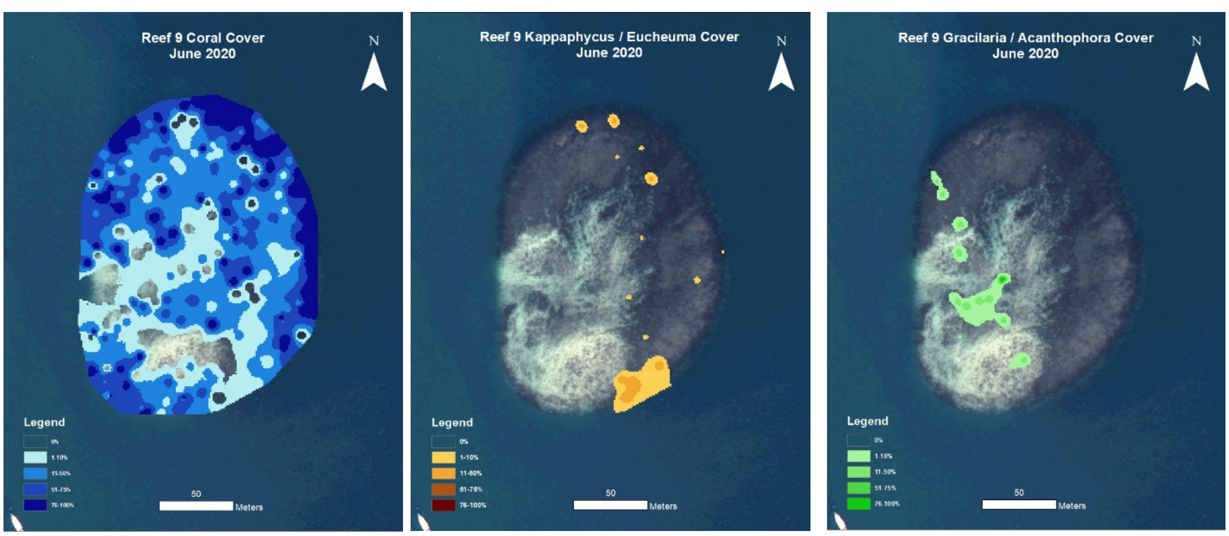
The Reef Restoration for Kāneʻohe Bay Project, implemented by the Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR) will generate environmental data and information, including benthic habitat maps, percent cover calculations of coral and algae, number and density of urchins released. Datasets will provide specifics on information collected and collection dates. Data will be collected by DAR staff according to the procedures described in project monitoring plan, and stored at the DAR Anuenue Fisheries Research Center (AFRC) on a shared server, with data back-ups on an external hard drive and on a laptop computer. Contact Kim Fuller, DAR Aquatic Biologist, kimberly.h.fuller@hawaii.gov, for more information or to make a data request. All future sub-recipients not identified in this plan will have as a condition of their contract acceptance of this data sharing plan. Any additional data sharing stipulations for future sub-recipients may be outlined at that time and described in their contract.

APPENDIX B

Marker 12



Reef 9



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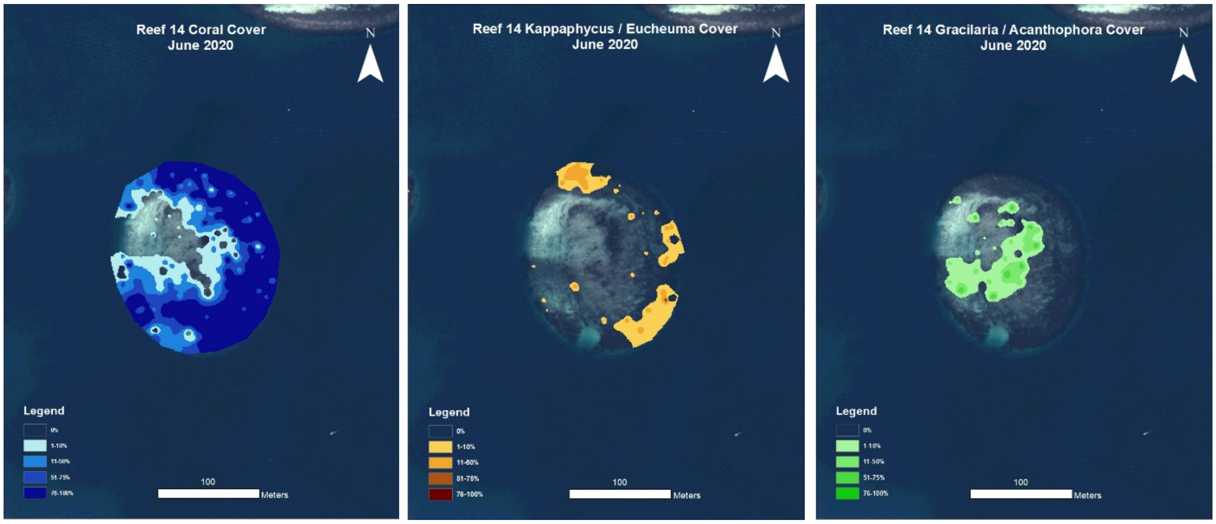

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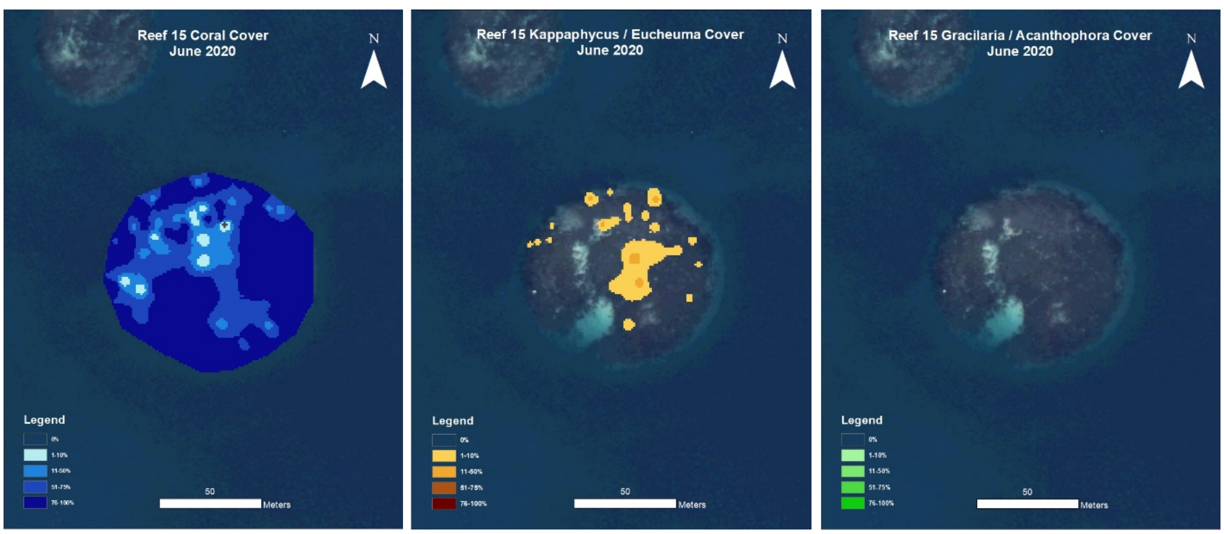

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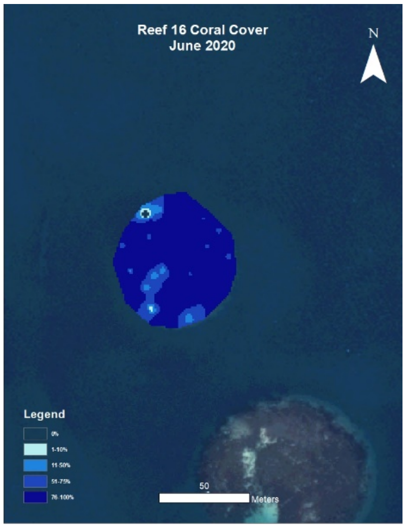

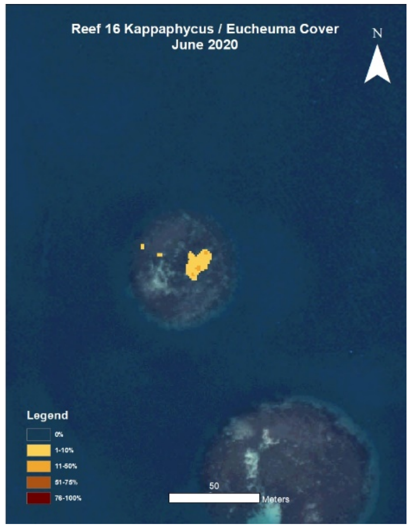

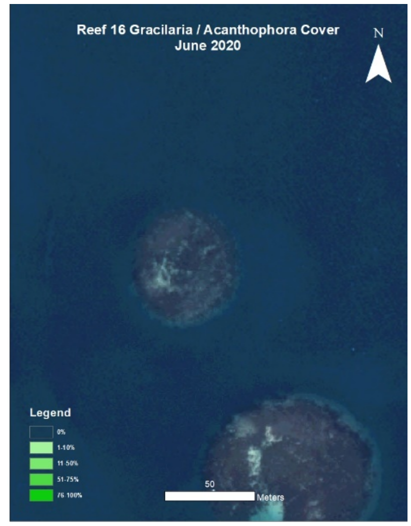

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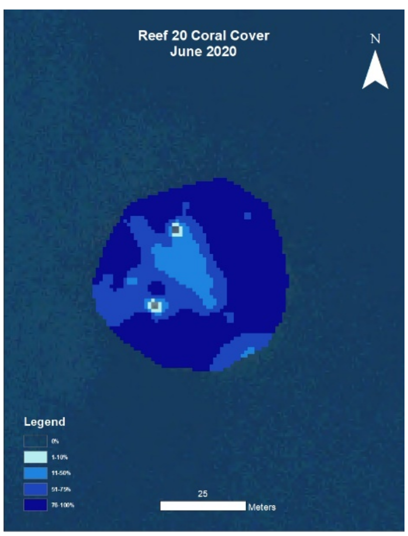

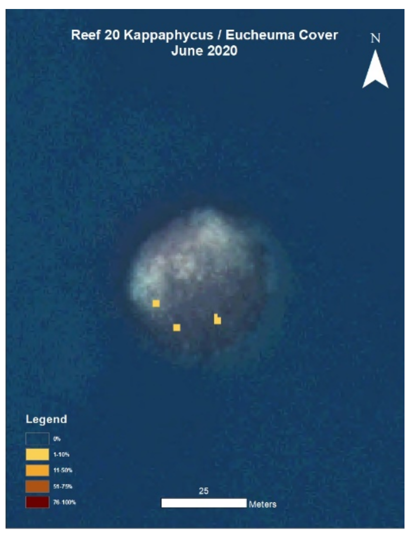

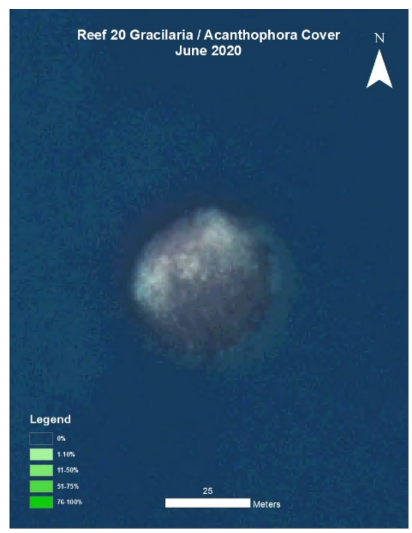

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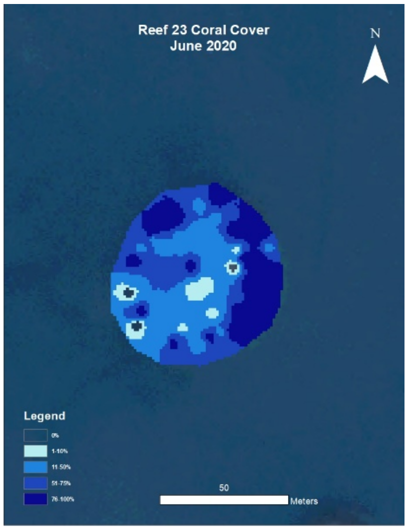

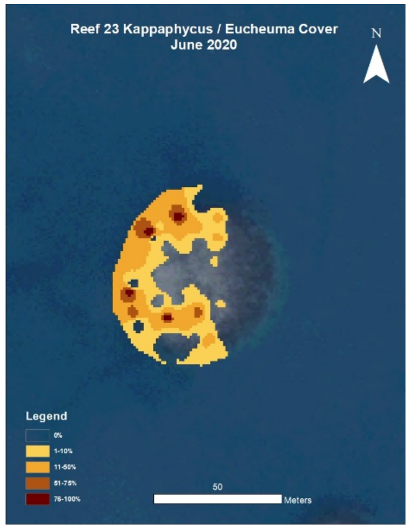

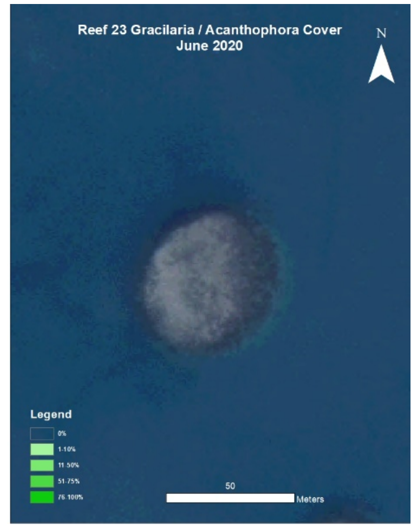

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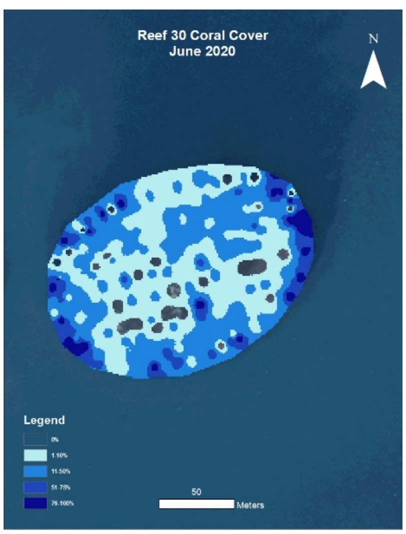

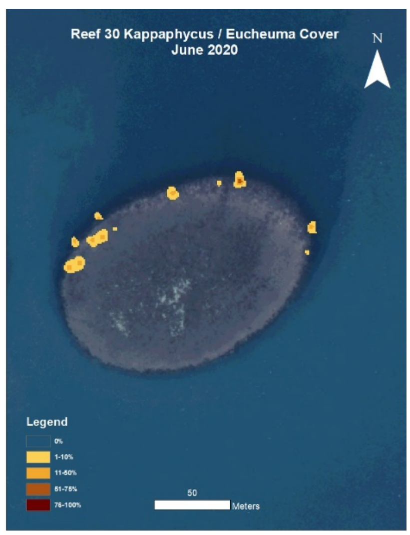

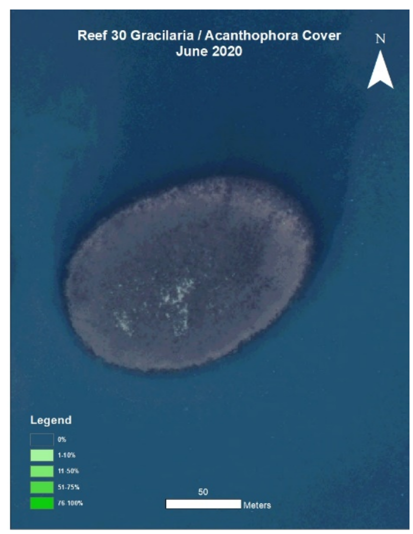

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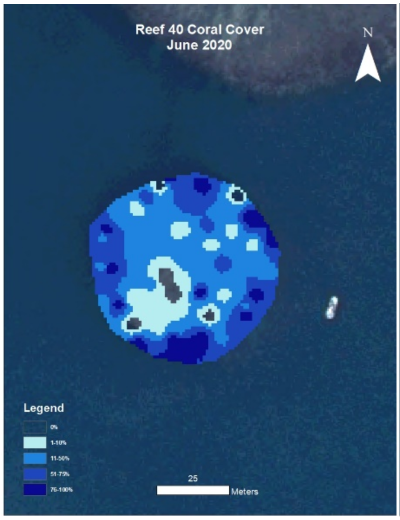

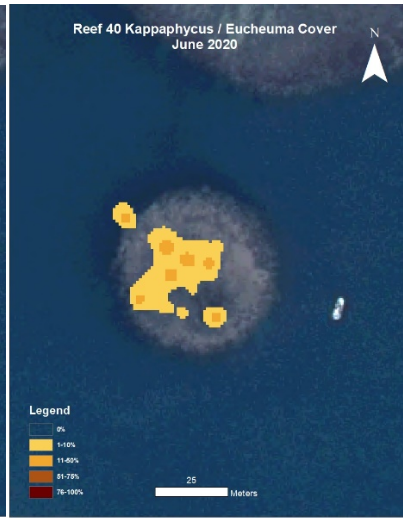

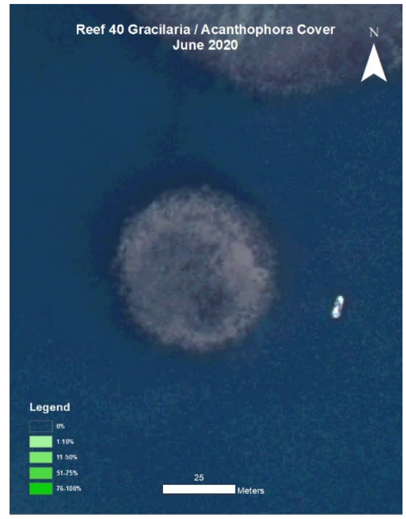

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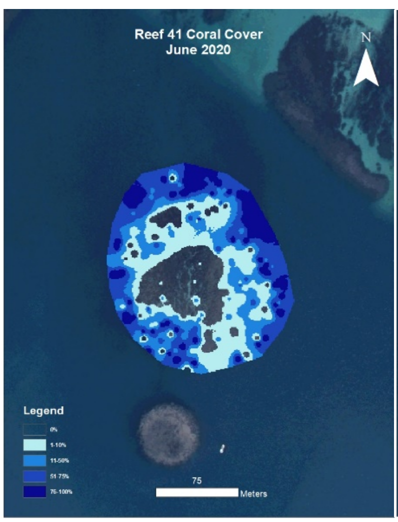
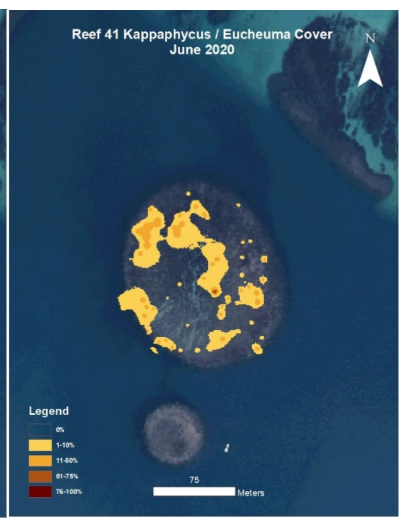
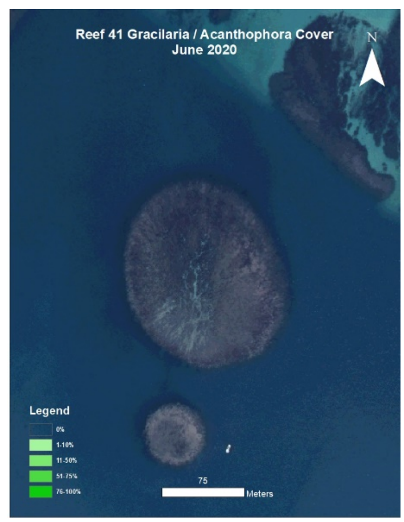
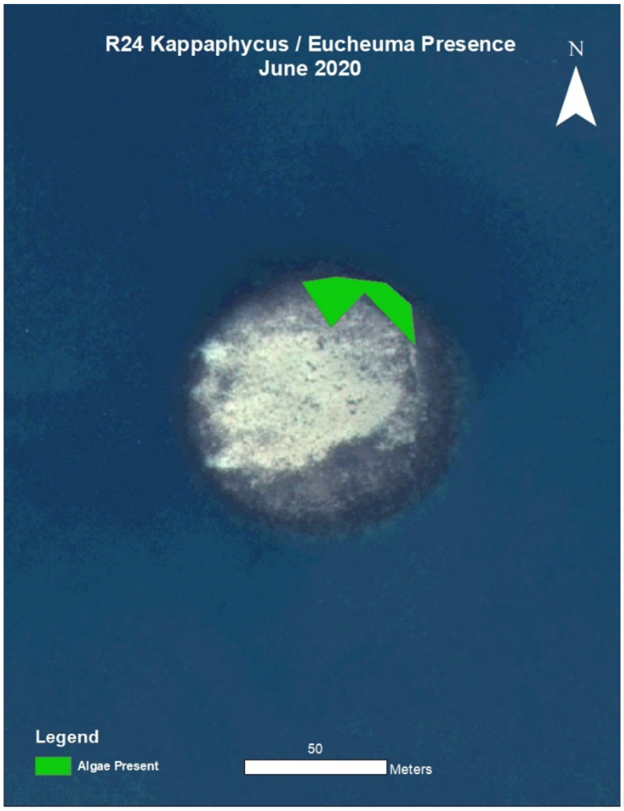
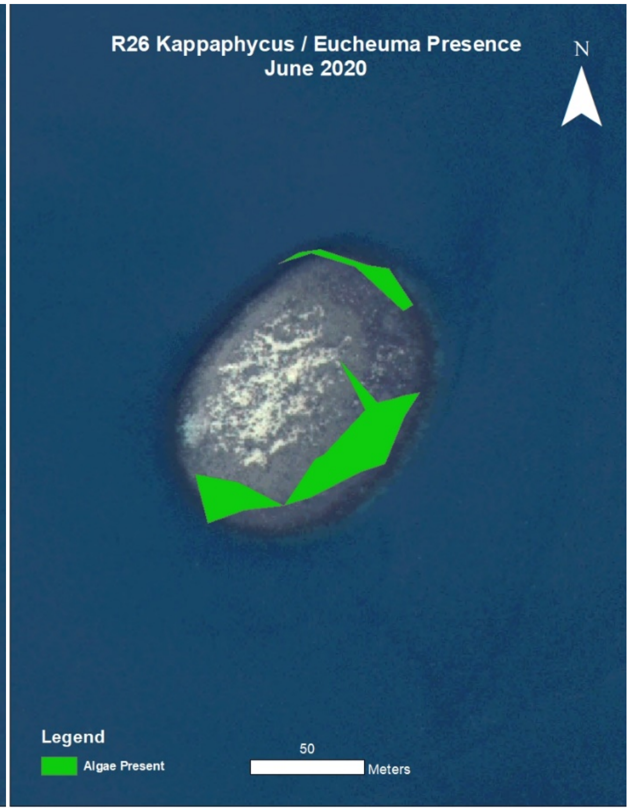






APPENDIX C


R24 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
50
Meters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June 2020
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Legend
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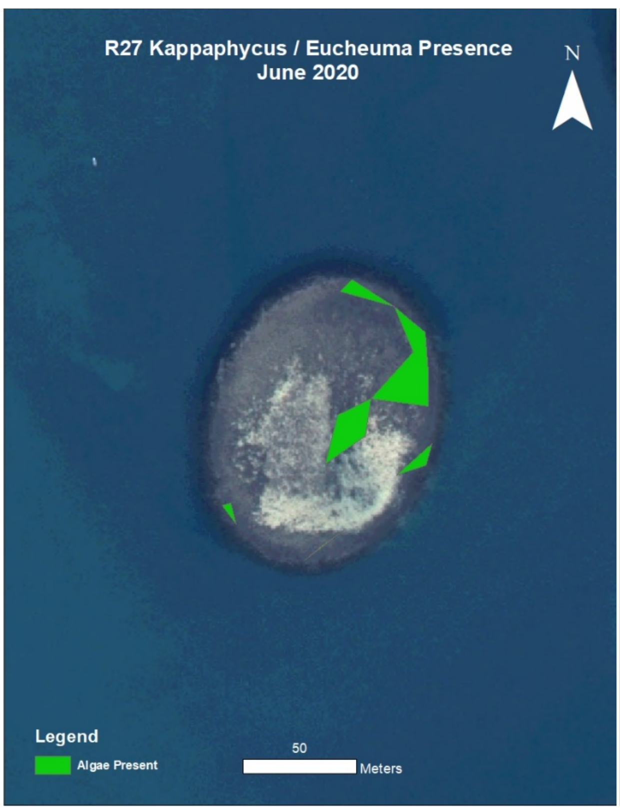
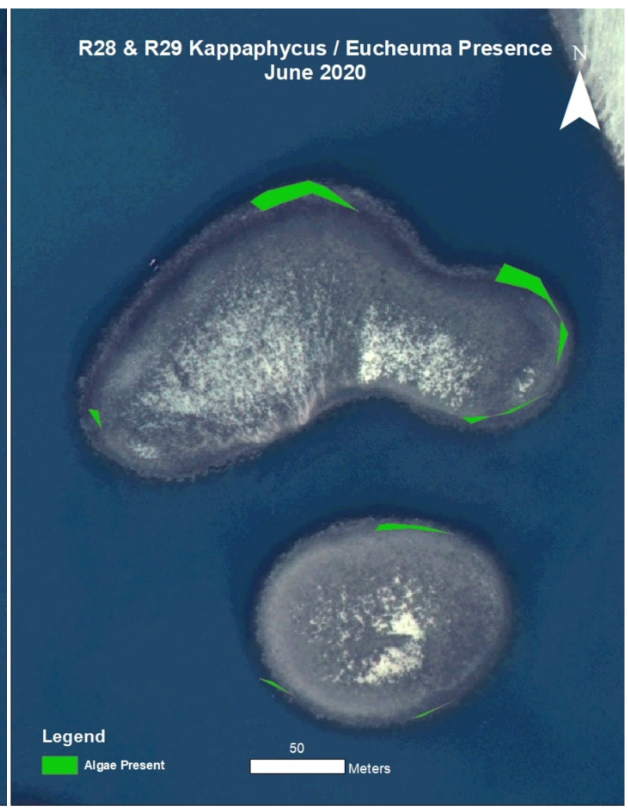
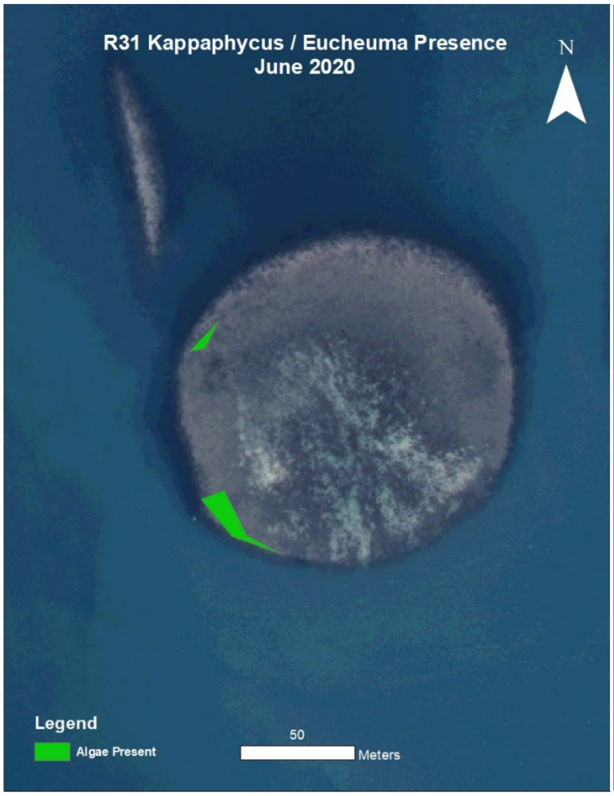
50
Meters


R27 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
50
Meters


R28 & R29 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
50
Meters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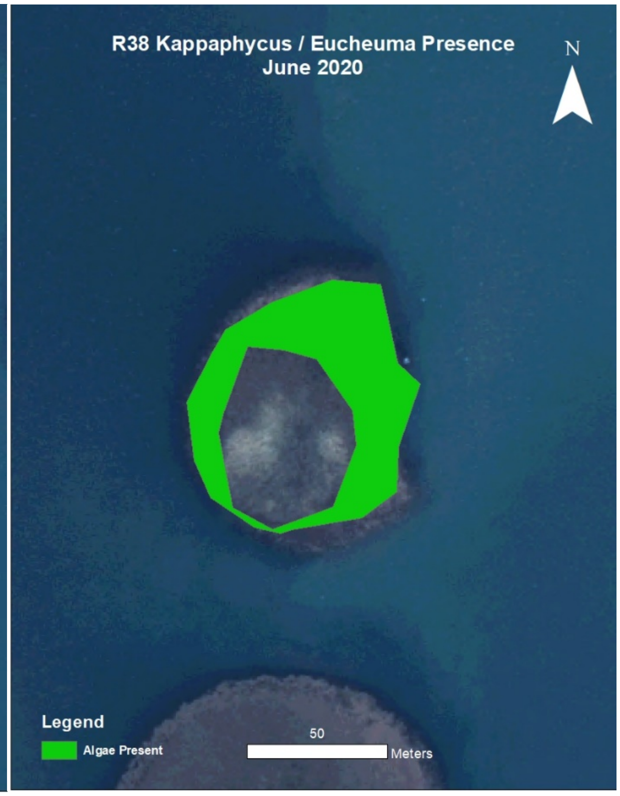
June 2020
N
Legend
Algae Present
50
Meters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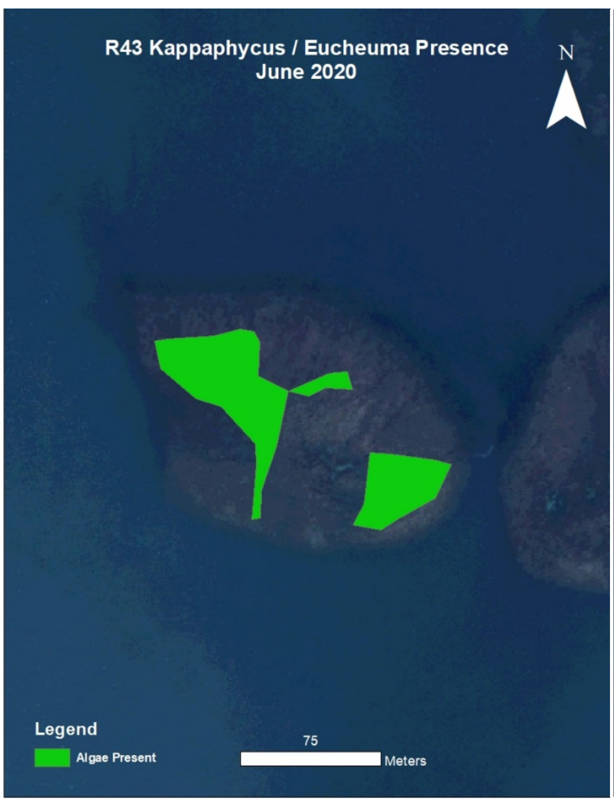
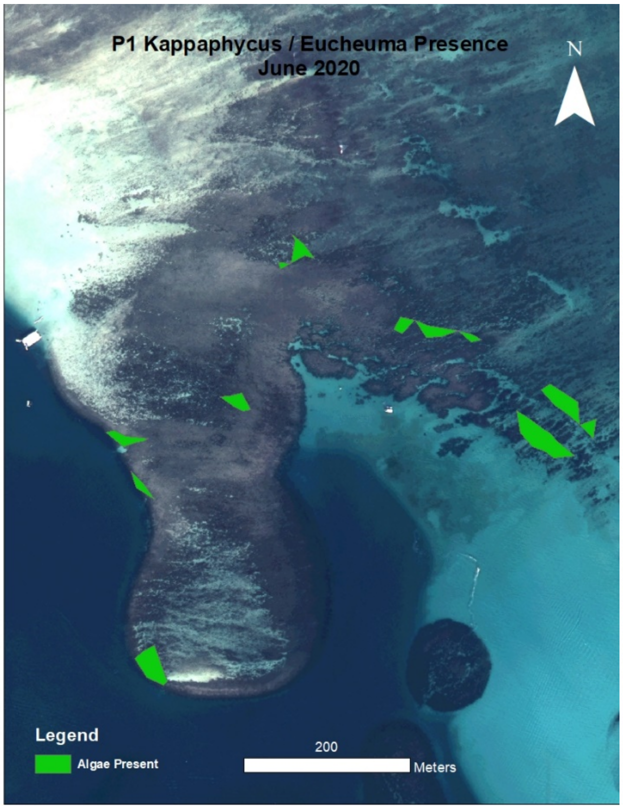
June 2020
N
Legend
Algae Present
50
Meters


R43 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
75
Meters


R44 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
100
Meters


P1 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
200
Meters


P3 Kappaphycus / Eucheuma Presence
June 2020
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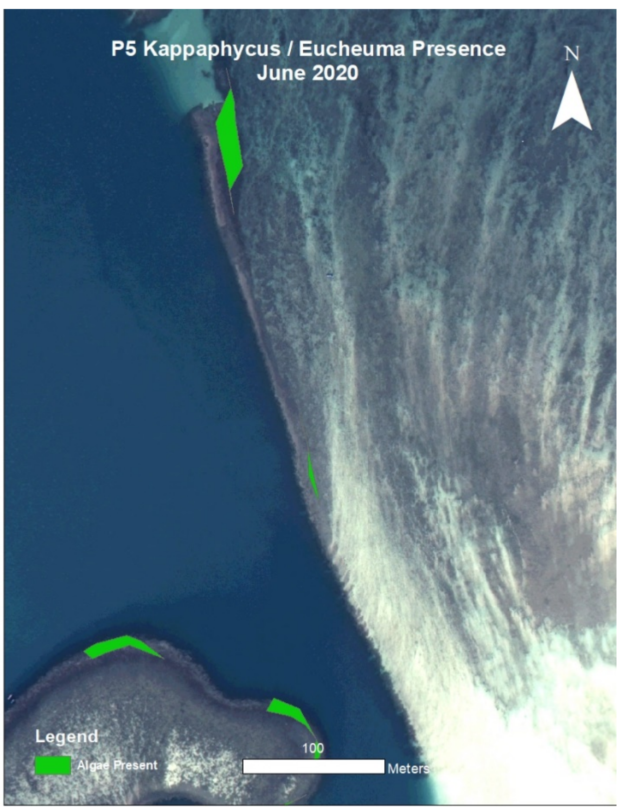
Legend
Algae Present
300
Meters


P5 Kappaphycus / Eucheuma Presence
June 2020
N
Legend
Algae Present
100
Meters