Hawaii Department of Land and Natural Resources

Hawaii Invasive Species Council

Research and Technology Grants

Development of Methods to Control Alien Algae on Hawaii's Reefs

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PROBLEM STATEMENT:

Hawaii's marine ecosystems support fishing and recreational activities, a tourism-based economy, and a cultural heritage. Currently, alien invasive algae present one of the most insidious threats to the health of Hawaii's coral reef ecosystems. Two mat-forming alien species, introduced in the 1970's for aquaculture research, are often unpalatable to native fish grazers, are highly invasive, and are capable of outcompeting and overgrowing corals. Without the development of an effective removal and control program, it is expected that these algae will continue to spread throughout the State, directly threatening the survival of Hawaii's coral reefs.

This project developed and tested methods designed to restore key areas of coral reef and ecosystems in Hawaii. Efforts were focused in Kaneohe Bay where highly invasive alien seaweeds--*Gracilaria salicornia* and *Kappaphycus/Eucheuma* spp.—have spread dramatically during the past decade (Rogers and Cox, 1999; Smith et al. 2002, 2004).

Support to date has been provided through NOAA-Hawaii Coral Reef Initiative, NOAA-Community Restoration Program, USFWS, The Nature Conservancy, National Fish and Wildlife Foundation, and University of Hawaii Sea Grant. The Hawaii Invasive Species Council grant enabled the expansion and continuation of research efforts through August, 2007.

Our research group spent considerable time in consultation with DLNR, DOH, and UH-Environmental Health and Safety Office (Diving Safety) to obtain permits that allowed the work to move forward as a collaborative research and development project. The

Project Coordinator, Project Supervisor, and Graduate Assistant will provide on-site coordination of day-to-day field work operations and monitoring, as well as implementation of laboratory cultures and replanting efforts, in addition to being responsible for producing detailed interim and final reports evaluating the successes and limitations of the proposed research.

Scientific Diving Technicians were hired to assess the feasibility of the mechanized underwater removal of alien algae as a method for marine invasive species control. It was required that divers be scientifically trained due to the 'proof of concept' nature of this research project as well as the scientific monitoring necessary to assess the effects of these invasive algae control approaches.

Scientific Diving Technicians were be required to hold and maintain current University of Hawaii Scientific Diver certification and have a thorough knowledge of Hawaiian marine species. Divers were briefed on all protocols and trained in the new techniques associated with this project.

Approach and Methods

The goal of this project was to assess methodologies to restore Hawaii's coral reef ecosystems through removal and control of alien invasive algae. Specific objectives were:

a) Developing and deploying a mechanical suction system capable of removing large volumes of algal biomass from reefs while minimizing damage to other reef organisms, and quantifying the impact of this technique on the native benthic community,
b) Experimentally examining the effectiveness of enhancing populations of native sea urchins as a means of increasing grazing pressure on invasive algae and reducing their ability to regrow following large-scale mechanical removal, and,
c) Monitoring reefs subjected to the above treatments to determine their immediate and long-term effectiveness in controlling invasive algae.

Site Selection: Initial sites selected for algal removal were in areas of Kaneohe Bay where blooms of the alien algae *Gracilaria salicornia* and *Kappaphycus/Eucheuma* spp. have been documented. Sites were selected at the margin of expanding algal blooms to help to prevent further spread of algae over new areas of coral reef. Adjacent to each removal site, a control site was established where the same survey protocols were followed but without removal of alien algae.

Pre-Removal Surveys: In order to determine both the effectiveness of the mechanical removal technique and its impact on the reef environment, baseline surveys were conducted prior to the removal of algal biomass. At each site, surveys quantified the abundance of fish, mobile invertebrates, and the composition of the benthic community, including reef building corals and native and alien marine algae

Fish and mobile invertebrates were enumerated via visual belt transect surveys, which have been shown to be highly repeatable and reasonably accurate (Brock, 1954; Sale, 1980). At each site, three 5m x 25m transects were established with both ends marked by permanently placed stainless steel stakes to allow re-sampling over time of the same transects. On each survey date observers swam the length of each transect at a constant speed, identifying all fishes and mobile invertebrates seen and estimating their length to place them into appropriate size categories.

Benthic community composition were determined by using a series of permanently placed photoquadrats (Brown et al. 1999). Ten haphazardly placed photoquadrats were established at each site with stainless steel stakes used to permanently mark the quadrat borders. Photographs were taken with a camera held at a fixed distance above the substratum in a PVC frame. Digital images were analyzed with the program Photogrid in which the benthic components under 100 randomly chosen points within the frame were recorded.

<u>*Mechanical Removal Protocol*</u>: A team of four diver-technicians operated a *venturi* suction device to mechanically remove alien algae at designated sites. The *venturi* system was mounted on a 24 x 15 foot pontoon-based barge. This platform has a total weight capacity of 20,800 pounds, allowing for a substantial amount of algae to be collected each trip.

A 6" collection hose (100' in length) was attached to the pump. One diver controlled the collection hose, with a second diver acting as a safety monitor. The collection hose ran to a sorting table on-board the barge where native organisms were removed for return to the reef. Alien algae was placed in burlap bags for off-loading. The alien algae biomass was then transferred to local farmers will used the biomass for composting and soil amendment.

A safety diver was posted on the surface to monitor the suction device, intake and discharge hoses, and collection. The pump was equipped with a step down diesel engine that allows suction to be adjusted to prevent the removal of heavier marine life or debris. Suction in this pump is created through a water vacuum and there are no fans or blades within the system. As a result, harm to any associated marine life that passes through the system is minimized. In areas with a very volume of algae, the suction device collected up to 750 pounds of algae per hour.

Maintenance removal operations were conducted in areas that showed extensive re-growth of algae to help maintain alien algal populations at low levels. As shown below, removal of algae that was shading and smothering corals had an immediate benefit to coral reef health.

<u>*Post-removal surveys*</u>: Experimental removal trials indicated that the positive impacts of algae removal are high while negative impacts are low or negligible. It was critical to determine the direct impact of the mechanical removal process on the reef community. We quantified the species, number, and biomass of non-target organisms removed with

the invasive algae. Ten 20 kg subsamples of collected algal material were examined at each site, all organisms other than the alien alga were removed, identified to species, weighed, recorded as intact, damaged, or dead, and if alive returned to the water. As mentioned above, the design of the *venturi* system greatly reduces damage to marine life in collection and as a result, the majority of native species associated with the alien algae biomass were returned unharmed to the environment.

Direct effects on the reef due to the removal process were quantified by swimming the established transects immediately following removal. Transects and photoquadrats were re-surveyed within one week after the removal of algal biomass, 1 month after removal, and then every two months until 1 year after removal. Very limited coral breakage or scars attributable to algal removal were recorded.

Complementary Approach: Urchins as Biocontrol Agents

Pilot projects demonstrated the ability of alien invasive algae species to recover following removal (Smith et al. 2004). In some areas, algae can re-grow and re-colonize quite rapidly. These experimental removal plots were quite small ($0.25m^2$), however, and rapid recovery was often the result of algae growing into the plots from neighboring, un-cleared areas or of drifting fragments settling in the removal plots and attaching to the substrate. It was expected and confirmed that the much larger scale of the removals in this project mitigated the importance of both re-growth from neighboring areas and re-colonization by fragments, due to decreased edge effects. However, the previous results emphasize that the conditions allowing these invasive algae blooms to occur (over-fishing, nutrient subsidy) are still in effect and recovery of algal populations is likely to threaten corals and other reefs organisms unless further steps are taken. We conducted experiments to determine if native urchins can be cultured to provide an effective biocontrol agent in combination with mechanical removal.

As part of earlier removal experiments, UH researchers placed native sea urchins (hawae), *Tripneustes gratilla*, into fences surrounding small ($0.25m^2$) algal removal plots. Results showed that these urchins were very successful at slowing the rate of algal regrowth, suggesting that these native sea urchins may be used as effective biocontrol agents to control these algal blooms. While promising, the methods used to obtain these results utilized high densities of urchins. The high experimental densities ($4\ ind/m^2$) used in these experiments may not be feasible to achieve over effective management and mitigation-scale areas. We also tested tagging methods in order to track sea urchins as biocontrol agents on Hawaii's reefs.

This project involved three main foci to investigate the control of alien algae:

Development and testing of mechanized removal methods ("Algal Supersucker")
Long-term monitoring of results of clearing alien algae biomass
Development of methods for rearing native sea urchins as biocontrol agents

RESULTS

Removal of Alien Algae from Coconut Island reef:

Table 1: Removal of alien algae (kg) with the supersucker from two sites on the leeward slope of the fringing reef surrounding Coconut Island.

Date	**Supersucker site #1**	**Supersucker site #2 T1**	**T2**
7/6/05	360	365	
7/19/05	630	292.5	
7/25/05	450		270
8/2/05	675	135	315
8/18/05	675		
8/23/05	540		
8/30/05	585		
9/15/05	315		
9/28/05	450		
10/28/05	360		
11/1/05	238.5		
11/10/05	360		
11/28/05	360		
12/14/05	202.5		
1/6/06	720		
Total (kg)	**6921**	**792.5**	**585**

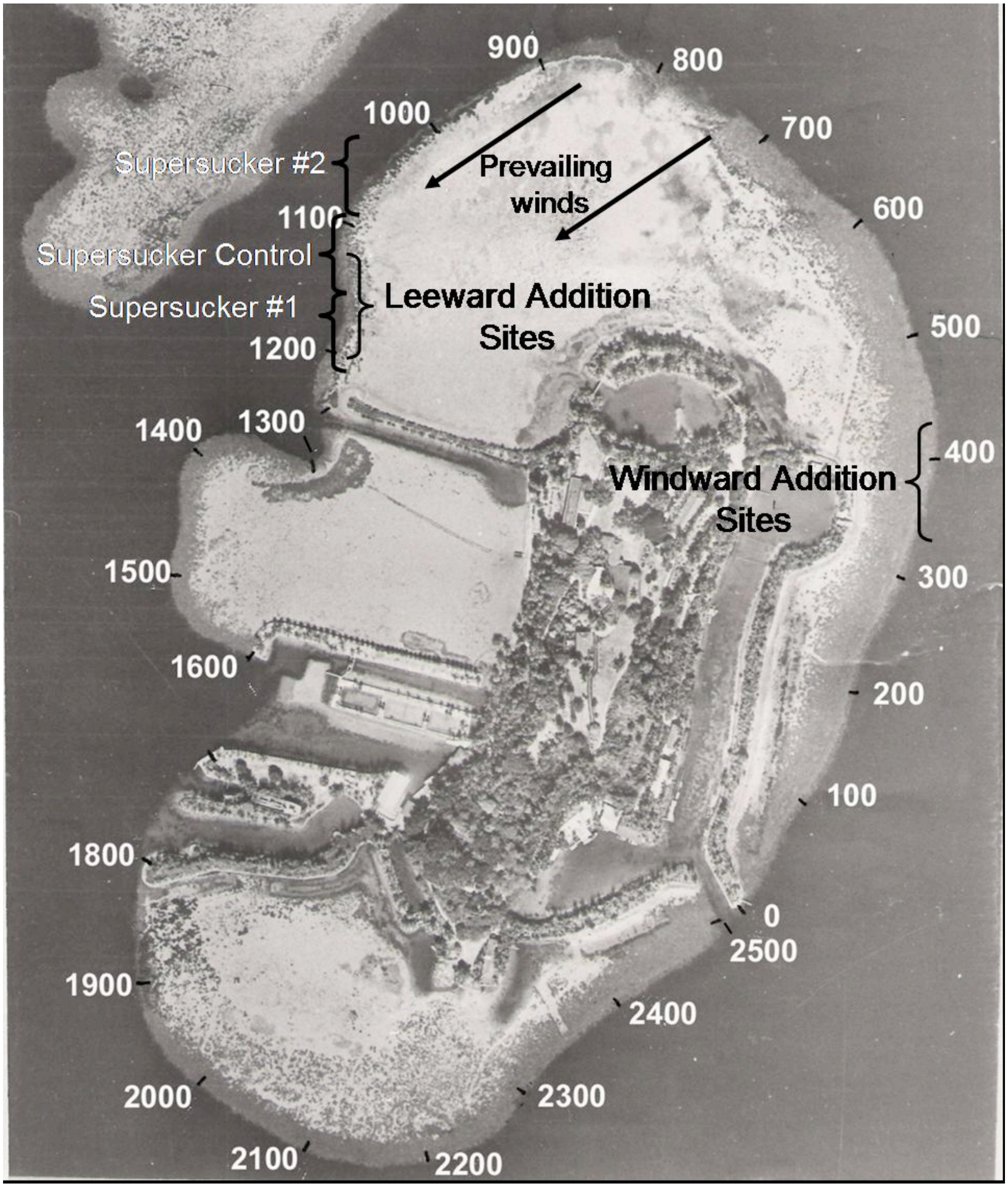


Figure 1: Aerial photograph of Coconut Island. The white numbers around the circumference of the reef indicate distance in m from the channel into the island's lagoon. "Addition sites" are the regions of the reef slope where 3 contiguous transects were established and *A. spicifera* added to the central transect. Supersucker sites #1 and #2 are sites at which *G. salicornia* was removed from the slope, while it was left undisturbed at the central control site.

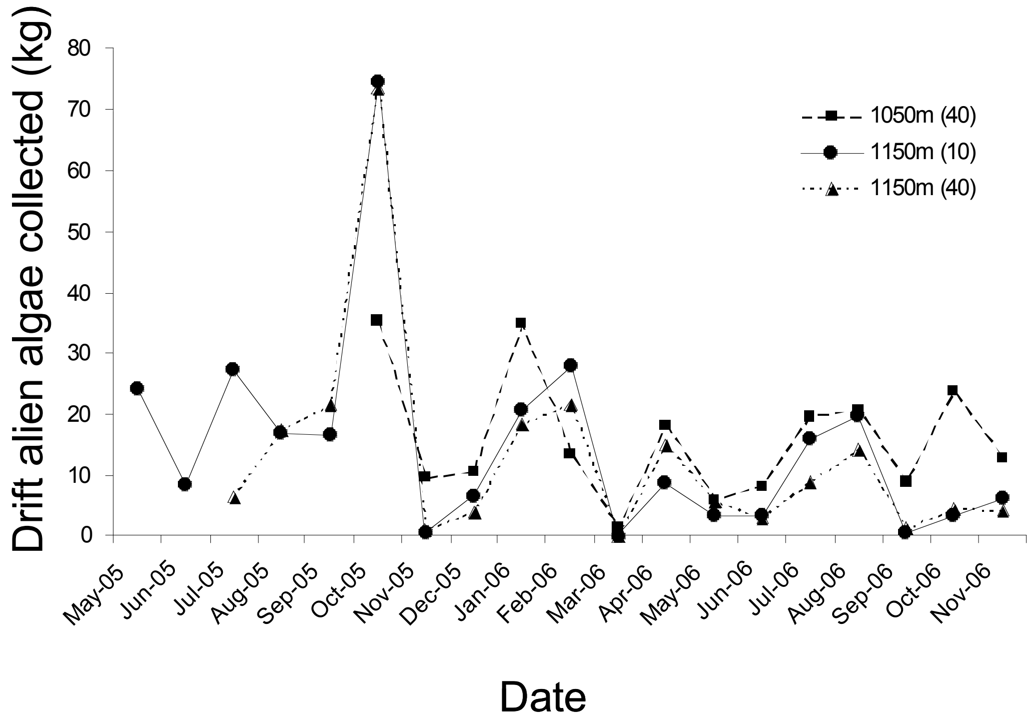


Figure 2: Biomass of alien algae collected per month in three traps on the reef flat of the Coconut Island reef over time. The first number of each site name give the location of the trap relative to the markings surrounding the reef crest of Coconut Island (Figure 1), the parenthetical number indicates the distance the trap was placed onto the flat from the reef crest.

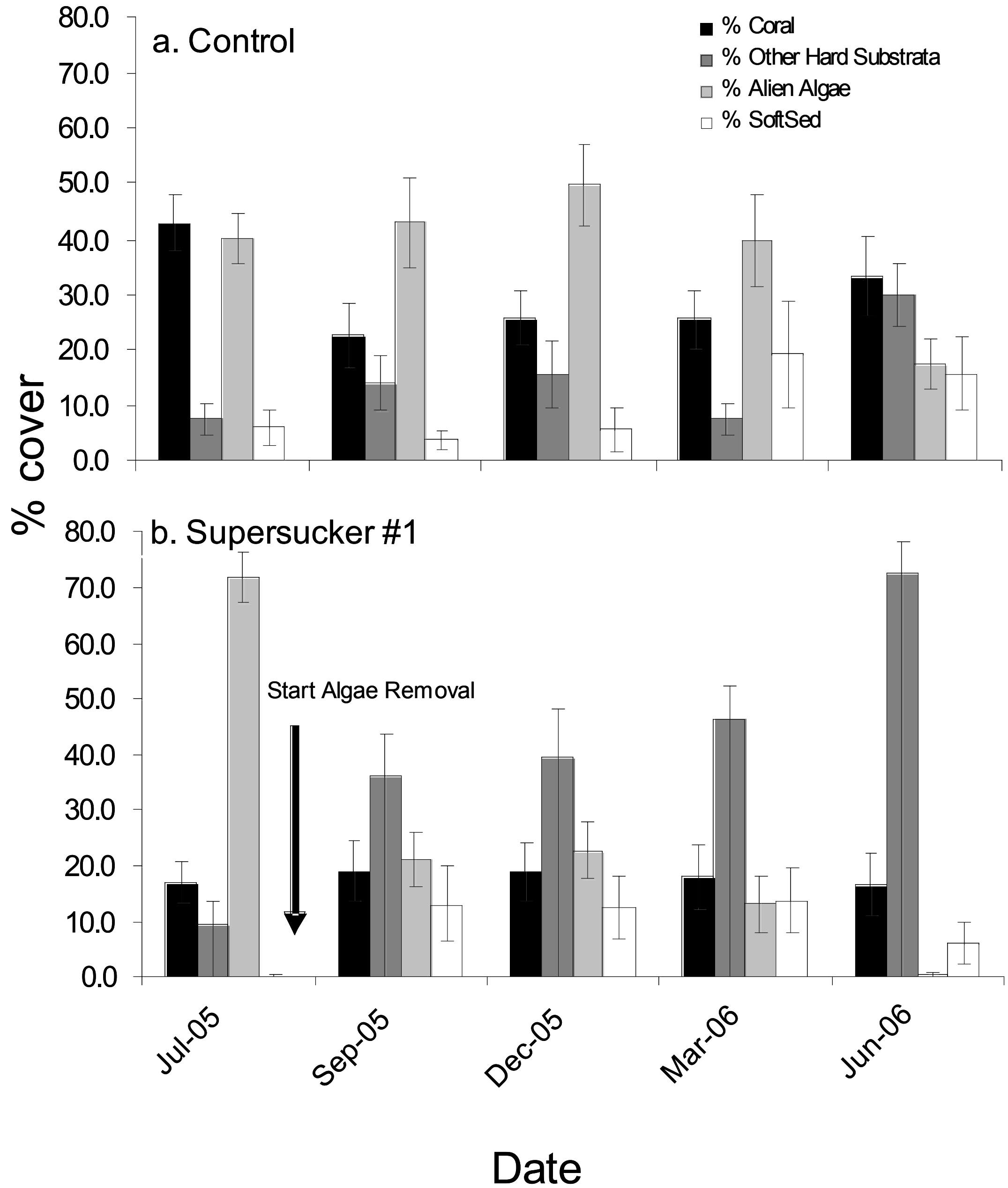


Figure 3: Percent cover of substratum components determined from ten photoquadrats at each of two sites on the leeward face of the reef surrounding Coconut Island versus time. The control site **(a)** was left undisturbed throughout, while all alien algae were removed from the removal site **(b,** Supersucker site #1) with the supersucker from July to December of 2005.

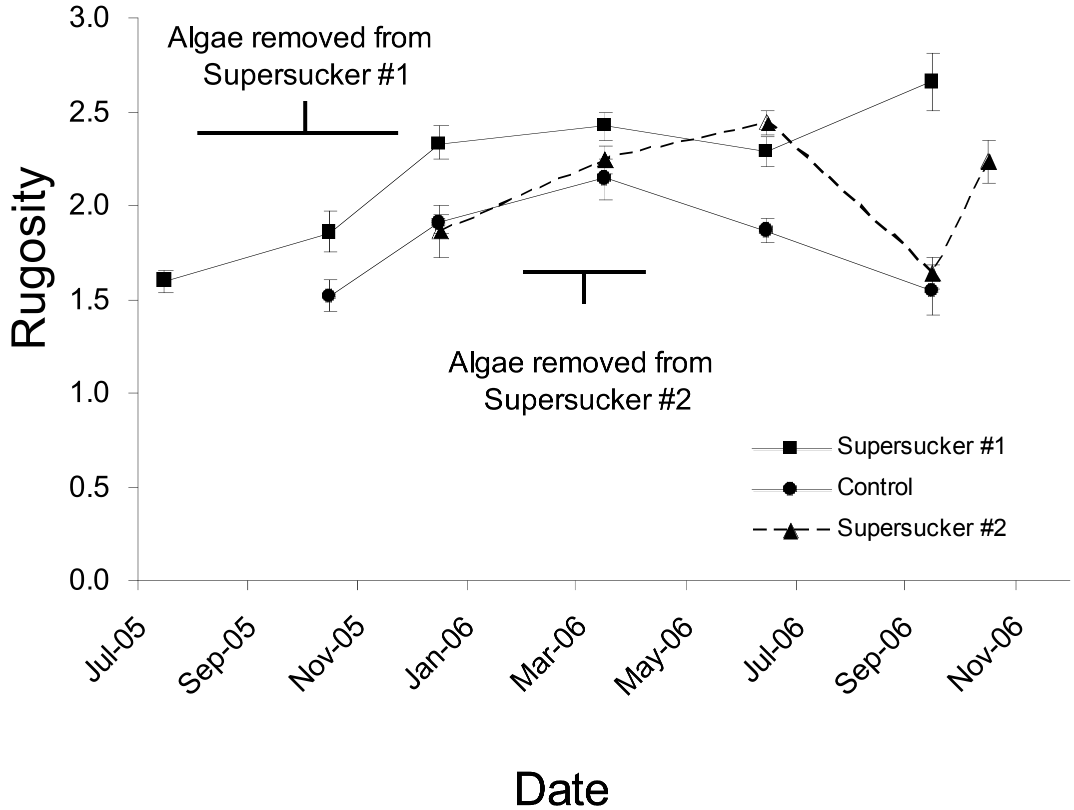


Figure 4: Rugosity (ratio of linear to topographical-contour distance) of the site on the leeward reef of Coconut Island from which alien algae were removed (Supersucker site #1) and the adjacent control site. The brackets indicate the times during which alien algae were originally removed from the removal site.

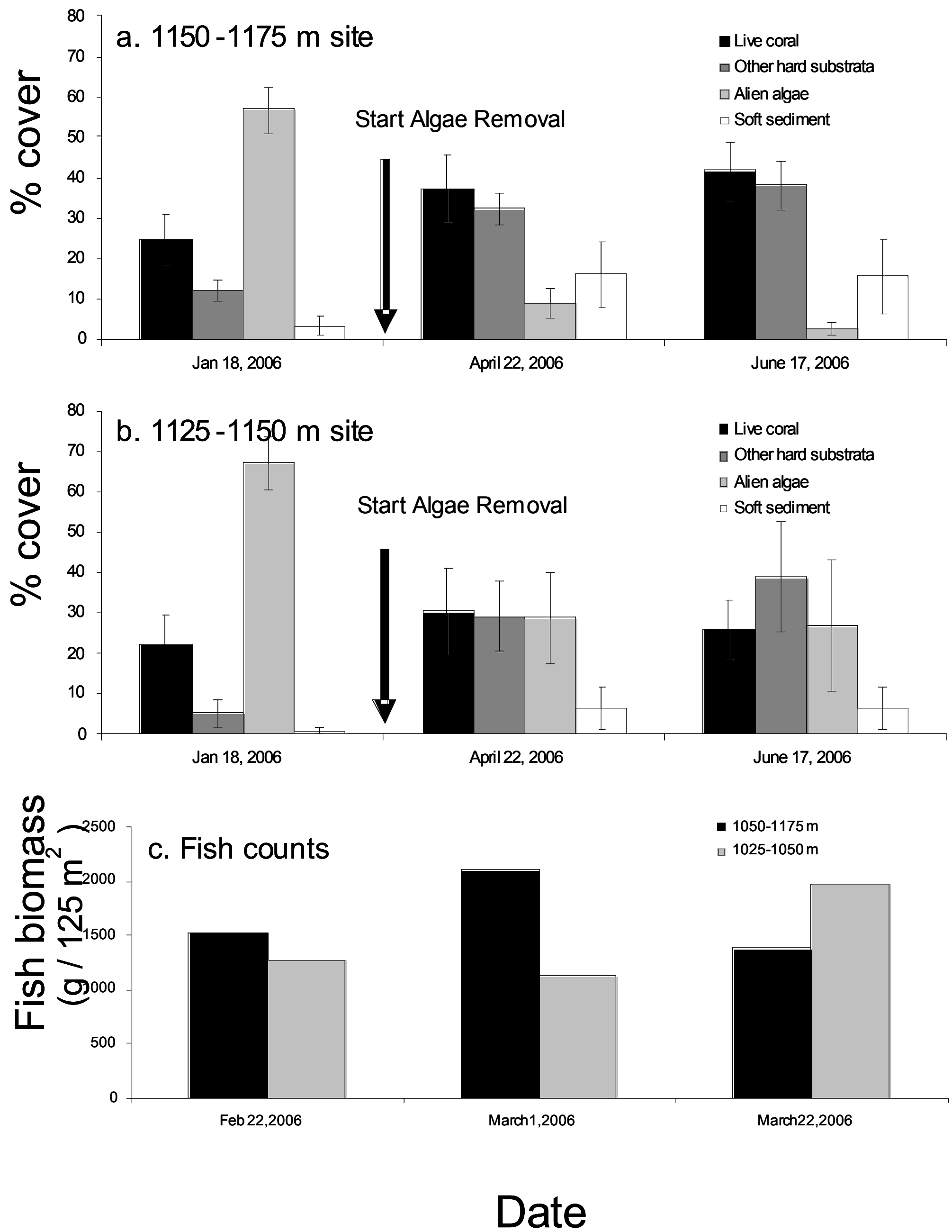


Figure 5: Fish biomass and benthic cover from two sites on the leeward slope of Coconut. No algae had been removed from either site at the Feb 22 sampling date, algae had only been removed from the T1 site by the March 1 sampling date, and algae had been removed from both sites by the March 22 date.

Rearing of native sea urchin (hawae) larvae:

A number of field experiments are on-going: 1) investigating growth rate of urchins by sex and location; 2) transect monitoring for retention on reefs; 3) investigating external tagging techniques; and 4) looking at urchin selectivity index of substrate/food preference.

After rearing sea urchin larvae to metamorphosis, our goals were to start a feeding experiment contrasting shellfish diet (mixed killed Instant Algae culture from Reed Mariculture) with a 50% *Chaetocerous*/50% *Isochrysis* mix. This experiment is on-going.

Maintenance issues encountered included keeping water supply hoses to the tanks clean, washing all equipment with fresh water before putting it away, wiping down tank lids to keep them free of salt water, and keeping the semi-enclosed culture facility clean.

We expanded to a two-tank system to allow replication. Previously, when the larval cultures crashed, we were not able to pinpoint a single reason. Under the two-tank system we were able to test various conditions one parameter at a time, which has led to a number of interesting findings:

1) The urchin larvae fared better with a mixed-species algal diet, rather than a single species. We were able to raise them to an age of 29 days using the instant algae (killed mixed-species microalgae), to a stage just prior to metamorphosis.

2) Larval cultures fared better with a flow rate between 100 and 200 mL/min to keep swimming. Higher flow may have helped alleviate contaminants, but higher than 200 mL/min crushed them against the standpipe.

3) Circulation fans in the tanks were crucial for keeping the larvae in the water column, but appeared to inflict mechanical damage on larvae younger than 5 days old. Further tests on this are ongoing.

4) Urchin larvae are very vulnerable to predation by ciliates, especially just after fertilization. It was unclear how ciliates were introduced to the culture system, but using advanced sterile techniques during tank maintenance minimized this.

Challenges to the successful rearing of urchins were numerous and included ciliate infestation, flow rate fluctuations, and temperature variations. Maintenance of sterile techniques while spawning and monitoring helped control ciliates, but these tiny organisms were deadly to the larvae once infected; future cultures will address advanced filtering or using antibiotics in the tanks. Variations in the flow rate killed one batch of larvae when a turbo snail washed down the pipe and got stuck in the catch valve, raising the flow up to 10x what is optimal for the larvae. We installed an upstream filter that alleviated this problem.

In addition, morning sun hitting the tanks caused the temperature in the top layer of water to get too warm for the larvae, and the optimum flow rate was insufficient to alleviate this effect through mixing alone. We moved the tanks further into the culture facility where they were shaded throughout the morning, and this seems to have helped. We also installed a new dosing pump and tubing that automated the feeding system.

Another advance was the streamlining of the data collection system and the organization of the interns. We employed five undergraduate interns who were trained to independently monitor the larvae. This included filtering water samples, sizing larvae, measuring and optimizing flow rate, examining water for presence of contaminants, accurately recording data, and maintaining the pump system in the boat house. Interns also maintained the broodstock and helped to develop tagging techniques for adults on the reef.

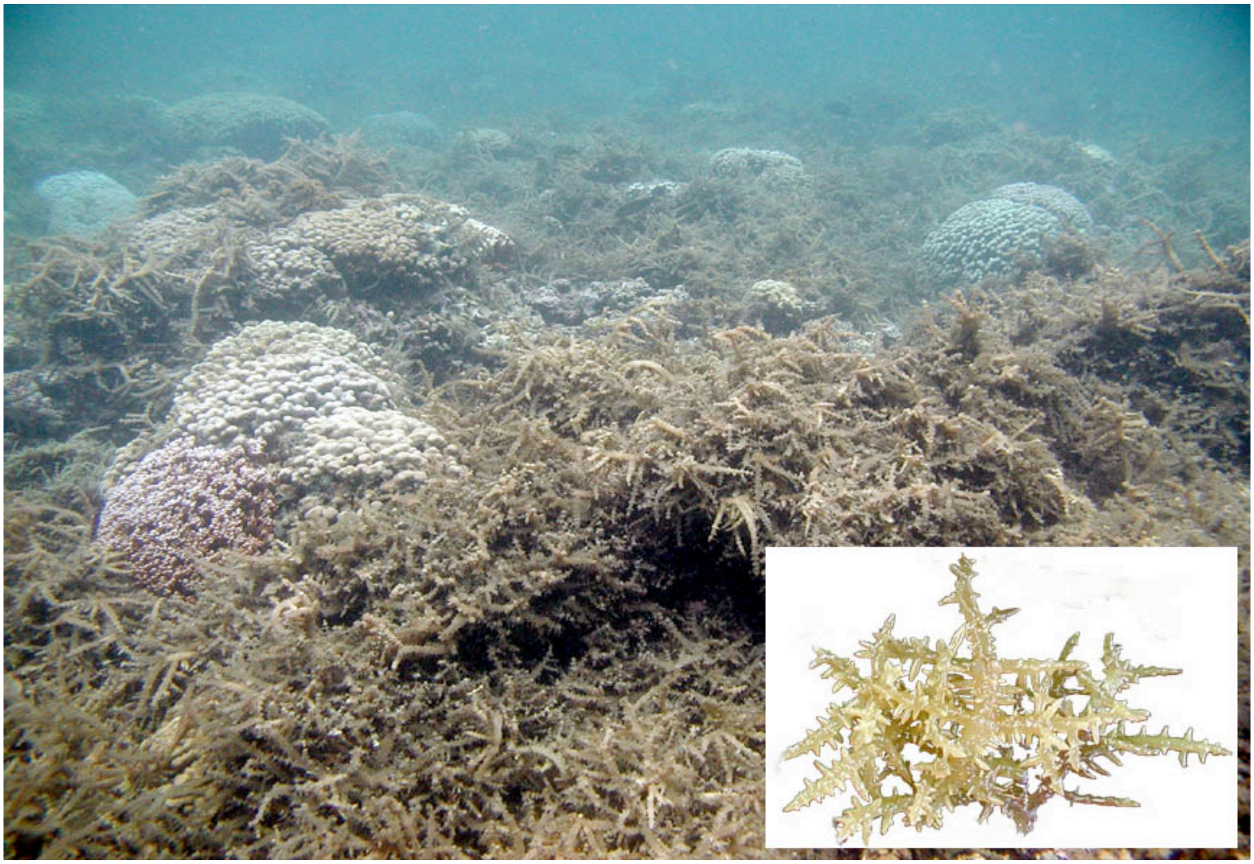
We raised several broods of urchin larvae nearly to metamorphosis, although they finally succumbed to predation by ciliates. In July, we were asked to relocate the urchin culture facility at HIMB due to a previous commitment of this space. We are now in the process of setting up a new larval culture lab in order to take advantage of the fall spawning peak, but we effectively lost two months of effort toward larval urchin rearing. Instead, we refocused our efforts toward tagging trials on adult urchins.

Threaded nylon screws with inscribed labels were inserted into adult urchin tests. These caused no mortality and have lasted over three months. Next steps are to test the longevity of the tags and movement of urchins in field experiments.

Citations:

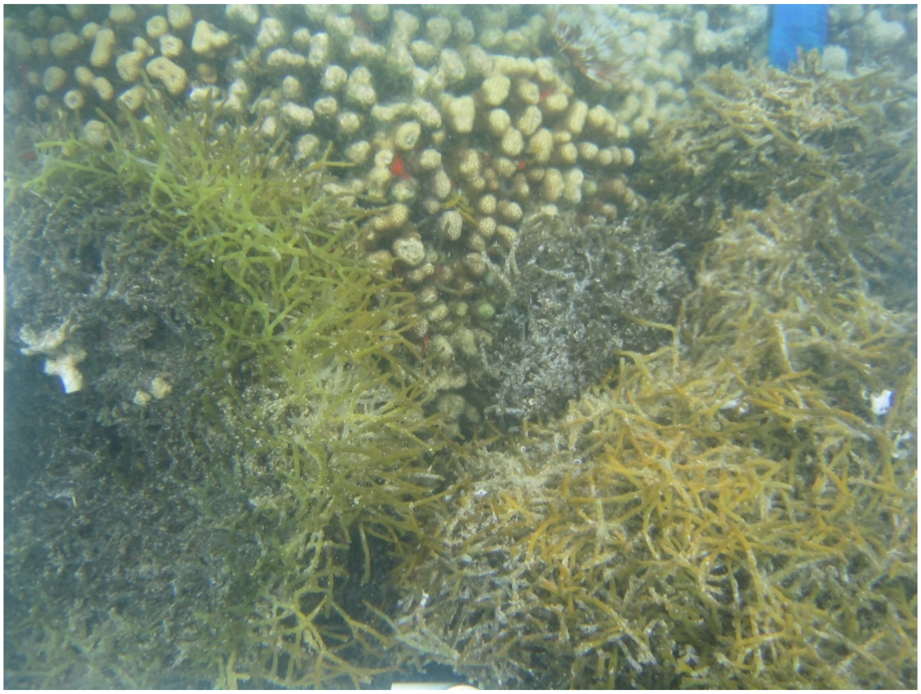
Smith, J.E., C.L. Hunter, E.J. Conklin, R. Most, T. Sauvage, C. Squair, and C.M. Smith. 2004. Ecology of the invasive red alga *Gracilaria salicornia* (Rhodophyta) on Oahu, Hawaii. Pacific Science. 58 (2): 325-343.

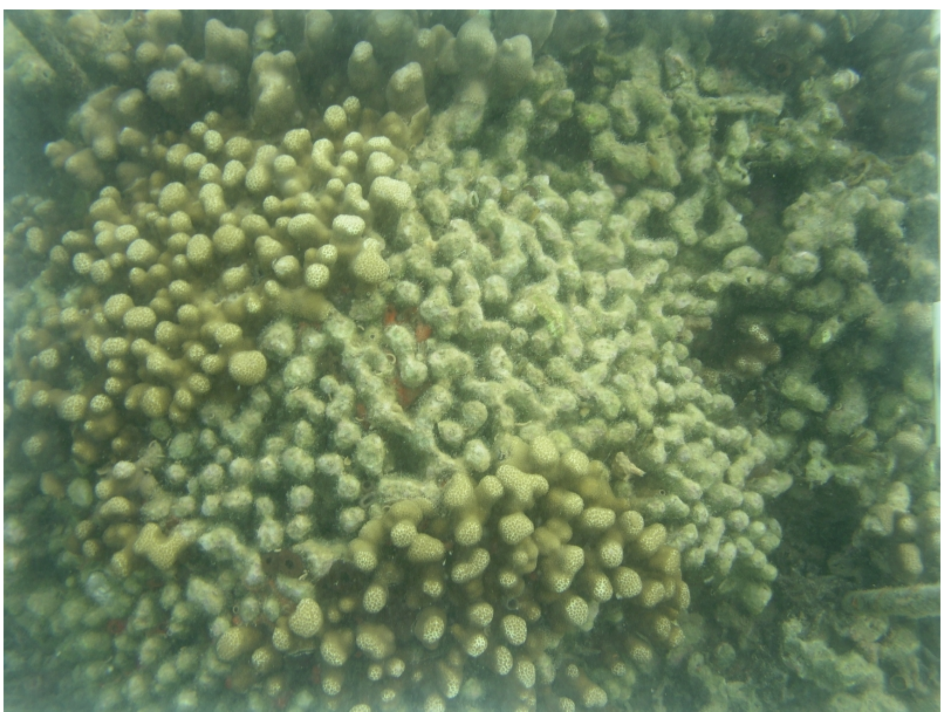
Smith, J.E., C.L. Hunter, and C.M. Smith. 2002. Distribution and reproductive characteristics of non-indigenous and invasive marine algae in the Hawaiian Islands. Pacific Science. 56(3):299-315.

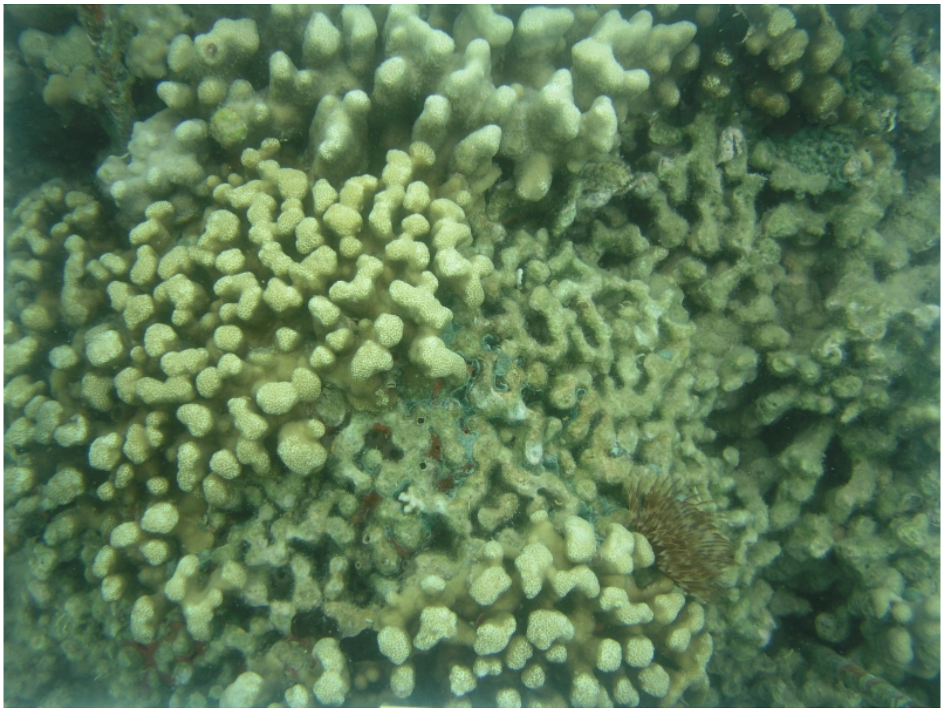


Invasive alien algae rapidly overgrows native finger coral in Kaneohe Bay.

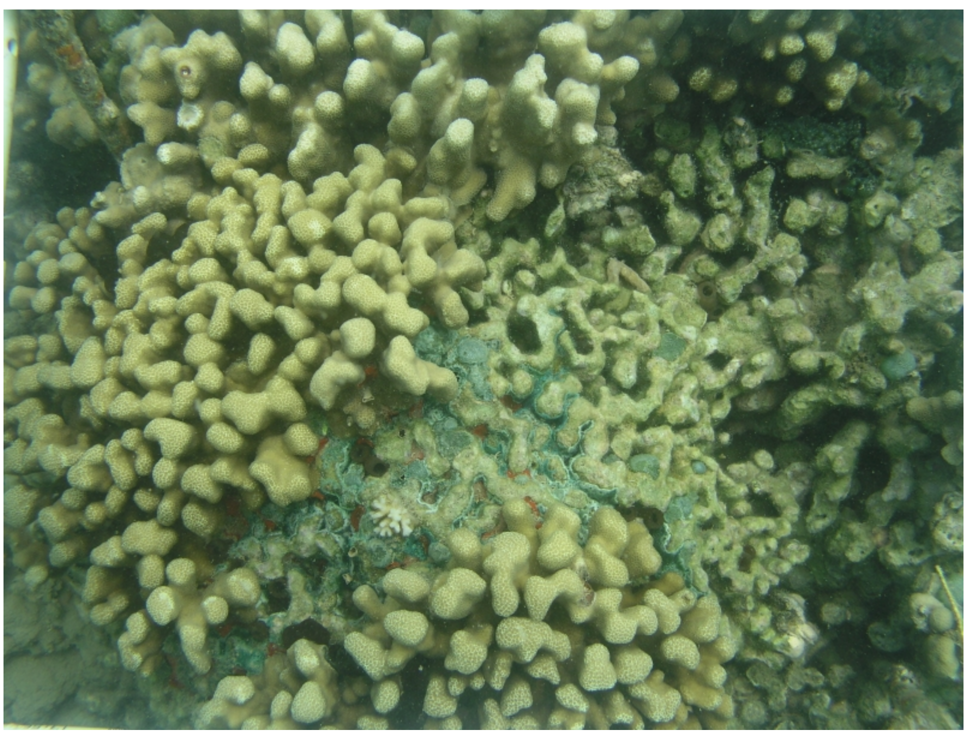
Super Sucker underway to alien algae removal site at Coconut Island.


Representative quadrat before mechanized removal of alien algae.


Representative quadrat four months after mechanized removal of alien algae.



Representative quadrat 11 months after mechanized removal of alien algae; note recruitment of coral (*Pocillopora* sp.) in lower middle of quadrat.



Representative quadrat 14 months after mechanized removal of alien algae; note growth of coral (*Pocillopora* sp.) in lower middle of quadrat.