Recovery of a Hawaiian reef flat community following the removal of the invasive alien algae *Avrainvillea amadelpha* in the Paikō area of Maunalua Bay, Hawai‘i.

Final Report

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Executive Summary

Invasive species are a significant threat to marine biodiversity and contribute to habitat degradation. On reefs in Hawaii, invasive alien algae (IAA) have proven particularly problematic, often aggressively displacing and killing native benthic species, causing cascading impacts throughout the coral reef-associated community.

Avrainvillea amadelpha, locally called leather mudweed, frequently inhabits soft or sandy bottom habitats, and can alter its environment by slowing water movement and trapping sediment. It can grow in dense beds, potentially displacing the native seagrass *Halophila hawaiiana* and other native algae species. In the Paikō area of Maunalua Bay, Oahu *A. amadelpha* has colonized the fine mud and trapped it inshore of the reef crest, thus altering the sediment composition of the Paikō area and potentially triggering a shift in the reef flat ecosystem from a community dominated by native algae and seagrass species, and sporadic coral colonies, to one dominated by three IAA: *A. amadelpha*, *Gracilaria salicornia*, and *Acanthophora spicifera*.

In an effort to restore the native reef flat community, The Nature Conservancy (TNC), in partnership with the community organization Mālama Maunalua, undertook a 27-acre IAA removal project in the Paikō area with the expectation that large-scale *A. amadelpha* removal would restore natural reef-flat processes, promote the flushing of fine terrestrial sediment off the reef flat, and allow natural recovery of the native ecosystem. This report presents the findings of TNC's benthic monitoring of the restoration for a 19-month period following IAA removal.

Prior to removal, two of the three most common taxa in the removal area were IAA: *A. amadelpha* and *Acanthophora spicifera*. Only *Chondria* spp., covering 11.9 ± 1.2% of the substratum was native. Non-native taxa covered 65.4 ± 2.6% of the bottom, compared to native algae taxa, which covered 39.7 ± 2.4%.

Following removal, the cover of *A. amadelpha* dropped from 57.9 ± 2.7% (mean ± SEM) cover to 2.6 ± 0.1%. Native algae cover also dropped post-removal, but has gradually increased over the 19 months following removal. The benthic community showed a significant shift in composition immediately following *A. amadelpha* removal from one dominated by IAA species, especially *A. amadelpha*, to one dominated by bare substratum. After 19 months, the recovery trajectory of the community suggests the benthic community is gradually recovering to a more native algal community than existed prior to *A. amadelpha* removal.

The seagrass *Halophila hawaiiana* was rare within the removal area both prior to and following *A. amadelpha* removal. *Halophila hawaiiana* spreads primarily though vegetative growth, and due to its initial rarity in the removal area, no significant increase in seagrass cover was expected by the project's end. While seagrass beds within the removal area showed no significant difference in their expansion rate (measured as daily relative linear growth) compared to beds outside the removal area, they showed a trend toward greater expansion rates compared to beds outside the removal area. This suggests that the seagrass beds within the project area are capitalizing on the absence of other algae species.

Sediment depth showed a significant decrease following removal of *A. amadelpha*, from a median depth of 3.4 cm to a median depth that generally did not exceed 2 cm (Figure 5), about half that present before *A. amadelpha* removal. Likewise, the percent cover of silt decreased.

These results show manual control of *A. amadelpha* on shallow reef flats is a promising restoration technique for Hawaiian coral reef flats impacted by *A. amadelpha* and other IAA species. While recovery of the community to a native algae community will take longer than 19 months, recovery appears to be on the desired (and predicted) trajectory toward a community with a higher percentage of native species than existed prior to *A. amadelpha* removal.

Introduction

The ability of invasive species to alter the composition and structure of native communities is well-document in terrestrial environments (Vitousek *et al.* 1997, Levine *et al.* 2003, Hejda *et al.* 2009). In contrast, studies documenting community-level impacts from invasive species in tropical coral reef systems are less common (Coles and Eldredge 2002, Molnar *et al.* 2008). Invasive species are recognized as a leading threat to marine biodiversity (Carlton and Geller 1993, Kappel 2005) and contribute to habitat degradation (Coles and Eldredge 2002, Kappel 2005). Impacts on coral reef communities have been attributed to invasive fish (Meister *et al.* 2005, Albins and Hixon 2008), corals (Parish and Baco 2007), and algae (Williams *et al.* 2006, Smith *et al.* 2004, Maragos *et al.* 1996). On Hawaiian reefs, invasive alien algae (IAA) have proven particularly problematic, often aggressively displacing and killing native benthic species, resulting in cascading impacts throughout the coral reef-associated community (Stimson *et al.* 2001, Smith *et al.* 2004, Williams *et al.* 2006).

Avrainvillea amadelpha, locally called leather mudweed, was first reported in Hawaii by Brostoff (1989), from samples collected off Koko Head and Kahe Point sometime after 1981. In the decades since its arrival, *A. amadelpha* has gradually spread across the south shore of Oahu (Smith *et al.* 2002). It frequently inhabits soft or sandy bottom habitats, and is capable of altering its environment, especially on shallow-water reef flats, by slowing water movement and trapping sediment. It can grow in dense beds, potentially displacing the native seagrass *Halophila hawaiiana* and other native algae species (Smith *et al.* 2002, but also see Peyton 2009). It serves as substrate for epiphytic species, and older blades are often covered with a diversity of native and introduced algal taxa (Smith *et al.* 2002).

The first observation of *A. amadelpha* in the Paikō area of Maunalua Bay, Oahu followed a large storm in 1987 that deposited a layer of terrestrial sediment on the reef flat (Peyton 2009). *Avrainvillea amadelpha* colonized the fine mud and trapped it inshore of the reef crest, thus altering the sediment composition of the Paikō area and potentially triggering a shift in the reef flat ecosystem from a community dominated by native algae and seagrass species, and sporadic coral colonies to one dominated by three IAA: *A. amadelpha, Gracilaria salicornia,* and *Acanthophora spicifera*. Prior to the start of a restoration project in 2010, *A. amadelpha* was the dominant species on much of the Paikō reef flat, exceeding 90% cover in some areas (HDAR, unpub. data).

In an effort to restore the native reef flat community, The Nature Conservancy (TNC), in partnership with the community organization Mālama Maunalua undertook an IAA removal project in the Paikō area of Maunalua Bay. This project removed *A. amadelpha* from 27 acres (10.9 hectares) of the Paikō reef flat between May 2010 and April 2011. Removal efforts at this scale have not been attempted before. While small-scale removals of *A. amadelpha* have been tried in the Paikō area with mixed success, it was hypothesized that large-scale *A. amadelpha* removal would restore natural processes on the Paikō reef flat, promoting the flushing of fine terrestrial sediment off the reef flat, and allowing natural recovery of the native ecosystem.

To assess the effectiveness of this restoration effort, TNC undertook a monitoring program to quantitatively assess changes in the benthic community prior to and following *A. amadelpha* removal. This report presents the findings 19 month post-removal and serves as TNC's final report under NOAA Grant entitled "Maunalua Bay Reef Restoration Project."

Methods

The Hawaii Division of Aquatic Resources (HDAR) has mapped the distribution of IAA, including *A. amadelpha*, throughout Maunalua Bay, Oahu. This information was used to delineate a 27-acre (10.9 hectare) area on the Paikō reef flat with high cover of *A. amadelpha*. Within this removal area, *Avrainvillea amadelpha* was carefully hand-extracted by field crews and transported to an upland composting facility. To facilitate the removal, the removal area was sub-divided into smaller 10 x 10 m "cells" and systematically cleared. Work progressed based on the ability of the crews to work within a given cell due to tidal height and other environmental conditions. Clearing the entire removal area took one year, from May 2010 until April 2011.

Benthic survey points were randomly selected within the *A. amadelpha* removal area using ArcGIS 9.0. This space-for-time design (Pickett 1989, Flemming 1999) allowed for simultaneous random sampling of areas that had yet to be cleared of *A. amadelpha*, as well as areas that been cleared from one to 19 months (Table 1). The length of time a survey point had been cleared was estimated from clearance information for each 10 x 10 m cell provided by the contractor.

Table 1. Number of sites surveyed at monthly intervals following the clearance of the invasive alien algae, *A. amadelpha*. Sites at 0 months were surveyed prior to clearing. 1032 randomly-selected sites were surveyed.

Month after Clearing	N	Month after Clearing	N
0	139	10	60
1	43	11	47
2	37	12	62
3	25	13	62
4	22	14	64
5	35	15	55
6	62	16	42
7	59	17	59
8	60	18	32
9	56	19	11

Between May 2010 and January 2012, the benthic community and sediment depth at 1,032 randomly-selected survey points were assessed using a point-intercept method in a 1 m^2 quadrat divided into a grid with 25 intersections. The benthic community under each intersection was identified to the lowest possible taxonomic level. If more than one taxa lay beneath an intersection (*e.g.,* a multi-species canopy was present), all of the taxa were identified. If no benthic organisms were present, the bare substrate was identified into one of four substrate categories: sand, silt, rubble, or limestone. Sediment "depth" was estimated by measuring the buried potion of a stick driven into the sediment until it hit hard substratum. Sediment depth was measured under four randomly-selected intersections within the quadrat. All findings are shown as mean ± standard error of the mean (SEM), unless specified otherwise.

The growth of fifteen seagrass beds (six inside the removal area and nine outside the removal area) was measured between October and December 2011. A marker was placed in the approximate center of the seagrass bed and the radius of the bed was measured such that two measurements lay along the longest dimension of the bed and the other two measurements were made perpendicular to the longest axis (Figure 1). The initial measurements were made in October 2011 and repeated between 49-86 days later. The relative linear growth along each of the four axes was calculated by subtracting the initial measurement from the final measurement and dividing by the initial measurement. The four values were averaged for each seagrass bed and divided by the number of days between measurements, yielding an average relative growth rate per day (m/day) for each bed. Relative growth was used to standardize for bed size, in the event that absolute growth was correlated with seagrass bed size.

Data were compiled and analyzed using standard univariate statistics or the multivariate statistics package PRIMER (ver. 6.1.6, PRIMER-E Ltd.). Due to non-normality, change in sediment depth was analyzed using a Kruskal-Wallis test. Analysis of similarities (ANOSIM) was used to examine differences in the benthic community before clearing and at one month intervals following clearing. A Similarities Percentages analysis (SIMPER) was undertaken to determine

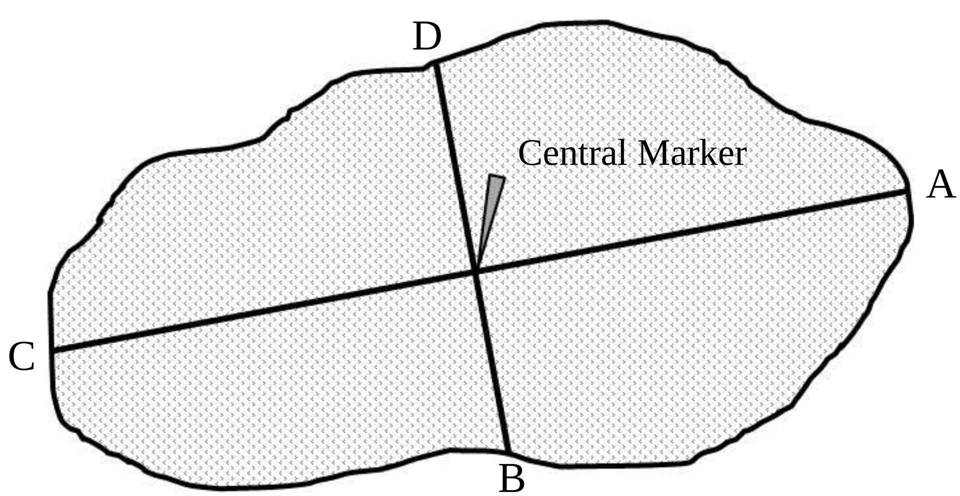

Figure 1. The growth of seagrass beds was estimated by measuring the change in distance from a central marker to the edge of the seagrass along the longest bed diameter (AC) and a perpendicular diameter (BD).

the contribution of each taxa to variations in the ANOSIM. While not a statistical test, SIMPER can provide insights by identifying the taxa that contributed the most to the observed similarities or dissimilarities among the groups used in the ANOSIM. Ecosystem trajectories were visualized using non-metric multidimensional scaling.

Results

Algae

Avrainvillea amadelpha was the dominant benthic taxa prior to removal, covering 57.9 ± 2.7% (mean ± SEM) of the substratum within the removal area. *A. amadelpha* showed a distinct spatial distribution (Figure 2), and formed a dense band between 51 and 200 m offshore, where it covered on average 73.8 ± 3.4% of the bottom. Following removal, the cover of *A. amadelpha* within the removal area dropped to 2.6 ± 0.1% (Table 2).

Prior to removal, two of the three most common taxa in the removal area were IAA: *A. amadelpha* and *Acanthophora spicifera*. Only *Chondria* spp., covering 11.9 ± 1.2% of the substratum was native. Non-native taxa covered 65.4 ± 2.6% of the bottom, compared to native algae taxa, which covered 39.7 ± 2.4% (Table 2). Initially, native taxa were found primarily growing as epiphytes on *A. amadelpha*. Following removal, all algal cover dropped, but gradually increased over the 19 months that the removal site was monitored (Figure 3).

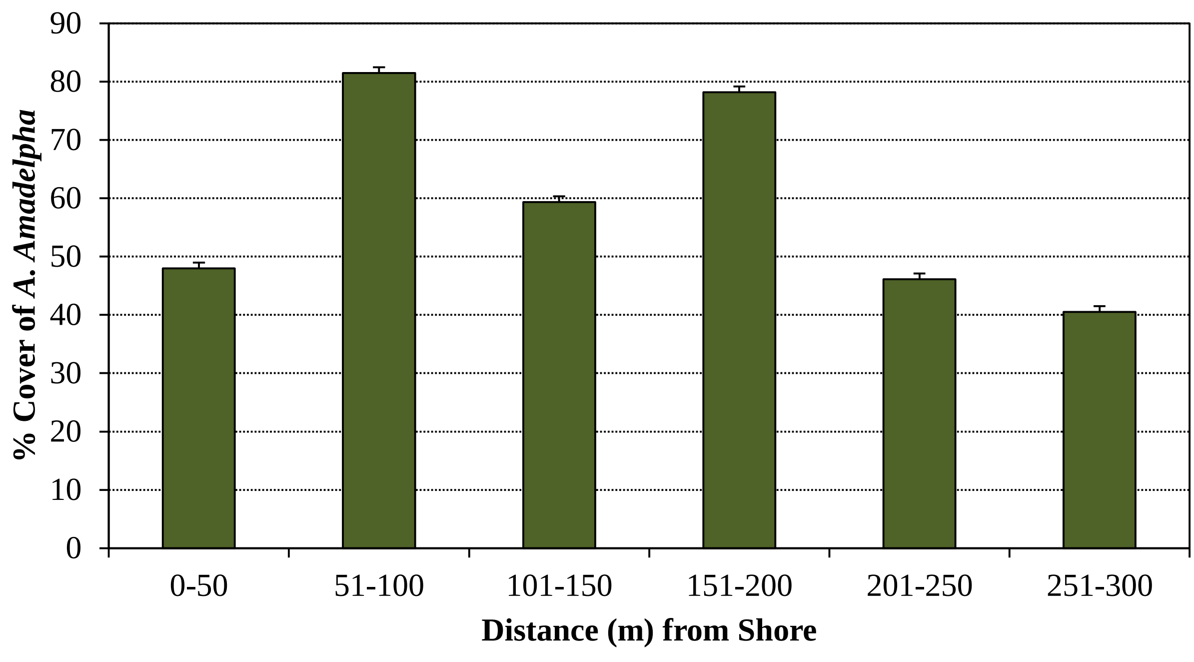

Figure 2. Average percent cover of the invasive alien algae, *Avrainvillea amadelpha* by distance from shore. Within the removal area, *A. amadelpha* was most common between 51 and 200 m from the shore where it covered an average of 73.8 ± 3.4% of the bottom. Error bars are SEM.

Table 2. The mean ± SEM percent of the bottom within the removal area covered by Native Algae, Invasive Alien Algae, A. amadelpha, and Seagrass (Halophila hawaiiana).

	Initial (Time=0)	Post-Clearance (Time=1)	Final (Time=19)
Native Algae	39.7 ± 2.4%	10.6 ± 1.8%	16.7 ± 2.7%
Invasive Alien Algae[1]	65.4 ± 2.6%	8.3 ± 2.5%	16.7 ± 3.8%
A. amadelpha	56.9 ± 2.7%	2.6 ± 0.1%	6.6 ± 2.4%
A. spicifera	21.6 ± 1.8%	2.6 ± 0.8%	7.2 ± 2.5%
G. salicornia	8.9 ± 1.4%	0.9 ± 0.3%	4.4 ± 3.1%
Seagrass	0.5 ± 0.4%	0.0%	1.5 ± 1.5%

[1]The sum of the cover for the three IAA species exceeds the total because *A. spicifera* and *G. salicornia* often grow epiphytically on *A. amadelpha*.

A total of 41 algal taxa were observed over the course of this project (Appendix 1). Algae diversity in the pre-removal quadrats averaged 5.8 ± 0.2 taxa. Following removal, diversity dropped to 3.1 ± 0.2 taxa, but rose to four taxa after 19 months.

Prior to *A. amadelpha* removal, non-native algae had the widest distribution across the project site. Of the 139 quadrats surveyed prior to removal, 130 quadrats (93.5%) contained at least one non-native taxa and 128 (92.1%) had *A. amadelpha* in them. While no single native algae taxa occurred in more than 55.4% of the quadrats (*Chondria* sp.), as a group, native species were also common across the removal area. Native taxa were found in 130 (93.5%) of the quadrats prior to *A. amadelpha* removal. The high occurrence of native taxa within the removal site was primarily due to native taxa growing epiphytically on *A. amadelpha*.

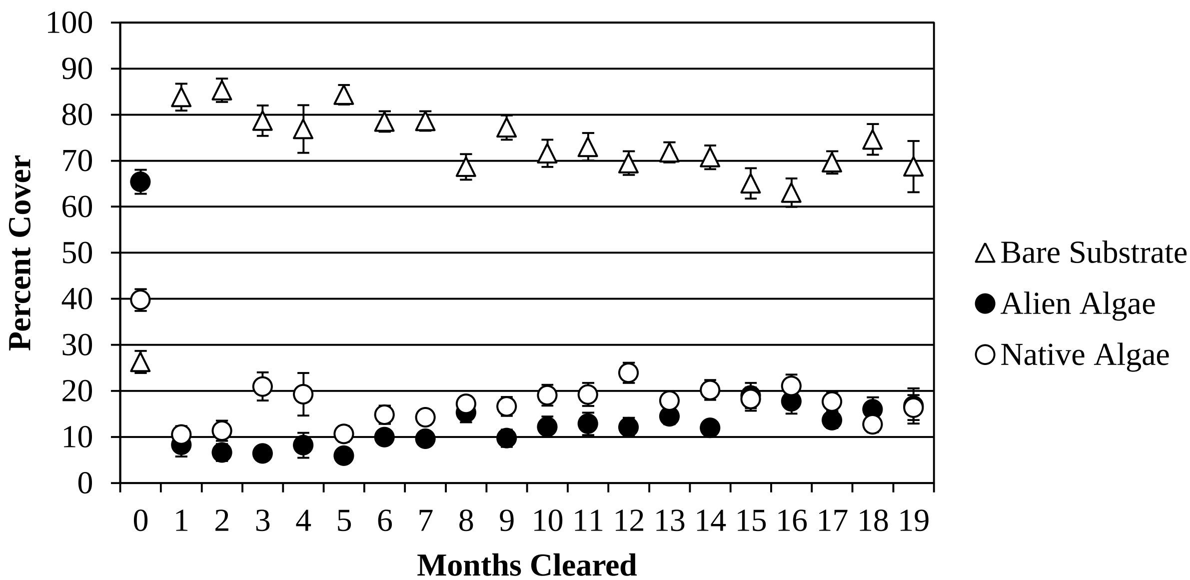

Figure 3. Mean percent cover of bare substrate, alien, and native algae in plots prior to removal of *A. amadelpha* (months cleared=0) and in plots that been cleared for one to twenty months. Error bars are SEM.

Seagrass

The seagrass *Halophila hawaiiana* was rare within the removal area, covering only 0.5 ± 0.4% of the bottom prior to *A. amadelpha* removal. *Halophila hawaiiana* spreads primarily though vegetative growth (Peyton 2009), and due to its initial rarity in the removal area, no significant increase in seagrass cover was expected by the project's end. The linear growth of beds within the removal area was compared to beds outside the area to examine if removal of *A. amadelpha* enhanced vegetative growth, thus increasing the ability of the seagrass to recolonize bare substrate.

Seagrass beds within the removal area showed no significant difference in their daily relative linear growth compared to beds outside the removal area. However, beds inside the removal area showed a trend toward higher median daily growth compared to beds outside the removal area. Beds inside the removal area grew 5.8 cm/day (Interquartile range (IQR): -3.5-6.4 cm/day) compared to 0.4 cm/day (IQR: -8.0-3.9 cm/day) for outside beds. High variability in the growth rate among beds, the short duration between the initial and final measurements, and a small sample size may be contributing to a non-significant finding.

Benthic Community

The benthic community showed a significant shift in composition immediately following removal of *A. amadelpha* (ANOSIM, R=0.152, p=0.0001). The community shifted from domination by IAA species, especially *A. amadelpha*, to a community dominated by bare substratum (Figure 4). The recovery trajectory of the community suggests the benthic community is gradually recovering to a more native algal community than existed prior to *A. amadelpha* removal.

A SIMPER analysis identified two taxa and one benthic category that contributed to 40.1% of the variation observed between quadrats that had not been cleared of *A. amadelpha* and quadrats that had been cleared for one month (Table 3a). A decrease in *A. amadelpha* explained the largest percent of the observed difference (17.4% explained). An increase in the cover of native *Spyridia* sp. explained the greatest amount of the difference in the community structure between quadrats surveyed one month following clearance and 19 months following clearance (Table 3b). Change in the cover of the four bare substratum types also explained >10% of the observed difference. Sand and silt decreased after 19 months of recovery, likely resulting in the observed increase in rubble. The decrease in exposed limestone cover may be the result of it being overgrown by new algae, especially *Spyridia* sp.

Some IAA species are regrowing within the cleared area (Figure 3), but these species explained less of the observed change in the community structure than did changes in cover of *Spyridia* and bare substratum. *Acanthophora spicifera* is the primary IAA species increasing in the cleared areas; *Avrainvillea amadelpha* is also regrowing, but at lower rate than *Acanthophora spicifera* after 19 months (Table 2).

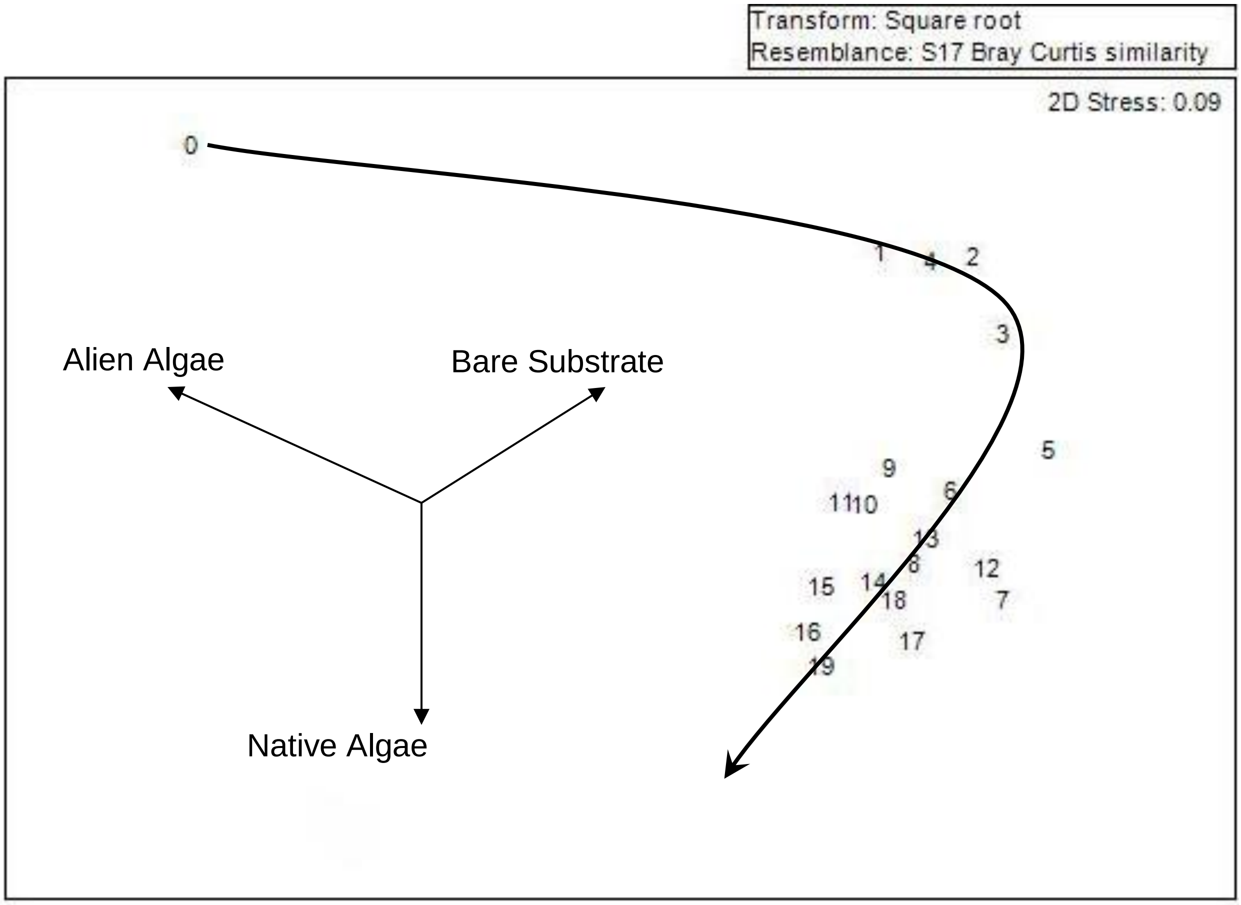

Figure 4. nMDS plot of benthic quadrats before the removal of the *A. amadelpha* and at one month intervals following its removal. Each point is average abundance of observed benthic taxa or bare substrate type in all 1 x 1 m^2 quadrats collected at for the monthly interval following clearance. Prior to removal (time=0) the community is significantly different from that immediately following removal (time=1). Communities in months the following *A. amadelpha* removal (times=1-5) are significantly different from later communities (times=16-19) (ANOSIM, R=0.152, p=0.0001). The curved arrow shows the general trajectory of recovery from a community initially dominated by IAA, to a community dominated by bare substrate following *A. amadelpha* removal, to a community gradually shifting toward one more dominated by native algae taxa.

Sediment Depth and Silt

Sediment depth showed a significant decrease following removal of *A. amadelpha* (Spearman rank correlation, $\rho=-0.217$, $p<0.0001$). Sediment had a median depth of 3.4 cm (IQR: 2.1-5.5 cm) in quadrats prior to removal of *A. amadelpha*. In plots that had been cleared between four and 19 months, median sediment depth generally did not exceed 2 cm (Figure 5), nearly half that present before *A. amadelpha* removal.

The percent cover of silt tended to be very low throughout the study, making analysis difficult. Prior to *A. amadelpha* removal, the percent cover of silt was 4.6 ± 1.0%. This increased significantly to 9.8 ± 2.8% one month after clearance and to 18.0 ± 4.0% two months after clearance. In subsequent months, the percent cover of silt decreased and eventually stabilized

Table 3. Results of a SIMPER analysis comparing communities prior to and following the removal of the *A. amadelpha*. Diss/SD=ratio dissimilarity to the standard deviation of the category; % Explained=the percent of the dissimilarity explained by the category; Cum. % Explained=is the cumulative percent of the total dissimilarity explained by the categories; Δ=the relative increase (+) or decrease (-) between the observations.

a) Prior to removal vs. One month after removal

Taxa/Benthic Category	Diss/SD[1]	% Explained	Cum. % Explained	Δ
Avrainvillea amadelpha	1.75	17.41	18.24	---
Sand	1.42	13.32	30.73	++
Acanthophora spicifera	1.41	9.20	39.92	--

b) One month after removal vs. 19 months after removal

Taxa/Benthic Category	Diss/SD[1]	% Explained	Cum. % Explained	Δ
Spyridia sp.	1.56	12.9	12.9	+++
Limestone	1.29	11.3	24.2	--
Rubble	1.10	11.1	35.3	+
Silt	0.79	10.1	45.4	--
Sand	1.13	10.1	55.5	-

[1]Values ≥1.4 indicate good discriminating taxa or benthic categories.

around 3.0% cover. While this increase in average cover of silt could represent the mobilization of the fine particles, it is more likely an artifact of the sampling technique. If algae were present beneath a sampling point, the sediment type was not recorded. Removing the algae exposed the underlying substratum, likely resulting in the observed increase.

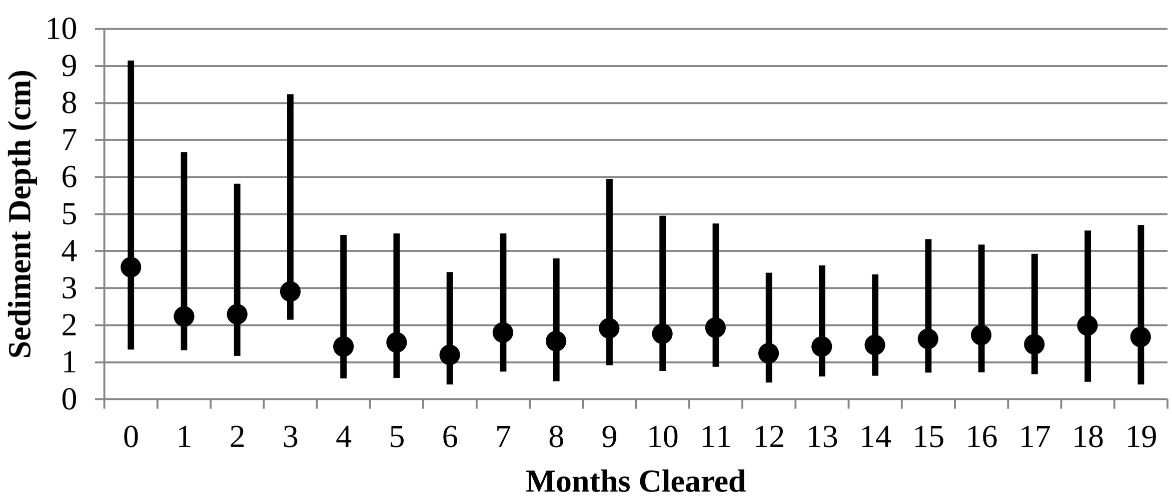

Figure 5. Median sediment depth and inter-quartile range (IQR) before *A. amadelpha* removal (time=0) and at one-month intervals following removal.

Discussion

Prior to this project, large-scale removal of marine algae had not been attempted as a restoration technique in Hawaii. Removals have been conducted as part of research experiments, but they generally small-scale, occurring in plots 100 m^2 or less in size (McClanahan *et al.* 1999, Edgar *et al.* 2004, Peyton 2009). The largest documented removal was conducted by McClanahan *et al.* (2001) on experimental plots averaging approximately 1000 m^2 (0.25 acres). This projected demonstrates the feasibility of large-scale algae removal by successfully clearing 27 acres (10.9 hectares) IAA from a coral reef flat.

Field crews were able to effectively hand-clear *A. amadelpha* from the removal area, reducing its cover from 56.9 ± 2.7% percent of the substratum to 2.6 ± 0.1%. *Avrainvillea amadelpha* is host species for other epiphytic algae (Smith *et al.* 2002), so it's removal resulted in the removal of nearly all algae from the area, radically altering the ecosystem. Following *A. amadelpha* removal, the percent of bare substrate increased significantly to 86.6 ± 1.8%, a 300% increase over the pre-removal cover. This shift in the benthic community had significant impacts on invertebrate communities (Longenecker *et al.* 2011) and nutrient cycling (Thomas and Peyton 2011). While studies have not been conducted, recovery of a native algae community is expected to result in the recovery of associated invertebrates and restoration of nutrient cycling.

Following *A. amadelpha* removal, the recovery of the Maunalua Bay reef flat community was expected to happen quickly. After 19 months complete recovery has not occurred for any component of the benthic community. However, the benthic community is showing a recovery trajectory toward a more native-dominated community with some IAA species in it. It is too early to determine if the community will continue on this trajectory or it if will eventually revert to a community similar that present prior to *A. amadelpha* removal. Currently, the data are suggestive of a continued recovery toward a more native-dominated system, but additional monitoring will be needed.

Data suggest that sediment characteristics within the removal area have changed. The percent cover of silt and total sediment depth has significantly decreased in the 19 months since *A. amadelpha* removal. Additionally, the percent of silt in the sediment has significantly decreased since *A. amadelpha* removal (Macduff 2011). The decrease in silt and sand at the site appears to be resulting in the exposure of hard bottom to which native algae species such as *Spyridia* sp. are attaching. Furthermore, the removal of soft sediment is encouraging because *A. amadelpha*, while capable of attaching to hard bottom, generally inhabits soft or sand substratum (Smith *et al.* 2002).

Seagrass was rare within the removal area prior to *A. amadelpha* removal and remained rare after 19 months. Native seagrasses spreads primarily through vegetative growth, so increases in the cover of seagrass was expected to take longer than 19 months and may require transplantation to be successful. Efforts to develop a viable transplantation method are underway (A. Murphy, pers. comm.). While not statistically significant, seagrass beds in the cleared removal area showed a trend toward higher daily relative linear growth rates compared to beds outside the removal area. In previous work, seagrass beds were shown to be capable of rapidly spreading into adjacent areas cleared of *A. amadelpha* (Peyton, 2009) and to be able to resist re-invasion. The data collected for this study support the observation of rapid seagrass bed expansion.

However, it is unclear at this time how decreasing soft sediment will eventually affect seagrass re-establishment.

Overall, these results show manual control of *A. amadelpha* on shallow water reef flats is a promising restoration technique for Hawaiian coral reef flats adversely impacted by *A. amadelpha* and other IAA species. While recovery of the community toward a native algae community will take longer than 19 months, recovery appears to be on the desired (and predicted) trajectory.

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Appendix 1
Mean percent cover (± SEM) for all taxa found within the project area. Values for the "Cleared" column are the mean of all quadrats regardless of how long they had been cleared of *Avrainvillea amadelpha*.

Taxa	**Status**	**Not Cleared**	**Cleared**
Avrainvillea amadelpha	Invasive Alien	57.9 ± 2.7	5.4 ± 0.3
Acanthophora spicifera	Invasive Alien	21.6 ± 1.8	5.9 ± 0.3
Sand	Bare Substratum	17.2 ± 1.9	49 ± 0.9
Chondria sp.	Native	11.9 ± 1.2	0.3 ± 0.1
Lyngbya spp.	Cyanobacteria	11.5 ± 2	3.2 ± 0.3
Halimeda sp.	Native	10.5 ± 1.4	1.5 ± 0.2
Gracilaria salicornia	Invasive Alien	8.9 ± 1.4	2.3 ± 0.2
Spyridia sp.	Native	7.5 ± 1.4	9.9 ± 0.4
Silt	Bare Substratum	4.6 ± 1	3.7 ± 0.4
Limestone	Bare Substratum	2.9 ± 0.5	11 ± 0.4
Dictyota sp.	Native	2.6 ± 0.5	0.1 ± 0
Centroseros sp.	Native	2 ± 0.5	0.1 ± 0
Rubble	Bare Substratum	1.6 ± 0.4	10.1 ± 0.6
Laurencia sp.	Native	1.6 ± 0.3	0.3 ± 0.1
Hypnea cervicornis	Native	1.1 ± 0.2	0.2 ± 0
Padina sp.	Native	1 ± 0.2	0.2 ± 0
Halophila hawaiiana	Seagrass	0.5 ± 0.4	0.5 ± 0.2
Valonia sp.	Native	0.5 ± 0.1	0.1 ± 0
Caulerpa taxifolia	Native	0.4 ± 0.3	0
Cyanobacteria	Cyanobacteria	0.3 ± 0.1	<0.1
Hypnea sp.	Native	0.2 ± 0.1	0.1 ± 0
Ceramium sp.	Native	0.1 ± 0.1	<0.1
Cucumber	Invertebrate	0.1 ± 0.1	0
Dictyosphaeria cavernosa	Native	0.1 ± 0.1	0.2 ± 0
Sponge	Invertebrate	0.1 ± 0.1	<0.1
Hydroclathrus clathratus	Native	0.1 ± 0	0 ± 0
Halimeda discoidea	Native	0	1.3 ± 0.2
Laurencia nidifica	Native	0	0.2 ± 0
Caulerpa sp.	Native	0	0.1 ± 0.1
Dictyota acutiloba	Native	0	0.1 ± 0
Gracilaria coronopifolia	Native	0	0.1 ± 0
Unknown	?	0	0.1 ± 0
Bornetella sp.	Native	0	<0.1
Bornetella sphaerica	Native	0	<0.1
Chnoospora sp.	Native	0	<0.1
Cladophora sp.	Native	0	<0.1
Codium sp.	Native	0	<0.1

Taxa	**Status**	**Not Cleared**	**Cleared**
Dasya sp.	Native	0	<0.1
Entromorpha sp.	Native	0	<0.1
Filamentous Red	?	0	<0.1
Gracilaria pervispalum	Native	0	<0.1
Gracilaria sp.	Native	0	<0.1
Hypnea musciformis	Invasive Alien	0	<0.1
Jania sp.	Native	0	<0.1
Liagora sp.	Native	0	<0.1
Neomeris sp.	Native	0	<0.1
Symploca sp.	Native	0	<0.1
Ventricaria sp.	Native	0	<0.1
Zooanthid	Invertebrate	0	<0.1