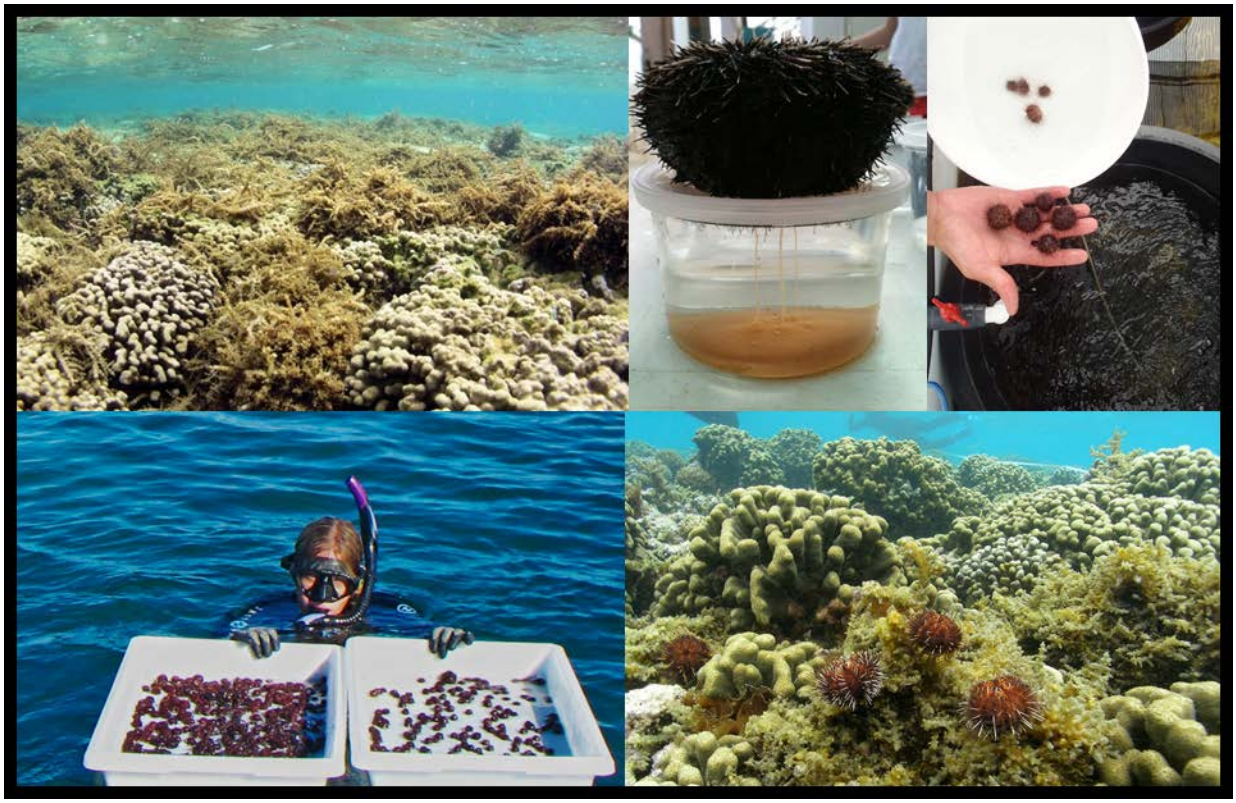
Cape Flattery Settlement Restoration Project: Restoring Reefs in Kāneʻohe Bay



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Division of Aquatic Resources

Aquatic Invasive Species Team

July - December 2018

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RESTORATION PLAN ACTIONS IMPLEMENTED

The Division of Aquatic Resources (DAR) continued Cape Flattery Mitigation efforts to combat invasive algae in Kāneʻohe Bay during the July to December 2018 reporting period. Urchin outplanting continued on new target reefs reprioritized for treatment, annual SNAP surveys were completed on the reprioritized reefs, processing of the photo monitoring on the coral reattachment plots continued, and reef marker installation has continued on patch reefs throughout Kāneʻohe Bay. Additionally, work has commenced for the Heʻeia watershed restoration plans.

All initial priority reefs (Reefs 20, 24, 28, 30, 31, 38 and 41) have been stocked with target numbers of urchins (*Tripneustes gratilla*). Urchin outplanting has progressed on newly identified priority reefs. These reefs were identified for treatment with urchins by first identifying reefs that had previously been treated, but were either understocked (Reefs 16 & 14) or whose urchins were removed and translocated to other reefs in the past (Reefs 26, 27 & 29). On these reefs, reconnaissance surveys of urchins and algae were conducted to assess the approximate number of urchins required to supplement each reef. After these reefs, three new priority areas (P1, P3, and P5A) on fringing and barrier reef areas around the sand bar and near shore were identified. Urchin outplanting progress on the original and newly added priority reefs can be seen in Table 1 and Figure 1.

The annual monitoring of Flattery reprioritized reefs began on August 20, 2018 and continued through August 31, 2018. The monitoring consisted of SNAP surveys of all reprioritized reefs using the same methods as the baseline surveys, which were conducted in March 2016. In an effort to create higher resolution maps of the extent of the algae present and urchin treatments, presence absence surveys of *Eucheuma/Kappaphycus* and urchins were added on to the original SNAP methodology. These data are being used to plan maintenance stocking of urchins but are not included in this report. Results of the monitoring are shown in Table 2 and 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	2016 SNAP patch 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	Reefs 14, 16, 26, 27, 29, P1, P3, and P5A added to priority list in February 2017.
Outplant native sea urchins to restoration area	Project Technicians, DAR Urchin Hatchery	April 2016 - end of project	In progress	Since the last reporting period, 60,750 urchins have been released on priority reefs	Targets reached for original priority reefs in February 2017. Outplanting continues on newly prioritized reefs.
Bi-annual reporting to the Cape Flattery trustee council	Monitoring Coordinator, DAR Aquatic Biologist	Bi-annual through end of project	In progress	Sixth progress report submitted	
Follow-up monitoring of coral and algae conducted annually	Monitoring Coordinator, Project Technicians	March – April, through end of project	Complete	Follow-up reef monitoring for original restoration reefs completed in March 2018	Monitoring for original priority reefs scheduled for March 2019
Maintenance of outplanted urchins	Monitoring Coordinator, Project Technicians	August 2018- end of project	In progress		
Identification of and continuation on future priority reefs	DAR Aquatic Biologist, Trustees	January 2017- end of project	Complete	Reefs 14, 16, 26, 27, 29, and three fringing reef areas identified	

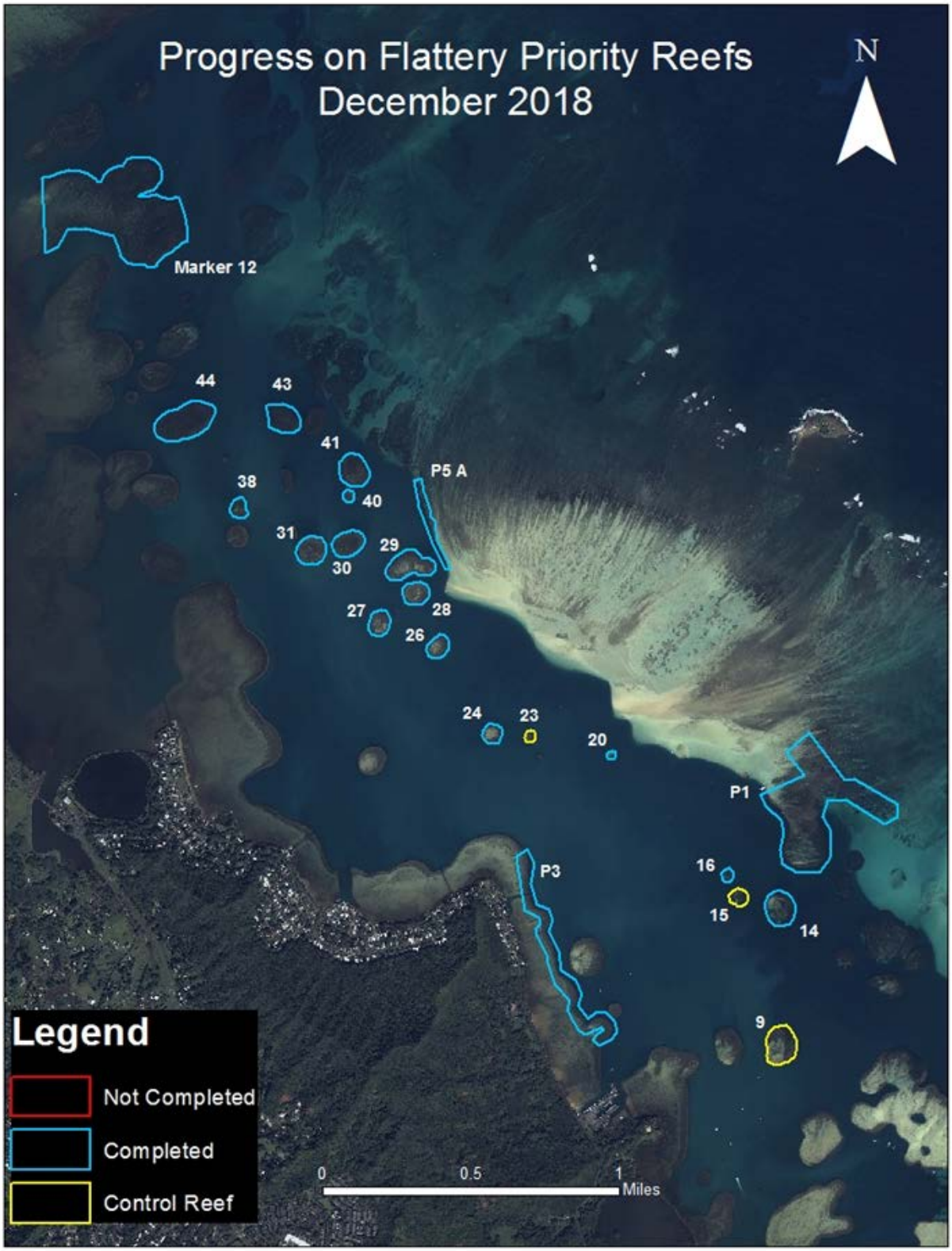

Figure 1: Invasive algae control progress on all priority reefs in Kāneʻohe Bay.

Table 2: Reef characteristics and progress on priority reefs in Kāneʻohe Bay.

		2016 SNAP Survey				2018 SNAP Survey					
Priority	**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 (2 urchins/m^2 of algae)**	**Number of urchins needed to reach target (as of Feb 2017)**
1	**Marker 12**	275,764	149,101	2,684	17,538	255,555	144,698	776	23,611	40,444* (*Increased to 60,000)	0
2	**44**	50,115	46,039	1,257	33	50,533	43,316	591	32	2,580	0
3	**43**	24,833	24,727	1,229	0	23,663	23,422	723	0	2,458	0
4	**41**	25,893	24,752	5,877	173	24,834	24,265	1,785	27	12,100	0
5	**40**	4,645	4,618	784	0	3,309	3,285	556	0	1,568	0
6	**38**	9,707	8,646	692	7	8,498	7,129	495	38	1,398	0
7	**31**	22,233	21,686	182	0	21,117	18,350	6	0	364	0
8	**30**	21,528	20,386	422	0	19,383	19,033	31	0	844	0
9	**28**	16,541	14,530	425	1,942	14,909	14,147	121	330	4,734	0
10	**24**	12,155	10,780	21	0	9,202	8,022	50	5	42	0
11	**20**	3,316	3,284	1	0	2,441	2,396	1	0	2	0
Control	**15**	8,570	8,458	1,753	0	7,789	7,761	2,221	0	N/A	N/A
Control	**9**	32,404	27,162	290	0	29,345	24,307	106	245	N/A	N/A
Control	**23**	5,017	4,996	208	0	3,700	3,681	599	0	N/A	N/A
TOTALS		**517,738**	**369,165**	**15,825**	**19,693**	**493,795**	**346,842**	**8,747**	**11,601**	**91,036**	**0**

Table 3: Reef characteristics and progress on reprioritized reefs in Kāneʻohe Bay.

		2018 SNAP Survey					
Priority	**Reef**	**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 (2 urchins/m^2 of algae)**	**Number of urchins needed to reach target**
1	**14**	22,004	17,247	4,719	4,631	9,438	0
2	**16**	3,061	3,762	217	217	434	0
3	**26**	11,911	10,503	2,191	0	4,382	0
4	**27**	12,851	10,804	1,368	33	2,736	0
5	**29**	29,861	27,982	566	911	1,132	0
6	**P1**	224,957	140,211	10,747	20,713	21,494	0
7	**P3**	92,577	86,751	319	551	638	0
8	**P5A**	19,906	16,882	4,054	2,334	8,108	0
TOTALS		417,128	314,142	24,181	29,390	48,362	**0**

URCHIN HATCHERY

During the period from July - December 2018, Flattery staff conducted four urchin spawning events, resulting in 130 wild urchins being spawned as well as additional urchins spawned from resident AFRC broodstock. 16,428 liters of phytoplankton were produced to feed urchin larvae, and 951.84 kg of macroalgae were produced to feed juvenile urchins. In total, 6,980,000 larvae were produced and moved into tanks for the settlement and grow-out phases during this reporting period. Of those, 60,550 grew to transplantation size (~10mm) and were released onto priority reefs (Table 3).

Table 4: DAR Urchin Hatchery monitoring metrics for July-December 2018

	Food production		**Urchin production**		
Date	**Phytoplankton produced (l) (for urchin larvae)**	**Macroalgae produced (kg) (for urchin juveniles)**	**Urchins collected for spawn**	**Number of larvae moved into settlement/grow out phase (x1000)**	**Number of hatchery urchins outplanted**
Jul 2018	3,433	188.24	40*	3,900	5,300
Aug 2018	560	166.04	0	0	3,700
Sept 2018	3,289	180.56	30*	4,800	2,000
Oct 2018	3,274	129	30*	4,800	10,300
Nov 2018	2,281	176	30*	4,800	25,750
Dec 2018	3,051	112	0	0	13,500
Totals	16,428	951.84	130	18,300	60,550

*Additional urchins spawned from resident AFRC broodstock

New Spat Count Estimation Procedures

The hatchery hosted four urchin spat count outreach events at AFRC involving students and colleagues from Kewalo Marine Lab, The Hawai'i Institute of Marine Biology (HIMB), Chaminade University, and the University of Hawai'i Marine Option Program (MOP). At three to four weeks post-settlement, settlement plates are removed individually and inspected for post-larvae (spat). Spat are counted and recorded and plates are moved into a new, larger tank for grow-out. This new process allows staff to predict the numbers of urchins produced up to three months in advance.

Sea Urchin Life Cycle

The hatchery successfully closed the lifecycle for *T. gratilla* in captivity at AFRC. Offspring from wild urchins were grown through adulthood at the hatchery. These hatchery raised animals were successfully spawned in November 2018 and the resulting larvae were reared through metamorphosis and settlement.

URCHIN OUTPLANTING

In total, 60,550 urchins were outplanted onto priority reefs during this period. November's total of 25,750 outplanted urchins was the highest monthly total and November 30 had the highest daily total of urchins (8,750) since the urchin hatchery began production. Following the February 2017 completion of initial priority reefs, work progressed on the additional priority reefs (see "Restoration Plan Actions Implemented" section), resulting in target numbers of urchins outplanted being reached on all additional priority reefs on December 11. Additional maintenance outplanting occurred on initial priority reefs that had algae present at greater than 5% coverage. Table 4 shows the urchin releases that have occurred from July - December 2018, including the number and destination of the urchins and the hours contributed by Flattery and DAR civil service staff.

Table 5: Urchin transplants for July - December 2018

Date	Urchin source	Reef Number	Number of Urchins Released	Area treated (m^2)	Work Hours	Flattery team members	DAR team members	Total Hours
7/12/18	Hatchery	P1	3,100	1,550	5	2	1	15
7/25/18	Hatchery	P1	200	100	3	1	1	6
7/27/18	Hatchery	P1	2,000	1,000	3	2	2	12
8/10/18	Hatchery	P1	2,000	1,000	4	2	0	8
8/31/18	Hatchery	P1	1,700	850	4	2	0	8
9/28/18	Hatchery	P1	2,000	1,000	4	2	0	8
10/10/18	Hatchery	P1	5,150	2,575	5	2	0	10
10/17/18	Hatchery	P1	5,150	2,575	5	3	0	15
11/2/18	Hatchery	R27, R29	6,400	3,200	4	3	1	16
11/7/18	Hatchery	R26, R27	4,900	2,450	5	2	1	15
11/14/18	Hatchery	P1	5,700	2,850	5	3	1	20
11/30/18	Hatchery	P5	8,750	4,375	6	2	2	24
12/11/18	Hatchery	P3, R26	6,000	3,000	5	2	2	20
12/13/18	Hatchery	R41	3,500	1,750	4	2	1	12
12/28/18	Hatchery	R38, R40, R43	4,000	2,000	4	2	2	16
Totals		10	60,550	30,275	66			205

ANNUAL MONITORING

Annual monitoring of the reprioritized reef (Figure 2) was conducted from August 20 to August 31, 2018. The monitoring consisted of SNAP surveys across all reefs, as detailed in the Monitoring Plan.

Figure 2: Reprioritized treatment reefs in Kāneʻohe Bay.

Coral Coverage

Coral distributions were variable throughout the survey area. Coral cover ranged from 3,762 m^2 to 140,211 m^2 (Figure 3). This variation is due to the fact that the areal extent of each reef surveyed is highly varied. The total area of the reprioritized restoration area covered by coral is estimated at 314,142 m^2.

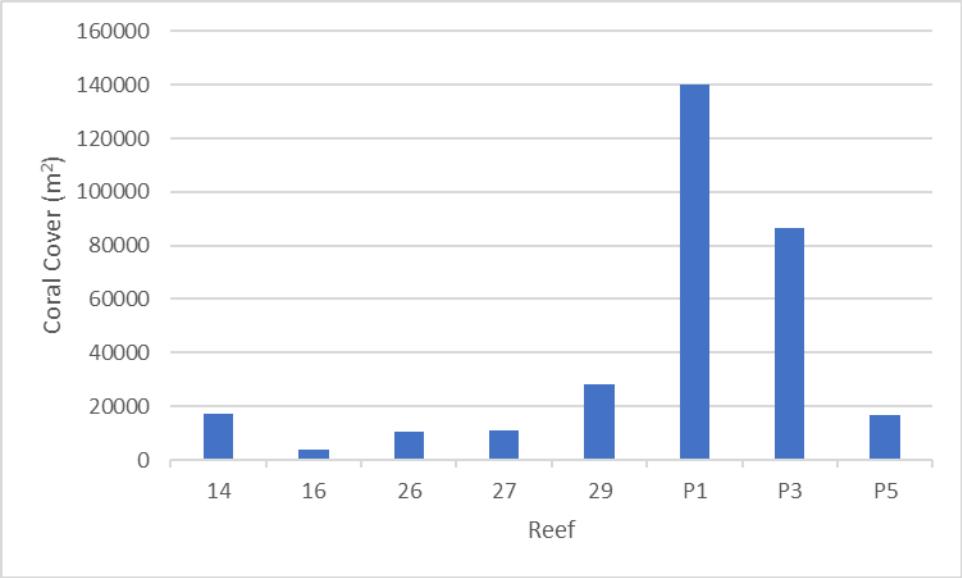

Figure 3: Coral cover (m^2) on reprioritized treatment reefs.

Invasive Algae

Invasive algae was found on all of the reprioritized reefs throughout the restoration area. *Eucheuma/Kappaphycus* was distributed throughout the restoration area and cover per reef varies from 217 m^2 to 10,747 m^2 (Figure 4). *Gracilaria/Acanthophora* was also distributed throughout the restoration area. Algae cover varies from 0 to 20,713 m^2 (Figure 5).

While these values appear low, it should be noted that these 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.

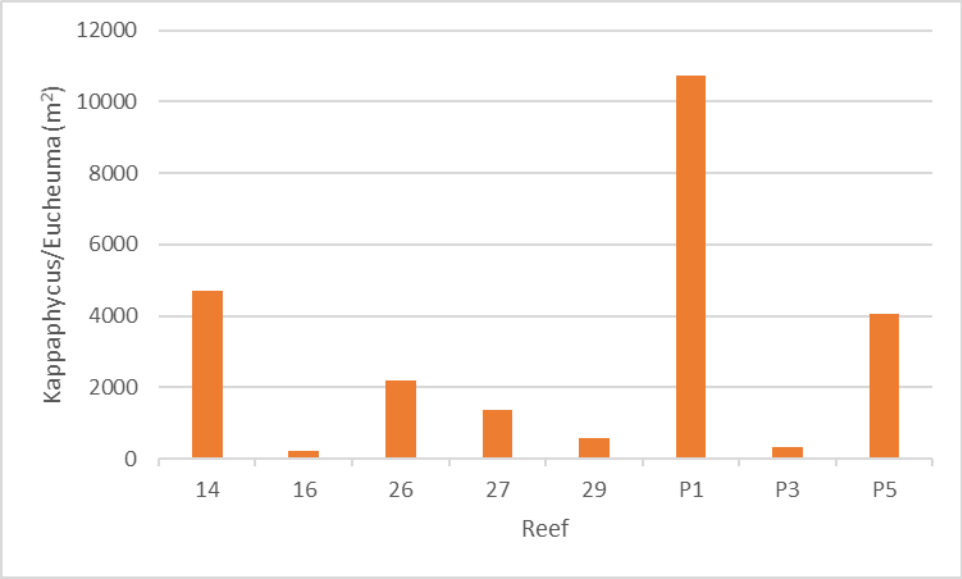

Figure 4: *Kappaphycus/Eucheuma* cover (m^2) on reprioritized treatment reefs.

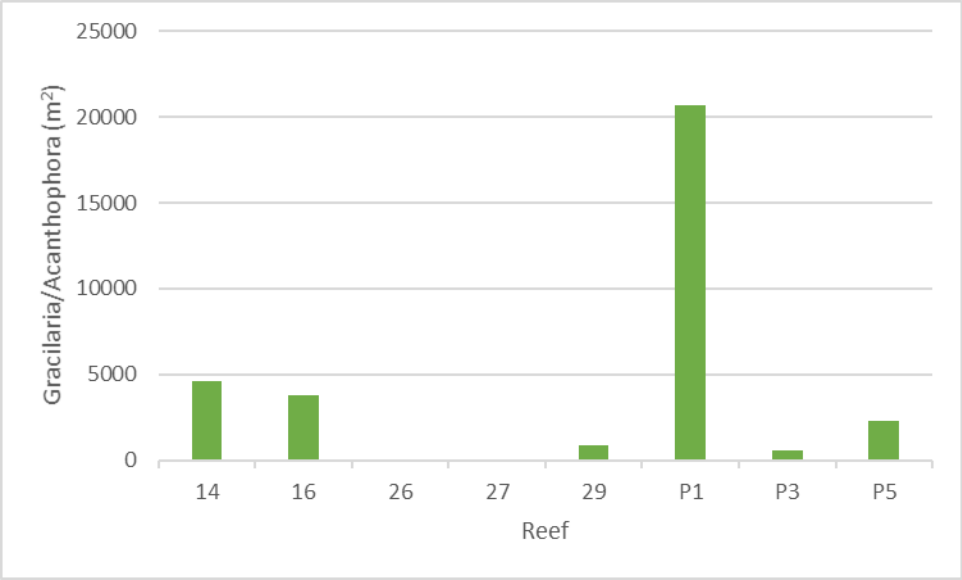

Figure 5: *Gracilaria/Acanthophora* cover (m^2) on reprioritized treatment reefs.

CORAL REATTACHMENT PILOT STUDY

Field measurements of individual colonies were abandoned due to them being time-consuming and prone to error. The photomosaic method was less invasive and required less time in the field, although the computer processing time was greater. Several trials were run and it was found that about 50 photos/m^2 were sufficient to produce an accurate, high-resolution photomosaic using this particular methodology, for our specific purposes. Reducing the number of photos input into Agisoft to generate the photomosaic reduced computer processing time.

Photo mosaics of the coral reattachment restoration plots were built and scaled using Agisoft. The resulting output product file was then spatially analyzed with ArcGIS to determine survivorship (colony counts) and percent coral coverage (Figure 6). Live coral colonies were originally hand traced in pre- and post-attachment mosaics. Methods developed by the National Oceanic and Atmospheric Administration Ecosystem Science Division were used for the one year mosaics monitoring assessment surveys. Coral colonies in Marker 12 post-attachment mosaic were estimated using data from Plot 1 post-attachment mosaic because the Marker 12 post-attachment images were not able to align in Agisoft and similar size fragments were transplanted to both study sites. Coral colony counts and percent cover in all other mosaics were calculated directly in ArcGIS.

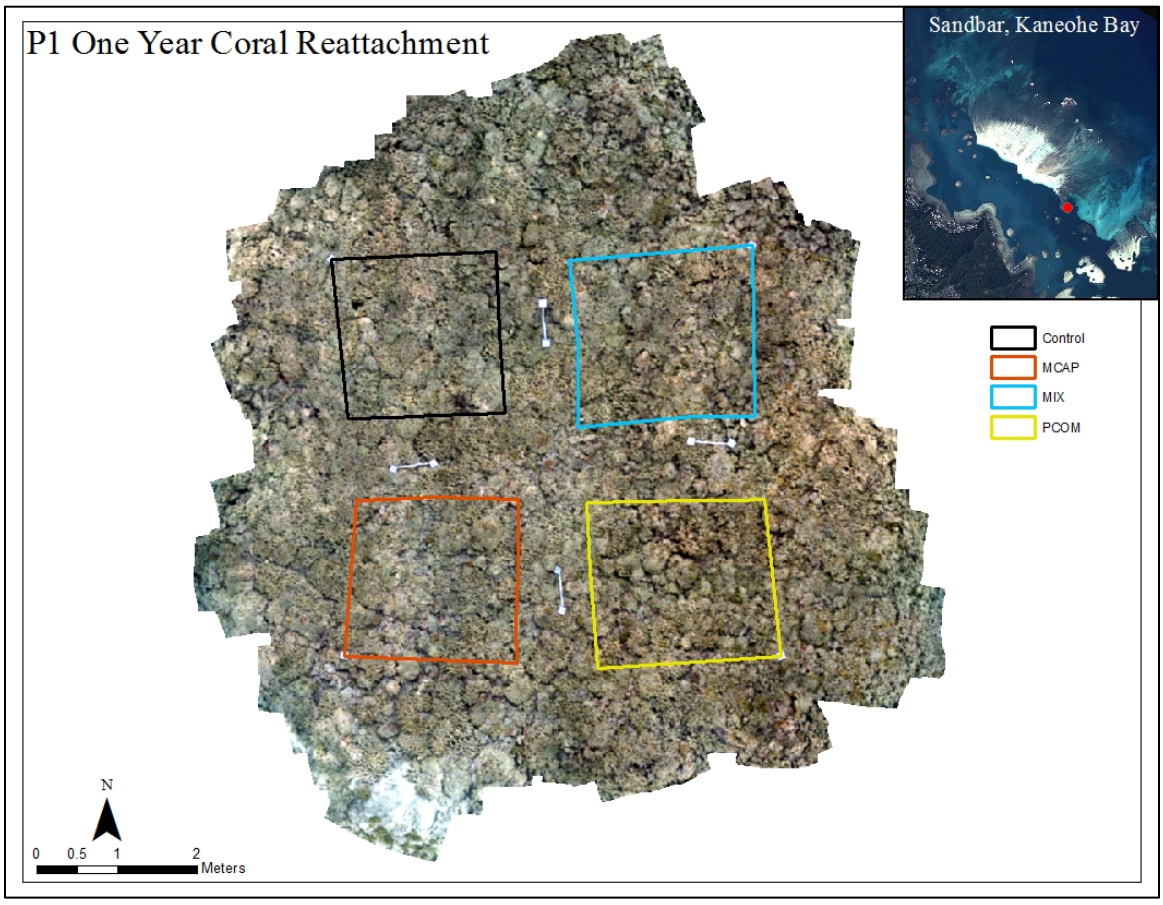

Figure 6. Processed photomosaic of the Plot 1 fringing reef priority site.

Porites compressa fragments had an average survivorship of 64% across all treatment plots and sites, while *Montipora capitata* had approximately 18.5% (Figure 7). Overall coral cover less than doubled in control plots after one year. During the same time interval coral cover in treatment plots one year following coral reattachment was about 13 times higher than pre-attachment coral cover (Figure 8). However, this equated to approximately 8.5% coral cover in treatment plots, which is still relatively low from an ecological standpoint (Figure 9).

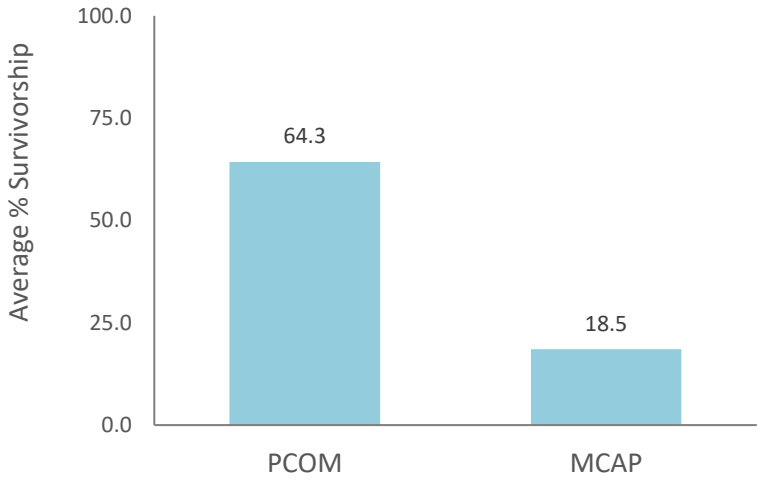

Figure 7. Survivorship (%) of coral fragments by species.

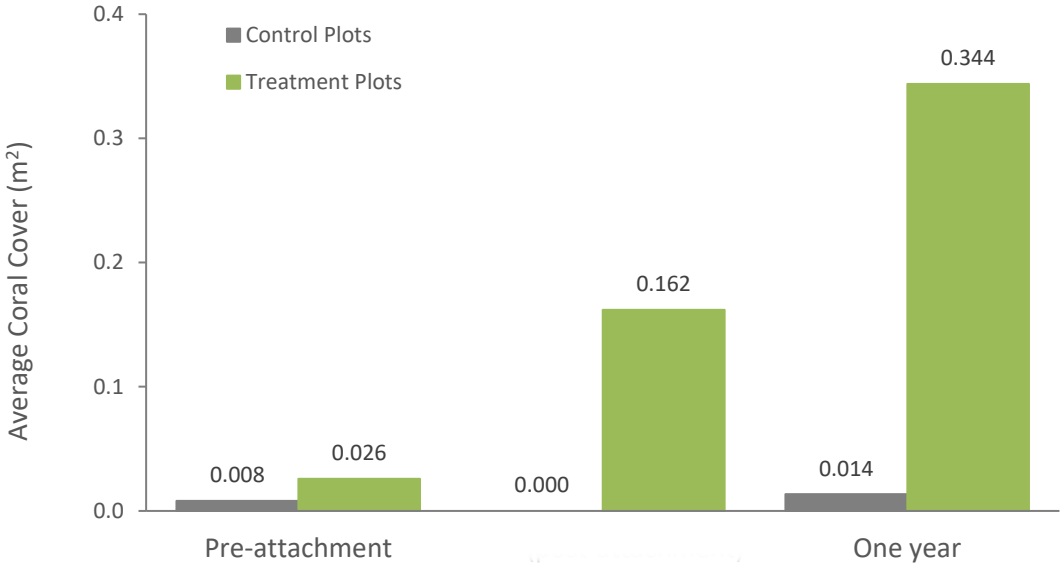

Figure 8. Coral cover (m^2) pre-attachment, post-attachment, and one year following attachment in control and treatment plots.

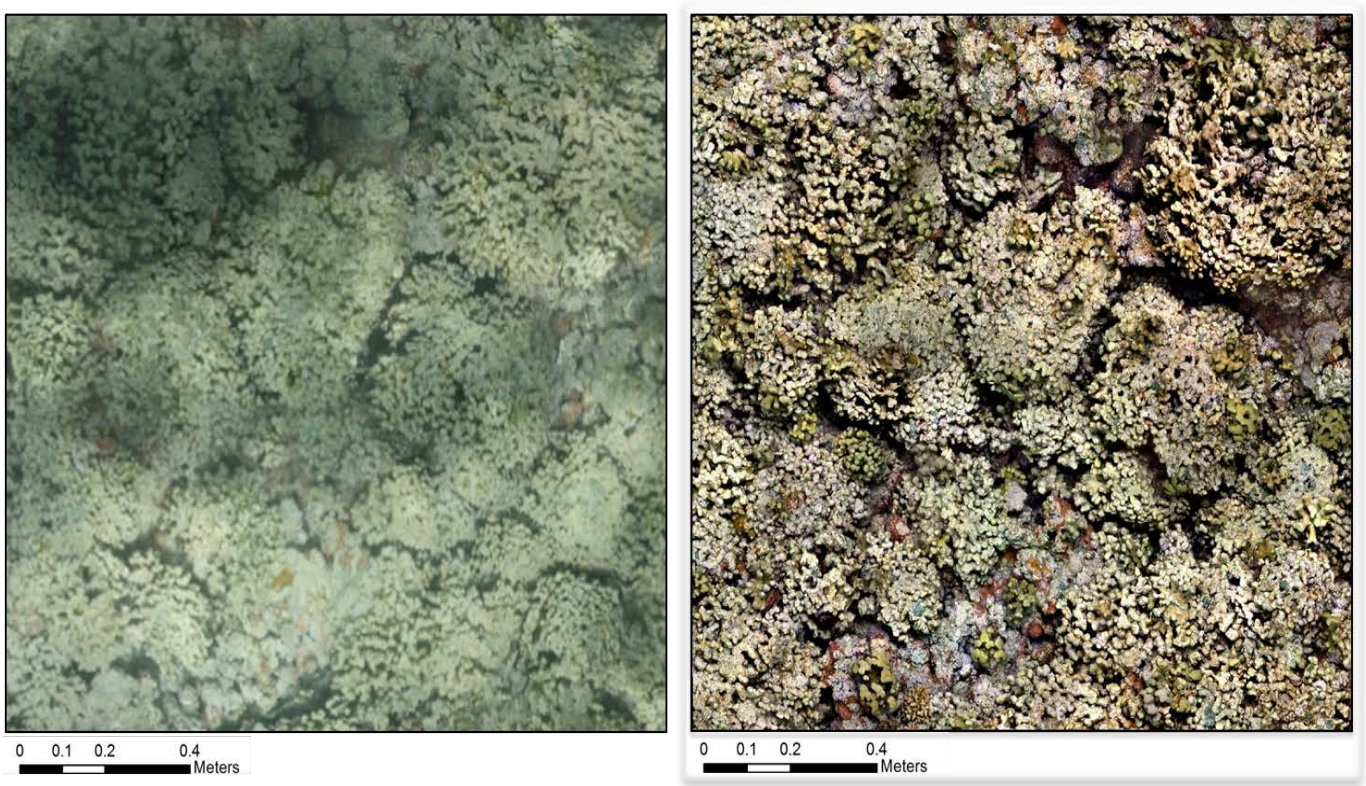

Figure 9. Example of a section of a photomosaic from Plot 1 *P. compressa* plot pre-attachment (left). The same area one year following attachment (right) contained more live coral tissue.

While overall coral cover exhibited a larger increase in treatment plots than in control plots, the ensuing coral cover was still relatively low. Using larger initial fragments which have been shown to have higher growth rates and survivorship may address this issue moving forward. The deployment of the pilot project highlighted the feasibility of collecting and reattaching "corals of opportunity", helped beta-test and refine attachment and monitoring methodology, and provided information for future restoration activities.

HE'EIA WATERSHED RESTORATION

Restoration plans are in development for the He'eia wetlands to protect and enhance the ecosystem of Kāne'ohe Bay by minimizing the effects of flood events, reducing sediment and nutrients, and creating habitat and fish passage for marine and estuarine species.

Aquatic biota monitoring and sampling protocols from stream mouth, wetland, and above wetland are being finalized. These protocols are being designed to fill data gaps and serve as baseline data for future actions in the entire He'eia watershed. The monitoring/sampling protocol is being developed collaboratively between The Nature Conservancy, Kako Oiwi and DAR staff.

A 2-dimensional hydrology model with a range of flow rates is being developed throughout the wetland. The initial model is expected to be completed in early 2019. The restoration design and presentation was delayed due to government shut-down. The Forest Service Restoration Team presentation of designs are currently scheduled for mid-March 2019. Sediment sources at mid-slope regions are being located and assessed and a site visit by a United State Geological Service (USGS) sediment expert is scheduled for Spring 2019. It is anticipated that additional details and insights will be gained on the mechanisms and locations of sediment delivery from the mid-slope regions above the He‘eia wetland.

OTHER PROGRESS

In July, representatives from United States Fish and Wildlife Services (USFWS) accompanied Flattery staff to Kāne‘ohe Bay for a site visit of patch reefs that were in the process of being treated with sea urchins. Julie Concannon and Michael Fry assisted Flattery staff with the outplanting of sea urchins and were given a tour of Kāne‘ohe Bay to see the progress of reef marker installation.

Reef markers continue to be placed on patch reefs determined to be likely grounding areas by vessels in Kāne‘ohe Bay (Figure 10). As of the end of this reporting period, 52 markers have been placed on 27 patch reefs. 15 additional markers are scheduled to be placed on 10 new reefs. The installation of markers has received excellent feedback from the Division of Boating and Ocean Recreation (DOBOR) and the boating community.

Figure 10: Reef marker installed on patch reef in Kāne‘ohe Bay.