Developing Coastal Wetland Restoration Techniques to Enhance Coastal Habitats at Āhua Reef, Joint Base Pearl Harbor Hickam, Hawai‘i (Legacy 11-320)

Abstract

This project was developed and completed by SWCA Environmental Consultants (SWCA) at Āhua Reef, a coastal wetland on Joint Base Pearl Harbor Hickam, O‘ahu, Hawai‘i. The objective of this study was to investigate species-specific techniques for seeding and outplanting Hawaiian coastal wetland plant species following different invasive species control strategies (i.e., herbiciding and manual removal of pickleweed) and subsequent management activities (i.e., weeding and supplemental watering) at Āhua Reef.

This study provides insights into the restoration of coastal wetlands in Hawai‘i. Results of this study suggest that it is possible to at least partially restore a highly degraded coastal wetland such as Āhua Reef. Before the experiment began, roughly 91% of the experimental squares were covered with invasive pickleweed (*Batis maritima*) and no native species were present. At the end of the five month study, the total percent cover of pickleweed over the experimental squares was 13% and native species cover (including outplanted and volunteer species) was 25%.

According to the Integrated Natural Resource Management Plan for the base, Āhua Reef should be managed to have less than 25% cover of pest plants including pickleweed and mangrove (*Rhizophora mangle*). Planting native species can jump-start the growth and production of native vegetation; however, long-term management and invasive species control program will be needed to restore Āhua Reef to a functional coastal wetland.

Project Specifics

Results of this experimental study apply specifically to the coastal wetland of Āhua Reef. However, natural resource managers managing coastal wetlands in Hawai‘i and other Pacific Islands can gain insight from the results of this study with regard to effective control strategies for pickleweed, as well as seeding and outplanting techniques for native wetland plant species.

Description of geographic setting:

Joint Base Pearl Harbor-Hickam (JBPHH) lies on the coastal plain along O‘ahu’s south shore. This study was conducted at Āhua Reef, a 1.6 hectare (4 acre) wetland and an adjacent expanse of mud and reef flat at JBPHH, immediately west of Honolulu International Airport (Figure 1). This wetland is largely degraded with the majority of area being invaded by non-native species, such as red mangrove (*Rhizophora mangle*), pickleweed (*Batis maritima*), and kiawe (*Prosopis pallida*). The coastal wetland of Āhua Reef is a harsh environment with uneven topography, complex hydrology, and very diverse and

Figure 1. Pickleweed invasion at Āhua Reef, Joint Base Pearl Harbor Hickam,

patchy soil conditions. Soil pH, moisture, and temperature vary widely at the study site. During high tides (> 2m), the inundated areas expand and remain submerged for varied periods of time. The salinity of ponds at the site ranged from 65 parts per thousand (ppt) to 126 ppt with average salinity of 96 ppt.

Principal investigators:
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Partners:

- DOD Legacy Resource Management Program: provided funding
- Environmental Office, Joint Base Pearl Harbor Hickam (Dr. Cory Campora, Mr. Joel Helm, Ms. Patty Coleman, Mr. Justin Fujimoto): provided guidance, administrative and logistic support and also funded the purchase of some native wetland plants for use in the experimental study.
- Boy Scouts of America Troop 97: volunteered labor to manually remove invasive weeds at the study site.
- University of Hawai‘i at Mānoa (Nicholas Srotzki and Adam Vergara): volunteered labor to remove invasive weeds from the study site.

Service branch: Navy and Air Force

Project location: Joint Base Pearl Harbor Hickam, Hawai‘i, Pacific

Installation size: 11,207 hectares (27,694 acres)

Installation primary mission: Joint Base Pearl Harbor-Hickam enables maximum mission readiness of their tenant commands and activities by providing the highest quality installation services, facilities support and quality of life programs.

Project dates: August 2011 to December 2012

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Purpose/Need

Hawai‘i has lost nearly 31% of its coastal wetlands as a result of human activities and the remaining coastal wetlands have been further degraded due to invasion by fast growing, non-native plants, particularly mangroves and pickleweed. These species displace native vegetation, choke out open water and mudflats necessary for Hawaiian waterbirds, trap sediments, and negatively affect water quality and hydrology.

Several Hawaiian waterbirds, such as Hawaiian stilt or ae‘o (*Himantopus mexicanus knudseni*), Hawaiian coot or ‘alae ke‘oke‘o (*Fulica alai*), Hawaiian gallinule or ‘alae ‘ula (*Gallinule chlororopus sandvicensis*), and Hawaiian duck or koloa maoli (*Anas wyviliana*), are endangered and therefore it is not surprising that most wetland research in Hawai‘i has focused on understanding the life history and habitat use of Hawaiian waterbirds. Constructed and restored wetlands in Hawai‘i are primarily designed and managed for open space and appropriate water levels which is desirable for waterbird habitat and

thus having a high percentage of vegetative cover is not appropriate to maximize this function.

Past Hawaiian wetland restoration efforts mostly involved removal of invasive vegetation to create habitat for endangered waterbirds. Much less attention has been given to developing restoration techniques for native wetland plants. To date, most wetland "restoration" efforts have involved removal of non-native invasive vegetation; however, to fully restore a wetland it is not only necessary to control invasive species, but also to return native plant species to these sites. The native planting efforts in Hawaiian wetlands are based on managers sharing knowledge via personal communication. Rarely has there been consistent monitoring of the outplanted native species for establishment success and survival; with the exception of Brimacombe's work in Honouliuli (Pearl Harbor), records of success and failure of native wetland plant restoration efforts are largely anecdotal.

Approach

Experimental Design

SWCA adopted a randomized block design to investigate the effect of two invasive species removal methods (herbicide versus mechanical removal), weeding, and supplemental water on outplantings and seeds of the following five native wetland species: ʻahuʻawa (*Cyperus javanicus*), *Cyperus polystachyos,* mauʻu ʻakiʻaki (*Fimbristylis cymosa*), ʻōhelo kai (*Lycium sandwicense*), and ʻākulikuli (*Sesuvium portulacastrum*).

Between September and October 2011, SWCA biologists established eight 14.5 m x 14.5 m squares at Āhua Reef. The squares were set up in areas dominated by pickleweed, avoiding large areas of mangrove and kiawe, as well as recreational trails. Within each block, we randomly assigned one square to receive the mechanical removal treatment and the other to receive the herbicide treatment.

Figure 2. Boy Scouts of America volunteers pulling pickleweed from mechanical squares

Pickleweed removal treatment

For the mechanical treatment pickleweed was hand pulled by the roots using hand tools such as picks and trowels (Figure 2) followed by rototilling the soil. For the herbicide treatment, a 1% solution of the herbicide Habitat® (EPA Reg No. 241-426) was applied using backpack sprayers by licensed pesticide applicators. Dead pickleweed was brushcut and removed from the plots.

Weeding/Watering treatment

In each square, four 6 x 6 m plots were then established. Each plot was randomly designated one of the four weeding and supplemental water treatments (watering + weeding, watering + no weeding, no watering + weeding, and no weeding + no watering). Weeding treatment plots were weeded every other month and watering treatment plots were watered once a week for eight minutes using a hose.

Species addition treatment

Each plot was further subdivided into four 3 m x 3 m subplots. The four subplots were randomly assigned one of the following four species addition treatments: outplants only, seeds only, outplants + seeds, and control (no outplants or seeds). All five native wetland species were outplanted in December 2011. Seeds of only three sedge species of *C. javanicus, C. polystachyos* and *F. cymosa* were seeded in February of 2011. Seeds were mixed in a solution of TripleTac® tackifier and poured into the subplots.

Data collection

This study was conducted for five months. Soil moisture, pH, and temperature were collected once prior to start of experiment. Survival and height of outplanted species, and percent cover of all species in the plots was recorded in January, March, and May of 2012. The presence and activity of waterbirds was recorded every week from January to May 2012.

Results

ʻĀkulikuli had the highest mean survival (85.4%) and cover (37.3%)of all native outplants at the end of the five month experiment.

Pickleweed was the most abundant (mean cover: 13.2%) non-native species that re-grew after initial removal treatments. However, weeding every other month decreased pickleweed cover in the plots that received weeding treatment.

Effect of pickleweed removal method

Survival (Table 1) and growth of all outplanted species was consistently higher across all outplanted species in mechanical treated squares than in squares treated Habitat® herbicide. The re-growth of weedy species, especially pickleweed, was also lower in the plots treated with Habitat® than in the plots in which pickleweed was manually removed.

Habitat® takes 3 to 5 days to dissipate in water, but, it takes 26 to 143 days to dissipate in soil. Native plants were transplanted 30 days post herbicide application under dry conditions. Outplants within the herbicide squares probably absorbed residual herbicide in the soil thereby showing poor survival and growth.

Table 1. Percent survival of outplanted native species in May 2012.
~P values based using Chi square tests.

Species	N	Survival (%)	Pickleweed Removal Treatment		
			Mechanical	Herbicide	*P~*
All	1,440	61.0	83.2	38.9	<0.001
Cyperus javanicus	288	57.7	78.5	36.6	<0.01
Cyperus polystachyos	288	44.1	74.3	14.4	<0.001
Fimbristylis cymosa	288	52.4	77.1	27.8	<0.001
Lycium sandwicense	288	65.6	89.6	41.7	<0.001
Sesuvium portulacastrum	288	85.4	96.5	74.3	<0.001

Effect of weeding/watering

Removal of weedy species and addition of supplemental water did not improve the survival and growth of the outplanted species. There were no differences in the survival and growth of the five outplanted native species between the two treatments of weed + water and no weed + no water. Furthermore, the survival and growth of ʻōhelo kai, ʻākulikuli, and all outplanted species combined (Figure 3) was higher in the no weed + no

water plots than in the plots that received just weeding or just watering treatments; however, these differences were only observed in the herbicided squares.

Reasons why we did not see any positive effects of weeding and watering could be: 1)The invasive weeds were not abundant enough at the end of this short five month study to have a negative impact on the survival and growth of the outplanted species through competition; 2) disturbance caused by watering the plants with a hose and using hand tools to remove weeds in close proximity to the native outplanted species had a negative effect on outplant seedlings; 3) the amount of supplemental water (eight minutes of spray over the entire plot once per week) was insufficient to have an overall positive impact in a harsh coastal wetland system such as Āhua Reef; and 4) the shading effect of weeds increased soil moisture in the plots and the presence of the halophyte weed pickleweed resulted in lower soil salinities thereby facilitating the survival and growth the other sedge species that are relatively less tolerant of high salinity and low moisture conditions.

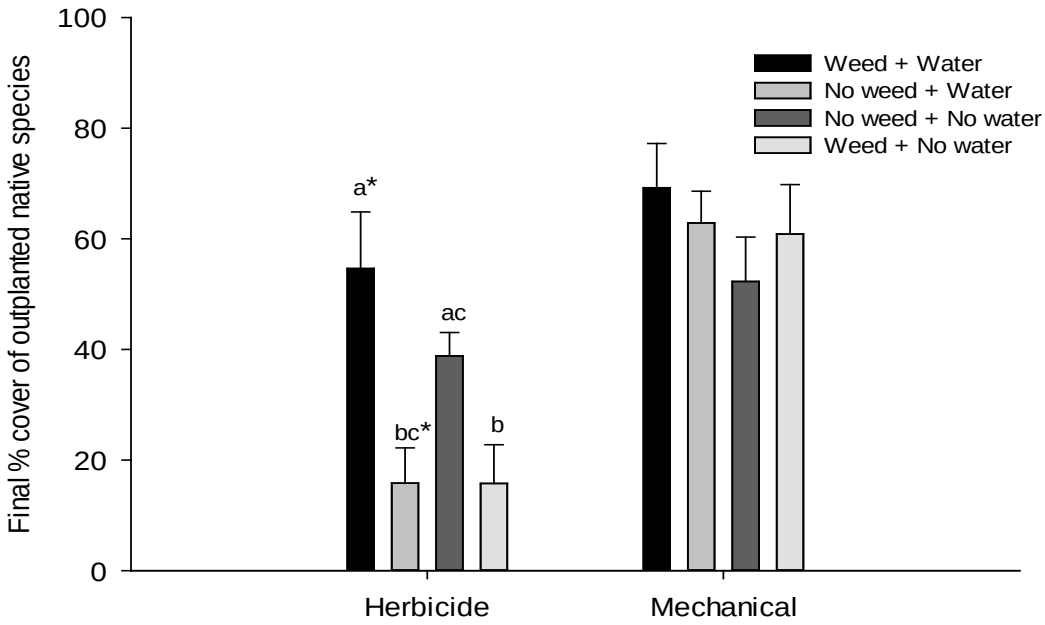

Figure 3. Final percent cover of all native outplanted species at the end of the experiment by pickleweed removal and weeding/watering treatments.

Seeding

Very little seed germination was observed. Seeding did not have any effect on the cover of outplanted species. Although a tackifier slurry was used to keep seeds within the experimental area, heavy rains may have washed seeds outside of the area. High soil salinity at Āhua Reef also might have prevented seed germination.

Waterbirds

Five waterbird species were recorded during the point count surveys - ‘auku‘u or black-crowned night heron (*Nycticorax nycticorax hoactli*), kōlea or Pacific golden-plover (*Pluvialis fulva*), ‘Ūlili or wandering tattler (*Tringa incanus*), manu-o-kū or white (fairy) tern (*Gygis alba*), and mallard x Hawaiian duck hybrid (*Anas platyrhynchos x wyvilliana*). Incidental waterbird observations also included: the endangered Hawaiian stilt (*Himantopus mexicanus knudseni),* black-bellied plover (*Pluvialis squatarola*), ‘akekeke or ruddy turnstone (*Arenaria interpres*), cattle egret (*Bubulcus ibis*), and hunakai or sanderling (*Calidris alba*). The Pacific golden-plover and wandering tattler, both migrants, were the most common species observed and were the only species observed foraging

or loafing within the experiment areas. Low waterbird activity at Āhua Reef could be due to heavy daily traffic of fisherman and residents of JBPHH for recreational activities, presence of invasive mammals like mongoose, cats, and rats, and lack of enforcement against off-leash dogs.

Benefit

Coastal wetlands in Hawaii and the Pacific, including those on military installations are degraded due to invasion by fast growing, non-native plants, particularly mangroves and pickleweed. On military installations, these species are not only a conservation concern but also impede military training activities, and are a security concern as they block line of sight. This project provided managers of coastal wetlands in Hawai'i and elsewhere in the Pacific strategies for the control of invasive weeds and information on the specific response of native wetland seeds and outplants to management practices of control, weeding, and watering.

Recommendations/Lessons learned

A long-term restoration plan with perhaps a phased approach should be developed for restoring Āhua Reef to a fully functioning coastal wetland. Habitat® is an effective herbicide that could be used for large scale control of invasive plants in wetlands. However, managers need to be cautious about planting of native species following application of Habitat®. The dissipation of Habitat® in the field varies with soil and water conditions. It is important to ensure that there is no residual Habitat® herbicide in the substrate at the time of outplanting with native wetland species. A time interval of 100-200 days is recommended between site preparation and outplanting to observe efficacy of the initial treatment, provide follow up treatment if necessary, and, more importantly, to allow for natural dissipation of the herbicide to occur.

Watering during the first month might be essential for the establishment of the outplanted species. However subsequent weeding and watering of the outplanted species may not be necessary at least for the first few months when the weeds are not abundant. However, if not weeded later it is likely that the outplanted natives would succumb to the aggressive growth of pickleweed, the dominant weed at Āhua Reef.

Selection of plant species for restoration should be based on environmental tolerances, growth requirements, competitive abilities and, if known, whether the species previously occurred at the restoration site. All five species tested in this study are suitable for outplanting at Āhua with 'ākulikuli having the highest survival and growth and *C. polystachyos* having the lowest survival and growth. More research should be conducted to test environmental factors which may hinder the survival and growth of these species. Factors examined should include tolerances to salinity, water, and nutrient levels and soil composition. Further research also needs to test the ability of native wetland plant species to directly compete with invasive wetland plant species.

The fact that we did not see recruitment of any of the native wetland species seeded within our study plots suggests that there is no seed bank of native coastal wetland plant species at Āhua Reef. Restoration efforts in the near future should focus on outplanting of native species. However, strategies for direct seeding should be explored under the different topographic and soil conditions because natural recruitment of native plants can provide a tremendous boost to the restoration efforts at Āhua Reef.

Endangered Hawaiian stilts have occasionally been observed foraging at Āhua Reef. Limited studies on Hawaiian wetlands indicate that native wetland plants harbor diverse and richer arthropod communities and, therefore, are more attractive to Hawaiian waterbirds than wetlands dominated by monocultures of invasive species. Due to the proximity of Ahua Reef to the Honolulu International Airport and the Bird Air Strike Hazard (BASH) zone, it is currently not managed for waterbirds. The USFWS Biological Opinion however stipulates that Ahua Reef be managed for open waters of 1 to 6 inch depth and that JBPHH should enforce their policy to restrict dogs from Ahua Reef. It is possible that the restoration of Ahua Reef to a fully functional coastal wetland might in fact draw certain species of waterbirds away from the BASH zone.

Communications

In October 2011, this study was presented at the 2011Hawaiian Wetland and Waterbird Workshop to gather input on the proposed methodology. During the course of this study, several volunteer events were held at the study site and SWCA shared information with the volunteers about the ecological importance of coastal wetlands and the native plants species that inhabit it. Preliminary results of this study were also presented at the annual Hawaii Conservation Conference in August 2012.

Additional Information

Developing Coastal Wetland Restoration Techniques to Enhance Coastal Habitats at Āhua Reef, Hickam AFB, HI, 2012. Fact sheet. Available at DENIX website.
To get a copy of the technical reports: "Developing Coastal Wetland Restoration Techniques to Enhance Coastal Habitats at Ahua Reef, Hickam AFB, HI" and "Direct Seeding for Restoration of Coastal Wetlands in Hawai'i" – contact Shahin Ansari sansari@swca.com at SWCA Environmental Consultants, Hawaii Office. The reports can also be accessed from the DENIX website.

SWCA has more than 20 offices throughout the continental United States and the Pacific Islands. The Hawai'i office is committed to applying sound science to find creative solutions to the challenging problems in natural resource management in the Pacific Region.