University California, Santa Cruz

Younger Lagoon Reserve

Annual Report 2014-2015

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Executive Summary

Over the past year Younger Lagoon Reserve continued to thrive as a living laboratory and outdoor classroom focused on supporting University-level teaching, research and public service while meeting the campus' Coastal Long Range Development Plan requirements for the protection and enhancement of all natural lands outside of the development areas of the Coastal Science Campus, including native habitat restoration of the 47-acre "Terrace Lands" as outlined in UCSC CLRDP and Coastal Development Permit. Over the past year we continued to increase our support of classes by hosting 15 instructors and 539 students within 12 UCSC undergraduate courses over 593 user days. Most formal education users were within the Environmental Studies and Ecology and Evolutionary Biology departments. Younger Lagoon Reserve-affiliated internships also supported 67 undergraduate students who were involved with research, education, and stewardship. The majority of interns were involved in restoration and monitoring activities on the Terrace Lands engaging in a wide range of projects, including investigations into cost effective methods for native habitat restoration, internship curriculum/handbook creation, small mammal research, invasive species management, and more. Beyond UCSC use, YLR continued to support and increase use by other groups such as the Monterey Bay Aquarium Watsonville Area Teens Conserving Habitats Program, Watsonville Wetlands Watch, Cabrillo College, Santa Cruz Bird Club, and local K-12 programs.

Restoration activities in FY 2014-2015 included weed control, planting of 2.3 acres, and seed collection. Beyond restoration work we continued to conduct other on-the-ground stewardship activities including trash hauls, removal of illegal camps, fence repair, and public education. This was the fourth year of CLRDP CCC compliance monitoring for restored Coastal Bluffs and Grassland areas. YLR is meeting or exceeding restoration targets for all monitored sites and is on track to meet the restoration goals for Phase 1. FY 2014-2015 represented the fifth full year of implementation of the CLRDP CCC Beach Access Management Plan related activities at Younger Lagoon Reserve. The University plans to submit a NOID to the CCC in summer 2016 that summarizes findings over the last 5 years and discusses the potential effect of controlled beach access on flora and fauna at Younger Lagoon.

In Summary, YLR continued to offer excellent field locations for undergraduate, graduate, and faculty ecological research, support ongoing research and meet all CLRDP related activities and requirements.

Introduction

This report provides an overview of the activities that were conducted at Younger Lagoon Reserve (YLR) during the 2014-2015 fiscal year (July 1, 2014 - June 30, 2015). Younger Lagoon continued to see increases in use and activity in general. Providing an outdoor classroom and living laboratory allows for experiential learning opportunities. These opportunities have profound impacts on students both professionally and personally. This was the seventh year we had fulltime staff on site managing the Reserve. As a direct result, the level of academic and public engagement increased and the Reserve is on target for implementing its obligations required under the Coastal Long Range Development Plan (CLRDP).

Younger Lagoon represents a unique reserve within the UCSC's Natural Reserve portfolio as it has open public access to a portion of the Reserve. Along with the challenges of public access (i.e. impacts to resources, protecting research equipment, protecting endangered and threatened species, implementing regulations, etc.) having public present on-site provides opportunities for outreach and education. During the past year, we continued to implement restoration activities on the Terrace Lands portion of the reserve and, as a direct result, interacted frequently with public users. These interactions have continued to provide opportunities for reserve staff and students to discuss the short and long-term objectives and goals of the restoration work, interpret the flora and fauna of YLR, and discuss ongoing planning and development efforts of the Marine Science Campus.

CLRDP Activities

Overview

This year represented the seventh year of CLRDP related activities at Younger Lagoon Reserve. The California Coastal Commission certified the CLRDP for the "Terrace Point" property in 2008. In July of 2008, approximately 47 acres of natural areas of the "Terrace Point" property were incorporated into the University of California Natural Reserve System as part of UCSC's Younger Lagoon Reserve. The inclusion of the 47 acres into YLR, along with continued management of the lagoon portion of YLR, was a requirement of the California Coastal Commission for the UCSC Marine Science Campus development.

The CLRDP requires that the entire Reserve be protected and that the newly incorporated Natural Reserves lands are restored over a 20-year period. Fulfilling the University's mission to support research and teaching, we continue to incorporate research and teaching into all aspects of restoration, monitoring, research and protection throughout YLR. The increased lands and access to restoration and monitoring projects are providing expanded opportunities for undergraduate experiential learning opportunities via class exercises, research opportunities, and internships.

NOID 2 (10-1) Beach Access Management Plan

This year represented the fifth full year of Beach Access Management Plan related activities at Younger Lagoon Reserve. Implementation Measure 3.6.3 of the CLRDP required that (through controlled visits) the public have access to Younger Lagoon Reserve beach and that a monitoring program be created and implemented to document the condition of native flora and fauna within Younger Lagoon and it's adjacent beach. The monitoring plan was to be implemented over a 5-year time period. At the end of the 5-year period (Winter 2015) results are to be compiled and included in a report that summarizes and assesses the effect of controlled beach access on flora and fauna. The report will be submitted to the California Coastal Commission. In March 2010, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development for Implementation Measure 3.6.3 of the CLRDP (NOID 2 (10-1)). Seymour Marine Discovery Center docent-led tours of the beach were offered twice a month throughout FY 2014-2015 and biological monitoring of the lagoon and adjacent beach was conducted quarterly in FY 2014-2015. A detailed report on activities under the Beach Access Management Plan is included as Appendix 1.

NOID 3 (10-2) Specific Resource Plan for the Enhancement and Protection of Terrace Lands at Younger Lagoon Reserve

The Resource Management Plan (RMP) within the CLRDP provides a broad outline with general recommendations and specific guidelines for resource protection, enhancement, and management of all areas outside of the mixed-use research and education zones on the MSC site (areas that will remain undeveloped). In addition to resource protection, the CLRDP requires extensive restoration, enhanced public access/education opportunities on site, and extensive monitoring and reporting requirements. The entire project is to be completed over 20 years and, as a condition of inception into the University of California Natural Reserve System, UCSC Campus has committed to providing perpetual funding for the project and continued management of YLR.

The SRP for Phase 1A and 1B of restoration (first 7 years) was approved by the CCC in September 2010. Phase 1A projects include Priority 1 weed removal, re-vegetation, baseline monitoring and selection of reference systems. Phase 1B projects include work in wetland areas, which will require further permitting from outside agencies (e.g. ACoE, USFWS, CDFG). Restoration of the Terrace lands continued throughout FY 2014-2015. Activities included weed control, planting and seed collection.

The SRP for Phase 1A and 1B of restoration (first 7 years) outlined detailed success criteria for each of the reserve's habitat types (Ruderal, Coyote Brush Grassland-Scrub, and Grassland, Coastal Bluffs, Wetlands, and Wetland Buffers). These criteria set an initial threshold of species richness and cover for specific habitat types throughout the restoration area. These criteria were further refined at the recommendation of the SAC based on results from reference site monitoring of local coastal terrace prairie grassland, seasonal wetland, and coastal scrub sites (See 2009-2010, 2010-2011, 2011-2012, 2012-2013, and 2013-2014 Annual Reports). FY 2014-2015 marked the fourth year of compliance monitoring for restored Coastal Bluffs and Grassland areas. A detailed compliance monitoring report is included in Appendix 2.

<u>Monitoring efforts in 2015-2016</u>

During the 2015-2016 field season, UCSC graduate student Josie Lesage and professor Dr. Karen Holl will conduct restoration compliance monitoring at restoration sites 2, 4 and 6 years post planting as per CLRDP requirements.

NOID 5 (12-2) Public Coastal Access Overlook and Overlook Improvements Project

In August 2012, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development NOID 5 (12-2) Public Coastal Access Overlook and Overlook Improvements Project. Construction on the Public Coastal Access Overlook and Overlook Improvements Project ("Overlooks Project") began in the winter of 2012/2013 and was completed in the spring of 2013. The project consisted of three new public coastal access overlooks, and improvements to two existing overlooks at UCSC's Marine Science Campus. Several of the overlooks, which are sited at the margins of development zones, therefore are within what is now the Younger Lagoon Reserve: Overlooks C and A are within development zones at the margin of the YLR, while the sites of overlooks D, E and F are within areas incorporated into the YLR as a condition of approval of the CLRDP. The project constructed publicly-accessible overlooks from which to view the ocean coast (Overlook F), Younger Lagoon (Overlook D), a seasonal wetland (W5) (Overlook A), and campus marine mammal pools (Overlook C) for which public access is otherwise limited due to safety hazards or for the protection of marine wildlife and habitats. The facilities will ultimately include interpretive signs and public amenities such as bicycle parking and benches to enhance public access to, and enjoyment of, these restricted and/or sensitive areas.

NOID 6 (13-1) Coastal Biology Building and Associated Greenhouses; Site Improvements Including Road, Infrastructure and Service Yards; Public Access Trails and Interpretative Panels; Wetland Connection in Specific Resource Plan Phase 1b; Sign Program; Parking Program; Lighting Plan.

In August 2013, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development NOID 6 (13-1) Coastal Biology Building and Associated Greenhouses; Site Improvements Including Road, Infrastructure and Service Yards; Public Access Trails and Interpretative Panels; Wetland Connection in Specific Resource Plan

Phase 1b; Sign Program; Parking Program; Lighting Plan. This project includes development of a new seawater lab building, three new parking lots along with a parking management program, a research greenhouse complex, and associated site work including proposed storm water treatment and infiltration features. It also consists of campus utility and circulation improvements to serve both the new lab building and future campus development under the CLRDP. The Project will develop a complex of public access and interpretive faclities, including pedestrian access trails, an interpretive program shelter, educational signage, and outdoor exhibits. This project includes mandated wetland restoration and habitat improvements as described in the Specific Resource Plan Phase 1b. This project also initiates campus wide parking, sign, and lighting programs.

In February and March of 2015, goats were brought to the site to clear the grub from areas that were being prepared for construction. In April, 2015, additional site prep work occurred, including final site clearing for the start of construction. Construction of the Coastal Biology Building and Infrastructure Projects began in May 2015. Initial construction activities included fencing, demolition, and grading.

In 1999, when the University purchased the land for the expanded MSC, a special exception was made in the campus code to allow leashed dogs on the bluff top trail that rings the YLR Terrace Lands. Since that time, the site had become popular with dog owners, many of whom do not obey the leash law. The CLRDP requires that all domesticated animals be eliminated from the campus. Parallel to the start of construction, implementation of the campus "no dog" policy began in May 2015. New signage and other activities were implemented to educate the community and the public about the policy change. Student Ambassadors from the campus Police Department were brought on site to help inform the public about the new "no dog" policy. In addition, a new temporary sign was installed at the CSC entrance about the new policy, and existing trail signs were modified to reflect the change as well.

Scientific Advisory Committee (SAC) Meetings / Recommendations

A critical component of the CLRDP was the creation of a Specific Restoration Plan (SRP) guided by a Scientific Advisory Committee (SAC). The SAC is comprised of four members: Dr.

Karen Holl (SAC chair) Professor and Chair of the Department of Environmental Studies at UCSC; Tim Hyland, Environmental Scientist, State Parks, Santa Cruz District; Bryan Largay, Conservation Director, Land Trust of Santa Cruz County; and Dr. Lisa Stratton, Director of Ecosystem Management, Cheadle Center for Biodiversity and Ecological Restoration, University of California, Santa Barbara (UCSB). SAC members met with reserve staff at YLR on May 5, 2015. This meeting included updates on current and future projects under the CLRDP, as well as restoration, research, and teaching activities at YLR.

Research Recommendations:

Efficacy of Exotic Control Strategies for Restoring Coastal Prairie Grasses

Research is needed to evaluate the efficiency of different strategies to control non-native forbs and grasses and reduce competition with planted native species as part of coastal prairie restoration efforts. Holl et al. aimed to test methods that would be suitable in a small grassland areas that are surrounding by housing, like Younger Lagoon Reserve. During summer/fall 2010 two senior thesis students and NRS staff set up a factorial experiment comparing several exotic control treatments including one-time (1×) tarping, two-time (2×) tarping, topsoil removal (scraping), herbicide, and a control (no treatment) crossed with applying mulch and not mulching. 2× tarped plots were irrigated in August 2010 and then covered with black plastic for ~2 months to shade out germinated seedlings, whereas both 1× and 2× tarped plots were tarped in the fall a couple of weeks following the first rains. This year Holl et al. collected the fifth year of data, which is reported in Souri (2015). The main results and recommendations are listed below and Souri's entire report is included in Appendix 3.

- As has been shown throughout the, herbicide was the most effective method for reducing non-native forb and grass cover and enhancing native grass cover.

- Over the years native grass cover in the treatments has converged and over the past couple years has only been consistently lower in the control/un-mulched treatment. In all the remaining treatments the native grass cover remains at above 25%.

- Interestingly, this year native grass cover in the scraped plots was similar to herbiciding and tarping. In the past, cover in the soil scraping plots was lower, but perhaps over time the reduced soil nutrients typical of scraped plots favored the native species.

- Although mulching was effective in controlling exotic grasses in the first couple of years, it has had minimal effect on native grass cover over the past few years.

Investigating Cost Effective Methods for Coastal Prairie Restoration

Cost effective methods to restore coastal prairie are needed, and due to its mission as part of the UC NRS and its restoration obligations under the CLRDP, YLR is uniquely positioned to contribute to research on best management practices for coastal prairie restoration. At the SAC's recommendation, in FY 2011-2012 Professor Karen Holl, doctoral student Lewis Reed and undergraduate students Tianjiano (T.J.) Adams and Mickie Tang initiated a case study of planting techniques for ecological restoration in coastal prairie systems. This research continued in FY 2012-2013 with the addition of doctoral student Jessi Hammond, in FY 2013-2014 with the addition of undergraduate student Eileen Arneson, and in FY 2014-2015 with the addition of undergraduate student Richard Schreiber and doctoral student Josie Lesage. This research aimed to test both planting design (planting the entire area or planting islands of seedlings that cover ~1/3rd of the area) to restore California coastal prairie at Younger Lagoon Natural Reserve. In addition, Arneson tested pre-planting mulching and post-planting mowing to control exotic weeds. In fall 2011, Adams and Tang set up 20, 10 × 10 m plots, five replicates of four treatments: (1) island planting mulch, (2) island planting no mulch, (3) full planting no-mulch, and (4) full planting mulch. Adams and Tang planted three native perennial grass species (*Stipa pulchra, Hordeum brachyantherum*, and *Bromus carinatus*); five forb species (*Achillea millefolium*, *Clarkia davyi*, *Grindelia stricta, Trifolium willdenovii*, and *Symphyotrichum chilense*); and one species of rush (*Juncus patens*). Seeding was done in November 2011 and planting was done in January 2012. Half of each plot was mowed in June of 2012, 2013, and 2014. At the end of 2013 the island planting no mulch treatment was removed, due to low success. In 2015 Schreiber collected the fourth year of data on the three remaining treatments; he monitored cover all planted native species, as well as cover of exotic grasses and exotic forbs as a guild. Most of the results from the four growing seasons (2011-2015) are presented Schreiber (2015). The main results and recommendations are listed below and Schreiber's entire report is included in Appendix 3.

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- The island planting treatment shows promise as a restoration treatment. Cover of native species was generally similar in island planting plots compared to full planting plots. Moreover, percent native cover was high (31 ± 20%) in island planting plots relative to most reference coastal prairie sites.

- Importantly, we found evidence of recruitment of a few species at the edge and outside island plots, in particular *Hordeum brachyantherum, Bromus carinatus,* and *Symphyotrichum chilense*, suggesting that some native species will spread over time.

- Whereas mulching had a strong positive effect on native cover in the first two years, after four years there was no apparent effect of mulching on native or exotic cover. Consistent with our prior research wood mulch seems to break down after two years.

- Likewise, mowing had no effect on native or exotic cover likely due to the late timing (June) during the growing season.

- Most of the species tested show good promise for restoration. All three grasses and the three forbs, *Achillea millefolium*, *Grindelia stricta,* and *Symphyotrichum chilense*, had significantly higher cover in planted than unplanted areas. *Trifolium willdenovii* had very low survival in the first year. *Clarkia davyi* and *Juncus patens* have had <1% cover the last two years.

Mowing for Coastal Prairie Restoration and Management

Cost effective, feasible methods to restore and manage coastal prairie are needed, and due to its mission as part of the UC NRS and its restoration obligations under the CLRDP, YLR is uniquely positioned to contribute to research on best management practices for coastal prairie restoration. At the SAC's recommendation, in FY 2012-2013, doctoral student Lewis Reed initiated a literature review of mowing techniques for ecological restoration in coastal prairie systems. This research continued in FY 2014-2015. The purpose of this review is to provide insights from the scientific literature to inform effective use of mowing as a management tool at Younger Lagoon Reserve. Mowing is one of the most readily available management strategies for a variety of land managers. This tool may be particularly important in sites such as the Younger Lagoon Reserve that are small and close to urban boundaries where other options such as grazing or fire and in some cases herbicide may be impractical. Reed's review demonstrates that mowing will have different outcomes depending factors such as the height, frequency, timing, and spatial arrangement of clipping and whether or not cut material is removed. In cases where other management tools are available, mowing may be an important part of integrated management schemes. Reed's entire report is included in Appendix 4.

Management Recommendations:

In FY 2014-2015 the SAC continued to discuss two ongoing management issues at YLR: 1) Domesticated Animals, specifically dogs, and 2) California Red-Legged Frog (CRLF) Ponds.

Dogs

In 1999, when the University purchased the land for the expanded MSC, a special exception was made in the campus code to allow leashed dogs on the bluff top trail that rings the YLR Terrace Lands. Since that time, the site has become popular with dog owners, many of whom do not obey the leash law. The CLRDP requires that all domesticated animals be eliminated from the campus. At the 2015 SAC meeting, YLR staff described their continued efforts to enforce the existing leash law on the campus and ongoing plans to eliminate all domesticated animals from the MSC per the CLRDP. Off leash dogs regularly chase wildlife in the reserve and disturb ongoing research and restoration projects. The SAC recommended continued education and outreach efforts with the public, LML staff and UCSC police.

California Red-Legged Frog (CRLF) Ponds

During the ACoE permitting process for projects impacting wetlands on the Coastal Science Campus (including restoration work in the upper terrace), the US Fish and Wildlife Service

(USFWS) was brought in for Section 7 consultation. Although USFWS approved the University's project as proposed, in April 2014, USFWS staff asked the campus to explore the feasibility of building CRLF pond(s) in the upper terrace as both a benefit to the local population and a demonstration of good faith / collaboration between UCSC and USFWS. There is no Habitat Conservation Plan (HCP) for the site, and there was not an explicit mitigation done for the destruction of CRLF upland habitat during the planning process.

With the support of the reserve, campus agreed to explore the possibility and staffs from both the Resource Conservation District (RCD) and USFWS Coastal Program made a site visit to discuss feasibility and conduct initial studies in the summer and fall of 2014. RCD staff completed a soil evaluation in October 2014 and found groundwater at less than 5' deep at one of the sample points (in sandy soils and in very dry conditions), and believe that CRLF ponds could be engineered on site to hold water for long enough to support breeding. The RCD was ready to move forward with putting together a proposal for designing and building the ponds (this would need to be evaluated by the SAC with our existing RMP obligations in mind - e.g. reconnect wetlands 1 and 2, etc.); however, due to unresolved questions including permitting (e.g. would the RCD's permits work for our site) and potential impacts to future projects, PP&C staff felt there was not enough information to move forward with further RCD planning and/or construction the ponds.

The SAC discussed the CRLF pond idea at its 2015 meeting, and is supportive of the idea of CRLF pond(s) in the upper terrace as a way to 1) increase collaboration between UCSC, YLR, and the USFWS, 2) potentially provide opportunities for CRLF teaching, research and outreach on the reserve, and 3) meet habitat restoration and wetland reconnection goals. Some SAC members expressed concerns about 1) whether the ponds would function as expected and 2) more broadly, whether or not CRLF ponds are even necessary in our area.

Photo Documentation

Photo point locations were established at ten locations within YLR. These locations were chosen to ensure coverage of all major areas on the Terrace. Photos were taken on May 6, 2014. At each photo point we collected the following information:

1. Photo point number
2. Date
3. Name of photographer
4. Bearing
5. Camera and lens size
6. Coordinates
7. Other comments

Photos are included in Appendix 4.

Restoration Activities

Restoration activities continued on the Terrace area of YLR and throughout the lagoon portion of the Reserve. Implementation was conducted largely by undergraduate students and community volunteers; thus, utilizing the reserve in a manner consistent with the programmatic objectives (facilitating research, education, and public service) of the University of California, Natural Reserves as well as leveraging funding to increase restoration work. Here we summarize some of the restoration activities that occurred on YLR during the past year.

Figure 1. Volunteers and undergraduate student interns pant native plants.

<u>Priority One Weed Removal</u>

Under the SRP, all priority-one weeds (Ice plant, Jubata grass, Monterey cypress, Cape Ivy, Panic veldgrass, Harding grass, French Broom and Monterey Pine) are to be controlled as they are detected throughout the Terrace Lands. Elimination of reproductive individuals is the goal; however, YLR is surrounded by priority-one weed seed sources and it is likely that there will always be a low level of priority-one weeds persisting on the terrace. In FY 2014-2015, reserve staff conducted weed patrols of the entire terrace, continued removing ice plant from the coastal bluffs, removed all Jubata grass re-sprouts from the terrace, removed all French Broom re-sprouts from the terrace, and removed all Cape Ivy re-sprouts from the west arm of the lagoon. In FY 2015-2016, reserve staff will continue weed control projects and patrols. Due to the long-lived seed bank of French Broom, proximity of mature Jubata grass and Panic veldgrass on adjacent properties, and known ability of Cape Ivy fragments to re-sprout, regular patrols and maintenance of these sites will be critical. Removal of new recruit Monterey Pine and Cypress will continue as will targeted removal of current individuals.

Seed Collection and Plant Propagation

In the summer and fall of 2014, reserve staff consulted with local experts to determine appropriate seed collection sites and collected seeds for restoration growing. These seeds were collected by YLR staff and student interns and propagated by the UCSC Teaching Greenhouse in the fall and winter of 2014/2015.

Restoration Planting

In FY 2014-2015, upland areas including northern coastal scrub habitats and coastal terrace prairie were planted with native seedlings (Figure 1).

Education

Instructional use at Younger Lagoon Reserve continued to increase this year. Courses encompassed a wide variety of disciplines. The increase in course use is a direct result of having fulltime staff on site that are able to actively engage faculty and students through outreach efforts in the classroom as well as providing on-the-ground assistance in teaching activities. The proximity of Younger Lagoon to the campus enables faculty and students to easily use the Reserve for a wide variety of instructional endeavors ranging from Restoration Ecology to Animal Tracking.

Undergraduate Students – Providing hands-on learning opportunities for future leaders

YLR's proximity to the UCSC Campus and Long Marine Laboratory make it an ideal setting for undergraduate teaching and research (Figure 2). In FY 2014-2015 the reserve hosted classes in Ecology, Entomology, Freshwater Ecology, Restoration Ecology, Ecology and Conservation in Practice Supercourse, Systematic Botany of Flowering Plants, Plant Ecology, Advanced Ecology and Evolutionary Biology Seminar, College 8 Service Learning Practicum, Freshwater / Wetland Ecology, and Animal Tracking (Table 1).

Figure 2. Dr. Karen Holl and ENVS 196 Senior Seminar in Coastal Habitat Restoration students in the field.

Internships and Senior Theses

In FY2014-2015, YLR staff sponsored over 50 undergraduate interns through the UCSC Environmental Studies Internship Office (Figure 3). The students ranged from entering freshman to graduating seniors and spent between 6 and 15 hours a week working on on-going restoration projects at the reserve. These projects included invasive species removal, re-vegetation with native species, seed collection, and propagation. Student-interns report a deep appreciation for the opportunity to obtain hands-on experience in their field of study.

Figure 3. Undergraduate student researchers at work on the reserve.

Table 1. Younger Lagoon Courses

Course Title	Institution (Department)	Instructor's Name
BIO 11C - Ecology	Cabrillo Community College	Allison Gong
SCIP 513 – Scientific Illustration Program Internship	California State University Monterey Bay (Scientific Illustration Program)	Jenny Keller

BIOE 85 – Natural History of the UCSC Natural Reserves	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Lewis Reed
BIOE 107 - Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	James Estes
BIOE 122/L - Invertebrate Zoology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Baldo Marinovic
BIOE 150 – Ecological Field Methods	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Don Croll,
BIOE 155 - Freshwater Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Joe Merz
BIOE 295 - Advanced Ecology and Evolutionary Biology Seminar	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Beth Shapiro
CLEI 55 - College Eight: Service Learning Practicum	University of California, Santa Cruz (College Eight)	Susan Watrus
CLEI 55 - Sustainability Internship	University of California, Santa Cruz (College Eight)	Susan Watrus
ENVS 104A/L - Environmental Field Methods (Summer)	University of California, Santa Cruz (Dept. of Environmental Studies)	Dan Brumbaugh
ENVS 160 - Restoration Ecology	University of California, Santa Cruz (Dept. of Environmental Studies)	Karen Holl
ENVS 162/L - Plant Physiological Ecology/Lab	University of California, Santa Cruz (Dept. of Environmental Studies)	Michael Loik
ENVS 167 - Freshwater / Wetland Ecology	University of California, Santa Cruz (Dept. of Environmental Studies)	Katie L Monsen
ENVS 83 / 183 - Younger Lagoon Reserve Stewardship Interns	University of California, Santa Cruz (Dept. of Environmental Studies)	Tim Brown

ENVS 84 / 184 - Younger Lagoon Reserve Stewardship Interns	University of California, Santa Cruz (Dept. of Environmental Studies)	Tim Brown
ENVS 196 – Senior Seminar: Coastal Habitat Restoration	University of California, Santa Cruz (Dept. of Environmental Studies)	Karen Holl
OPERS Animal Tracking class	University of California, Santa Cruz (OPERS)	Chris M Lay

Research

Due in part to its relatively small size and lack of facilities, YLR is unlikely to host many single-site research projects in biology or ecology. However, as one of the few remaining coastal lagoons in California, YLR is well suited to act as one of many research sites in a multi-sited project. Additionally, the close proximity to campus makes it an ideal place for faculty to conduct pilot and our small-scale studies as well as for undergraduate research opportunities. In FY 2014-2015 we approved 8 research applications.

Faculty Research Highlight: Institute for the Study of Ecological and Evolutionary Climate Impacts (ISEECI) Drought Experiment

The UC-wide Institute for the Study of Ecological and Evolutionary Climate Impacts (ISEECI) offers a platform for synthesizing past, current and future environmental change research, and for understanding and potentially mitigating future climate impacts. ISEECI leverages the UC Natural Reserve System as a biologically and geographically diverse laboratory to study the effects of climate change on California ecosystems. Led by a consortium of UC scientists, ISEECI coordinates mechanistic studies and biotic surveys across broad geographic scales. Through this network, ISEECI seeks to test the feasibility of novel approaches for discovering ecosystem-wide responses to climate change. ISEECI then assess how inferences collected across sites might be used to mitigate impacts to ecosystems, ecosystem services and cascading impacts on human systems. ISEECI is developing "next generation" sampling protocols to capture ecological, genetic and physiological responses. This information will provide an integrated understanding of the impact of climate change on California's biota and the services these organisms provide.

With support from ISEECI, the first UC Drought Experiment was built during the spring and summer of 2015 at YLR. The experiment is compliant with the DroughtNet International Drought Experiment protocol for comparison to 88 other sites worldwide. Other sites are planned and being installed are located at the McLaughlin Reserve, Box Springs Reserve, two locations in the Boyd Deep Canyon Desert Research Center. This work is being coordinated by Dr. Michael Loik UCSC, and done in collaboration with Dr. Susan Harrison UCD, Dr. Elsa Cleland UCSD, Dr. Jeffrey Diez UCR, Dr. Darrel Jenerette UCR, and Dr. Louis Santiago UCR.

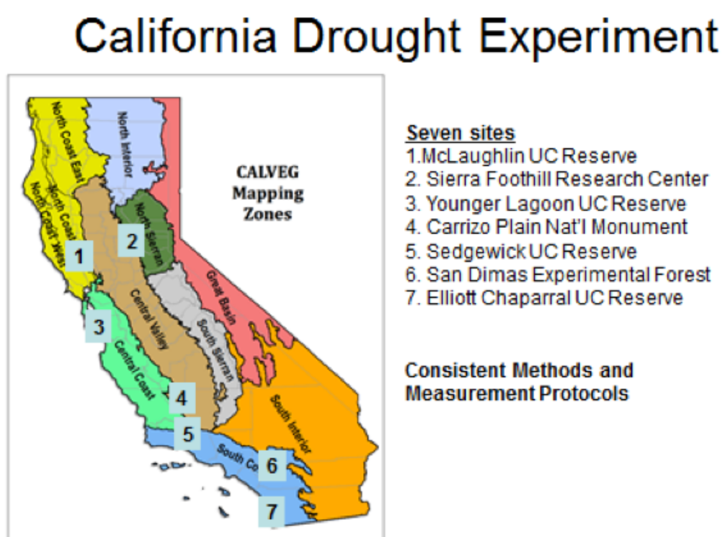

Figure 4. California Drought Experiment Sites.

The Drought Experiment (Figure 5) sites at UCSC include: (1) Younger Lagoon UC Natural Reserve at the Marine Campus; (2) the UCSC Arboretum; and (3) Marshall Field of the UCSC Campus Natural Reserve. This spans an elevation gradient of about 300 m with changes in rainfall, temperature, and fog.

Fog-collectors are co-located with shelters at each site. Effects of soil water on species composition and productivity will be compared for invaded grassland with 60% rainfall removal, and for ambient, invaded coastal prairie grassland (“control”; no rainfall shelters).
At Younger Lagoon Loik et al. are also conducting experiments with a restoration context by comparing effects of drought on planted native seedlings in comparison to planted native seedlings with 60% rainfall removal. They also have water addition plots available for experiments.

There are 5 plots per treatment. Size = 2 X 2 m, with a 1 m buffer around the 4 m^2 square plot. Plots were laid and pre-treatment data collection (species composition, productivity, ecosystem CO_2 and H_2O fluxes) were conducted in April and May 2015. Leaf-level water potential and photosynthesis were measured for select species.

Loik et al. also constructed one prototype shelter in May. These activities made up the laboratory section activities for ENVS 162/L Plant Physiological Ecology during Spring 2015. Plots were trenched to 50 cm deep and lined with 6 mm plastic to prevent lateral water flow and root encroachment. Shelters are constructed of lightweight metal and rainfall is intercepted using clear, v-shaped polycarbonate troughs.

With *ISEECI* support, Loik et al will soon begin to construct the remaining shelters, monitor soil moisture and temperature, as well as air temperature and relative humidity near the ground under the shelters. The UC Drought Experiment is one of several sites collecting data or under construction as part of the California Drought Experiment, which is a sub-network of both *ISEECI* and *DroughtNet*. Three of these sites are planning on adding a native species restoration component.

Undergraduate Research Highlights

Undergraduate Richard Schreiber completed a senior internship projects with the UCSC Natural Reserves in June 2015. His project, entitled ‘Effect of Planting Design, Mulching and Mowing on Coastal Prairie Restoration’ was a case study of planting and weed control techniques for ecological restoration in coastal prairie systems. Schreiber worked closely with Reserve

Manager, Elizabeth Howard, Restoration Steward Tim Brown, Graduate Student Josie Lesage and Faculty Advisor Karen Holl to ensure that his results and recommendations would influence future restoration and management activities.

Publications

In FY 2014-2015, Dr. Karen Holl published two papers based on data from restoration-related research at Younger Lagoon Reserve. Both publications include undergraduate students, graduate students, and NRS staff co-authors. Both publications are included in Appendix 6.

Holl et al., 2014. Efficacy of Exotic Control Strategies for Restoring Coastal Prairie Grasses. *Invasive Plant Science and Management* 7:590–598.

Holl et al., 2014. Constraints on Direct Seeding of Coastal Prairie Species: Lessons Learned for Restoration. *Grasslands* 4:24.

Public Service

Public service use at Younger Lagoon Reserve continued to increase this year. Public service users encompassed a wide variety of groups. The increase in public service use is a direct result of having fulltime staff on site that are able to actively engage public groups through outreach efforts as well as providing on-the-ground assistance in public service activities. The proximity of Younger Lagoon to the town of Santa Cruz enables members of the public to easily use the Reserve for a wide variety of approved endeavors ranging from birding to K-12 teaching.

Monterey Bay Aquarium Watsonville Area Teens Conserving Habitats (WATCH) Program

YLR's proximity to the urban center of the city and county of Santa Cruz make it an ideal setting for public service. In FY 2014-2015 the reserve began a partnership with the Seymour Marine Discovery Center (SMDC) and the Monterey Bay Aquarium Watsonville Area Teens Conserving Habitats (WATCH) program. WATCH is a program offered only at Pajaro Valley, Watsonville and Aptos high schools in Watsonville, California. This year-long program begins in the summer and extends throughout the school year. During the two-week summer component, students explore the Pajaro River Watershed and Younger Lagoon Reserve, meet with local scientists and participate in inquiry-based learning. They also learn about environmental issues in their community and participate in local restoration efforts. After the summer, the same students enroll in a WATCH science class at their high school and develop their own field research project based on an environmental topic at either Elkhorn Slough (Pajaro Valley and Watsonville High Schools) or Younger Lagoon Reserve (Aptos High School). Students visit their field sites once a week for ten weeks in the fall to collect data, and work during the winter and spring to analyze, write-up, and present their data (Figure 5). They work with Monterey Bay Aquarium staff and teachers, SMDC staff, YLR staff and undergraduate interns, as well as scientists and educators from the community to complete their projects. Upon completion of the projects, students receive a scholarship and community service hours needed for graduation.

Figure 5. WATCH program participants at work on the reserve.

Reserve Use

The greatest educational user group for YLR in FY 2014-2015 was once again undergraduate education, breakdown of all user groups are included in Table 2. YLR was used by UC Santa Cruz, UC Davis, UC Santa Barbara, Yerba Buena High School, Delta High School, St Andrew's Episcopal School, US Geological Survey, California Department of Fish and Game, NOAA, Save Our Shores, Seymour Marine Discovery Center, Santa Cruz Bird Club, PRBO Conservation Science, California Native Plants Society, Audubon California, American Conservation Experience, and several local and regional volunteer groups (Table 3).

Table 2. Younger Lagoon Total Use

	UC Home		UC Away		CSU System		CA Com'ty. Colleges		Other CA Colleges		U.S. Colleges		Int'l Colleges		Gov't		NGOs		For-Profit Business		K-12 Schools		Others		TOTALS	
	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days
UNIVERSITY-LEVEL RESEARCH																										
Graduate Student	6	71	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	73
Undergraduate Student	7	105	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	106
Faculty	2	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9
Professional	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
SUB-TOTALS	15	185	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	190
UNIVERSITY-LEVEL CLASSES																										
Graduate Student	27	77	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	87
Undergraduate Student	610	2178	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	2228
Faculty	11	35	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	36
Professional	3	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	53
SUB-TOTALS	651	2343	0	0	51	60	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	703	2404
PUBLIC SERVICE																										
Arts/Humanities (non-student/faculty/postdoc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Graduate Student	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Undergraduate Student	0	0	0	0	0	0	0	0	0	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	11	11
Faculty	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Research Scientist	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
K-12 Instructor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	152	0	0	7	152
K-12 Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	826	0	0	103	826
Professional	6	15	0	0	0	0	0	0	0	0	0	0	0	0	1	1	6	61	0	0	0	0	0	0	13	77
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	0	0	0	0	2405	3119	2406	3134
Docent	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	41	42
Volunteer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	21	201	22	202
SUB-TOTALS	48	57	1	1	0	0	0	0	0	0	11	11	0	0	1	1	9	79	0	0	110	978	2427	3321	2607	4448
TOTALS:	**714**	**2585**	**5**	**6**	**51**	**60**	**1**	**1**	**0**	**0**	**11**	**11**	**0**	**0**	**1**	**1**	**9**	**79**	**0**	**0**	**110**	**978**	**2427**	**3321**	**3329**	**7042**

*Other includes members of the public who took the SMDC's daily tour. Although all tours include information on YLR, we estimate that 10% of these visitors can be reasonably counted as users

Table 3. Younger Lagoon Group Affiliations

University of California Campus	**Non-governmental organizations**
University of California, Los Angeles	American Conservation Experience
University of California, San Diego	Audubon Society
University of California, Santa Barbara	Land Trust of Santa Cruz County
University of California, Santa Cruz	Monterey Bay Aquarium WATCH Program
California State Universities	Santa Cruz Bird Club
California State University, Monterey Bay	Seymour Marine Discovery Center
	Watsonville Wetlands Watch
California Community College	
Cabrillo Community College	**Governmental Agencies**
	California State Parks
Universities outside California	
University of Utah	
	Volunteer Groups
K-12 system	UCSC Wilderness Orientation
Aptos High School	
Delta High School	
Pajaro Valley High School	
Yerba Buena High School	

Summary

FY 2014-2015 was a successful year for YLR. The reserve continued to move forward with restoration, initiated new projects, strengthened collaborations, and developed new relation The increase in student and course use is a direct result of having superb staff on sight that actively engaged with students, faculty, and the public. In turn, we are able to achieve our mission of supporting education, research, and public education as well as meet the environmental stewardship obligations the University of California has committed to with California Coastal Commission and the State of California in general. We look forward to continuing this exciting and important work in FY 2015-2016.

UCSC Natural Reserves Advisory Committee

Charge

The committee provides oversight of on- and off-campus natural reserves of instructional and research interest. It is responsible for developing program vision and policy for the management and use of the UCSC Campus Reserve and of the four UC Natural Reserves System holdings: Año Nuevo Island Reserve, Landels-Hill Big Creek Reserve, Younger Lagoon Reserve and Fort Ord Reserve. The committee coordinates with the systemwide NRS Advisory Committee that advises on policy for all NRS reserves.

In addition to the chair (Faculty Director), membership of the committee is comprised of faculty advisors to each reserve, one faculty representative at large, one non-senate academic appointment, one staff representative, one graduate student and two undergraduate students. The Faculty Director, in consultation with the Dean and the Administrative Director of the UCSC Natural Reserves, appoints the committee. Membership terms begin September 1 unless otherwise specified.

DURATION OF APPOINTMENTS

Faculty Director: 5 years

Faculty Advisors: 3 years

Non-Senate Academic, Staff, and Students: 1 year

Members may be reappointed at the discretion of the Faculty Director in consultation with the Administrative Director.

Hours/Quarter: Chair/NRS Representative-20, Members-10
Reports to: Division of Physical & Biological Sciences Dean

MEMBERSHIPS

Faculty Director of the Natural Reserve System	Don Croll Associate Professor, Ecology & Evolutionary Biology Long Marine Lab, Center for Ocean Health (831) 459-3610 – croll@biology.ucsc.edu
Younger Lagoon Reserve Faculty Advisor	Karen Holl Professor, Environmental Studies Environmental Studies Department (831) 459-3668 – kholl@ucsc.edu
Año Nuevo Reserve Faculty Advisor	Daniel Costa Professor, Ecology & Evolutionary Biology Long Marine Lab, Center for Ocean Health

	(831) 459-2786 – costa@biology.ucsc.edu
UCSC Campus Reserve Faculty Advisor	Greg Gilbert Professor, Environmental Studies Environmental Studies Department (831) 459-5002 – ggilbert@ucsc.edu
Fort Ord Reserve Faculty Advisor	Laurel Fox Professor, Ecology & Evolutionary Biology EE Biology/Earth & Marine Sciences (831) 459-2533 – fox@biology.ucsc.edu
Landels-Hill Big Creek Reserve Faculty Advisor	Peter Raimondi Professor, Ecology & Evolutionary Biology Long Marine Lab, Center for Ocean Health (831) 459-5674 – raimondi@biology.ucsc.edu
Faculty Advisor at Large	Erika Zavaleta Assistant Professor, Environmental Studies Environmental Studies Department (831) 459-5011 – zavaleta@ucsc.edu
1 Non-Senate Academic	Chris Lay Lecturer and Museum Curator, Environmental Studies Environmental Studies Department (831) 459-4763 – cml@ucsc.edu
1 Staff	James Velzy Greenhouse Manager Greenhouse/MCD Biology (831) 459-3485 – jhvelzy@ucsc.edu
2 Graduate Student	Sarah Peterson Ecology & Evolutionary Biology Department sarahpeterson23@gmail.com
	Jessica Hammond Environmental Studies Department jessica.e.hammond@gmail.com
2 Undergraduate Students	Nikki Hanson Ecology & Evolutionary Biology Department nehanson@ucsc.edu
	CatherineSchied Environmental Studies Department cvschied@ucsc.edu
4 Ex-Officio	Gage H. Dayton, Advisory Committee Convenor Administrative Director, UCSC Natural Reserves

c/o Environmental Studies Department
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Physical and Biological Sciences Dean's Office
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Younger Lagoon Reserve Scientific Advisory Committee (SAC)

Charge

As outlined in the in the CLRDP, restoration, enhancement, and management activities on the Marine Science Campus will be guided by a Scientific Advisory Committee (SAC) that is made up of independent professionals and academicians experienced in and knowledgeable about the habitats of the natural areas on the Marine Science Campus. The SAC shall guide the development of Specific Resource Plans, which shall be consistent with the performance standards set forth in the Resource Management Plan (RMP), and which may be adapted periodically based on findings from ongoing restoration work. The RMP goals and performance standards may be adjusted as directed by the SAC in coordination with the Executive Director to ensure the success of Campus restoration, enhancement, and management efforts. As such, the RMP goals and performance standards are not static requirements per se so much as initial guidelines that may be refined during the SAC process so long as such refinement is consistent with current professional restoration, enhancement, and management goals and standards, and with achieving high quality open space and natural habitat area in perpetuity consistent with this CLRDP. RMP adjustments in this respect may require a CLRDP amendment, unless the Executive Director determines that an amendment is not necessary.

The committee provides guidance for the restoration, enhancement, and management efforts at YLR, and collaborates with YLR staff on the creation and implementation of the Specific Resource Plan as outlined in CLRDP Implementation Measure 3.2.10 (below).

Implementation Measure 3.2.10 – Natural Areas Habitat Management. *Within six (6) months of CLRDP certification, the University in consultation with the Executive Director of the California Coastal Commission shall convene a scientific advisory committee (SAC) to guide the restoration, enhancement, and management of natural areas (i.e., all areas outside defined development zones, except for Younger Lagoon Reserve) on the Marine Science Campus (see Appendix A). Natural areas restoration, enhancement, and management may be completed in up to three phases corresponding to dividing the natural area into thirds (i.e., where Phase 1 accounts for at least one-third of the natural area, Phase 1 plus Phase 2 accounts for at least two thirds, and all of the three phases together account for all of the natural area). All restoration, enhancement, and management activities shall be guided by Specific Resource Plans developed by the University in accordance with the SAC and the criteria contained in the Resource Management Plan (Appendix A) and current professional standards for such plans. The SAC shall be responsible for guiding development of Specific Resource Plans and shall complete its work on the Specific Resource Plan for Phase I restoration and enhancement efforts within four (4) months of convening. The content of Specific Resource Plans shall be consistent with the performance standards set forth in Appendix A, which may be adapted periodically based on findings from ongoing restoration work. The University shall file a Notice of Impending Development for Phase I work within one (1) year of CLRDP certification. All natural areas restoration and enhancement shall be completed within 20 years of CLRDP certification, with interim benchmarks that at least one-third of the restoration and enhancement shall be completed within seven years of CLRDP certification and that at least two-thirds shall be completed within 14 years of CLRDP certification.*

The SAC was seated in January 2009. In addition to the chair, membership of the committee is comprised of three independent professionals and academicians experienced in and knowledgeable about the habitats of the natural areas on the Marine Science Campus. Brief bios of the four SAC members are below.

Dr. Karen Holl- Professor, Environmental Studies, University of California at Santa Cruz (UCSC).

Dr. Karen Holl has been on the faculty in the Environmental Studies Department at the University of California, Santa Cruz for over 15 years. She has conducted research on restoration ecology in a wide variety of ecosystems, including tropical rain forests, eastern hardwood forests, chaparral, grassland, and riparian systems in California. She has published over 50 journal articles and book chapters on restoring damaged ecosystems and is on the editorial board of the journal Restoration Ecology. She teaches the Restoration Ecology class at UCSC and supervises many of the undergraduate students who work on the UCSC Natural Reserves. She regularly advises numerous public and private agencies along the Central California Coast on land management issues. She recently was selected as an Aldo Leopold Leadership Fellow. Dr. Holl's expertise in restoration ecology, experimental design and data analysis, as well as her affiliation with UCSC and her excellent rapport with University students and staff make her an irreplaceable member of the Scientific Advisory Committee.

Dr. Holl received a Ph.D. in Biology from Virginia Polytechnic Institute and State University, and a Bachelors degree in Biology from Stanford University.

Tim Hyland - Environmental Scientist, State Parks, Santa Cruz District.

Mr. Hyland has worked in the field of wildlands restoration for over 15 years. Much of his work has focused on coastal scrub, dune, and wetland restoration at sites throughout the Central Coast, including Wilder Ranch State Park (located approximately one mile west of YLR). He has extensive experience in restoration planning and implementation, vegetation mapping, exotic species control, and native plant propagation. In addition, Mr. Hyland is highly skilled in public education and outreach. His long tenure with California State Parks and direct experience in designing and implementing large-scale restoration projects make him a valuable member of the Scientific Advisory Committee.

Mr. Hyland has a B.A. from California Polytechnic State University, San Luis Obispo.

Bryan Largay – Conservation Director, Land Trust of Santa Cruz County.

Mr. Largay has worked in the fields of hydrology, water quality, and wetlands for fourteen years with a focus on restoration and wildlife habitat. He has conducted wetland restoration, watershed hydrology, and water quality investigations and designed measures to control erosion and treat water quality problems using vegetation. Much of his work has focused on collaborative water quality protection projects with agricultural landowners and growers. He has worked to solve water resource problems with a broad array of individuals, including scientists, planners, engineers, growers, private landowners, and contractors. Prior to joining the staff of

The Land Trust of Snata Cruz County, he worked as the Tidal Wetland Project Director at Elkhorn Slough National Estuarine Research Reserve (ESSNER) and participated in the Tidal Wetland Project as a member of the Science Panel and Model Advisory Team. Mr. Largay's experience working on complex, large-scale restoration projects with agricultural neighbors in a non-profit setting make him a very important addition to the Scientific Advisory Committee.

Mr. Largay received an M.S. in Hydrologic Sciences at U.C. Davis, and a Bachelor's degree at Princeton University.

Dr. Lisa Stratton - Director of Ecosystem Management, Cheadle Center for Biodiversity and Ecological Restoration, U University of California, Santa Barbara (UCSB).

Dr. Lisa Stratton has worked in the field of science-based restoration for over 15 years. She has extensive experience in restoration planning and implementation in conjunction with campus construction projects. Much of her work at UCSB has focused on involving students and faculty in the Cheadle Center's restoration projects. Dr. Stratton's work at the UCSB has provided her with a rare understanding of some of the unique challenges and opportunities YLR staff face as they undertake the restoration project at YLR. Her combined experience in wildlands restoration and management, scientific research, and working within the University of California system make her a very important member of the Scientific Advisory Committee.

Dr. Stratton received a Ph.D. in Botany and Ecology from the University of Hawai'i, a M.S. in Conservation Biology and Sustainable Development from the University of Wisconsin-Madison, and a Bachelors degree in Comparative Literature from Stanford University

Publications

Holl et al., 2014. Efficacy of Exotic Control Strategies for Restoring Coastal Prairie Grasses. *Invasive Plant Science and Management* 7:590–598.

Holl et al., 2014. Constraints on Direct Seeding of Coastal Prairie Species: Lessons Learned for Restoration. *Grasslands* 4:24.

Lesage, Josie, 2015. Compliance Monitoring Report for the Coastal Bluff Grassland at Younger Lagoon Reserve, Spring 2015. Prepared for the California Coastal Commission and Younger Lagoon Reserve Scientific Advisory Committee, 2014.

Reed, 2015. Mowing for Coastal Prairie Restoration and Management. Prepared for the California Coastal Commission and Younger Lagoon Reserve Scientific Advisory Committee, 2014.

Appendix 1. California Coastal Commission monitoring report

Younger Lagoon Natural Reserve

Beach Monitoring Report

2015

Younger Lagoon Fish Surveys

Beth Howard and Gage Dayton
Younger Lagoon Natural Reserve

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Overview and Executive Summary

In March 2010, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development Implementation for Implementation Measure 3.6.3 of the CLRDP (NOID 10-1). NOID 10-1 requires that (through controlled visits) the public have access to Younger Lagoon Reserve beach and that a monitoring program be created and implemented to document the condition of native flora and fauna within Younger Lagoon and it's beach. The monitoring plan was to be implemented over a 5-year time period. At the end of the 5-year period (Winter 2015) results were to be compiled and included in a report that summarizes and discusses the potential effect of controlled beach access on flora and fauna at Younger Lagoon.

This document serves as both a summary report for activities under NOID 10-1 that have taken place since our previous report at the end of fiscal year 2014 and a summary report for the entire 5-year monitoring program. All year's results are included. Data collected indicate that Younger Lagoon supports a wide variety of native flora and fauna, provides habitat for sensitive and threatened species, and supports a very unique beach dune community. In general, in comparison to the other local beaches surveyed native plant species richness is greatest at YLR and Natural Bridges; however, there is quite a bit of annual variation among the sites. A parameter that we quantified in 2012, and is evident from visual observation and photo documentation, is the presence of dune hummocks and downed woody material at YLR, both of which are almost entirely absent at local beaches due to human use. These features provide habitat for plant species such as the succulent plant dudleya, which grow on downed woody material and dune hummocks at YLR, as well as burrowing owls that use burrows in hummocks and seek shelter beneath downed woody material at YLR. The relatively natural state of YLR beach and dune vegetation is unique among most pocket beaches in Santa Cruz County and likely represents a glimpse into what many of the pocket beaches in the greater Monterey Bay area looked like prior to significant human disturbance. Open access to the beach would likely result in the loss of the unique ecological characteristics of the site and certainly reduce it's effectiveness as a research area for scientific study. Controlled beach access through the Seymour Center docent led tours, provides an appropriate level of controlled access that enables people to see and learn about the lagoon habitat while limiting impacts to the system. We recommend that this continue.

Although only required to monitor the YLR beach, YLR staff, faculty, and the Scientific Advisory Committee decided to monitor nearby beaches with varying levels of use (Natural Bridges and Sand Plant Beach) during the 5 year period in order to examine differences in the flora, fauna and use among the three sites. This effort required hundreds of hours of staff and student time, as well as coordination with State Parks staff. Moving forward, YLR staff will continue to monitor YLR as required in IM 3.6.3; however, we will no longer monitor at Natural Bridges State Beach or Sand Plant Beach as we feel the past 5 years of data collection have provided us with adequate information to assess beach resources.

Per IM 3.6.3 of the CLRDP (NOID 10-1), the University plans to submit a NOID to the CCC in 2016.

Introduction

Nearly 45 years ago, the University of California Natural Reserve System (UCNRS) began to assemble, for scientific study, a system of protected sites that would broadly represent California's rich ecological diversity. Today the UC Natural Reserve System is composed of 39 reserves that encompass approximately 750,000 acres of protected natural land available for university-level instruction, research, and public service. The University of California Natural Reserve System supports research and education through it's mission of contributing "*to the understanding and wise management of the Earth and its natural systems by supporting university-level teaching, research, and public service at protected natural areas throughout California*." By creating this system of outdoor classrooms and laboratories and making it available specifically for long-term study and education, the NRS supports a variety of disciplines that require fieldwork in wildland ecosystems. UC Santa Cruz administers four UC Reserves: Younger Lagoon Natural Reserve, Año Nuevo Island Reserve, Landels-Hill Big Creek Reserve, and Fort Ord Natural Reserve.

The objective of the beach monitoring program is to document the presence and distribution of flora and fauna within Younger Lagoon Natural Reserve (YLR) and to evaluate changes in distribution and density over time. Additionally, YLR staff decided to monitor nearby beaches with varying levels of use (Natural Bridges and Sand Plant Beach) in order to examine differences in the flora and fauna among the three sites. Importantly, the data collected in this study provides a quantitative assessment of various attributes (species composition, abundance, etc.) but it is realized that the sites vary significantly from one another and there is no replication. Thus, although these data comparisons are informative there are significant constraints that make meaningful statistical comparisons between the sites impossible. As such, while results shouldn't necessarily be used to create strict prescriptions.

This report is both a report for activities under NOID 10-1 during Fiscal Year (FY) 2014 (July 1, 2014 – June 30, 2015) and a summary report for the entire 5-year monitoring program. Data for each monitoring objective have been added to previous year's data; thus, the results for this reporting period have been combined with all previous findings. As a result, this report provides a running summary of our findings starting from the inception of the study and running through the end of FY 2014-2015.

Younger Lagoon Access History

History of Public Access to Younger Lagoon Beach

Prior to 1972, Younger Beach was privately owned and closed to the public. The owners (Donald and Marion Younger) actively patrolled for, and removed, trespassers from their property, including the beach. In 1972, the Younger Family donated approximately 40 acres of their property to the University of California for the study and protection of the marine environment. These lands included Younger Lagoon and Beach (approximately 25 acres), and an adjoining parcel of land (approximately 15 acres) which became the site of the original Long Marine Laboratory (LML). At the time of their donation, Donald and Marion Younger intended that the lagoon, beach and surrounding slopes be protected in perpetuity by the University as a bird sanctuary.

In the years between the donation of the property and the start of LML construction (1976), the University leased the future LML site back to farmers who had been farming the property for the Younger family prior to the donation. During those years, the same no trespassing rules for the beach were enforced as they had been when the property was owned by the Younger family.

Once construction of Long Marine Lab began in 1976, the land was no longer under the watch of the farmers, and public pressure on the beach began to increase. Many Santa Cruz locals remember the next several years at Younger Beach fondly as it became a popular nude beach. The increased public access had a noticeable impact on the flora and fauna of the beach, and was not in accordance with the intention of the original donation by the Younger family. By 1978 discussions had begun between the University and the California Coastal Commission regarding the impact of uncontrolled public access to the beach. In 1981, it was decided that the impacts to Younger Beach were significant and the California Coastal Commission, under coastal permit P-1859, closed uncontrolled access to the beach.

After the approval of coastal permit P-1859, the University began to actively patrol the beach for trespass and to educate the public about the closure. After YLR was incorporated into the UCNRS in 1986, users were required to fill out applications, or contact NRS staff, for specific research, education, or outreach efforts. As the LML campus grew, a protective berm and fencing were constructed around the perimeter of the lagoon, and informational 'beach closed' signs were posted on the cliffs above the beach. Over time, trespass decreased and the reduced public access had a noticeable positive impact on the flora and fauna of the beach.

Public access to YLR beach came to the forefront again during the CLRDP negotiation process (2000-2008). At the time negotiations began, YLR supported a rich composition of plant and animal species despite being surrounded by agricultural and urban development. Reserve staff were concerned that any increase in public access could threaten the already heavily impacted habitat. At the time of CLRDP certification (2010), all parties agreed to the Beach Access Management Plan outlined in NOID 10-1. Under the Beach Access Management Plan, the YLR beach remains closed to unsupervised public access and the reserve is implementing a management and monitoring plan that includes docent-guided tours.

Because of the importance of maintaining a natural and pristine environment (Figure 1) and protecting scientific studies and equipment, uncontrolled access to YLR is not allowed. Uncontrolled use of YLR is likely to have a negative impact on native coastal flora and fauna that inhabit the reserve, hamper research endeavors, and impact the area for future scientific and educational endeavors. Rather than an open public access policy, users are required to fill out applications, or contact NRS staff, for specific research, education, or outreach efforts. In 2010 YLR began hosting docent-guided tours that are offered by the Seymour Marine Discovery Center (SMDC).

Beach Access Tours

Beach access tours are offered two times per month (one tour on a weekday and one on a weekend). The extent of the beach access area varies depending upon the location of plants (i.e. foot traffic is seaward of the dune vegetation) and tidal conditions. Thus, the exact access area is determined by vegetation and tide level and may vary slightly from time to time. The trail provides an interpretive experience for visitors that begins with a narrative history of the Natural Reserves, an overview of the lagoon, a walk through a restored coastal scrub habitat with viewing opportunities of the rear dune, and ends up on the beach. Tours are led by SMDC docents trained in the natural history and ecology of YLR and provide detailed information about flora, fauna, geology, and the UC Natural Reserve System. Tour curriculum focuses on the unique ecology of the YLR beach, and was first presented to SMDC docents during the regular winter docent training program in 2010. YLR Beach tours began in the spring of 2010 and are advertised via the SMDC website: http://www2.ucsc.edu/seymourcenter/calendar.html and filled via phone reservation: (831) 459-3800. The SMDC allocates tour spaces and keeps track of all user data. Tours are limited to twelve (12) persons and are best suited for adults in good physical condition and children over 10 years of age. Public members entering YLR are required to adhere to the UCNRS Reserve Use guidelines.

Figure 1. Burrowing owl on the beach at Younger Lagoon.

Study Areas

Flora, fauna, and human use were monitored at Natural Bridges State Park, Younger Lagoon Natural Reserve, and Little Wilder/Sand Plant Beach (Figure 2). These three sites have similar characteristics (all have beach and lagoon habitat), are within close proximity to one another, and experience varying levels of human use. Although site characteristics are similar in many ways, they are also different in many ways, and these differences likely influence species composition. Three of the primary differences among the sites are human use levels, composition of adjacent upland habitat, and the overall size of the beach and wetland areas.

Younger Lagoon Reserve

Younger Lagoon Reserve is located in Santa Cruz County, approximately 4.5 miles from the main UC Santa Cruz campus; adjacent to the UC Santa Cruz Long Marine Laboratory. One of the few relatively undisturbed wetlands remaining on the California Central Coast, Younger Lagoon Reserve encompasses a remnant Y-shaped lagoon on the open coast just north of Monterey Bay. For most of the year, the lagoon is cut off from the ocean by a sand barrier. During the winter and spring months, the sand barrier at the mouth of Younger Lagoon breaches briefly connecting the lagoon to the ocean. The lagoon system provides protected habitat for 100 resident and migratory bird species. Approximately 25 species of water and land birds breed at the reserve, while more than 60 migratory bird species overwinter or stop to rest and feed. Opossums, weasels, brush rabbits, ground squirrels, deer mice, coyote, bobcat, woodrat, raccoon, and skunk are known to occupy the lagoon; gray and red foxes as well as mountain lion have also been sighted. Reserve habitats include salt and freshwater marsh, backdune pickleweed areas, steep bluffs with dense coastal scrub, pocket sand beach, grassland, and dense willow thickets.

Sand Plant Beach ("Little Wilder")

Sand Plant Beach is located in Santa Cruz County, approximately 1.5 miles west of YLR adjacent to Wilder Ranch State Park. Sand Plant Beach is approximately 23 acres and includes a pocket beach, dunes, cliffs and lagoon. It is open to the public for recreational use from dawn until dusk, 365 days a year; however, requires a hike to get to it and thus experiences less human use than many of the more accessible beaches in Santa Cruz. The surrounding Wilder Ranch State Park covers approximately 7,000 acres and allows human, bike and equestrian access. Much of the interior lagoon/upland habitat has been modified for agricultural production and/or ranching over the past century. Today most of the vegetation that persists inland of the lagoon is dominated by freshwater emergent vegetation and willow thickets. Major wetland restoration projects have increased native flora and fauna in the area (Friends of Santa Cruz State Parks, 2010).

Natural Bridges Lagoon

Natural Bridges Lagoon is located in Santa Cruz County, approximately 0.5 miles east of YLR on the urban edge of the city of Santa Cruz CA in Natural Bridges State Park. Natural Bridges Lagoon, beach, and State Park encompasses approximately 63 acres and includes a wide pocket beach, lagoon, cliffs, and diverse upland habitat (scrub, grass, iceplant, willow thicket, live oak, eucalyptus, and cypress). The park is world-renowned for its yearly migration of monarch butterflies and famous natural bridge. Natural Bridges State Park allows human access as well as dogs that are on leash and remain on paved roads and in parking lots (Friends of Santa Cruz State Parks, 2010). The beach is a popular destination at all times of the year; however, it is especially popular in the spring, summer, and fall months.

Figure 2. Study areas.

Methods

User Data

User data from tours conducted by the SMDC, as well as research and education use of YLR, were recorded and maintained by SMDC and YLR Staff. User data from educational programs and fee collection are recorded and maintained by California State Parks staff for Natural Bridges State Parks. No user data was available for Sand Plant Beach.

Human Beach Use

We used remote cameras to quantify human use of Sand Plant Beach, YLR, and Natural Bridges. Cameras were placed along the eastern edge of Sand Plant Beach and Natural Bridges Beach and at the western edge of Younger Lagoon quarterly with each separate sampling events each consisting of two days. Cameras were set to automatically take photos at 15 minute intervals. Number of people were quantified for 15 minute intervals during the day (camera times varied across sampling periods due to day length and postion; however, were standardized within each sampling period). The total survey area varied between sites and among individual sampling efforts due the placement of the camera and available habitat for human users at the time of the survey (i.e. often less beach area surveyed at Sand Plant Beach compared to Younger Lagoon and Natural Bridges). In order to control for area, specific regions of photos were chosen and number of individuals within each region were counted; thus, the number of people counted per unit area and time was standardized. We used the largest survey area during each sampling period to standardize use within each specific region of the beach during each sampling effort. Thus, if a particular site had more or less habitat monitored, the number of individuals was standardized across sites making comparisons comparable.

Photo Documentation of Younger Lagoon Natural Reserve

Photo point locations were established at four locations within YLR (Figure 3). These locations were chosen to ensure coverage of all major areas of the beach. Photos were taken once during the reporting period. At each photo point we collected photo point number, date, name of photographer, bearing, and camera and lens size.

Tidewater Goby Surveys

Tidewater goby surveys were conducted at YLR, Natural Bridges, and Sand Plant Beach quarterly each year of the study. Surveys were conducted using a 4.5 ft x 9 ft beach seine with 1/8 inch mesh. The objectives of the surveys were to document tidewater goby presence and evidence of breeding activity (determined by the presence of multiple size/age classes). All fish were identified to species and counted. When individuals exceeded ~50 per seine haul, counts were estimated. Sampling was conducted with the goal of surveying the various habitats within each site (e.g. sand, sedge, willow, pickleweed, deep, shallow, etc.); thus, different numbers of seine hauls were conducted at each site. Species richness was compared among sites.

Figure 3. Locations of monitoring points, plots, and regions for YLR beach. Monitoring areas varied between sampling efforts depending upon the high water mark, vegetation patterns, and water levels.

Species Composition and Coverage of Beach Dune Vegetation

Dune vegetation from the lowest (nearest to the mean high tide line) occurring terrestrial plant to 10 meters inland into the strand vegetation was surveyed quarterly throughout the study period. The exact location and extent of the area surveyed each time varied depending upon the location of the “lowest” plant detected during each sampling effort. At each location we established a 50-m east-west transect across the dune vegetation and measured the distance from the estimated mean high tide line to the “lowest” plant on the beach. Herbaceous species composition was measured by visual estimation of absolute cover for each species in ten 0.25 m^2 quadrats along the transect. Quadrats were placed every 5 m on alternating sides of the transect starting at a randomly selected point between 1 and 5 meters (a total of 10 quadrats per transect). A clear plastic card with squares representing 1, 5, and 10% of the sampling frame was used to help guide visual cover estimations. Species cover (native and exotic), bare ground, and litter were estimated at 5% intervals. Litter was specifically defined as residue from previous year’s growth while any senescent material that was recognizable as growth from earlier in the current growing season was counted as cover for that species. After all cover estimates had been made, we conducted surveys within 2 m of either side of the transect (a 4 × 50 m belt). In the belt transects, individual plants were recorded as either seedlings or greater than 1 year old. Presence of flowers and seeds was also noted.

Non-avian Vertebrate Monitoring

Tracks

Vertebrate tracks were measured using raked sand plots at each site quarterly throughout the study period. Tracking stations were placed throughout the beach area in constriction zones where vegetation was absent. The objective of these surveys was simply to detect what species use the beach habitat. As such, size of plot varied from approximately depending upon the amount of available open sandy area at each location. Track stations were raked each evening and checked for tracks in the morning. Stations remained open for two days during each monitoring bout. Tracks were identified to species when possible. Species composition was summarized; however, abundance was not quantified due to the fact that most often tracks cannot be used to identify individual animals (e.g. a single individual could walk across the plot multiple times).

Small Mammals

Sherman live traps were place at each site for two nights every quarter of the study period. A total of 30 traps were placed at each site and sampled for a period of two evenings (60 trap nights per sampling bout). Traps were set at dusk and collected at dawn. Each trap was baited with rolled oats and piece of synthetic bedding material was placed in each trap to ensure animals did not get too cold. Individuals were identified to species, marked with a unique ear tag, and released at the site of capture.

Invertebrate Monitoring

Terrestrial invertebrates on beach habitat were monitored by placing 12 oz plastic containers (pit fall traps) at each tracking station (one at each corner of the plot) during tracking efforts. Traps were buried to the lip of the container and checked each morning and all individuals were collected, identified, and counted.

Avian Monitoring

We conducted ocular surveys of birds on the beach, lagoon, and cliff habitats at each site. Survey locations were selected along one edge of the beach on the cliff. At YLR and Sand Plant Beach the entire beach area, fore portion of the lagoon, and western cliff were surveyed from the eastern edge of the lagoon. At YLR the top and western face of the rock stack that is located at the beach/ocean edge was also surveyed. At Natural Bridges surveys were conducted from the eastern edge of the beach on the cliff adjacent to De Anza Mobile Home Park or from the beach to the west; fore lagoon and approximately the western ¼ of the beach area (including beach/ocean interface) was included in the survey area. Survey areas were chosen with the goal of surveying approximately the same area and types of habitat. Counts were recorded quarterly throughout the study. Surveys were conducted in the dawn or dusk hours within approximately 2 hours of sunrise or sunset and of one another. Data from the two days during each sampling effort were combined and individuals were identified and counted.

Results

User Data

Younger Lagoon Reserve

There were a wide variety of public and non-profit research and educational groups that used Younger Lagoon (Table 1). The greatest user group for YLR was undergraduate education, a breakdown of all user groups is included in Table 2. The greatest user group was “other” which consists primarily of public tour groups to the edge of the Lagoon at the marine mammal overlook during marine mammal tours at the Seymour Center. Those users (represent 10% of the individuals that attended SMDC tours outside of the YLR beach tours) were provided an overlook of the lagoon, interpretive information via docent led tours, and opportunities to read interpretive material presented on signs about the reserve; however, did not access the beach. During the 14-15 fiscal year a total of 77 participants went on the Seymour Center docent led Younger Lagoon tours. Since the start of the Seymour Center docent led tours, nearly 98 tours have gone out and more than 438 visitors have participated.

Table 1. Younger Lagoon user affiliations.

University of California Campus	**Non-governmental organizations**
University of California, Los Angeles	American Conservation Experience
University of California, San Diego	Audubon Society
University of California, Santa Barbara	Land Trust of Santa Cruz County
University of California, Santa Cruz	Monterey Bay Aquarium WATCH Program
California State Universities	Santa Cruz Bird Club
California State University, Monterey Bay	Seymour Marine Discovery Center
	Watsonville Wetlands Watch
California Community College	
Cabrillo Community College	**Governmental Agencies**
	California State Parks
Universities outside California	
University of Utah	
	Volunteer Groups
K-12 system	UCSC Wilderness Orientation
Aptos High School	
Delta High School	
Pajaro Valley High School	
Yerba Buena High School	

Table 2. Younger Lagoon Total Use.

	UC Home		UC Away		CSU System		CA Com'ty. Colleges		Other CA Colleges		U.S. Colleges		Int'l Colleges		Gov't		NGOs		For-Profit Business		K-12 Schools		Others		TOTALS	
	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days	Users	Days
UNIVERSITY-LEVEL RESEARCH																										
Graduate Student	6	71	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	73
Undergraduate Student	7	105	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	106
Faculty	2	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9
Professional	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
SUB-TOTALS	15	185	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	190
UNIVERSITY-LEVEL CLASSES																										
Graduate Student	27	77	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	87
Undergraduate Student	610	2178	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	2228
Faculty	11	35	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	36
Professional	3	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	53
SUB-TOTALS	651	2343	0	0	51	60	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	703	2404
PUBLIC SERVICE																										
Arts/Humanities (non-student/faculty/postdoc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Graduate Student	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Undergraduate Student	0	0	0	0	0	0	0	0	0	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	11	11
Faculty	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Research Scientist	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
K-12 Instructor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	152	0	0	7	152
K-12 Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	826	0	0	103	826
Professional	6	15	0	0	0	0	0	0	0	0	0	0	0	0	1	1	6	61	0	0	0	0	0	0	13	77
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	0	0	0	0	2405	3119	2406	3134
Docent	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	41	42
Volunteer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	21	201	22	202
SUB-TOTALS	48	57	1	1	0	0	0	0	0	0	11	11	0	0	1	1	9	79	0	0	110	978	2427	3321	2607	4448
TOTALS:	714	2585	5	6	51	60	1	1	0	0	11	11	0	0	1	1	9	79	0	0	110	978	2427	3321	3329	7042

*Other includes members of the public who took the SMDC'sdaily tour. Although all tours include information on YLR, we estimate that 10% of these visitors can be reasonably counted as users.

Sand Plant Beach (Little Wilder)

Sand Plant Beach is located adjacent to Wilder State Park and is frequented by Wilder State Park visitors along a coastal bluff trail. Because of the size of Wilder Ranch State Park (over 7,000 acres, with over 35 miles of trails) and its multiple points of access, it is unknown exactly how many people visit Sand Plant Beach each year. However, even though it requires a hike it is one of the more popular beaches along this section of Wilder Ranch as there is relatively easy access along the coastal bluff trail.

Natural Bridges Lagoon

We did not obtain user data for Natural Reserves during the survey period; however, more than 925,000 people are estimated to have visited Natural Bridges State Park in 2005 (Santa Cruz State Parks 2010). The proportion of those visitors that use the beach and lagoon habitat is unknown. It is likely that the number of visitors remains in this range from year to year.

Human Use During Survey Efforts

Number of users at each beach during the survey efforts varied among beaches as well as between sampling dates. However, the pattern of total use (Table 3; Figures 4-5) and the number of people per photo (15 minute interval standardized for area surveyed) was highly consistent across sampling periods with overall use being highest at Natural Bridges and lowest at Younger Lagoon. Examples of photos captured during a typical monitoring session in 2010 are included as Figure 6.

Table 3. Number of people observed in photo human use monitoring.

Site	Month	[1]Total # of people	[1]Ave # of People / 15 minute
Natural Bridges	May, 2010	313	3.13
Sand Plant	May, 2010	92	1.21
Younger Lagoon	May, 2010	2	0.28
Natural Bridges	August, 2010	224	2.69
Sand Plant	August, 2010	15	0.17
Younger Lagoon	August, 2010	0	0
Natural Bridges	November, 2010	207	2.07
Sand Plant	November, 2010	7	0.17
Younger Lagoon	November, 2010	1	0.02
Natural Bridges	February, 2011	185	2.64
Sand Plant	February, 2011	10	0.25
Younger Lagoon	February, 2011	2	0.06

Site	Month	[1]Total # of people	[1]Ave # of People / 15 minute
Natural Bridges	May, 2011	236	2.8
Sand Plant	May, 2011	13	0.38
Younger Lagoon	May, 2011	5	0.18
Natural Bridges	July, 2011	795	2.44
Sand Plant	July, 2011	7	0.25
Younger Lagoon	July, 2011	0	0
Natural Bridges	December, 2011	49	0.63
Sand Plant	December, 2011	39	1.16
Younger Lagoon	December, 2011	0	0
Natural Bridges	April, 2012	442	6.93
Sand Plant	April, 2012	120	2.05
Younger Lagoon	April, 2012	0	0
Natural Bridges	May, 2012	624	2.67
Sand Plant	May, 2012	14	0.19
Younger Lagoon	May, 2012	0	0
Natural Bridges	October, 2012	210	4.84
Sand Plant	October, 2012	83	1.06
Younger Lagoon	October, 2012	3	0.04
Natural Bridges	January, 2013	100	4.90
Sand Plant	January, 2013	24	0.81
Younger Lagoon	January, 2013	9	0.11
Natural Bridges	May, 2013	615	19.81
Sand Plant	May, 2013	21	0.52
Younger Lagoon	May, 2013	0	0
Natural Bridges	July, 2013	560	25.42
Sand Plant	July, 2013	29	0.96
Younger Lagoon	July, 2013	5	0.06
Natural Bridges	November, 2013	3.44	13.04
Sand Plant	November, 2013	6	0.19
Younger Lagoon	November, 2013	12	0.15
Natural Bridges	February, 2014	71	6.37
Sand Plant	February, 2014	6	0.20
Younger Lagoon	February, 2014	1	0.01

Site	Month	[1]Total # of people	[1]Ave # of People / 15 minute
Natural Bridges	June, 2014	1723	21.01
Sand Plant	June, 2014	239	2.92
Younger Lagoon	June, 2014	2	0.02
Natural Bridges	August, 2014	852	23.68
Sand Plant	August, 2014	227	2.52
Younger Lagoon	August, 2014	2	0.02
Natural Bridges	November, 2014	2131	21.69
Sand Plant	November, 2014	146	1.78
Younger Lagoon	November, 2014	2	0.02
Natural Bridges	January, 2015	1889	23.04
Sand Plant	January, 2015	225	2.75
Younger Lagoon	January, 2015	11	0.13
Natural Bridges	April, 2015	699	7.13
Sand Plant	April, 2015	-	-
Younger Lagoon	April, 2015	0	0

[1]Standardized by area surveyed.

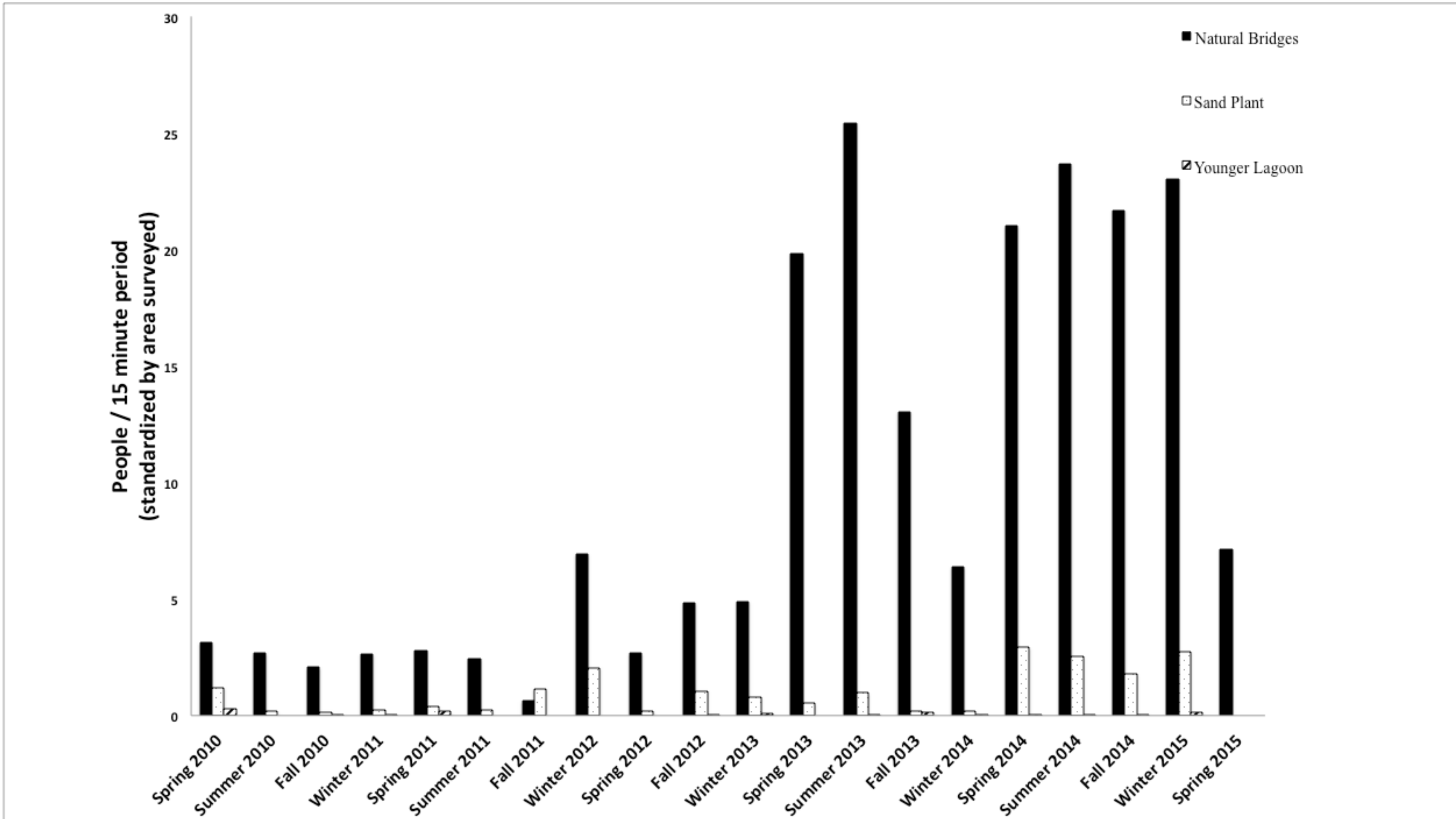

Figure 4. Average number of people per 15-minute interval at Natural Bridges, Sand Plant Beach, and Younger Lagoon Reserve. Data in Fall 2011 was collected in December. No camera monitoring was conducted in Summer of 2012. Missing data for Sand Plant in April 2012.

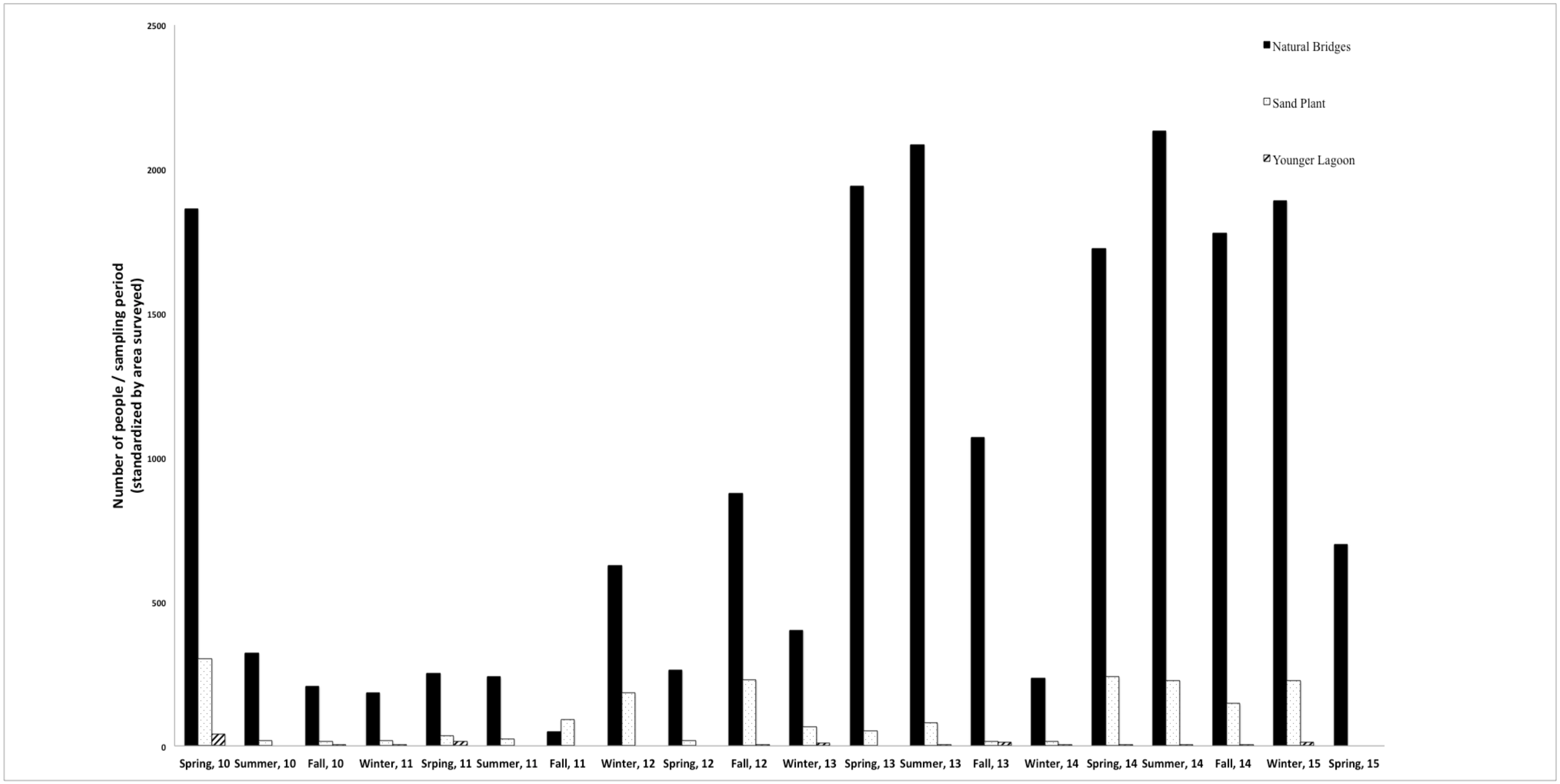

Figure 5. Total number of people counted in photographs. Data in Fall 2011 was collected in December. No camera monitoring was conducted in Summer of 2012. Missing data for Sand Plant in April 2012

Figure 6. Photos captured by remote camera during the Spring 2010 monitoring effort. Top to bottom: Sand Plant Beach, Natural Bridges, and Younger Lagoon.

Photo Documentation of YLR

Photos were taken one time during each reporting period. Photos for this years report are included as Appendix 1.

Tidewater Goby Surveys

Tidewater goby were found at all sites; however, were absent from Natural Bridges when the lagoon dried completely during one of the sampling events. Evidence of breeding (multiple size classes) was also observed at each site. Fish species richness was greatest at Natural Bridges and Younger Lagoon (Table 4).

Table 4. Vertebrate species encountered at Sand Plant Beach, Younger Lagoon, and Natural Bridges.

	Tidewater Goby	**Stickleback**	**Sculpin**	**Mosquito Fish**	**Halibut**	**CRLF[1]**	**Bluegill**
April 9, 2010							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X	X				
August 13, 2010							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X	X	X			
November 18, 2010							
Little Wilder	X	X					
Younger Lagoon	X						
Natural Bridges	X	X	X	X			
February 23, 2011							
Little Wilder	X	X					
Younger Lagoon	X						
Natural Bridges	X	X	X	X			
May 12, 2011							
Little Wilder	X	X					
Younger Lagoon	X	X	X		X		
Natural Bridges	X	X	X				
August 8, 2011							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X					

December 12, 2011					
Little Wilder	X	X			
Younger Lagoon	X				
Natural Bridges	X	X			
March 8, 2012					
Little Wilder	X	X			
Younger Lagoon	X				
Natural Bridges	X	X			
May 15, 2012					
Little Wilder	X	X			
Younger Lagoon	X	X			
Natural Bridges	X	X	X		
August 29, 2012					
Little Wilder	X	X			X
Younger Lagoon	X	X			X
Natural Bridges	X	X			
October 23, 2012					
Little Wilder	X	X			
Younger Lagoon	X	X			
Natural Bridges	X	X			
February 2, 2013					
Little Wilder	X	X			
Younger Lagoon	X	X			
Natural Bridges	X	X			
May 6, 2013					
Little Wilder	X	X			X
Younger Lagoon	X	X			X
Natural Bridges	X	X			
July 16, 2013					
Little Wilder	X	X			X
Younger Lagoon	X	X			
Natural Bridges	X	X		X	
November 14, 2013					
Little Wilder	X	X			
Younger Lagoon	X	X			
Natural Bridges					
February 21, 2014					
Little Wilder	X	X			
Younger Lagoon	X	X			
Natural Bridges	X				

May 2, 2014							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X						
August 11, 2014							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X					
November 25, 2014							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X					
January 26, 2015							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X						
April 13, 2015							
Little Wilder	X	X					
Younger Lagoon	X	X					
Natural Bridges	X	X					X
No. of sites	3	3	2	2	1	2	1

[1]CRLF = California Red-legged Frog (*Rana draytonii*). Tadpoles have been observed at Little Wilder. Juveniles, young of year, and adults have been observed at YLR and Little Wilder.

Species Composition and Coverage of Beach Dune Vegetation

Evidence of reproduction (flowers, seeds, and seedlings) of native and non-native vegetation has been detected at all three sites. Distance from mean high tide to the lowest plant on the beach is consistently greatest at Natural Bridges and lowest at Little Wilder and Younger Lagoon (Table 5). Plant cover was generally higher at Sand Plant and Younger Lagoon (as exhibited by proportion of bare ground) but varied across sampling efforts (Figure 7).

Native plant species richness has consistently been greatest at Younger Lagoon; however, it has varied across sampling periods and been highest at Natural Bridges for the past year (Figure 8). Mean proportion of non-native species is greatest at Natural Bridges (53%) and least at Younger Lagoon and Sand Plant Beach (26%) (Table 6).

Table 5. Distance (m) from mean high tide to the lowest plant on the beach.

Site	Spring, 10	Summer, 10	Fall, 10	Winter, 11	Spring, 11	Summer, 11	Fall, 11	Winter, 12	Spring, 12
Younger Lagoon	56	51	20	42	55	49	26	30	28
Sand Plant Beach	33	34	56	56	40	51	29	31	38
Natural Bridges	128	130	141	146	146	138	155	160	123

Site	Summer, 12	Fall, 12	Winter, 13	Spring, 13	Summer, 13	Fall, 13	Winter, 14	Spring, 14
Younger Lagoon	47	20	30	36	37.3	32.1	26.4	36.5
Sand Plant Beach	35	38	31	41	48.1	49.9	45.6	24.2
Natural Bridges	91	75	100	72	88.9	107.3	87.4	83.2

Site	Summer, 14	Fall, 14	Winter, 15	Spring, 15
Younger Lagoon	21.4	10	26.4	19.5
Sand Plant Beach	27.5	31	24.5	29.2
Natural Bridges	74.3	89.4	71	75.8

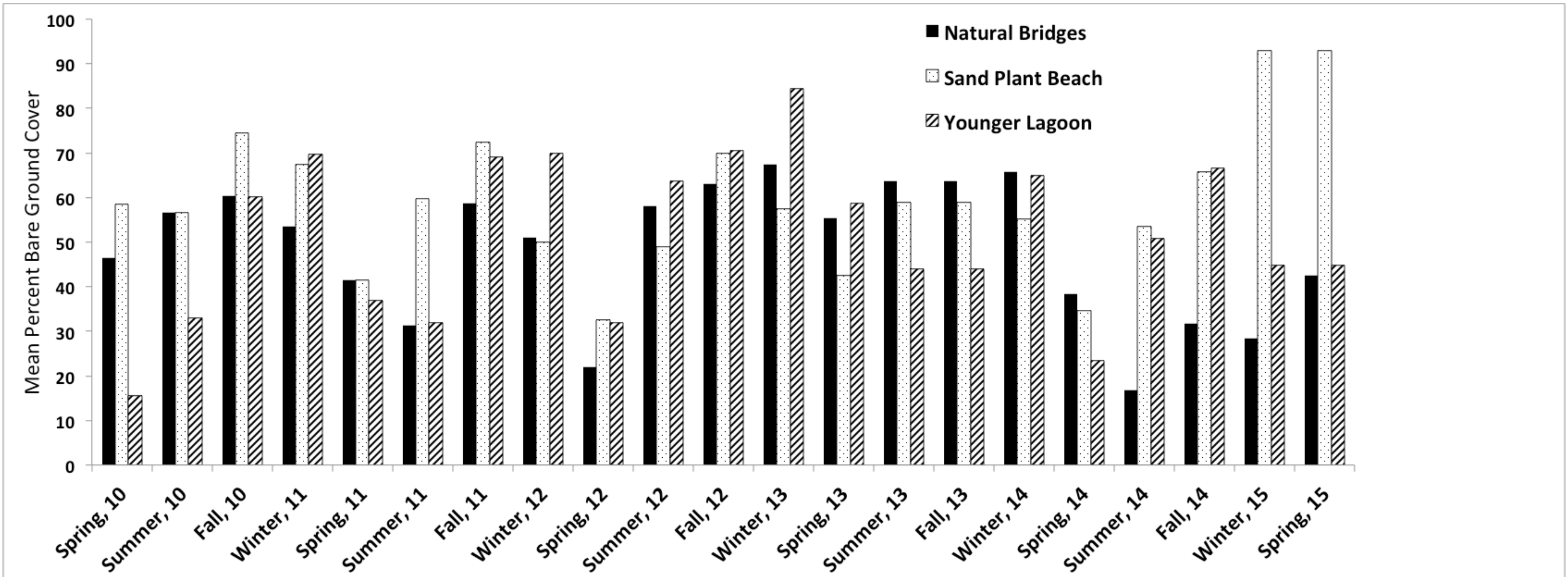

Figure 7. Mean percent bare ground encountered at each site.

Table 5. Number and proportion of native and non-native plant species encountered during surveys at each site. Mean is calculated across all samples.

Site	Spring, 10	Summer, 10	Fall, 10	Winter, 11	Spring, 11	Summer, 12	Fall, 11	W
Natural Bridges								
Native	7 (41%)	8 (44%)	9 (60%)	8 (44%)	9 (43%)	6 (67%)	8 (62%)	9
Non-native	10 (59%)	10 (56%)	5 (40%)	10 (66%)	12 (57%)	9 (33%)	5 (38%)	10
Total	17	18	14	18	21	15	13	
Younger Lagoon								
Native	11 (85%)	11 (85%)	11 (85%)	11 (73%)	12 (80%)	13 (81%)	9 (82%)	6
Non-native	2 (15%)	2 (15%)	2 (15%)	4 (27%)	3 (20%)	3 (19%)	2 (18%)	6
Total	13	13	13	15	15	16	11	
Sand Plant Beach								
Native	7 (88%)	7 (63%)	7 (70%)	8 (80%)	7 (88%)	7 (88%)	9 (82%)	3
Non-native	1 (12%)	2 (37%)	3 (30%)	2 (20%)	1 (12%)	1 (12%)	2 (18%)	6
Total	8	9	10	10	8	8	11	

Site	Summer, 12	Fall, 12	Winter, 13	Spring, 13	Summer, 13	Fall, 13	Winter, 14
Natural Bridges							
Native	5 (35%)	10 (59%)	7 (88%)	9 (56%)	7 (37%)	6 (35%)	6 (43%)
Non-native	9 (65%)	7 (41%)	8 (12%)	6 (44%)	12 (63%)	11 (65%)	8 (57%)
Total	14	17	15	16	19	17	14
Younger Lagoon							
Native	12 (67%)	7 (88%)	9 (69%)	12 (75%)	13 (72%)	14 (74%)	10 (83%)
Non-native	6 (33%)	1 (12%)	4 (31%)	4 (25%)	5 (28%)	5 (26%)	2 (17%)
Total	18	8	13	16	18	19	12
Sand Plant Beach							
Native	2 (40%)	3 (50%)	4 (100%)	4 (67%)	6 (100%)	6 (100%)	5 (100%)
Non-native	3 (60%)	3 (50%)	0 (0%)	2 (33%)	0 (0%)	0 (0%)	0 (0%)
Total	5	6	4	6	6	6	5

Site	Summer, 14	Fall, 14	Winter, 15	Spring, 15	Proportion of native and non-native species across all sample periods
Natural Bridges					
Native	5 (42%)	5 (45%)	4 (33%)	5 (31%)	**47%**
Non-native	7 (58%)	6 (55%)	8 (67%)	11 (69%)	**53%**
Total	12	11	12	16	
Younger Lagoon					
Native	9 (69%)	5 (62%	10 (67%)	10 (67%)	**82%**
Non-native	4 (31%)	3 (38%)	5 (33%)	5 (33%)	**18%**
Total	13	8	15	15	
Sand Plant Beach					

Native	4 (50%)	4 (40%)	5 (50%)	5 (42%)	**75%**
Non-native	4 (50%)	6 (60%)	5 (50%	7 (58%)	**25%**
Total	8	10	10	12	

Track Plate Monitoring

Native species richness of mammals detected in raked sand plots was greatest equal across all sites (n = 8). Ground squirrel were not detected at Natural Bridges and deer have not been detected in our track surveys at YLR or Little Wilder (Table 7). It is likely that ground squirrel occur at Natural Bridges and deer have been observed at Younger Lagoon Reserve in the upland habitat and are also likely using upland habitat at Little Wilder; however, they were not detected in our survey efforts. Dogs and bicycles were detected at Natural Bridges and Sand Plant Beach and vehicles were detected at Natural Bridges (Table 7). Frequency of detection and species richness for each species is summarized in Table 8.

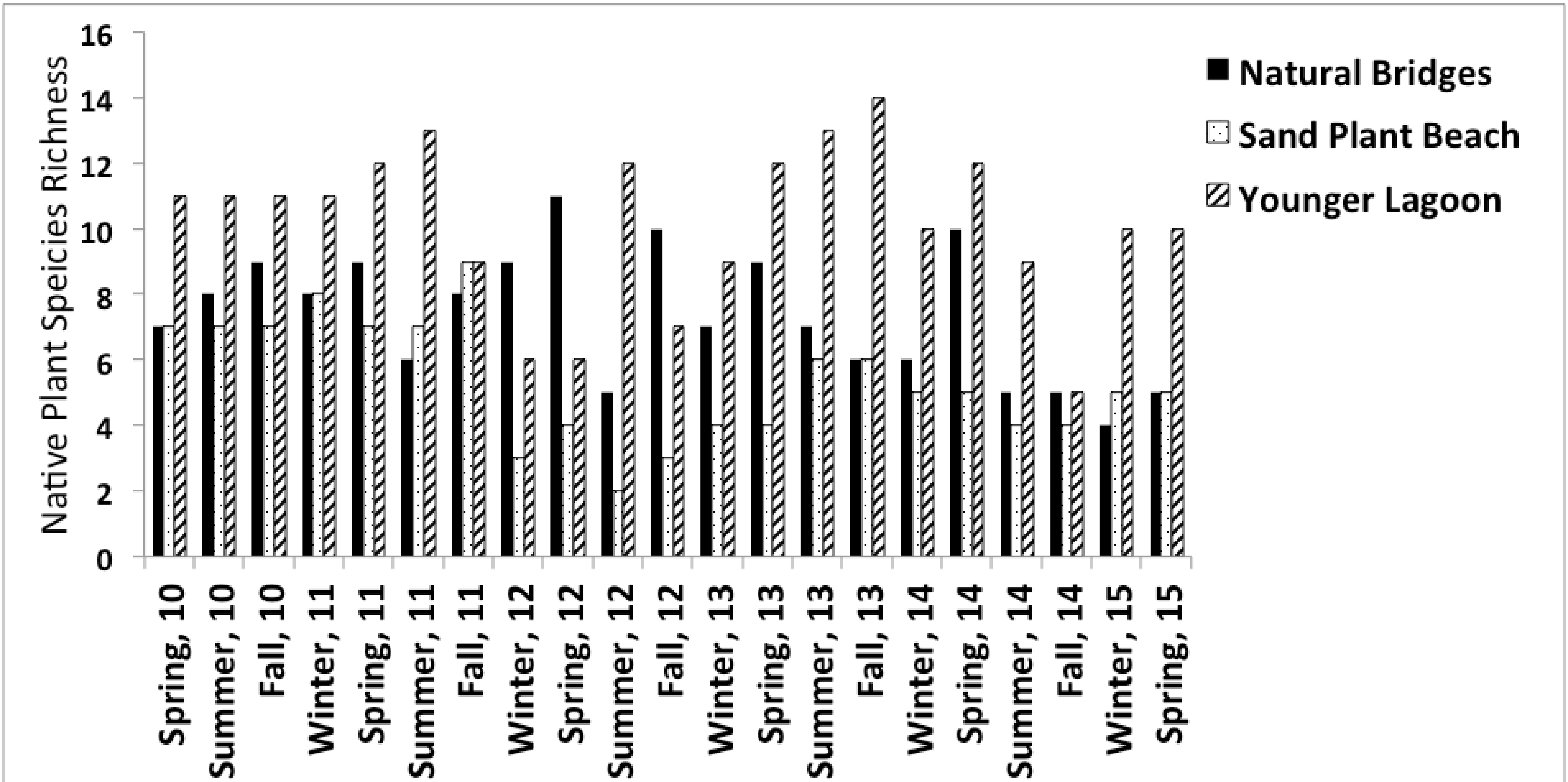

Figure 8. Number of native plant species encountered at each site.

Table 6. Summary of track plate sampling effort at each site.

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
May 1-2, 2010													
Little Wilder	X			X	X	X			X	X			X
Younger Lagoon	X	X		X	X								X
Natural Bridges	X	X		X	X				X	X	X	X	X
August 11-12, 2010													
Little Wilder		X		X	X							X	X
Younger Lagoon	X	X	X	X		X							
Natural Bridges	X	X	X									X	X
November 17-18, 2010													
Little Wilder	X		X	X					X				X
Younger Lagoon	X	X											X
Natural Bridges	X	X		X							X	X	X
February 8 -9, 2011													
Little Wilder	X			X	X				X	X			X
Younger Lagoon	X	X			X				X				
Natural Bridges		X		X					X		X		X
May 3 - 4, 2011													
Little Wilder	X		X	X									
Younger Lagoon		X	X	X	X				X				
Natural Bridges		X			X				X			X	X
July 22 - 23, 2011													
Little Wilder	X	X			X				X				X
Younger Lagoon	X	X	X	X	X								
Natural Bridges	X	X	X		X							X	X
March 8 & 9, 2012													

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
Little Wilder	X								X				X
Younger Lagoon				X					X				
Natural Bridges							X				X	X	X
May 15 & 16, 2012													
Little Wilder	X		X	X									X
Younger Lagoon	X	X		X					X				
Natural Bridges	X			X				X				X	X
August 16 & 17, 2012													
Little Wilder	X	X	X	X	X		X		X				X
Younger Lagoon	X	X		X		X	X						
Natural Bridges	X	X	X	X	X		X				X	X	X
October 22 & 23, 2012													
Little Wilder	X						X		X				X
Younger Lagoon		X		X					X				X
Natural Bridges			X		X		X				X		X
January 16 & 17, 2013													
Little Wilder	X			X					X				X
Younger Lagoon	X	X		X					X				X
Natural Bridges		X		X	X				X			X	X
May 15 & 16, 2013													
Little Wilder	X			X	X								X
Younger Lagoon	X	X		X					X				X
Natural Bridges	X	X			X							X	X
July 18 & 19, 2013													
Little Wilder	X	X		X					X			X	X
Younger Lagoon	X	X		X					X				
Natural Bridges		X		X	X						X	X	X
October 21 & 22, 2013													
Little Wilder		X		X									

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
Younger Lagoon		X		X					X				X
Natural Bridges	X	X			X				X		X	X	X
February10 &11, 2014													
Little Wilder	X	X		X									X
Younger Lagoon									X				X
Natural Bridges		X			X						X		X
April 27 & 28, 2014													
Little Wilder		X		X					X				X
Younger Lagoon		X							X				
Natural Bridges		X		X	X						X	X	X
July 30-31, 2014													
Little Wilder		X		X					X				X
Younger Lagoon		X		X					X				
Natural Bridges		X			X		X		X		X	X	X
November 4-5, 2014													
Little Wilder				X					X			X	X
Younger Lagoon		X		X					X				
Natural Bridges		X					X				X		X
January 26-27, 2015													
Little Wilder	X								X				X
Younger Lagoon	X	X		X			X						X
Natural Bridges	X				X		X		X		X	X	X
April 14-15, 2015													
Little Wilder	X	X							X				X
Younger Lagoon	X	X		X					X				
Natural Bridges	X				X		X		X		X	X	X
	3	3	3	3	3	2	3	1	3	2	1	2	3

[1]Unidentified small rodent.

Table. 8 Frequency of occurrence, and native species richness, of animals and human use types at Little Wilder, Younger Lagoon, and Natural Bridges through spring 2015 track plate sampling efforts. Actual detections are included parenthetically.

Site	Rodent	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human	[1]Native sp. richness
Little Wilder	(15) 71%	(10) 48%	(4) 19%	(15) 71%	(6) 29%	(1) 6%	(2) 10%	0%	(15) 71%	(2) 10%	0%	(3) 14%	(19) 91%	8
Younger Lagoon	(13) 62%	(18) 86%	(2) 10%	(17) 81%	(6) 29%	(2) 13%	(2) 10%	0%	(13) 62%	0%	0%	0%	(8) 38%	8
Natural Bridges	(9) 43%	(15) 71%	(4) 19%	(9) 43%	(13) 62%	0%	(8) 38%	(1) 5%	(9) 43%	(1) 5%	(14) 67%	(16) 76%	(21) 100%	8

[1]Bicycle, vehicle, dog, and human excluded.

Small Mammal Trapping

A total of 235 individual small mammals representing four species have been captured during small mammal trapping efforts. Species richness was greatest at Younger Lagoon and Sand Plant (Table 9).

Table 7. Summary of Sherman trapping effort at Sand Plant, Younger Lagoon, and Natural Bridges beaches.

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
April 24 -25, 2010					
Little Wilder	8	5			**13**
Younger Lagoon	2				**2**
Natural Bridges			3		**3**
August 11-12, 2010					
Little Wilder	5	4			**9**
Younger Lagoon			1		**1**
Natural Bridges					**0**
November 15-16, 2010					
Little Wilder	5	1			**6**
Younger Lagoon				1	**1**
Natural Bridges		3	1		**4**
February 15-16, 2011					
Little Wilder	5				**5**
Younger Lagoon	6	5	0		**11**
Natural Bridges			2		**2**
April 29-30, 2011					
Little Wilder	4				**4**
Younger Lagoon	1				**1**
Natural Bridges					**0**
August 8-9, 2011					
Little Wilder	6	2			**8**
Younger Lagoon	3		3		**6**
Natural Bridges		1	5		**6**
March 30, 2012					
Little Wilder	6				**6**
Younger Lagoon	1		1		**2**
Natural Bridges		5	2		**7**

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
May 15-16, 2012					
Little Wilder	4	1			**5**
Younger Lagoon	3				**3**
Natural Bridges		5			**5**
August 25-26, 2012					
Little Wilder	4				**4**
Younger Lagoon	3				**3**
Natural Bridges		4	2		**6**
November 5-6, 2013					
Little Wilder	2		1		**3**
Younger Lagoon	3				**3**
Natural Bridges		3	1		**4**
January 13-14, 2013					
Little Wilder	2		4		**6**
Younger Lagoon	2				**2**
Natural Bridges		2	1		**3**
May 1-2, 2013					
Little Wilder	1		1		**2**
Younger Lagoon	3		2		**5**
Natural Bridges		5			**5**
July 16-17, 2013					
Little Wilder	3		1		**4**
Younger Lagoon	1				**1**
Natural Bridges			1		**1**
October 22-23, 2013					
Little Wilder	5	1		1	**7**
Younger Lagoon	1				**1**
Natural Bridges		1	2		**3**
February 12-13, 2014					
Little Wilder	2	1	1		**4**
Younger Lagoon	1		1		**2**
Natural Bridges		2			**2**
April 28-29, 2014					
Little Wilder	4	1			**5**
Younger Lagoon	3		1		**4**
Natural Bridges	1				**1**

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
July 30-31, 2014					
Little Wilder	1	1			**2**
Younger Lagoon	2				**2**
Natural Bridges	1		1		**2**
November 4-5, 2014					
Little Wilder	3	1			**4**
Younger Lagoon	4				**4**
Natural Bridges	2	1	3		**6**
January 26-27, 2015					
Little Wilder	3		1		**4**
Younger Lagoon	4		5		**9**
Natural Bridges			3		**3**
April 14-15, 2015					
Little Wilder	2		3		**5**
Younger Lagoon	3				**3**
Natural Bridges					**0**
July 8-9, 2015					
Little Wilder	2		4		**9**
Younger Lagoon	3				**5**
Natural Bridges		1	7		**8**
TOTAL	**130**	**56**	**64**	**2**	**235**

[1]Pema = *Peromyscus maniculatus*; Mica = *Microtus californicus*; Rema = *Reithrodontomys megalotis*; Rara = *Rattus norvegicus*. [2]Escaped before positive ID; however, suspected to be Norway Rat.

Invertebrate Monitoring

Over all, Younger Lagoon consistently had the greatest number of individuals captured; however, patterns of species richness varied among sampling sessions (Figures 9-10). This may have been at least partially due to trapping methodology and disturbance as raccoons and perhaps coyote disturbed sample cups during some of the sampling efforts. Individuals were identified as distinct taxa; however, at the time of the writing of this report they have not been taxonomically keyed out.

Avian Surveys

Avian species vaired among sites and sampling dates (Table 10); however, number of species and abundance were consistently greatest at Natural Bridges and Younger Lagoon.

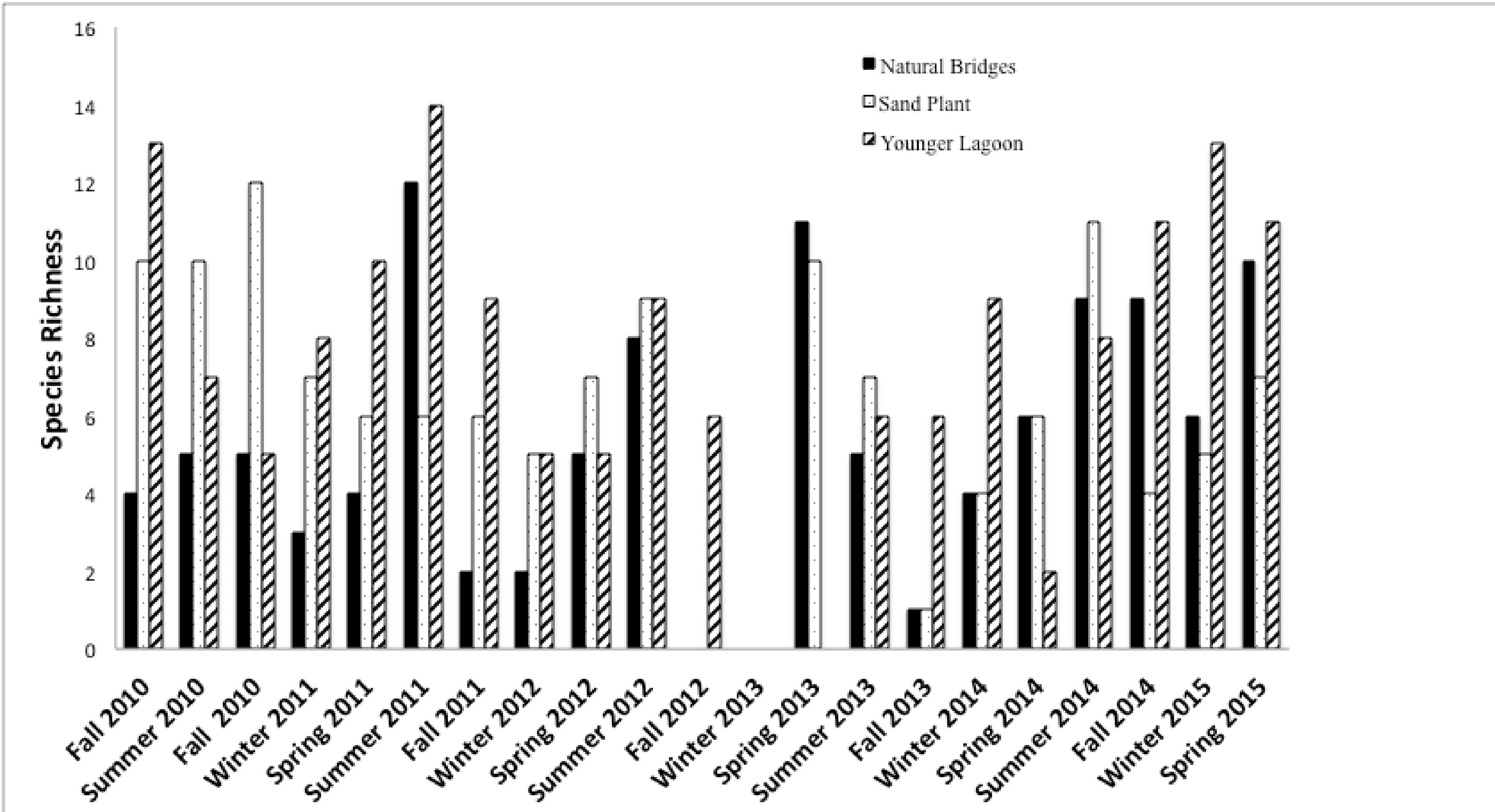

Figure 9. Species richness of invertebrates across all beaches

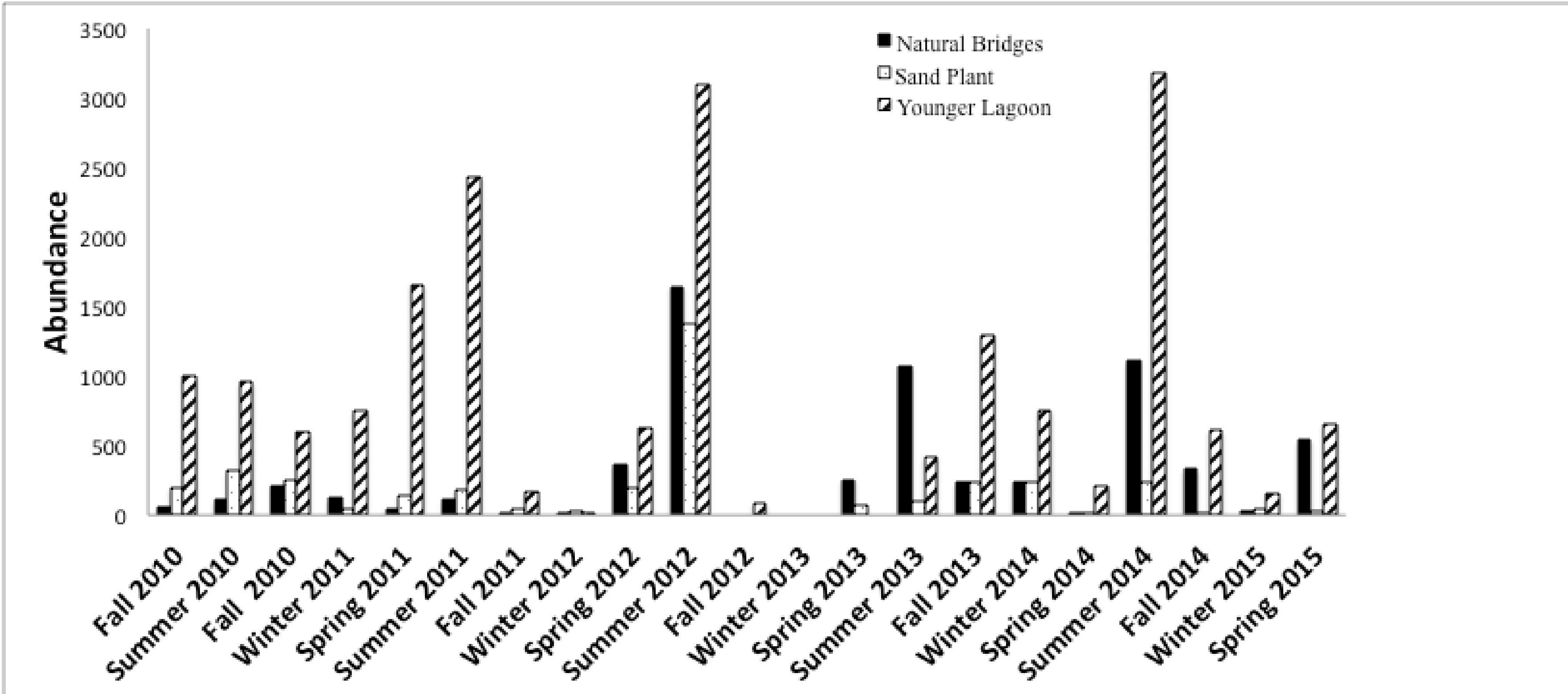

Figure 10. Total abundance of invertebrates at Natural Bridges, Sand Plant Beach, and Younger Lagoon beaches.

Table 8. Summary of bird surveys at Sand Plant Beach, Younger Lagoon, and Natural Bridges beaches.

Site	AMCR	AMPE	BBPL	BCNH	BASW	BLOY	BLPH	BLTU	BRBL	BRPE	BUHE	CAGO	CAGU	CLSW	CORA	COOT	DOCO	DUSP	EUST	GRHE	GREG	GRTE	HEGU	KILL	LOCU	MALL	MAGO
April 24 & 26, 2010																											
Little Wilder																										2	
Younger Lagoon																										3	
Natural Bridges									2															1			
August 11-12, 2010																											
Little Wilder																							1				
Younger Lagoon						2											1		1				2	2	1	10	
Natural Bridges	2								19															1			
November 15 & 16, 2010																											
Little Wilder																				3							
Younger Lagoon								1		27						2		3	1								
Natural Bridges									1											2	2		24	4			
February 15 & 16, 2011																											
Little Wilder																										2	
Younger Lagoon																	5										
Natural Bridges	3								2		1		58												3	4	
May 3 & 4, 2011																											
Little Wilder	2									8																4	
Younger Lagoon																											
Natural Bridges	1						1						3				6				1			7	4	4	1
July 22 & 23, 2011																											
Little Wilder					4		1							4									8				
Younger Lagoon																											
Natural Bridges	9				4				6								10						48			7	
March 29 & 30, 2012																											
Little Wilder													1													5	
Younger Lagoon									5							3			2					1		8	
Natural Bridges								1														2				10	3
May 15 & 16, 2012																											
Little Wilder																											
Younger Lagoon						3			2										2					3		2	

Natural Bridges	1								1																	6	
Site	AMCR	AMPE	BBPL	BCNH	BASW	BLOY	BLPH	BLTU	BRBL	BRPE	BUHE	CAGO	CAGU	CLSW	CORA	COOT	DOCO	DUSP	EUST	GRHE	GREG	GRTE	HEGU	KILL	LOCU	MALL	MAGO
August 25 & 26, 2012																											
Little Wilder													2		2									3			
Younger Lagoon		1				1	1						4													4	
Natural Bridges													1											5		1	
November 5& 6, 2012																											
Little Wilder																5											
Younger Lagoon									4							8								5			
Natural Bridges	2																							4		9	
January 13&14, 2013																											
Little Wilder																											
Younger Lagoon						1					1					5											
Natural Bridges															1					1							
May 1 & 2, 2013																											
Little Wilder																											
Younger Lagoon									1			2							2							3	
Natural Bridges	2																				2					4	
July 16-17, 2013																											
Little Wilder				1									1		1												
Younger Lagoon				1			2		7				2							1				2		25	
Natural Bridges							2		1				1							1			11	1			
October 22-23, 2013																											
Little Wilder													1		2												
Younger Lagoon			3				3						2				1		1				300	4			1
Natural Bridges	2		1							1			3										3			2	
February 13-14, 2014																											
Little Wilder												6														2	
Younger Lagoon																					1						
Natural Bridges	1																									2	
April 27-28, 2014																											
Little Wilder	3									20																6	
Younger Lagoon						8				13		2												3		6	
Natural Bridges	3					2				11			7	2			8				1			1		4	

Site	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG	SPSA	SURF	WEGU	WESA	WHIM	**Richness**	**Diversity**
April 24 & 26, 2010																				
Little Wilder																2			**1**	**0.30**
Younger Lagoon													2			2			**3**	**0.49**
Natural Bridges								2					2						**2**	**0.20**
August 11-12, 2010																				
Little Wilder																			**1**	**0.36**
Younger Lagoon													4			32			**9**	**1.15**
Natural Bridges																3			**5**	**0.71**
November 15 & 16, 2010																				
Little Wilder																1			**2**	**0.20**
Younger Lagoon				15							11			1		4			**9**	**1.05**
Natural Bridges	2										140		1	1		17		1	**11**	**1.85**
February 15 & 16, 2011																				
Little Wilder																6				**0.66**
Younger Lagoon												1								**1.42**
Natural Bridges				47									18			6		19		**1.46**
May 3 & 4, 2011																				
Little Wilder			2			35										5		1		**1.20**
Younger Lagoon																				**1.08**
Natural Bridges										1						16		7		**0.83**
July 22 & 23, 2011																				
Little Wilder						17							1			1				**0.90**
Younger Lagoon																				**0.88**
Natural Bridges						3				2			2			81		1		**1.51**
March 29 & 30, 2012																				
Little Wilder																				**0.67**
Younger Lagoon				13									2			16		2		**0.90**
Natural Bridges						2					65		2			10		5		**1.45**
May 15 & 16, 2012																				
Little Wilder																4		5		**0.66**
Younger Lagoon				25		5				1			2			15				**1.00**
Natural Bridges													2							**1.47**

Site	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG	SPSA	SURF	WEGU	WESA	WHIM	**Richness**	**Diversity**
August 25 & 26, 2012																				
Little Wilder																				**0.30**
Younger Lagoon				35				8		1			1			7				**0.89**
Natural Bridges														1		5	1			**0.34**
November 5& 6, 2012																				
Little Wilder																1				**0.89**
Younger Lagoon				14			1			4			2			3		10		**0.34**
Natural Bridges													2	1	2			12		**0.63**
January 13&14, 2013																				
Little Wilder																				**0.63**
Younger Lagoon				3	1						38	1	1							**1.15**
Natural Bridges													1			11				**0.62**
May 1 & 2, 2013																				
Little Wilder						8										2				**00**
Younger Lagoon		2		9												11		2		**0.55**
Natural Bridges																23		2		**0.83**
July 16-17, 2013																				
Little Wilder						7													**4**	**0.59**
Younger Lagoon				8		1							4						**10**	**0.99**
Natural Bridges																10			**7**	**0.82**
October 22-23, 2013																				
Little Wilder																			**2**	
Younger Lagoon				33									3			150		26	**13**	**0.20**
Natural Bridges													4			110		24	**8**	**2.19**
																				1.78
February 13-14, 2014																				
Little Wilder										1						103			**4**	
Younger Lagoon				8									4			7		10	**5**	
Natural Bridges													1			19		24	**5**	
April 27-28, 2014																				
Little Wilder						4										24		2	**6**	**1.13**
Younger Lagoon						8			1							2		2	**9**	**0.82**
Natural Bridges																18		7	**11**	**0.91**

Discussion

Conducting biological monitoring at Natural Bridges, Younger Lagoon, and Sand Plant/Little Wilder Beach provided general insight into differences and similarities between flora and fauna, as well as the intensity of human use, across these three coastal beach/lagoon habitats. These sites are in close proximity to one another and share many ecological similarities; however, it is important to realize that these sites are different in many ways (size, proximity to the city, access, adjacent upland habitat, etc.).

Vertebrate surveys reveal, that with the exception of avian diversity and richness, the three sites continue to be relatively similar to one another. In general, Sand Plant Beach had the greatest small mammal abundance which may be a result of the extensive freshwater vegetation directly adjacent to the beach and the close proximity of upland scrub on the lagoon sides to the relatively confined beach. Track survey results were also similar across sites. The beaches are similar enough to one another that the species suite is more or less the same. One potential difference that would be of interest is whether or not the frequency of use at a finer temporal scale (e.g. per day) varies across sites.

The most profound differences between the three sites are the plant community, dune system (including downed wood), and amount of human use. In general, the proportion of native plant species richness has been greatest at YLR whereas non-native species richness was the lowest at YLR. Over the past three years, Natural Bridges has had a rise in total number of native species, this is likely due to at least in part to the relatively diverse upland habitat towards the back of the lagoon. Although, the mechanisms responsible for shaping the vegetation patterns that have been observed are unknown for certain, it is very likely that increased human use has resulted in direct impacts to vegetation and perhaps resulted in the introduction of non-native species. A parameter that we have mapped, and is evident from visual observation and photo documentation, is the presence of dune hummocks and downed woody material at YLR, both of which are almost entirely absent at Sand Plant Beach and Natural Bridges (Figure 11). It is likely that the hummocks and woody material are absent at Natural Bridges and Little Wilder due to human trampling, collection, and burning. These features provide habitat for plant species such as the succulent plant dudleya, which grow on downed woody material and dune hummocks at YLR, as well as burrowing owls that use burrows in hummocks and seek shelter beneath downed woody material at YLR. Although Younger Lagoon does experience human use, the intensity and number of users is far less than both Sand Plant Beach and Natural Bridges. Additionally, users of the YLR beach are educated about the reserve, unique natural features, and are not allowed to collect woody material or trample dune vegetation. The relatively natural state of YLR beach and dune vegetation is unique among the three sites and most pocket beaches in Santa Cruz County and likely represents a glimpse into what many of the pocket beaches in the greater Monterey Bay area looked like prior to significant human disturbance.

Figure 11. Younger Lagoon dune map. Survey data and resulting elevation model output shows topographic features on Younger Lagoon Beach.

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Appendix 1. Younger Lagoon Photos.

YLR Beach Photopoint #1. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #1. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #1. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #2. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #2. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #2. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #2. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #3. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #3. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

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YLR Beach Photopoint #3. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #4. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #4. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #4. May 6, 2014. Photographer: Jordan Isken. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #4. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

Appendix 2. Compliance monitoring report

Compliance Monitoring Report for Coastal Prairie and Wetland Buffer Restoration Sites at Younger Lagoon Reserve
Spring 2015

Introduction

In keeping with the goals of the restoration plan for the Younger Lagoon Reserve prepared for the California Coastal Commission (UCNRS 2010), native plant community restoration activities have continued to move forward with the help of reserve employees, interns, and volunteers. This report presents the results of the 2015 monitoring of the lower terrace coastal prairie/grassland habitat plantings of 2010/2011 and 2012/2013, as well as the Wetland 6 Buffer plantings of 2012/2013. Restoration efforts are within target richness and native cover goals for all of the planted areas described above.

Methods

Planting

Seeds for the coastal prairie planting projects were primarily collected from local reference sites along coastal Santa Cruz and San Mateo Counties. The seeds were typically grown D7 conetainers™ for several weeks in the UCSC greenhouses before being introduced to the site. Site preparation prior to planting typically involved some hand-pulling of large weeds (such as *Carpobrotus edulis*) and or herbicide and tarping. A heavy layer of wood chip mulch (~10-15 cm) was also applied to planting sites prior to planting to suppress subsequent weed emergence. Teams of volunteers, interns, and staff planted the native plugs primarily between December and February using dibblers. Some plantings received supplemental irrigation to help ensure establishment of the new plants. Follow up management included some hand-pulling and spot spraying of herbicide for emerging weeds, as well as biannual mowing to reduce weed seed set while allowing native perennial species to drop seed.

The Wetland 6 buffer area was planted in the winter of 2012/2013 using grassland and wetland species planted at 18” spacing. The site was prepared by tarping all vegetation with black plastic twice prior to planting. Post-planting management has included ongoing hand-weeding, as well as biannual mowing to reduce weed seed set while allowing native perennial species to drop seed.

Sampling

Vegetation sampling of the coastal prairie/grassland and Wetland 6 Buffer habitats followed protocols described in Holl and Reed (2010). To measure cover, a 0.25 × 1 m quadrat was placed on alternating sides of a 50 m transect tape every 5 m, for a total of ten quadrats per 50 m transect. Cover was measured using a modified Braun-Blanquet class system within each quadrat, with increases in 5% intervals, starting with 0-5%. The midpoint each cover class was used for data analysis (e.g. 2.5%, 7.5%, etc.). Richness was measured using a 2-m belt transect on either side of the 50-m transect tape to visually detect any species not measured in the cover quadrat sampling.

In the lower terrace grassland, three 50-m transects and one 45-m transect were placed parallel to the coastal bluff, and were positioned to maximize coverage of the planted area (Figure 1). This yielded a total of 39 cover quadrats in the 2011 coastal prairie/grassland planting site. The 2013 coastal prairie/grassland plantings were measured using three 50-m transects, for a total of 30 quadrats. All three transects were split into two parallel portions to better fit the site (Figure 2). The Wetland 6 Buffer habitat was measured with one 50-m transect for 10 total quadrat sampling frames, also split to better fit the site (Figure 3). For the 2011 and

2013 coastal prairie/grassland plantings, cover and richness were averaged across transects/quadrats.

All sites are expected to meet the targets laid out for coastal prairie/grassland restoration, with the 2011 site expected to meet 4 year post planting targets, and both the 2013 coastal prairie/grassland and Wetland 6 Buffer sites expected to meet 2 year post planting targets. Goals for all habitat types available in Appendix 1.

Results

Observed native cover surpassed target requirements in all three sites (Table 1). In the 2011 grassland planting site, cover was 27.7 ± 3.8%, exceeding the goal of ≥ 15%. The 2013 coastal prairie/grassland site had a cover of 31.2 ± 4.1%, exceeding the target of ≥ 5%. Finally, the 2013 Wetland 6 Buffer planting site had a native cover value of 29.5 ± 6.0%, also exceeding the ≥ 5% goal.

Native species richness was also at or above target levels in all three planted sites. The 2011 coastal prairie/grassland had a richness of 9.8 ± 0.6, and the 2013 coastal prairie/grassland site has a native richness of 6.3 ± 1.2; both sites surpassed the ≥ 6 species richness target. The 2013 Wetland 6 Buffer site also met the two year post-planting goal of ≥ 6 species with a total richness of 6.0 native species. All restoration sites had evidence of recruitment.

Discussion

The restoration of the coastal prairie/grassland and Wetland 6 buffer sites continues to achieve the targets laid out for the California Coastal Commission (UCNRS 2010) for coastal prairie/grassland restoration.

Despite severe drought conditions, the 2011 coastal prairie/grassland planting has maintained relatively constant native plant cover since the previous monitoring period – from 28.1 ± 18.8% cover in 2013 to 27.7 ± 3.8% in 2015 (Hammond 2013 Report). Furthermore, the overall species richness at the 2011 planting site has increased over the last two years, from 6.4 ± 0.8 in 2013 to 9.8 ± 0.6 in 2015 (Hammond 2013 Report). The apparent increase in species richness is potentially the result of dispersal, growth of planted species so they enter into the quadrats, or differences in transect sampling locations from year to year, as no additional plantings have occurred. The richness and covers values are similar to those reported at local reference sites, although slightly lower than reference sites with continued active management (grazing, fire) and no history of agriculture (Holl and Reed 2010).

The Wetland 6 Buffer and 2013 coastal prairie/grassland sites also area met or exceeded the two year native cover and richness targets set out for the California Coastal Commission. As richness in the 2013 coastal prairie/grassland and Wetland 6 Buffer sites barely meet the target for species richness, additional plantings could improve the diversity of the habitat into the future to better meet and exceed restoration targets.

Overall, the restoration efforts at Younger Lagoon Reserve are meeting their target goals. Management strategies to date appear to be maintaining native cover in restored coastal prairie/grassland areas, and native species richness has increased in some plots.

Tables and Figures

Figure 1: Maps of transect locations (in red) in the 2011 grassland/coastal prairie planting site.

Figure 2: Map of transect locations (in red) in the 2013 grassland/coastal prairie planting site. Note that transects are split to fit at the site.

Figure 3. Map of transect locations (in red) in the 2013 Wetland 6 buffer planting site. Note that the transect is split to fit at the site.

Table 1. Table of native species cover and richness targets and observed values (± SE) at the 2011 and 2013 Grassland/Coastal Prairie and the 2013 Wetland 6 Buffer restoration sites at YLR.

	Restoration Site		
	2011 Grassland	**2013 Grassland**	**2013 Wetland**
Observed Native Cover	27.7 ± 3.8%	31.2 ± 4.1%	29.5 ± 6.0
Target Native Cover	≥ 15%	≥ 5%	≥ 10%
Observed Native Richness	9.8 ± 0.6	6.3 ± 1.2	6
Target Native Richness	≥ 6 species	≥ 6 species	≥ 6 species

Table 2. Table of the native species observed in the 2011 and 2013 Grassland/Coastal Prairie and the 2013 Wetland 6 Buffer restoration sites at YLR. Chart shows species found in at least one transect for each site. Growth forms abbreviated (PF=Perennial Forb, PG=Perennial Grass, PGRM=Perennial Graminoid, S=Shrub).

Scientific Name	Common name	Growth Form	2011 Grassland	2013 Grassland	W6 Buffer
Achillea millefolium	yarrow	PF	x	x	X
Baccharis glutinosa	marsh baccharis	PF	x	x	
Chlorogalum pomeridianum	soaproot	PF	x		

Erigeron glaucus	seaside daisy	PF	x		
Eriophyllum staechadifolium	lizard tail	PF	x		
Ranunculus californica	California buttercup	PF	x		
Symphyotrichum chilense	Pacific aster	PF	x		
Eriogonoum latifolium	coast buckwheat	PF	x		
Grindelia stricta	gumweed	PF	x	x	x
Fragaria chiloensis	beach strawberry	PF			x
Prunella vulgaris	selfheal	PF			x
Bromus carinatus	California brome	PG	x	x	
Danthonia californica	California oatgrass	PG		x	
Elymus glaucus	blue wild rye	PG	x	x	
Festuca californica	California fescue	PG	x		
Hordeum brachyantherum	meadow barley	PG	x	x	x
Stipa pulchra	purple needle grass	PG	x	x	
Juncus patens	spreading rush	PGRM	x		x
Baccharis pilularis	coyote brush	S	x	x	
Lupinus arboreus	yellow bush lupine	S	x		
		Total Observed Richness:	18	9	6

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UCSC Natural Reserves Staff and the Younger Lagoon Reserve Scientific Advisory Committee (UCNRS). 2010. Enhancement and Protection of Terrace Lands at Younger Lagoon Reserve. Plan prepared for the California Coastal Commission.

Appendix 1 – Compliance Monitoring Standards for YLR Restoration Efforts

Excerpted from: UCSC Natural Reserves Staff and the Younger Lagoon Reserve Scientific Advisory Committee (UCNRS). 2010. Enhancement and Protection of Terrace Lands at Younger Lagoon Reserve. Plan prepared for the California Coastal Commission.

Coastal Bluffs
Performance Standard: 8 native plant species appropriate for habitat established in planted areas to comprise 40% cover.

Years Post Planting	Goal
2 years after planting	4 or more native plant species established comprising > 20% cover and evidence of natural recruitment present
4 years after planting	8 or more native plant species established comprising > 30% cover and evidence of natural recruitment present
6 years after planting and every 5 years after that	8 or more native plant species established comprising > 40% cover and evidence of natural recruitment present

Grassland / Coastal Prairie
Performance Standard: 8 native plant species appropriate for habitat established in planted areas to comprise 25% cover.

Years Post Planting	Goal
2 years after planting	6 or more native plant species established comprising > 5% cover and evidence of natural recruitment present
4 years after planting	6 or more native plant species established comprising > 15% cover and evidence of natural recruitment present
6 years after planting and every 5 years after that	6 or more native plant species established comprising > 25% cover and evidence of natural recruitment present

Scrub
Performance Standard: 8 native plant species appropriate for habitat established in planted areas to comprise 40% cover.

Years Post Planting	Goal
2 years after planting	6 or more native plant species established comprising > 10% cover and evidence of natural recruitment present

4 years after planting	6 or more native plant species established comprising > 25% cover and evidence of natural recruitment present
6 years after planting and every 5 years after that	6 or more native plant species established comprising >40 % cover and evidence of natural recruitment present

Appendix 3. Student intern reports

Mowing for Management Goals at Younger Lagoon Reserve

Lewis Reed

Abstract

Mowing is one of the most readily available management strategies for a variety of land managers. This tool may be particularly important in sites such as Younger Lagoon Reserve that are small and close to urban boundaries where other options such as grazing, fire, and, in some cases, herbicide may be impractical. We can expect that mowing will have different outcomes depending on factors such as the height, frequency, timing, and spatial arrangement of clipping and whether or not cut material is removed. In cases where other management tools are available, mowing may be an important part of integrated management plans. The purpose of this paper is to provide insights from the scientific literature to inform effective use of mowing as a management tool at Younger Lagoon Reserve.

Introduction

Younger Lagoon Reserve (YLR) is a small (~72 acres) natural reserve located on the terrace lands immediately west of the town of Santa Cruz. As part of the UC Natural Reserve System, the site is managed as a resource for teaching and research in addition to its value for ecological conservation. The natural communities of the terrace lands, which include coastal prairie, coastal scrub, and seasonal wetlands, are an extremely precious resource as they are inherently scarce in spatial extent. Existing only in a narrow strip along the immediate coastal zone, these communities have been subjected to extensive development for intensive agriculture and urbanization throughout their historic range. The habitats at YLR have been influenced by these same forces, resulting in a history of cultivation that has depleted native vegetation over much of the reserve. Designation of the site as a reserve within the UC NRS provides a unique and valuable opportunity to expand our knowledge of restoration of these ecosystems and how we can manage their coexistence within the broader context of campus development and the surrounding community of Santa Cruz.

There are several constraints to vegetation management at YLR. Because of its relatively small size and proximity to the urban interface, the manipulation of landscape level disturbance regimes such as fire and grazing are relatively impractical management options at the reserve. The presence of jurisdictional wetlands within the site and overall proximity to the ocean constrains the use of herbicide in some parts of the reserve. With these limitations, mowing is one of the most versatile and readily available tools for vegetation management at YLR.

Review of the Literature

Developing effective management strategies specific to YLR will best be achieved through onsite adaptive management but this process can usefully be informed by a review of the scientific literature. Mowing is one of the most common management tools used on sites that have herbaceous vegetation and has frequently been used as an experimental manipulation in ecological studies. The following review is intended to provide some insight as to the types of responses we can expect from mowing, and to inspire thoughtful application of this technique to meet vegetation management goals at YLR.

Functions of mowing as a form of ecological disturbance.

Disturbance regimes are a major factor governing the structure and function of ecosystems. To begin with, it may be useful to think of mowing as a form of managed disturbance. From this perspective we can make some generalizations about the potential effects of mowing as a form of disturbance on vegetation in managed ecosystems. Disturbance regimes influence the dynamic of succession in part governing the extent to which communities found in the terrace lands are dominated by shrubs or herbaceous species (Ford and Hayes 2007). Studies in Mediterranean systems have shown that disturbance (clipping, tilling, or burning), by influencing succession dynamics, tended to favor annual grasses and legumes over perennials, and that clipping specifically tends to favor short statured species over tall species (Marron & Jeffries 2001, Holl & Hayes 2003, Merou et al. 2013). In a study on clipping and litter removal in Mediteranean grasslands in Italy, both clipping and litter removal lead to greater diversity and tended to favor annuals and biennial species over two dominant perennial grasses (Bonanomi et al. 2006).

The process of simply opening the canopy that results from mowing activities serves numerous functions in grasslands and coastal scrub plant communities. Increased light exposure at the soil surface is critical for the germination of some species (Gao et al. 2009). Disturbance of the canopy may stimulate dormant meristem tissue and promote the production of new shoots in woody and herbaceous species. The removal or breakdown of standing dead material during disturbance events increases light exposure to photosynthetically active tissue of remaining live plants thus changing tissue quality and net primary productivity at the community level.

The effects of disturbance on vegetation can scale up to influence habitat for wildlife in the affected community. Altered physiognomy of plant communities resulting from management such as clipping is an important habitat parameter for animals using the terrace lands and, in some cases, may be even more important than plant community composition in their habitat selection (Gill et al. 2006). As an example, consider two special status birds that both use terrace lands of central coastal California but have contrasting habitat needs: the western burrowing owl and the short eared owl. Both are crepuscular, ground-nesting species that forage and roost in coastal grasslands. The distribution of these two species, which seem to have a great deal of niche overlap, may be strongly influenced by a key habitat parameter that is affected by local disturbance regimes: vegetation height. Burrowing owls prefer short-statured grasslands that we may expect under conditions of frequent disturbance while short-eared owls prefer taller statured grasslands with standing thatch that develop under less disturbed conditions (Heckert et al. 1999, Poulin et al. 2005). This contrast exemplifies how management of plant communities with tools such as mowing may scale up to influence habitat potential for special status species.

Generalizations about mowing

Several studies have examined the effects of mowing in grasslands. Holl and Hayes (2003) found that clipping intermittently throughout the growing season in California coastal prairies led to decreases in exotic grasses, increases in exotic forbs, and no effect on native perennial grasses. Maron and Jeffries (2001) found that spring mowing in a comparable ecosystem increased forb richness with no effect on grasses, and that native grasses could subsequently be increased through seeding. In an oak savanna system in British Columbia, Gonzales and Clements (2010) found that mowing lead to a shift in dominance from exotic grasses to native grasses but only when plots were fenced to exclude large herbivores. These studies demonstrate that mowing can be an effective management tool for shifting species composition in grasslands.

One frequently observed outcome of mowing and other disturbances in grasslands is that increased intensity in terms of frequency or height reduction tends to favor forbs over grasses and annuals over perennials (Marron & Jeffries 2001, Holl & Hayes 2003, Bonanomi et al. 2006, Merou et al. 2013). There is an important caveat however in that species specific responses regardless of functional guild may be highly dependent on specifically how mowing is applied and the community context.

Mowing to achieve specific management goals

The outcomes of mowing will vary depending on several factors that managers can manipulate such as the timing of application, the frequency of application, and the height of cutting. The influence of these parameters on management outcomes will depend on how target and non-target species vary in their susceptibility to damage from mowing and their differing ability to capitalize on conditions created as a result of mowing.

Timing may be one of the most important parameters affecting the community outcomes of mowing. Wolkovich and Cleland (2011) advocate an approach of phenology-based management in which managers take advantage of differences in phenological niche space between targeted invasive species and non-target members of invaded communities. Plants are likely to be more vulnerable to damage from mowing during reproductive stages when they have elevated resource allocation to above ground tissues, such as the transition into flowering or fruit development (Wilson & Clark 2001, Gao et al. 2009). Differences in the timing of resource allocation between target and non-target species may create windows of opportunity for selective management. This may be particularly effective with annuals or short lived perennials that rely heavily on annual seed production to sustain their populations.

Maztek and Hill (2012) were able to demonstrate selective management of yellow star thistle (*Centaurea solstitialis*) using mowing that targeted this species' relatively late flowering phenology. They mowed experimental plots to 5cm once in the growing season when ~25% of plants had open flowers and few individuals had produced mature seeds. At this time (August), in their study site (Mendocino County) most non-target species had already completed annual reproduction and either senesced or gone dormant. Over the three years of their study, star thistle biomass was reduced by 92-95% and star thistle seed bank was reduced by 92-100% as compared to controls. The late season mowing in this study had no significant effect on perennials or other annuals. Similarly, Aigner and Woerly (2011) were able to reduce cover of the invasive annual grass *Aegilops triuncialis* with mowing that targeted its relatively late reproductive stage. The targeted invader was reduced by 48% while native grasses showed no significant response and native forbs as a whole had greater abundance in mowed plots. While these very successful examples of timed mowing focus on annuals, work by Wilson and Clark (2001) and literature on management of perennial hay fields (including species such as *Holcus lanatus* that are invasive in California coastal prairies) suggests that perennial species can also be negatively impacted by mowing during the flowering stage (Smith & Jones 1991, Smith et al. 1996, Kramberger et al. 2005).

However, the success of timed mowing to control invasive species by targeting seed production has been variable. In a coastal sage scrub system, Haselquist et al. (2013) attempted to use timed mowing to reduce exotic annual grasses and found no significant reduction. In this case, the authors suggest that late rains (post treatment) may have allowed impacted plants to recover. Other authors have demonstrated potential for this kind of phenology-based management using mowing, but warn managers that this technique may have less impact or even have positive effects on targeted invaders when individuals exhibit a high degree of basal branching or when there is sufficient soil moisture present to accommodate re-growth of impacted plants (DiTomaso 2000, Benefield et al. 2001, Volseky et al. 2011).

Another important aspect of mowing that managers can manipulate to create more selective outcomes is cutting height. Wilson and Clark (2001) successfully used mowing as a selective tool based on height to shift composition in experimental plots in an eastern Oregon prairie from dominance by the invasive exotic perennial grass *Arrhenantherum elatius* to dominance of two native perennial grasses. In this case the invader had similar phenology to two important native species in the system (*Danthonia californica* and *Festuca romeri*) but had shoot growth that was distinctly taller in stature. In treatments that involved mowing when *A. elatius* height was greater than the two native species of interest, *A. elatius* cover was reduced by about 70% while the native *D. californica* increased 5-7 times in treatment plots as compared to controls. The authors note that few significant effects in native or non-native perennials in this system were observed until at least two years of treatment had been carried out.

Frequency of mowing can also influence management outcomes. Mowing to target some species may require more than one cutting. Whereas mowing to reduce seed production in annuals may be accomplished with a single carefully timed cutting (Maztek and Hill 2007), perennial species will likely require multiple cuts to reduce their biomass or relative abundance.

Wilson and Clark (2001) found that repeated cuttings were more effective at reducing cover and flowering density of the invasive perennial grass *Arrhenantherum elatius*. Frequent mowing within a growing season has also been shown to lower vegetation stature and tends to favor forbs and reduce grass dominance (Hayes and Holl 2003, Williams et al. 2007, Hayes and Holl 2011). Hayes and Holl (2011) observed that frequent mowing (within one growing season) strongly favored the short statured native perennial grass *Danthonia californica* in a least one of three sites in central coastal California. The authors noted a high degree of site-to-site and inter-annual variability in community responses to mowing frequency in their ten year experiment.

Unintended consequences and potential negative effects

In planning a management strategy it is important to consider the community context. Actions that are highly effective for one goal may have unintended consequences depending on what other species are present in the community. As an example, timed mowing to target annual grasses in favor of native perennials may also benefit exotic forbs such as vetch (*Vicia sp.*) or thistles (*Cirsium sp., Carduus sp, Centarea sp.*). Ideal clipping time for some weed management may correspond to nesting periods for some grassland birds. Some species may have a high capacity to exhibit compensatory responses to clipping (DiTomaso 2000, Callaway et al. 2006, Pysek et al. 2007). There is also a growing body of literature demonstrating that management actions including mowing can act as a selecting force on managed populations yielding varieties of weed species that are resistant to a particular management strategy (Suzuki 2008, Voller et al. 2013). While it is impossible to predict all possible outcomes of our management actions, careful consideration of community context and functional traits of community constituents will help managers anticipate what additional actions may be useful to avoid unintended consequences of their chosen management action.

Integration

While mowing alone can be a useful management strategy, it can also be an important part of integrated management schemes. Several studies have demonstrated improved effectiveness of herbicide application following pretreatment with mowing, which in some cases can be a result of the combined impact of each management strategy on a targeted invader. In other cases, mowing may simply serve as a mechanism to increase exposure of live tissue of the targeted invader to herbicide application (Manaco et al. 2005, Kyser et al. 2007, Robertson et al. 2013). Such integrated approaches may improve effectiveness and reduce the risk of adapted resistance in targeted species (Wilson et al. 2008, Voller et al. 2013).

The prospective use of other strategies should not be dismissed. Several studies have demonstrated the potential value of prescribed fire, live stock grazing, and herbicide in meeting vegetation management goals in coastal communities of California's central coast (D'Antonio et al. 2005, Manaco et al. 2005, Kyser et al. 2007, Aigner & Woerly 2011). For immediate and ongoing management at YLR, mowing, by virtue of its simple availability remains an important management strategy. Engagement with the existing literature on mowing and development of student research projects and adaptive management based on mowing strategies will inform improved management at YLR and other conservation lands.

Management scenarios at YLR

The general aim of resource management at YLR is to protect and enhance natural resources for conservation of the site's unique biodiversity, and to sustain its viability as a teaching and research site (UCNRS). The history of cultivation and other land use have left the terrace lands at YLR mostly dominated by exotic species, including a preponderance of annual grasses and forbs of Eurasian origin and a few vestigial or pioneering native species, such as creeping wild rye (*Elymus triticoides*) and Coyote bush (*Baccharis pilularis*)(Holl & Reed 2010). Management efforts generally fall into three categories: control or eradication of particularly problematic invasive species throughout the reserve; restoration of native communities on degraded sites; and a relatively new and increasingly important category of management of restored sites to sustain native cover and diversity. In all cases, managers are faced with fundamental challenge of devising strategies that focus on target species while minimizing impact on non-target species when both coexist in a community context. Regardless of species composition, altering physical structure of plant communities (height and patchiness) may be desirable for some management goals.

While much of the vegetative cover on the terrace lands of YLR is comprised of exotic species, some may be considered more problematic than others. Species such as velvet grass (*Holcus lanatus*) or poison hemlock (*Conium maculatum*) are known to be particularly competitive with other vegetation and capable of reducing habitat value for other species. Management strategies that reduce the abundance of such high priority invasive species may be desirable even when they are primarily competing with other exotic species of lesser concern, such as the plethora of exotic annual grasses that have been naturalized, and to sustain some habitat value to other species on the reserve.

Restoration of the natural communities of the terrace lands has been a major part of the land management at YLR. Reserve staff, students, and volunteers have undertaken ambitious projects to restore native coastal scrub and grasslands and these projects have been extremely successful in terms of establishing native cover and richness. One of the first challenges in these restoration projects is to reduce the presence of competitive weeds prior to introducing native propagules. Once native vegetation is established, some level of management will likely be required to minimize emergence of invasive species, to promote growth and reproduction of native species, and to maintain a desired physiognomy for the restored community (i.e. to prevent native shrub encroachment in grassland sites). The following section explores a hypothetical management scenario based on actual conditions at YLR.

Coastal prairie restoration at YLR as a case study on considerations for integrating mowing into ongoing management.

The coastal prairie restoration sites at YLR provide an interesting example of how mowing based on differences in life histories between target and non-target species may be used to meet management goals. While restoration efforts are ongoing at YLR, there are currently sizable areas in which a suite of native perennial grasses and forbs have been established for at least two years. These projects have typically surpassed their stated goals in terms of targets for species richness and native cover (Reed 2012, Hammond 2013, Hammond 2014, Lesage 2015). However, quality of these sites is compromised by several invasive exotic species such as the grasses *Festuca perennis*, *Bromus diandrus*, and *Festuca myuros* and the forbs *Raphanus sativus*, *Helminthotheca echioides* and *Medicago polymorpha*. Several life history factors of both the desired native vegetation and the undesired exotic species can help inform how mowing might best be used to favor dominance of the native community, and can help managers anticipate what follow up actions may be needed as the community responds to a mowing event.

The planted native community in this case is comprised of herbaceous perennials (*Stipa pulchra*, *Danthonia californica*, *Elymus glaucus*, *Prunella vulgaris*, *Achillea millefolium* and *Grindelia stricta*) that should be fairly resistant to the impact of a single mowing event in the growing season (sustained cover of these species is more contingent on re-growth to which they are well adapted rather than recruitment of new seedlings from year to year). The short lived exotic grasses in this scenario (*Bromus sp., Festuca sp.*) rely heavily on annual recruitment of seedlings to maintain their populations and are thus likely to be the species most vulnerable to mowing techniques that aim to prevent seed production. However, the exotic forbs of concern here are likely to benefit from mowing that targets annual grass seed production. Tap-rooted rosette forming plants such as *Raphanus sativus* and *Helminthotheca echioides* will likely be able to recover and produce seed after mowing, while prostrate species such as *Medicago polymorpha* may evade impact of mowing altogether and subsequently benefit from the increased light exposure resulting from reduced grass canopy.

Given the wide variation in growth forms and phenologies of the invaders in this site, no single action will likely be effective for all targeted species. In this case, it may be best to start with a spring mowing regime that targets the taller exotic grasses *Festuca perennis* and *Bromus diandrus* when most individuals have well developed flowers but few developing seeds (this may require more than one mowing). Later in the growing season, the re-growing exotic forbs could be targeted with spot-applied herbicide or by hand removal. During the following growing season, assuming results of the first year treatments are satisfactory, the second year of mowing might take place earlier to better target the shorter statured and earlier flowering *Festuca myuros*. While this management scheme is hypothetical, it is illustrative of how consideration of life histories can inform selective management with mowing and how mowing might be part of an effective integrated management approach.

Conclusion

Mowing is one of the most readily available tools for vegetation management at YLR and has strong potential to influence trajectories of composition, structure, and function in communities of the coastal terrace lands. Managers can alter the impact of mowing by choosing the timing, frequency, and height of cutting and by choosing whether or not to remove clipped material. In some cases mowing alone may be an effective way to achieve a specific management objective, but it may also be used in conjunction with other strategies to improve their efficacy. Designing a mowing strategy should start with consideration of key life history characteristics of target and non-target species in the managed community such as phenolgy, growth form, and height at time of mowing. The review and recommendations presented here are intended to help guide the development of effective mowing strategies and to inspire thoughtful development of research projects at YLR and site specific adaptive management.

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Effect of Planting Design, Mulching and Mowing on Coastal Prairie Restoration

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Abstract

Coastal prairie ecosystems are under pressure from development and are almost ubiquitously invaded by exotic grasses and forbs. Restoration on these sites is often difficult due to limited native seed bank, lack of historical disturbances and variable climatic and edaphic conditions. In order to determine the viability of applied nucleation (planting in islands or clumps of seedlings), mulching, and mowing in coastal prairie restoration I followed up on a four season long restoration planting experiment at Younger Lagoon Reserve. Prior to implementation of the experimental plots, the grassland used was characterized by exotic grasses and forbs as is common to coastal prairies with similar agricultural history. Several exotic species control measures, namely mowing and mulching, were crossed with full planted and nucleation planted plots to test their effectiveness. Three native grasses, *Bromus carinatus*, *Stipa pulchra,* and *Hordeum brachyantherum*, and three native forbs, *Achillea millefolium*, *Grindelia stricta,* and *Symphyotrichum chilense* persisted into the fourth season and were evaluated for percent cover, and movement outside of nucleation plantings. Exotic grass and forb species were evaluated as guilds. I wanted to determine if planted natives were recruiting outside of planted areas so I compared interior, edge and outside of nucleation plantings. Any amount of cover outside of planting zones suggests successful recruitment. I found no difference by treatment for total native cover ($F=0.81$, $p=0.86$), and percent native cover was high (31% ±20) in nucleation plots relative to most reference coastal prairie sites. Neither mulching nor mowing had a significant effect on exotic species cover ($p>0.3$). *G.stricta* showed lower percent cover in un-mulched treatments ($p=0.0066$). *H. brachyantherum* had higher percent cover in un-mulched full planted treatments ($p=0.014$). I found no difference for the other planted native species by exotic control treatments or planting design ($p>0.8$). All species were observed outside of planted areas and three, *B. carinatus, H. brachyantherum,* and *A. millefolium,* were seen in adjacent plots at least 1 m from where they were planted. My results suggest that applied nucleation can be as effective as full planting in coastal prairie restoration and that even if effects of mulching on exotic control diminish over time; increased cover of species aided early on will persist. Applied nucleation should be considered as a cost effective coastal prairie planting design as it used a third of the labor and plant material and was as effective as full planting.

Introduction

California coastal prairie is a habitat type under pressure from agriculture and development, and is almost ubiquitously degraded by human activity and invaded by exotic European annual grasses and forbs (Ford & Hayes 2007). Invasion and dominance of exotic grass and forb species in these coastal prairie ecosystems is often related to the levels of anthropogenic disturbance(s) such as tillage for agriculture, overgrazing with cattle, and recreation or development (Ford & Hayes 2007). This invasion can be especially detrimental for some native grass species; for example, the exotic grass species, *Bromus diandrus*, has been shown to compete with native bunch grass, *Stipa pulchra*, and modify the microhabitat to favor annual exotic species (Molinari & D'Antonio 2014). In the absence of natural historical disturbance regimes such as fire and grazing by macro fauna, it is important to develop alternative methods to control exotic grasses in order to favor native vegetation (Hayes & Holl 2003; MacDougall & Turkington 2007).

Restoration of coastal prairie at Younger Lagoon Reserve (YLR), managed by the University of California, Santa Cruz's Natural Reserve System is especially difficult as the coastal prairie habitat has been completely replaced by exotic annual grasses due to past agricultural use and isolation from seed recruitment (Stern, 2013). Restoration in prairie systems is challenging because native species are often seed and dispersal limited (MacDougall & Turkington 2007; Hayes & Holl 2003; UCSC 2010). With no existing native seed bank, grassland restoration efforts at Younger Lagoon have relied on collecting seed off-site (Tang 2013; UCSC 2010). Seed collection, plant propagation, and planting out nursery stock or seedlings all increase costs of restoration projects but are essential to coastal prairie restoration at YLR.

Four years ago, student researchers set up an experiment to test the efficacy of several restoration techniques for restoring coastal prairie (Tang 2013; Arneson 2014). They compared two planting treatments, applied nucleation (planting seedlings in patches or islands) as opposed to planting the full areas. These planting treatments were crossed with two common weed control methods, mulching and mowing treatments (Tang 2013, and Arneson 2014).

Applied nucleation plantings mimic natural recruitment which takes place in plant community succession (Corbin and Holl 2012). In natural succession, grasslands are first colonized by species which can successfully establish and act as nurse species, increasing recruitment and survivorship to later successional species (Middleton & Bever 2012; Schöb et al. 2013). Applied nucleation restoration planting designs use less labor and plant material and are therefore cheaper, and have shown equal success compared to full planted restoration (Corbin and Holl 2012), and may better mimic the habitat heterogeneity associated with natural ecosystems (Schramm 1990). Precision Prairie Reconstruction (PPR) is the only analogous restoration technique to applied nucleation which has been tried in prairie ecosystems and has shown to have similar recovery of native species richness in 25% and 100% seeded treatments (Grygiel et al. 2009). This is promising but little is known about how applied nucleation can affect percent native cover or recruitment in a grassland setting. In previous years the YLR applied nucleation plots were shown to have equal, (Tang 2013), or higher, (Arneson 2014), percent cover of native planted species than full planted plots. This is despite the fact that nucleation plots were planted with a third as many plants. But, Arneson (2014) combined samples from entire applied nucleation plots and did not compare cover in planted and unplanted areas, so it is unclear how much native cover has spread outside of nucleation plantings.

Mulching has been used in grassland restoration to reduce exotic species dominance upon planting but the term can be applied to several ecologically different techniques. Wood chip mulching materials have a coarse texture, high ability to increase soil moisture, and are able to decrease soil nitrogen through increased biological nitrogen mineralization resulting from the increased carbon (Zink

& Allen 1998; Holl et al. 2014). In a study at Younger Lagoon Reserve, Holl et al. (2014), showed decreased cover of exotic grasses and forbs and increased survivorship of planted native grasses and forbs. However, consistent with findings on my study plots at YLR, suppressive effects of mulch were only observed in the first two years (Arneson 2014; Holl et al 2014) because wood mulch had broken down in that time period. Mulching is sometimes defined as chopping of aboveground plant material and leaving it on the surface as mulch (Kahmen & Poschlod 2008; Gaisler et al. 2013). This form of mulching is similar to some mowing techniques used in studies mentioned earlier (Hayes & Holl 2003; Prevéy et al. 2014). Mulching with woodchips in grassland restoration is markedly different than mulching using only standing biomass.

At my study site, Tang (2013) found that mulching treatments had higher planted native grass and forb survival and reduced percent cover of exotic grass. By the third season however, no significant difference was seen in native or exotic grass percent cover, but it is important to note survival of planted individuals was not evaluated due to difficulty locating individuals by the third season (Arneson 2014). Mowing has had mixed results with lower percent exotic grass cover in mowed treatments in the first and second season (Tang 2013) and higher exotic grass cover in the third season (Arneson 2014). Recruitment data did not evaluate grasses due to difficulty and showed low recruitment in year two of native forbs with more recruitment within mulched plots (Tang 2013). In year three similar trends were seen but sample size was too low (Arneson 2014).

After planting, prairie restoration requires ongoing exotic species management in order to favor native species. Mowing has been used in grassland restoration in order to mimic effects of natural grazing and as a method to control exotics and favor native grasses and forbs (MacDougall & Turkington 2007; Stanley et al. 2011; Valkó et al. 2012). Experiments have shown that mowing reduces dominance by tall statured exotic grasses, favoring shorter stature forb and grass species (Hayes & Holl 2003; MacDougall & Turkington 2007; Stanley et al. 2011; Prevéy et al. 2014; Valkó et al. 2012). In some studies, mowing showed a shift to native forbs and grasses, (MacDougall & Turkington 2007; Stanley et al. 2011; Valkó et al. 2012), while others found mowing to increase exotic forb cover (Prevéy et al. 2014; Hayes & Holl 2003). Also mowing in California coastal prairie has highly site specific effects (Hayes & Holl 2003).

Earlier data from the current study plots showed that mowing resulted in decreased survival of native grasses in the first two years of the experiment but also reduced percent exotic grass cover (Tang 2013). In the third growing season mowing reduced cover of *Bromus carinatus*, and had no effect on *Stipa pulchra, Hordeum brachyantherum*, and native forb species (Arneson 2014). Mowing actually increased percent cover of exotic grasses in the third season (Arneson 2014); this result is unexpected and may have resulted from persistent drought, (Arneson 2014), or possibly sampling error. Mowing may be interacting with the drought in novel ways. Grasslands invaded by tall stature exotic grass have been characterized as being light limited (MacDougall & Turkington 2007; Molinari & D'Antonio 2014) and mowing may have allowed exotic grasses, which make up the majority of the seed bank to germinate more readily and utilize what little water is available. Non-mowed treatments may have increased intraspecific competition between exotic grasses, with dry standing biomass from previous years reducing germination and growth.

In the fourth season after planting I resurveyed the experimental coastal prairie plots. I expected that applied nucleation plots would be equal with fully planted plots in percent cover of planted native species. To determine recruitment outside of planted nucleation plots, this season I compared inside, edge, and outside of nucleation plots. I estimated percent cover of all native grasses and forbs for each planted species and exotic grasses and forbs as guilds.

I expected that percent cover of native grasses and forbs would be highest inside planting area, decrease on the edge, and be lowest outside of the planting area. Even small amounts of percent native grass or forb cover on the edge and outside of planted areas suggest successful recruitment. New recruitment is unlikely due to the drought conditions. Also due to the continued drought conditions, I expect that mowing treatments will have higher percent exotic grass cover as was found in the third season (Arneson 2014). Without mulch being reapplied, I expect no effect of mulching treatments in the fourth season, consistent with findings of Holl et al. (2014) and Arneson (2014), that mulch degrades and has no effect past two growing seasons.

Materials and Methods

Younger Lagoon Reserve

The experimental site is located in highly invaded coastal prairie habitat on the southwest area of the Younger Lagoon Natural Reserve which is located on the western edge of the city of Santa Cruz, California. The reserve is managed by the University of Santa Cruz Natural Reserve System (UCSC NRS) which oversees research and restoration of the site. Restoration of approximately 19 hectares of sensitive habitat is mandated in the Coastal Long Range Development Plan which was negotiated between UCSC and the California Coastal Commission (Stern 2013). Student research is included in the mission of the UCSC NRS and is why student research has led to the design, implementation, and resurvey of numerous experimental and observational studies at Younger Lagoon. This resurvey of the applied nucleation experiment designed and surveyed by former student researchers is a part of this continued research.

Experimental design

The experiment was designed and set up in 2011 to test the applicability of applied nucleation (or island planting) in coastal prairie ecosystem restoration, specifically at Younger Lagoon Reserve and nearby analogous sites. The following experimental design set up is taken from Tang (2013):

[In October 2011, prior to the start of the experiment, the entire study area was mowed and sprayed with a glyphosate herbicide to reduce the cover of exotic background vegetation. The area was also fenced to exclude rabbits and humans. We marked plot boundaries and randomly assigned the plot treatments. We added wood mulch (comprised mostly of coast redwood, tanbark oak, bay laurel, and Monterey cypress) to the plots that were assigned a mulch treatment. In January 2012, a few days before planting, we applied a second round of glyphosate herbicide.

The study was set up as a split-plot design with four main treatments crossed with a mowing treatment. We set up 20 10×10-m plots with 1-m buffers between the plots; each plot was randomly assigned one of four main treatments for five replicates of each treatment: 1) fully-planted with mulch (F-M), 2) fully-planted with no mulch (F-NM), 3) island planting with mulch (I-M), and 4) island planting with no mulch (I-NM). We planted three native perennial grass species: *Stipa pulchra* (formerly *Nassella pulchra*), *Hordeum brachyantherum*, and *Bromus carinatus*.

We planted five forb species: *Achillea millefolium*, *Clarkia davyi*, *Grindelia stricta, Trifolium willdenovii*, and *Symphyotrichum chilense* (formerly *Aster chilensis*). We also planted one species of rush, *Juncus patens* (Table 1). We collected native plant seeds during June-September 2011 from local sites with characteristics similar to that of YLR. The seeds were processed and then propagated as seedling plugs at the UCSC Greenhouses and at a local native plant nursery (Central Coast Wilds). All seedlings (except *Symphyotrichum chilense*) were approximately three months old at the time of planting in late January 2012 and had individual covers of ≤0.25 dm2. *Symphyotrichum chilense* seedlings had delayed germination and were planted in May 2012.

The entire 10×10-m area of each fully-planted plot was planted in 22 rows of 22 plants for a total of 484 plants per plot (Fig. 2A). The plugs were planted at a distance of 45.45 cm from each other and plot boundaries. Each row was planted with a single species, and there were 11 rows of forbs/rushes and 11 rows of grasses. In each plot, there were two rows of A. *millefolium*, *C. davyi*, *G. stricta*, *T. wildenovii*, *J. patens*; one row of *Symphyotrichum chilense;* four rows of *H. brachyantherum* and *B. carinatus*; and three rows of *Stipa pulchra* planted in an alternating pattern. The forbs/rushes were planted on one side of each plot, and the grasses were planted on the other side. This layout was designed to allow the use of broadleaf and grass-specific herbicides for future control of exotic species.

One third of the 10×10-m area of each island plot was planted with plugs. The seedlings were planted in four 2.25×2.25-m islands with 2.5 m between each island and 1.5 m between the islands and plot boundaries (Fig. 2B). Each island had 6 rows of 6 plants, for a total of 144 plants per plot. As in the fully-planted plots, the plugs were planted 45.45 cm apart, and each row had one species. There were two forb/rush islands and two grass islands, with forbs/rushes on one side of the plot and grasses on the other side. Each forb/rush island had one row of each species, and each grass island had two rows of each species planted in an alternating pattern.

In late May 2012 {repeated in May 2013 and 2014}, four months into the experiment and after the first round of vegetation monitoring by Adams (2012) and Heaston (2012), we mowed half of every plot. Plots were mowed perpendicular to planted rows, so half of the forbs/rushes and half of the grasses were mowed. We encountered difficulties with obtaining a permit to use a grass-specific herbicide at the study site, so we mowed as an alternative management technique to control exotic regrowth which was primarily grasses.]

Data collection

I collected data from April 21st through April 28th, 2015. Data collection methods adapted from Arneson (2014). Plots were split into four, 4 x 4 m subplots representing four treatment combinations;

grass x mowed, grass x un-mowed, forb x mowed, and forb x un-mowed (not 5 x 5 m due to 1 m buffer from edge). Full planted plots had four randomly placed 1 x 0.25 m quadrats in each subplot totaling 16 per plot. Nucleation planted plots had two middle planting area, two edge of planting area and two outside of planting area quadrats located randomly. I therefore, sampled 24 quadrats for each nucleation planted plot. Samples were randomized using an imaginary numbered grid delineated by two transects running perpendicular, 1 m from the edge of the subplot, and using a random number generator. This layout was modified for nucleation planted plots by creating zones for each of the three locations within each subplot (Fig. 6). I adjusted to always place quadrats perpendicular to planted rows.

In each quadrat I estimated percent individual native grass and forb species to the nearest 5% interval for estimates >5%; for example if I estimated cover to be 20-25% then I assigned 22.5%. For percent cover <5% percent, I estimated native grass and forb cover by species to the nearest 1%. Estimation of exotic grasses and forbs was done similarly, only I grouped them into two guilds to avoid difficulties of identification to species. Due to canopy overlap percent cover per quadrat can equal >100%.

Data analysis

Data were analyzed using JMP pro version 11 statistical software. Data were transformed using an arc-sine square-root transformation in order to meet assumptions of normality and homogeneity of variance. To compare among treatments I used three-way analysis of variance with treatment (full-planting no mulch, full-planting plus mulch and nucleation planting plus mulch) and mowing as the main effects, plus planting guild (grasses/frobs) and their interactions. Percent cover for thatch, bare ground, and *J. patens* were too low and I did not include them in the analysis. For applied nucleation recruitment data three-way ANOVA was also used with location and mowing as the main effects, and planting guild as well as their interactions. Where significance was seen with a treatment or interaction follow up multiple comparison analysis was done using post hoc Tukey's test to determine the differences among treatments or interactions.

Results:

Average exotic grass cover was 68% (±18 SD) and exotic forb cover was 27% (± 17 SD). There was no effect of mowing, mulching, planting design or the interactions among them on exotic grass or exotic forb percent cover (Table 1). Two of three native grasses, *B. carinatus* and *S. pulchra,* were higher in percent cover in areas planted with grasses but there were no effects of planting design, mulching or mowing. Two native forbs, *A. millefolium,* and *S. chilense,* likewise were higher in forb planted areas but no difference was shown for planting treatments, mowing or interactions among them (Table 1). *H. brachyantherum* cover was significantly higher in full planted no mulch plots then mulched island planted plots (F=9.93, n=60, DF=11,48, p=0.0374, Fig. 1). *G. stricta* percent cover was lower in un-mulched full planted plots than in mulched full planted plots (F=6.17, n=60, DF=11,48, p=0.0066, Fig. 1), and mulched island planted plots (F=6.17, n=60, DF=11,48, p=0.012, Fig. 1). Percent cover for thatch, bare ground, and *J. patens* were all < 1.5% (± 2.5 SD) on average.

Total native cover was not significantly different across planting design treatments (F=0.81, n=60, DF=2,48, p=0.86, Fig. 2). I saw no statistical difference in total native cover for mowing, grass/forb treatments, as well as the interactions among them and planting designs (p>0.10, Fig. 2). Total native percent cover was variable ranging from a mean of just 11±9% in mowed, forb and full planted no mulch plots, to 40±30% in forb and full planted mulched, mowed treatments (Fig. 2).

Within applied nucleation planted plots percent cover of native planted species was recorded on the edge and outside of planted areas (Fig. 3). *B. carinatus, H. brachyantherum,* and *A. millefolium* have recruited into adjacent subplots where they were not planted (Figure 3). Exotic grass cover was higher outside than on the edge or inside of planted locations (F=4.3, n=60, DF=2, 48, p=0.019, Fig. 4). Within island planted plots mowing treatment showed a greater percent cover of exotic forbs (F=5.4, n=60, DF=1,48, p=0.025, Fig. 5). For *H. brachyantherum*, percent cover decreased significantly from inside islands, to on the edge, to outside grass planted islands, and was lower still in forb planted island subplots (Figure 3; Table 2). *G. stricta* had higher cover on the edge of planting plots then outside of planted plots (F=4.18, n= 60, DF=11,48, p=0.0297, Fig. 3; Table 2). *B. carinatus, H. brachyantherum, S. pulchra, A. millefolium, H. brachyantherum,* and *S. chilense* were all higher in percent cover in their respective planted island plots than ones in which they were not planted (p<0.05), but were not significantly different among planting locations.

Discussion:

Into the fourth season of growth the applied nucleation planting treatment showed no difference from full planted plots in native planted species as well as exotic species cover). This suggest that, consistent with Arneson (2014), and Tang (2013), applied nucleation planting designs are a viable option for returning native cover in coastal prairie ecosystems. This is important as restoration in these ecosystems which are seed limited can be costly and labor intensive (Holl et al. 2014) and applied nucleation, as tested, uses a third of the labor and plant material as full planting (Tang 2013). This finding is consistent with findings in tropical forest restoration where nucleation showed similar cover and was more economical than full planting (Zahawi et al. 2013). Similarly, this result gives evidence to support the suggestion by Corbin and Holl (2012) that applied nucleation is likely effective in ecosystems other than tropical forests. For the six individual planted native species which had persisted, I found effects of treatments on only *H. brachyantherum,* which had higher cover on un-mulched treatments, and *G. stricta* showed higher percent cover in mulched treatments. This suggests that increased survival of *G. stricta* observed in the first growing season in mulched plots persisted into the fourth season. All planted native species showed higher cover in their planted subplots.

While mulching has shown to have an effect on native species survival in the first season, my results are consistent with Holl et al. (2014) and Arneson (2014) who found no effect on exotic species cover in the third growing season. Also consistent with reduced survivorship of planted natives in un-mulched treatments in these earlier studies on the site, *G. stricta* percent cover is higher in mulched plots (Fig. 1). Conversely, *H. brachyantherum* showed significantly higher cover in un-mulched treatments. Combined, these finding suggest that mulching is important in reducing weed competition early in establishment of restoration plantings and can increased survivorship of some native species while negatively affecting others. Although it was not statistically significantly lower, the lowest percent cover of total native species, (11±9%), was in un-mulched, mowed treatments (Fig. 2). This is consistent with findings of Tang (2013) that mulching increased survivorship while mowing reduced it, and alludes to further complexity in the interaction among treatments.

The mowing treatment plots had similar native and exotic cover within all planting treatment by the fourth year to un-mowed treatment plots. Although I found no effect of mowing among the treatments for the overall comparison, within island planted plots there was higher percent cover of exotic forbs for mowed subplots (Figure 5). This is consistent with findings of others working in similar prairie ecosystems (Prevéy et al. 2014; Hayes & Holl 2003). This varied result I found, combined with highly varied sight specific effects of mowing (Hayes & Holl 2003), and differential effects of varied timing and height of mowing (Wilson & Clark 2001), suggest that mowing can be a useful tool for returning native cover but is highly dynamic and should be tailored by location and particular goal. Findings of Wilson & Clark (2001) suggest that mowing earlier in spring or twice (once in spring and once in fall) may be more effective in reducing exotic species and allowing native cover and seedbank reestablishment. Combining mowing with other treatments, like mulching and nucleation planting, only increases this complexity of interactions but have proven to be effective tools for exotic management and native species re-establishment.

When comparing nucleation plots only, I found that all six persistent planted native species showed cover along the edge of, and outside of planted areas of the plots (Fig. 3). This result combined with findings of Grygiel et al. (2014), who saw native forbs recruiting outside of seeded patches, suggest that applied nucleation is mimicking natural succession through spreading and seed bank enrichment. My results suggest that all of the native species that were planted and were able to persist are able to recruit through either spreading or increasing the native seed bank. I found several native species, *B. carinatus, H. brachyantherum,* and *A. millefolium,* showing percent cover in opposite subplots to the ones that they were planted in (Fig. 3). These species were found greater than one meter from original planted location and suggest these particular species may be especially suited to coastal prairie restoration establishment.

In the fourth season total native grass cover in nucleation plots was 21% in grass planted plots, but more importantly total native cover was 31% overall in nucleation plots. This is over 10% higher than the Phase 1, Specific Resource Plans, 7-year goal for total native species cover in the main YLR restoration plan for grassland restoration goals (Arneson 2014, and UCSC 2010), and suggests nucleation planting can be effective to reach and exceed this native species cover goal of more than 20% cover. Arneson (2014) found percent cover of native grasses in the third year of the experiment was 25% which is 5% over the SRP. Total native species cover is a better indicator of success as the SRP does not specify between grass and forb native cover. Differences among movement of individual species cover suggest that some species which develop slower recruit slower but may also be important in establishing long term native cover and native seed bank.

Long term studies are important in understanding restoration plantings dynamics over realistic time scales for plant establishment and for effects of treatments to take place. Over the course of the study, mulching's effect of reducing exotic species cover diminished in the third season while higher/lower survival of planted native species persisted as higher/lower cover into season four (Tang 2013; Arneson 2014). Also, mowing treatments showed lower exotic grass cover in the second season and showed higher exotic grass cover in the third with no effect in the fourth (Tang 2013; Arneson 2014). Wilson & Clark (2001) showed that differential effects of mowing treatments were not felt until several seasons of treatment in an Oregon prairie ecosystem. Restoration plans are often over long periods and restoration experiments must match these longer time periods in order for them to reveal effects of planting designs or exotic control treatments in the long term.

Planting native grass and forb species together, such as mosaic planting, better replicates natural variation in abundance of native grasses and forbs (Schramm 1990), and higher species richness has shown to reduce invasion by exotics in grassland ecosystems by filling more functional groups (Zaveleta & Hulvey 2004). Zaveleta & Hulvey (2004) also show how even rare species have an effect in invasibility of planted native ecosystems. Further work restoring coastal prairie at Younger Lagoon Reserve should consider planting in nucleation style designs to reduce effort and cost, and should include both native grass and forb species together to improve functional diversity and increase durability of these plantings. Managers must consider this based on their particular goals and realize that forb/grass specific herbicides will not be useful in this mixed planting style.

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Tables and Figures

	Treatment	G/F	Mowed	Treatment *G/F	Treatment *Mowed	Mowed*G /F	Treatment *Mowed* G/F
Exotic Grass	F=0.12 (p=0.90)	F=0.067 (p=0.80)	F=0.30 (p=0.61)	F=0.26 (p=0.77)	F=1.2 (p=0.33)	F=0.0002 (p=0.99)	F=0.51 (p=0.60)
Exotic Forbs	F=0.10 (p=0.90)	F=0.077 (p=0.78)	F=1.0 (p=0.32)	F=0.61 (p=0.55)	F=0.82 (p=0.45)	F=0.056 (p=0.81)	F=0.50 (p=0.61)
Bromus carinatus	F=1.2 (p=0.32)	F=33 (p<0.0001)	F=0.77 (p=0.39)	F=1.1 (p=0.33)	F=1.7 (p=0.19)	F=0.98 (p=0.32)	F=1.1 (p=0.33)
Hordium brachyant herum	F=3.4 (p=0.041)	F=99 (p<0.0001)	F=0.0003 (p=0.99)	F=1.1 (p=0.35)	F=0.12 (p=0.89)	F=2.6 (p=0.12)	F=0.14 (p=0.87)
Stipa pulchra	F=1.1 (0.34)	F=26 (p<0.0001)	F=0.0007 (p=0.98)	F=1.1 (0.34)	F=1.4 (p=0.25)	F=0.0007 (p=0.98)	F=1.4 (p=0.25)
Grindelia stricta	F=4.7 (p=0.013)	F=27 (p<0.0001)	F=1.4 (p=0.25)	F=4.7 (p=0.013)	F=2.8 (p=0.070)	F=1.4 (p=0.25)	F=2.8 (p=0.070)
Achillea millefoliu m	F=0.94 (p=0.40)	F=26 (p<0.0001)	F=1.4 (p=0.24)	F=1.3 (p=0.28)	F=0.65 (p=0.52)	F=0.72 (p=0.40)	F=1.3 (p=0.28)
Symphyotr ichum chilense	F=2.5 (p=0.95)	F=9.6 (p=0.0033)	F=0.0007 (p=0.98)	F=2.4 (p=0.095)	F=0.55 (p=0.58)	F=0.0007 (p=0.98)	F=0.55 (p=0.58)

Table 1. Statistics table showing F- and p-values for the ANOVAs testing the effect of treatments and interactions among them on cover of exotic and planted species in the fourth season of an island planting coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Values were calculated using JMP pro 11.

	G/F	**Mowed**	**Location**	**Location* Mowed**	**Location* G/F**	**G/F*Mowed**	**G/F*Mowed*Location**
Exotic Grass	F=0.141 (p=0.71)	F=1.1 (p=0.30)	F=4.3 (p=0.019)	F=1.0 (=0.40)	F=0.50 (p=0.61)	F=0.01 (p=0.92)	F=0.14 (p=0.87)
Exotic Forbs	F=0.0063 (p=0.93)	F=5.358 (p=0.025)	F=0.087 (p=0.92)	F=0.70 (p=0.50)	F=0.10 (p=0.90)	F=0.29 (p=0.59)	F=0.25 (p=0.78)
Hordium brachyantherum	F=72 (p<0.0001)	F=0.30 (p=0.60)	F=9.2 (p=0.0004)	F=2.8 (p=0.073)	F=12 (p<0.0001)	F=1.1 (p=0.30)	F=3.2 (p=0.047)
Grindelia stricta	F=26 (p<0.0001)	F=1.3 (p=0.26)	F=3.8 (p=0.030)	F=0.45 (p=0.64)	F=3.8 (p=0.030)	F=1.3 (p=0.26)	F=0.45 (p=0.64)

Table 2. Statistics table showing F- and p-values for the ANOVAs testing the effect of treatments, and locations within subplots, as well as interactions among them, on cover of exotic and planted species in island planted plots in the fourth season of a coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. *Bromus carinatus, Stipa pulchra, Achillea millefolium* and, *Symphyotrichum chilense* were excluded because they showed no effect of treatments or interactions among them except for having higher percent cover in their respective planting island subplots. Values were calculated using JMP pro 11.

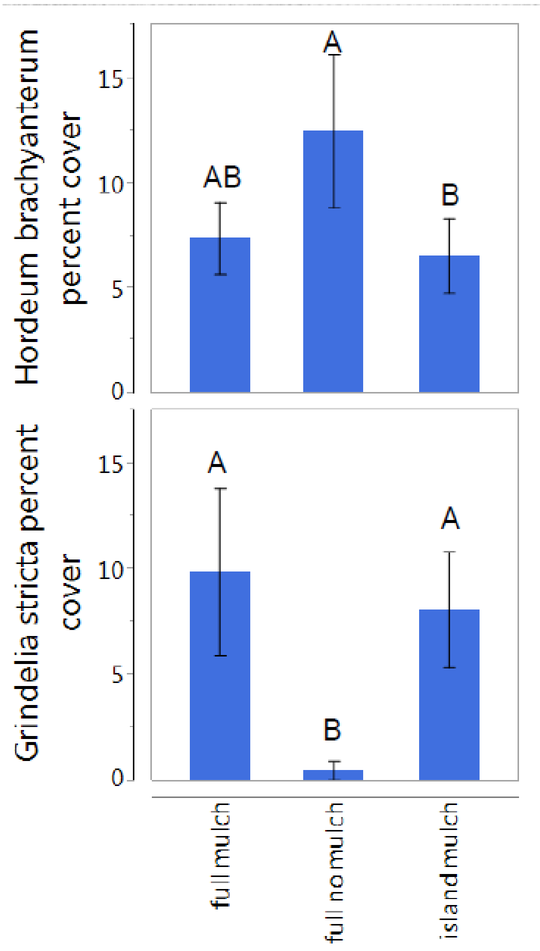

Figure 1. Differences in percent cover for *Hordeum brachyantherum* and *Grindelia stricta* by planting treatments for an island planting design coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Significant differences indicated where no letters are in common. Error bars represent 1± standard error from the mean.

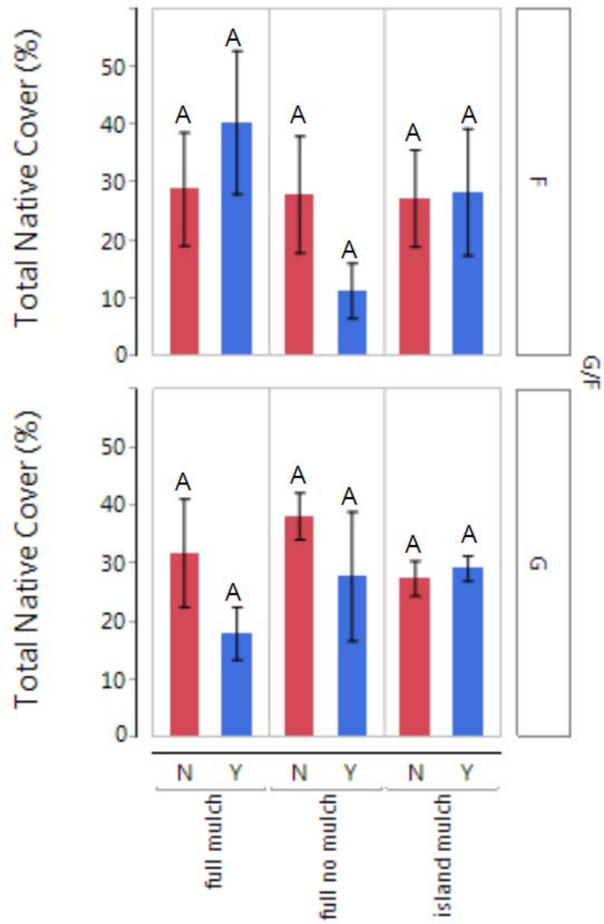

Figure 2. Differences in total native plant cover among planting treatments, between mowed (Y) and un-mowed (N) treatments, and between grass (G) and forb (F) planted subplots for an island planting design coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Significant differences indicated where no letters are in common. Error bars show1± standard error.

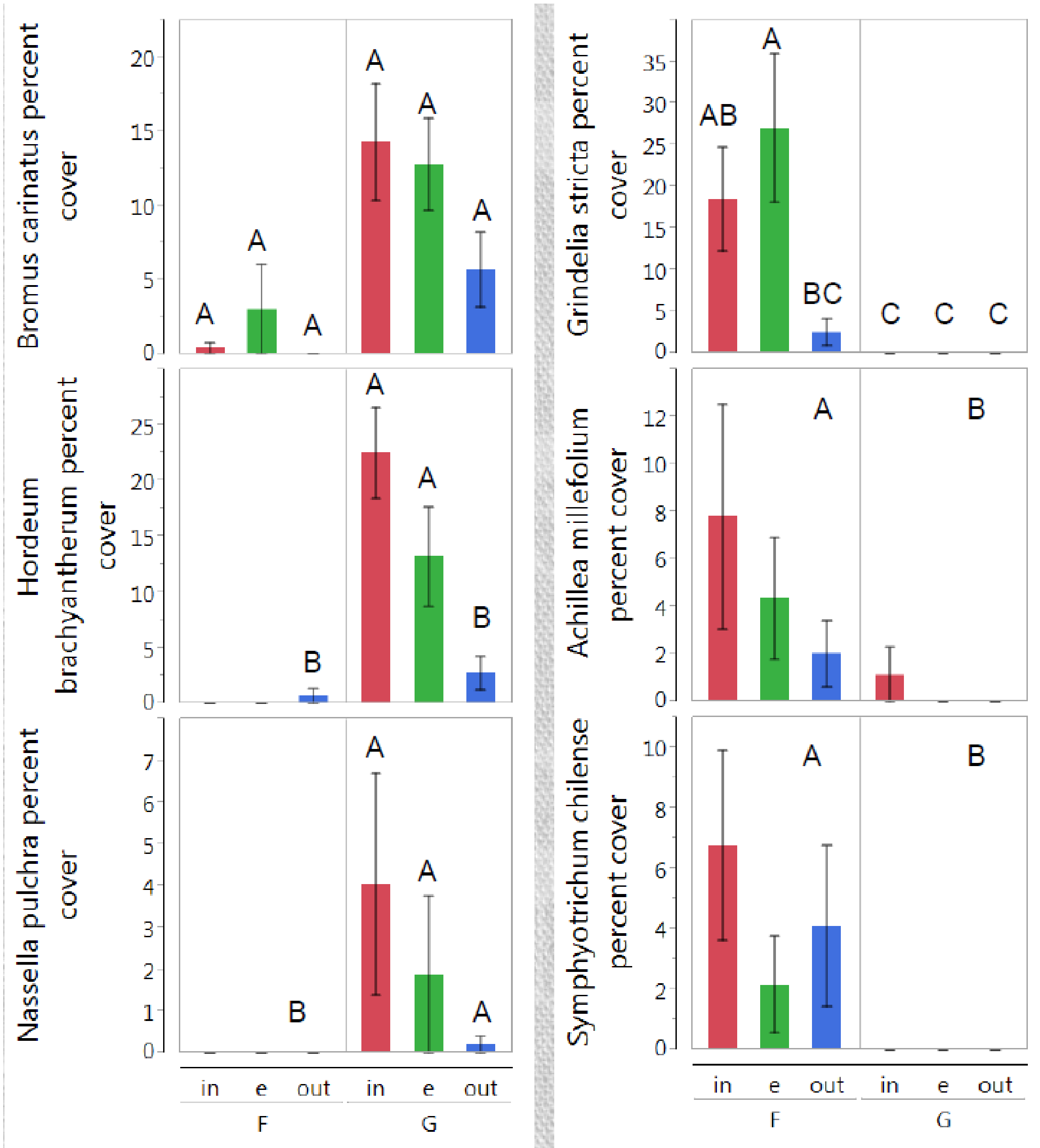

Figure 3. Differences in total native grass and forb species cover among interior (in), along the edge (e), and outside (out) of island planted plots between grass (G) and forb (F) planted island subplots for an island planting design coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Significant differences indicated where no letters are in common. Error bars show1± standard error.

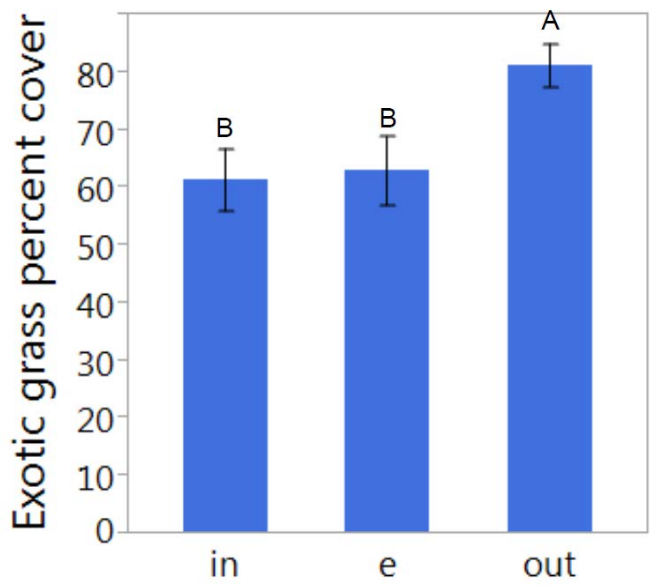

Figure 4. Differences in total exotic grass cover among interior (in), along the edge (e), and outside (out) of island planted plots for an island planting design coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Significant differences indicated where no letters are in common. Error bars show1± standard error.

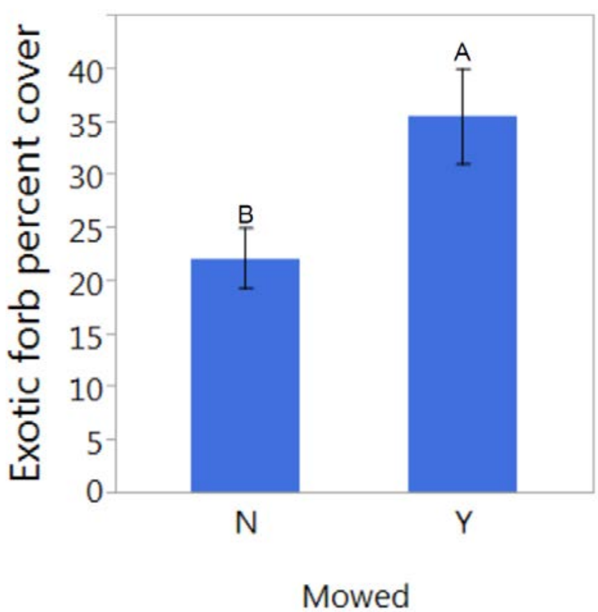

Figure 5. Difference between mowed (Y) and un-mowed (N) treatments in exotic forb cover in island planted plots for an island planting design coastal prairie restoration experiment at Younger Lagoon Reserve, Santa Cruz County, CA. Significant differences indicated where no letters are in common. Error bars show1± standard error.

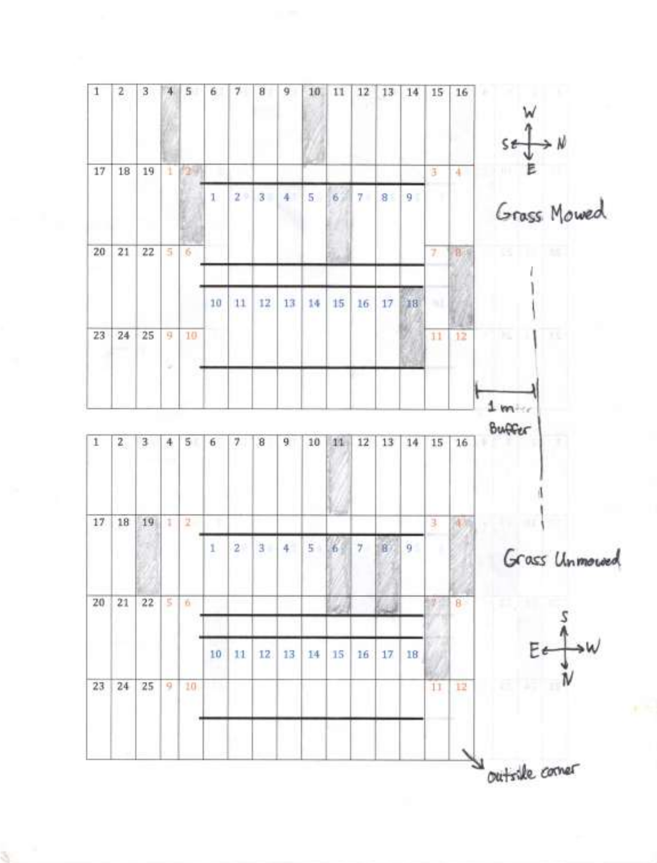

Figure 6. Example random sampling diagram for nucleation planted plots for a coastal prairie restoration experiment at Younger Lagoon Reserve located in Santa Cruz County, CA.

Bijan Souri
Dr. Karen Holl
Research Thesis

Comparing Different Weed Control Techniques To Restore Native Coastal Prairie Grasses

Abstract

Coastal prairies have been highly impacted by humans and are difficult to restore, due in large part to exotic species competition. Therefore it is important to understand which exotic species removal techniques are most efficient and practical for large-scale restoration and long-term projects. In this study, I compared the efficacy of five different weed removal techniques: 1x tarping, 2x tarping, herbicide, scraping, and mulching. Previous students established an experiment in 2010 with different weed control treatments and planted the plots with three native grass species: *Stipa pulchra*, *Hordeum brachyantherum*, and *Elymus glaucus*. I monitored native and exotic forb and grass cover five years after initial plot set up. I found that herbicide, scraping, and 2x tarping treatments all positively affected the cover of the native grasses, *Elymus glaucus* (ELGL) and *Hordeum brachyantherum* (HOBR). Herbicide treated plots have been consistent throughout all 5 years of monitoring and still seem to be a favored management choice for large and small scale restoration. While mulching significantly reduced exotic grass and forb cover in the first couple of years, by year five it had no effect on any plant guild. Scraping has become effective as a restoration strategy over time. This study demonstrates the importance of long-term data as well as which treatments to consider for large-scale grassland restoration.

Introduction

As global land usage by humans continues to increase as a result of many factors such as urban expansion and growing populations, there has been a rapid decline in pristine land unaffected by human activities. Unregulated cultivation of these lands poses a serious issue to environmental quality, as conventional farming practices often do not consider long-term effects. For example, tillage systems have been shown to have an effect on weed seed bank densities (Moonene, 2004). Agricultural use, as well as changing climate conditions has ultimately led to severe degradation of soil quality (Zucca, Canu, & Previtali, 2010). This poor quality of soil has disturbed key ecological functions such as nutrient cycling, water availability, and has introduced exotic plant species (Traoré et al. 2015). Such an example of this degradation can be seen when one examines the California coastal grasslands, which are being stressed by non-native and invasive grass as well as forb species (Ford and Hayes 2007). Although native grass and forb species are highly tolerant to dynamic climatic and abiotic variance, the perseverance of native grass cover is challenged by the competition for resources of non-native and native species alike.

Grassland restoration is one of the most difficult fields of restoration because plant species in these systems, both annual and perennial, are dependent on disturbance regimes such as fire and grazing (Ford and Hayes 2007). Disturbance regimes are the foundation of grasslands and need to be understood in order to design grassland restoration projects. Therefore, it is critical to test a variance of different grassland methodologies on a small scale.

In 2010 a grassland restoration experiment was established to compare five different methods to control non-native species at Younger Lagoon Reserve: tarping, soil scraping, mulching, and herbicide application. Younger Lagoon reserve is a 28.4-hectare reserve consisting of wetland and coastal prairie, located on the central California coast, north of Monterey Bay. Historically, Younger Lagoon was subject to heavy conventional agriculture and land use, which degrades grasslands and makes them difficult to restore. This is the 5th year of monitoring the efficacy of each treatment by collecting data on the vegetation guilds of the native and non-native grasses. Prior to establishing my hypothesis, I will give a brief overview of each of these five treatments.

One method used to control weeds in both agriculture and restoration is solarization, a method in which one covers an area with plastic tarp to produce high soil temperatures and conditions unfavorable to the soil seed bank. Although the central coast has cooler climates through the natural distribution of fog, one study found that solarization, by means of black plastic tarp, in such temperate climates could control various species of invasive weeds during the warmest time of year (Lambrecht et al. 2010). Under such conditions, tarping was found to be effective insofar as it was able to control various species of invasive weeds; thus allowing for native plants to grow more freely. Tarping (laying down dark plastic) is also used as a form of weed suppression by shading out unwanted, recently-germinated weed seedlings. Tarping, although shown to have multiple benefits requires the use of plastic, which poses many environmental and biological hazards (Goldberger et al. 2015; Syberg et al. 2015). In addition tarping is costly and application is highly labor-intensive (Holl et al. 2014) making it impractical for large scales.

Topsoil-removal, also known as scraping, can be an effective technique to reduce the number of weeds in upper soil profile (Geissen et al, 2013). Removal of the first 5 to 10 centimeters of the soil can disturb non-native and invasive plants as well as remove unwanted weed seeds from the seed-bank. A 2006 study by Buisson and colleagues showed scraping to be helpful for species such as *Stipa pulchra* through the reduction of nutrients and the exotic seed bank. Scraping has the potential to alter soil nutrient availability and biotic conditions; in some cases the reduction in nutrients available favors native species (Rasran, Vogt, & Jensen, 2007). Although topsoil removal can be a useful method to control unwanted growth, it can be damaging to the system. Heavy machinery can cause soil compaction and hard pans (Miyazaki et al. 2010; Geissen et al. 2013). There are also challenges associated with disposal of removed topsoil. Because it is less labor intensive than tarping and tractors are practical and commonly used tools, scraping has the potential to be utilized for large-scale restoration projects (Holl et al. 2014; Buisson et al. 2009).

Mulch and herbicide are frequently used in restoration efforts to suppress invasive and non-native plants (Doležal et al. 2011; Mollard et al. 2014; Annen et al. 2005). Mulch has various benefits such as preserving soil moisture content, regulating soil temperature, and suppressing unwanted weed growth (Mollard, 2014). Mulching, although seen to be a multipurpose tool for restoration, can be labor intensive to spread and have monetarily steep barriers of access (Angulo, 2014). Broad leaf herbicides such as glyphosate, commonly known as Round-Up™, have a broad spectrum of use insofar as they are broadcast over target areas and kill off all living plants. Although herbicides pose possible human and environmental health risks, herbicides have been shown to be the most cost-effective and large-scale remedy in restoration efforts (Annen et al, 2005).

After examining past research focused on the benefits and drawbacks of mulching, scraping, tarping, and herbicides at Young Lagoon Reserve, I have come to a two-part hypothesis. First, I predict that without reapplication the effects of mulching will diminish over time. Second, I anticipate based on past studies that herbicide treatment will continue to be the most effective treatment insofar as it allows for the growth of native plants, while it kills, suppresses, and lowers the growth of non-native, invasive species.

Methods

Project Design and Field Data Collection

To establish which restoration methods are most effective for coastal prairie ecosystems, an initial experiment was established at Younger Lagoon Reserve by Chan (2011) and De Silva (2011). The following text in brackets, describes the plot layout and setup, written by Sara Angulo, 2014.

[[Five blocks of five 5 x 5 meter plots, located ~40-50 meters from the ocean, were fenced and mowed. Within each block, the plots were randomly assigned one of the following treatments: topsoil removal, tarping once (x1), tarping twice (x2), herbicide, or control. For each plot, two 2.5 x 5 meter areas were marked off – one received mulch, and the other did not receive mulch. A 0.5-meter buffer separates each plot, and four out of the five treatment blocks are the same distance from the edge of the bluff (Russell, 2012).

The experiment began with tarping x2 in August 2010, during which the plots were irrigated for 10 minutes per day for a period of 18 days (Chan, 2011). Following irrigation, black plastic tarps were laid over the vegetation for 6.5 weeks (Chan, 2011). The tarps were then removed, and left uncovered for 18 days in October 2010. After this period, tarps were then reapplied at the same time as the tarping x1 treatment in early November 2010. The tarps were left in place for both treatments for a period of eight weeks. Mulch was applied directly after all tarps were removed in January 2011.

The scraping treatments, begun in October 2010, consisted of using a tractor to remove the first 5 centimeters of topsoil from the plots (Russell, 2012). Mulch was then applied immediately after topsoil removal.

For herbicide treatments, a solution of glyphosate in the form of Round-up Pro®, water, and blue dye was applied in the amount of 88.7-ml per plot or 3.5-ml per square meter. The solution was applied twice; the first application occurred on 18 November 2010, and the second on 5 January 2011 (Chan, 2011). Mulch was applied after the second herbicide application.

The control plots received no treatment other than mowing, which was administered to all plots. This treatment also received mulch after mowing.

Following all treatments and mulch application, all plots were planted with three native grass species, which were grown at the UCSC greenhouse from seeds collected locally at Franklin Point (Russell 2012). *Stipa pulchra* was planted 14 January 2011, *Elymus glaucus* on 21 January, and *Hordeum brachyantherum* on 6 February (Chan 2011).**]]**

Methods for Data Collection in 2015

The following sampling methods were designed to account for the native grasses that were planted in rows, which showed a potential to bias our data during quadrant placement. These data were collected from 21-27, April 2015, representing the 5th consecutive year of data collection. To locate and navigate the treatment block, we used a pre-existing map of the experimental site. Sampling methodology followed a standardized procedure, established by the prior years of data collection. Because the plots were treated half with mulch and half without, measuring tape was used to divide each plot into an east (non-mulched) and west (mulched) half, 2.5 meters marked as the midpoint (Fig. 1). To sample for percent of vegetative ground cover, we segregated each half plot into 4 rows: A, B, C, and D. as shown in Figure 1, which were divided into four columns. To avoid additional sampling bias, prior to collection, I used a random-number-generator to choose which column was sampled. To avoid potential edge effects we measured in 0.5m from the edge of each plot before laying out our quadrats. We measured percent cover using 5% classes, starting from 0-5%. The estimated percent cover was recorded as the mid-point of each class. For example, a percent cover estimated at 35-40% would be recorded as 37.5% cover. Percent cover values were recorded for, native grasses, non-native grasses, and non-native forbs. For native grass cover, we separately measured cover of the three planted native grass species; *S. pulchra*, *H. brachyantherum*, and *E. glaucus.* For non-native forbs; *Raphanus sativus* (wild radish), *Cirsium vulgare* and *Carduus pyncnocephalus* (thistle), and any non-native forbs, were measured separately but summed for analysis. Lastly, I measured percent of bare ground, litter and mulch was also measured. Using Microsoft Excel, I calculated totals for native cover, non-native grass cover, and non-native forb cover. The data were analyzed using the statistical application JMP. We determined the effects of treatment, mulch, and treatment x mulch interaction on the different plant species by using a two-way analyses of variance (ANOVA). When there was a significant treatment effect we compared individual treatments using a Tukey's multiple comparison procedure.

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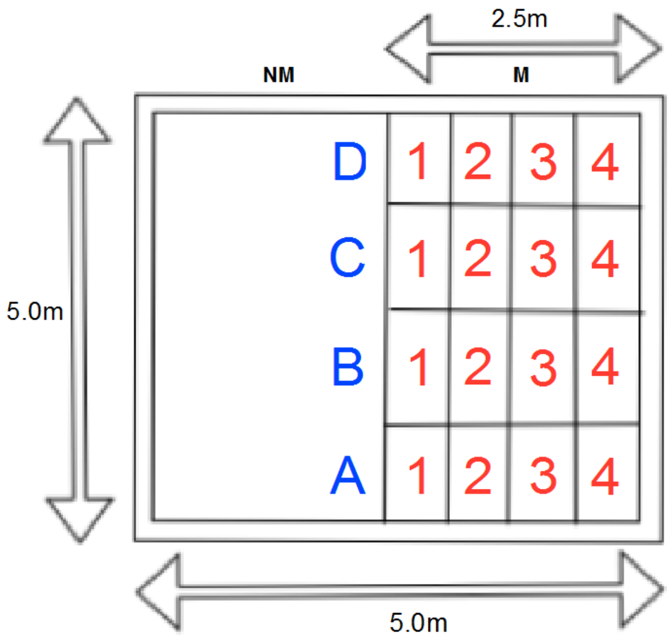

Fig. 1
Plot Diagram & Sampling Methods
Diagram shows the general layout of each plot. The layout on the mulched (M) side is identical to the non-mulched (NM) side. 1 sample was taken from each row (A,B,C,D) on both sides for 8 samples per plot.

Results

Elymus glaucus cover was lowest in the control plots, intermediate in scraped and 1x tarping plots, and highest in herbicide plots (Table 1, Figure 2); mulching did not affect *E. glaucus* cover.

There was a treatment x mulch effect on *Hordeum brachyantherum*. Interestingly there was a higher percent cover of *Hordeum brachyantherum* in the herbicide/no mulch plots (Figure 3) and cover was lowest in the 2x tarping and control/no much plots. *Stipa pulchra* cover was the lowest over all for the three native grasses (Mean value ±SE) and was not affected by either treatment or mulch.

Non-native grasses cover was lower in scraping, herbicide, and 2x tarping treated plots than in the control (Table 1, Figure 4). Lastly, there was a treatment x mulch effect on total native grasses. Similar to *H. brachyantherum*, total native grass cover was highest in herbicide/ no mulch plots and lowest in scraped/no mulch plots with intermediate values in most of the rest of the treatments (Table 1, Figure 5).

TABLE 1. ANOVA of the effect of treatment and mulch on cover of individual native grass species and exotic plant guilds. Values are F (p).

Statistically significant result.
Highly statistically significant result.

Variable	Treatment	Mulch	Treatment x Mulch
Percent Cover			
Stipa pulchra	5.55 (0.1335)	0.24 (0.6205)	1.18 (0.3064)
Hordeum brachyantherum	2.03 (0.0848)	0.96 (0.9911)	2.46 (0.0426*)
Elymus glaucus	3.10 (0.0177*)	0.04 (0.8374)	0.65 (0.6300)
Non-native forb	1.04 (0.3905)	0.69 (0.4058)	1.15 (0.3340)
Non-native grasses	5.48 (0.0003*)	1.27 (0.2592)	0.95 (0.4310)
Native grasses	5.74 (0.0002*)	1.01 (0.3164)	2.88 (0.0240*)

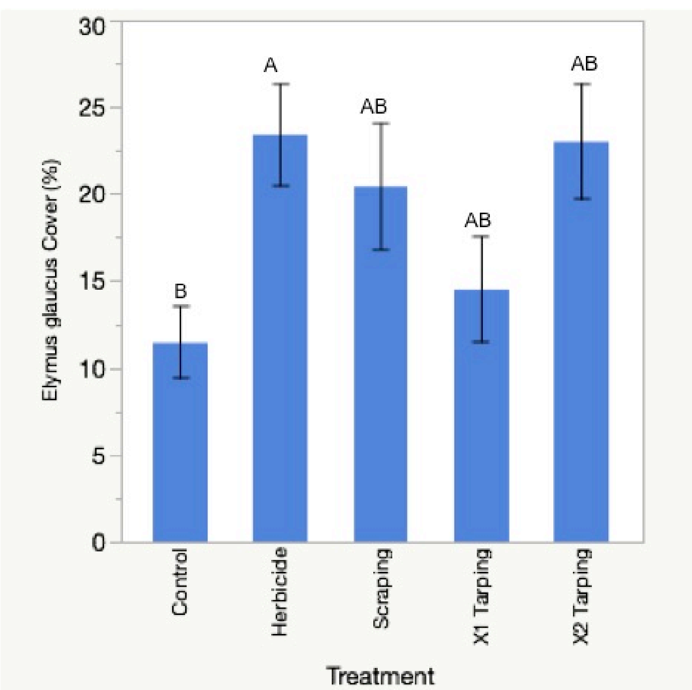

Figure 2. Mean percent cover *Elymus glaucus* (± 1 SE), Bars not connected by same letter are significantly different. Using Tukey's post-hoc comparison procedure. ($p < 0.05$)

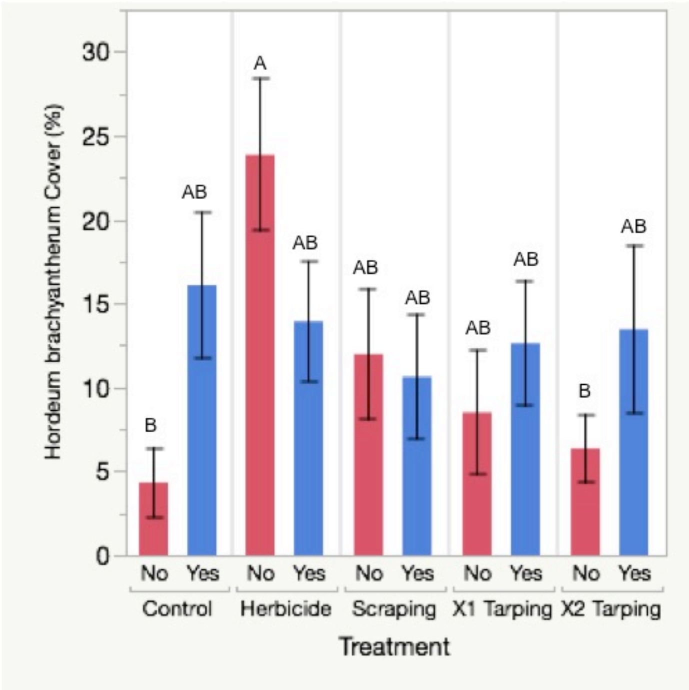

Figure 3. Mean percent cover *Hordeum brachyantherum* (± 1 SE). Bars not connected by same letter are significantly different. Using Tukey's post-hoc comparison procedure. ($p< 0.05$)

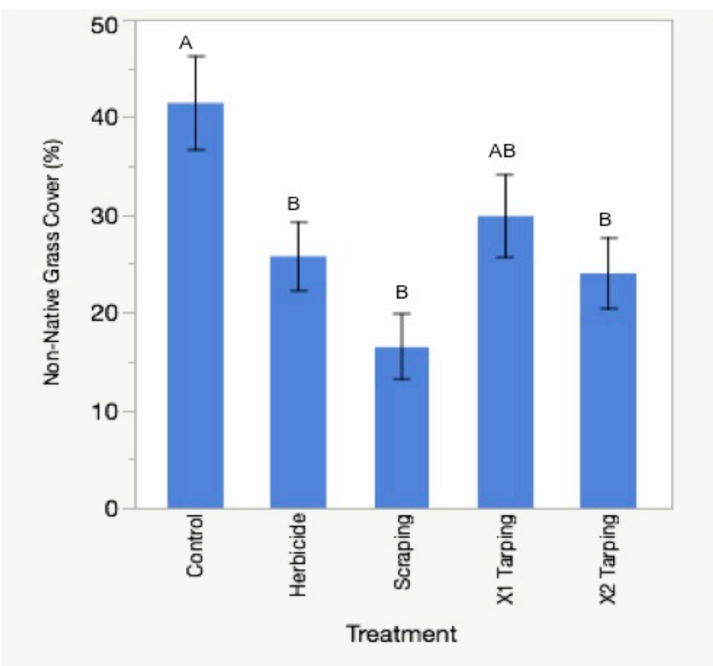

Figure 4. Mean percent cover of non-native grass (± 1 SE). Bars not connected by same letter are significantly different. Using Tukey's post-hoc comparison procedure. ($p < 0.05$)

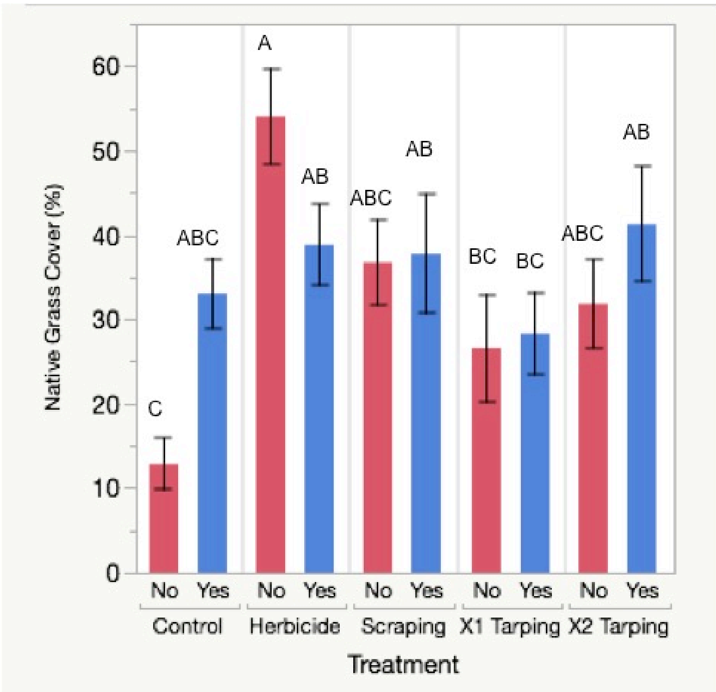

Figure 5. Mean percent cover of native grasses (± 1 SE). Bars not connected by same letter are significantly different. Using Tukey's post-hoc comparison procedure. ($p < 0.05$)

Discussion

Herbicides have consistently been effective at controlling non-native species and favoring native grasses over the course of this research, consistent with many other studies such as Bahm et al. (2014). Herbicide has been effective for restoration and has been shown to be cost effective, rendering it practical (Holl el al. 2014). Although herbicide treatment seems to be the most likely considered management strategy, there are concerns with the human and environmental risks (Papadakis, Vryzas, & Kotopoulou, 2015). Glyphosate, the active ingredient in Round-Up herbicide has shown to be a carcinogen due to its tumor promoting effects (George et al. 2010). It is important to analyze the potential toxicological risks when considering the use of a chemical treatment.

Scraping, over this longer term, has shown to be an effective strategy to control non-native grasses and enhance native grasses. Scraping was not recommended previously because results showed it to have poor effectiveness in weed suppression and promotion of native growth in the first few years (Holl et al. 2014), but now has proven to be superior to 1x tarping. These results suggest that scraping could be an effective strategy at small scales. At large scales, there are concerns regarding the potential physical damage heavy machinery can cause as well as disposal methods of the removed topsoil. The potential risks involved with heavy machinery to a system should be analyzed further because tractors can cause soil compaction and hard pans (Miyazaki, 2010). Further research should test the effectiveness of scraping in different locations and on different scales as well as consider possible disposal methods for removed topsoil.

Tarping does not seem to be as promising as it was earlier in studies. Both 1x tarping and 2x tarping had been consistently effective at supporting native growth and controlling weeds in previous years (Holl et al. 2014). Previous costs and benefits analyzed considered tarping to be a moderately useful tool for small-scale restoration, but in comparison with my data I do not recommend it without frequent maintenance and monitoring, which will add to the costs of tarping.

A mulching effect was almost non-existent in the plots this year. My results showed mulch alone had no significant effects on any individual plant species or plant guild in spring 2015. Previous data supported mulch to be effective at suppressing exotic growth in the past growing seasons, but due to its ephemeral characteristic, majority of the mulch has decomposed (Holl et al. 2014). Further research should examine the longevity of different mulch types to find out if the mulches are effective at suppressing exotics long enough to build and sustain a native seed bank.

If considering human and environmental health risk as a factor, scraping could rank as a much more viable treatment because it negates the use of environmentally harmful plastic as used in tarping and the use of known carcinogenic chemicals such as glyphosate in broad spectrum herbicides (e.g. Round Up, George et. al. 2010; Goldberger et al. 2015; Syberg et al. 2015).

After seeing a shift in scraping results I think further research should be done on the effects of scraping. I recommend monitoring once more in spring 2016. Long-term data is important, especially when considering management strategies for large-scale projects. Lastly, I recommend more research be done to test the effects of these treatments at other sites. Oftentimes results can be site-specific and not fully account for a range of possible site conditions (Lawrence, Rew, & Maxwell, 2015).

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Appendix 4. Photo monitoring


YLR Beach Photopoint #1. April 6, 2015. Photographer: Devyn Friedfel. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide


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YLR Beach Photopoint #4. May 6, 2014. Photographer: Jordan Isken. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

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Appendix 5. NOID 7 (14-1) Marine Mammal Pool Renovations

Notice of Impending Development 7 (14-1)

Supporting Information

see CLRDP 8.2.5

Table of Contents

1. Project Report

1a. NOID 7 (14-1) Project Description

The proposed Project would renovate and expand the existing 20,200-sf outdoor marine mammal pool facility at the UC Santa Cruz Marine Science Campus. The renovations would include re-coating of the pool surfaces, structural repairs to the pools, upgrades to the surrounding decks and observation areas, mechanical upgrades, and fencing improvements to meet current regulatory, building code and accessibility requirements. The Project would also expand the facility by about 2,894 sf to accommodate enlargement of the largest pool by 32 feet in length. The expansion would involve removing an existing fence, excavation of a portion of a berm, excavation to a depth of up to 30 feet for the pool expansion, construction of a new retaining wall, and new fencing. A new driveway to the south of the facility would be created for construction access. The Project also includes improvements to existing above-ground tanks and the installation of one new tank at the California Department of Fish and Wildlife (CDFW) facility at the Marine Science Campus, to provide temporary accommodation of the animals that would be displaced by construction. Figure 1 shows the Project location. The existing site plans for the UCSC mammal pool facility and the CDFW facility, and the proposed improvements at each site are shown on Figures 2 through 5.

The Project would be constructed at two separate sites on the Marine Science Campus: the Long Marine Lab's marine mammal pool facility, and an outdoor yard at the CDFW facility. The Long Marine Lab's marine mammal pool facility is located between and adjacent to two lab and lab support buildings: the 6,200-gsf Doyle Research building and the 3,700-gsf Younger building. Two caretaker residence trailers are located south and east of the mammal pool facility. The earthen berm separating the Long Marine Lab development from Younger Lagoon Reserve bounds the mammal pool facility on the west. At the top of the berm, a public access boardwalk provides views of the mammal pools and Younger Lagoon Reserve.

The temporary tanks that would house the marine mammals during the renovation and expansion of the main marine mammal pool facility would be within a fenced, gravel service yard at the CDFW facility. The yard is developed with several existing above-ground tanks, pens for holding sea otters, and associated seawater and life support equipment. CDFW buildings lie to the east and west, and an unpaved driveway along the northwest boundary of the yard provides access to the yard. There is currently also one above-ground tank located south of the CDFW yard that will be moved within the yard as part of the Project.

Project Background, Need and Objectives

The marine mammal pool facility at the UCSC Marine Science Campus consists of five large in-ground concrete pools ranging from about 490 sf to about 1,730 sf, two smaller fiberglass pools, and six small, concrete in-ground pools. Three 25-foot diameter concrete pools and four smaller in-ground concrete pools were part of the original marine mammal infrastructure constructed in 1978. The two largest pools, one 30-foot-diameter, the other, an oblong, 1,730 sf pool, were added in 1985. The concrete pools are 3.5 to 10 feet deep, the fiberglass pools, 42 to 52 inches deep. Seawater is supplied to all pools via a gravity flow system from 36-foot tall storage tanks located in the pool yard complex. Two interconnected recirculation systems provide high-rate sand filtration, chlorination, and gas-fired heating of the seawater in the five large pools.

The five larger, older concrete pools exhibit signs of structural failure, including some cracking, spalling and some rusty bleeding from reinforcing steel. All of the raised working decks around the pools are of wood construction, and many show signs of wood rot and breakdown. These wooden decks and the wooden supports for the fencing are difficult to maintain to federal animal holding sanitary standards.

The objectives of the Project are:

- Address the structural breakdown and deterioration of the coating of the existing pools
- Provide improvements necessary to meet current regulatory standards for animal holding facilities, and current building code and accessibility requirements
- Expand the research capability by providing enough pool length to allow larger vertebrates adequate swim and glide distance for scientific observation and animal exercise, and greater water depths for the study of diving behaviors and physiology
- Anticipate future regulatory changes that would require larger and deeper pool spaces for certain species.
- Provide temporary facilities and relocation of resident marine mammals during construction.

Detailed Project Description

Pool Expansion

The dolphin pool would be expanded by 32 feet in length, and a portion of it deepened from 10 feet to a maximum of 30 feet. To accommodate the expansion, the existing southern fence of the mammal pool facility would be moved south about 16 feet. A new ramp would be constructed to provide access to the dolphin pool underwater viewing area. A new retaining wall would be constructed on the east-facing slope of the berm to support the new ramp and the pool expansion. The existing 8-foot-tall wooden fence along the western boundary of the facility would be removed to accommodate construction of a new ramp and retaining wall. The fence would be reconstructed using materials salvaged from the existing fence.

Excavation for the pool expansion would remove a portion of the eastern slope of the berm that divides the Long Marine Lab facilities from the Younger Lagoon Reserve. Existing utilities within the footprint of the pool expansion, including storm drain, natural gas line, light poles, and sewer line, would be relocated. All of the utility lines replacements would be within the existing developed area in and adjacent to the expanded mammal pool facility.

Renovation of Existing Facility

The liners of the five existing concrete pools would be removed, the pools walls and floor slabs would be repaired, and new coating applied. The existing wooden decks would be removed and replaced with new decking made of recycled HDPE lumber. Existing ramps and stairs throughout the facility would be removed and replaced.

The existing subsurface observation room beneath the deck on the west side of the dolphin pool would remain, but would be shortened, and the trainer platform locally widened to create a slide-out area for the animals. Existing 8-foot wood fencing along the western boundary of the facility would be removed and reconstructed using materials salvaged from the existing fence. Fencing within the facility, and a sun shade on 12-foot poles over portions of the facility would also be removed and replaced.

Mechanical Systems and Utilities

Improvements to the seawater circulation system within the existing mechanical area of the mammal pool facility would include new pumps and piping in the immediate area of the existing filters and pumps, and heat recovery exchangers in the seawater recirculation system within the existing seawater pool structures.

Existing utilities within the footprint of the pool expansion, including storm drain, natural gas line, and a light pole would be relocated. All of the utility lines replacements would be within the existing developed area in and adjacent to the expanded mammal pool facility. The Project would not increase water demand. New energy use would be limited to a new 20-25 Hp pump and two new, 1 Hp storm sump pumps, and offset by a new heat recovery exchangers in the seawater recirculation system.

Storm Water Drainage

The Project would increase impervious surface by approximately 1,500 sf, which includes the new pool area. A storm water infiltration basin would be created south of the new fence. The infiltration basin would be designed to maintain storm water run-off volumes from the site at or below the limits established by the CLRDP.

Photovoltaics/Solar Thermal System

As an optional project element, the Campus is considering installing photovoltaic panels on west-facing roofs of the Younger and Doyle buildings, over the Doyle building alone, or over a portion of the Seymour Center parking lot, across McAllister Way from the UCSC mammal pool facility. Depending on the location and size of the array, installed capacity could be between 23 KW and 64 KW with between 27,000 and 87,000 kwh/year produced. As an alternative, the Campus is also considering installing a solar thermal system on the roof of the Younger Building. This system would act as a preheat loop for the existing mammal pool boilers, to offset part of the need to operate the boilers. Preliminary calculations show this system could potentially provide offset of approximately 885 MMBTU/ year of heating with 211,000 lbs of CO_2 emissions avoided. Installation of solar hot water or photovoltaic panels on one or both of the buildings would require removal of the existing roof, installation of a new roof, and improvements to the framing as well as installation of the panels and associated equipment and utility connections. The proposed photovoltaic system at the Seymour Center parking lot would consist of an 8,000 sf panel array on a canopy supported on 8- to 14-foot columns.

Temporary Tanks at Department of Fish and Wildlife Facility

At the CDFW facility, existing tanks would be refurbished, and an existing 30-ft-diameter, 5-ft deep fiberglass tank currently located outside the CDFW yard would be an installed on an existing concrete slab. New decking, ramp and stairs would be added. The new pools would be connected to the existing seawater supply and return that serves the area.

Improvements would be made to existing fencing surrounding the existing CDFW facility, and 12-foot-tall posts would be added to support new sunshades.

Sustainable Design Elements

Sustainability refers to principles of physical development, institutional operation, and organizational efficiency that meet the needs of present users without compromising the ability of future users to meet their needs—particularly with regard to the use of natural resources. Accordingly, the University of California has adopted the UC Policy on Sustainable Practices (formerly the Policy on Green Building, Clean Energy, and Sustainable Transportation).

The Sustainable Practices Policy (revised August 2013) recommends that university operations incorporate the principles of energy efficiency and sustainability in capital projects; minimize the use of non-renewable energy; incorporate alternative means of transportation to and from and within the campus; and continue to provide affordable on-campus housing to reduce commute volumes. To comply with the Sustainable Practices Policy, the Project must achieve a US Green Building Council LEED-NC certification of at least “Silver,” and register with PG&E’s Savings by Design program[1].

[1] LEED-NC applies to new building and major renovations of existing buildings. PG&E’s Savings By Design program offers cash incentives and technical assistance to help maximize energy performance in commercial new construction projects.

The proposed Project does not fall into any of the LEED categories, which are all based around occupied buildings. Therefore, the Campus will not seek LEED certification for the Project

The proposed Project includes the following sustainable design elements.

- System to recover heat from pool overflows to eliminate need for additional boiler capacity.
- Use of recycled materials such as HDPE lumber, salvaged fencing and cement replacement in concrete
- Optional Photovoltaic System to offset part/all of increased electrical demand
- Optional Solar Thermal System to offset part of current boiler capacity and reduce CO_2 emissions.

Population

The proposed Project would support the research of existing faculty and would not result in an increase in the faculty, staff, or student population.

Construction Schedule and Staging

The probable schedule includes two phases of construction. Construction of the improvements at the CDFW facility would begin in August or September 2014 and would be completed after an approximate 3 month duration. The second phase of construction at the main Long Marine Lab mammal pool facility would then begin after the CDFW improvements are complete and would be completed a year later. The research animals would be moved to the CDFW facility for the year of construction at the LML facility. The second phase of construction may be delayed to avoid conflict with other activities on the Marine Science Campus, or to accommodate the schedules of the research groups affected by the move.

The Project would generate approximately 100 cubic yards (cy) of demolition waste. Approximately 885 cy of soil and rock would be exported. If suitable, some or all of this material may be used on the campus as fill for the Coastal Biology Building Project (see “Cumulative Project,” below). Demolition, grading and excavation would overlap, over a period of about three months. Assuming 16 cy per truck-load, this would result in a total of 62 trips over the three month period. The number of daily construction worker and vendor trips to the site would vary by phase, with a maximum of between 10 and 20 daily trips during the period when demolition, grading, excavation, and trenching for utilities may overlap.

A new gravel driveway, with an area of about 600 sf, would be constructed to provide construction access to the southern end of the mammal pool facility from McAllister Way through the existing primary seawater system outdoor mechanical area. After construction is completed, the area would be restored. Construction staging, including contractor vehicle parking, would be provided in gravel and asphalt Campus vehicle parking areas adjacent to McAllister Way east of the UCSC mammal pool facility and in an employee parking area. As an alternative, after the existing, unoccupied greenhouses west of McAllister Way are demolished for construction of the Coastal Biology Building Project, a portion of the greenhouse area may be available for staging for the Mammal Pool Renovation and Expansion Project.

1b. CLRDP Consistency Determination

As stated in Policy 1.1 (Development Consistency), "Development shall be deemed consistent with the CLRDP if it is consistent with the provisions of Chapters 5, 6, 7, 8, 9, and Appendices A and B."

The following is a list of all the Policies, Implementation Measures and Figures found in Chapter 5. Those that apply directly to this NOID are highlighted in black and followed with a comment regarding the project's consistency. In addition, sections of Chapters 6, 7, 8, 9, and Appendices A and B that also apply to this NOID are referenced with comments.

CHAPTER 5 Long Range Land Use Development Plan

5.1 Application of the Long Range Land Use Development Plan

Policy 1.1 Development Consistency

The University finds the project contemplated under NOID 7 (14-1) to be consistent with the CLRDP.

IM 1.1.1 Figures of Chapter 5.

As described below, the project is consistent with Figures 5.1 – 5.4, which show the "kinds, locations, maximum size and intensity" of allowed development. The project is also consistent with Chapters 5, 6, 7, 8, 9, and Appendices A and B and the type and locational restrictions of Section 5.2.

~~IM 1.1.2 Lease Agreements.~~

~~IM 1.1.3 Federal In-holding and CLRDP.~~

Policy 1.2 University Commitments

The project does not trigger any of the University Commitments identified in Chapter 9 or elsewhere in the CLRDP.

5.2. Land Use

Figure 5.1 Building Program

The CLRDP building program includes up to 70,000 sf of new outdoor research area. The Outdoor Research Yard Expansion Project, which was completed in 2010, added 3,200 sf to the Outdoor Research Area in the Lower Terrace development zone. The proposed Mammal Pool Expansion and Renovation Project would expand the existing outdoor research area by 2,894 sf. This would bring the total area of Outdoor Research Yard space constructed under the CLRDP to 6,094 sf, which is within the 70,000 sf allowed in the CLRDP building program and the 10,000 sf allowed in the Lower Terrace Development Zone.

Figure 5.2 Land Use Diagram

The expansion of the marine mammal pool facility would be on land designated for Research and Education Mixed Use, within the Lower Terrace Development Zone. The project is consistent with this designation.

Figure 5.3 Locational Restrictions for Building Program

On the lower terrace west of McAllister Way, building development is limited to "uses that integrally relate to existing development or research activities in the development zone, need a location adjacent to YLR, or otherwise require a more isolated location (IM 4.2.14)." The proposed Project would directly support the existing research activities within the mammal pool facility, and therefore is consistent with this requirement.

Stable Urban / Rural Boundary

Policy 2.1 Maintaining a Stable Urban / Rural Boundary

IM 2.1.1 Over sizing of Utility Lines Prohibited.

New utility lines would be limited to connection with existing seawater distribution lines, and new electrical lines to connect PV with existing electrical distribution system

IM 2.1.2 Utility Prohibition Zone.

No new utility lines are proposed in the utility prohibition zone.

Policy 2.2 Strengthening the Urban / Rural Boundary through the Protection of Adjacent Agricultural Resources

IM 2.2.1 Setback of Development and Uses from Adjacent Agricultural Use.

Project is not within 300 feet of established crop lines.

Policy 2.3 Designing for the Urban Edge

IM 2.3.1 Cluster Development.

Project construction would be within Research and Education Mixed Use areas.

IM 2.3.2 Impervious Coverage.

Project would increase impervious surface by about 1,500 feet in Lower Terrace Development Zone, which would not cause impervious surface area to exceed the standard set in the IM.

~~IM 2.3.3 Windbreak/Screening Trees~~

IM 2.3.4 Buildout Planning.

Expansion of the outdoor research yard in the Lower Terrace development zone is specifically allowed in the CLRDP.

~~IM 2.3.5 Interim Weed Abatement Measures for Undeveloped Land Within Development Zones.~~

~~**Short-term and Caretaker Accommodations**~~

~~**Policy 2.4 Short-term and Caretaker Accommodations**~~

~~IM 2.4.1 Short-Term Accommodation Use Restrictions.~~

~~IM 2.4.2 Caretaker Accommodations.~~

~~IM 2.4.3 Use Conversion.~~

Campus Land Uses Limited to Marine / Coastal Research and Education, Resource Protection, and Public Access

Policy 2.5 Ensuring Appropriate Land Uses on the Marine Science Campus

Project would renovate and expand an existing coastal dependent research facility.

5.3 Natural Resource Protection

Policy 3.1 Protection of the Marine Environment

IM 3.1.1 Seawater System.

Project would not expand seawater system.

IM 3.1.2 Discharge of Drainage/Storm water.

The project would add 1,500 sf of impervious surface in the Lower Terrace Development Zone. This would result in an increase in runoff to the seawater system discharge. The project includes an infiltration basin to comply with CLRDP requirements for maintaining runoff flow rates and pollutant removal.

Policy 3.2 Protection and Restoration of Habitat Areas

~~IM 3.2.1 Restoration of Wetlands on the Marine Science Campus.~~

~~IM 3.2.2 Management of Terrace Wetlands.~~

~~IM 3.2.3 Protection and Enhancement of Wildlife Movement.~~

~~IM 3.2.4 Management of Special Status Species Habitat.~~

~~IM 3.2.5 Protect Habitat Areas From Human Intrusion.~~

~~IM 3.2.6 Natural Area Management.~~

~~IM 3.2.7 Management of Water Quality and Drainage Features.~~

~~IM 3.2.8 Maintenance and Monitoring of Terrace Habitats.~~

~~IM 3.2.9 Wetland Buffers.~~

~~IM 3.2.10 Natural Areas Habitat Management.~~

IM 3.2.11 CRLF Protection.

Project biotic assessment included survey for CRLF habitat. Project includes mitigation to avoid take of CRLF.

IM 3.2.12 USFWS Consultation Required

Documentation of consultation is included (appendix__)

~~IM 3.2.13 Rodenticides.~~

IM 3.2.14 Non-Invasive Native Plant Species Required.

Planting plans comply with this requirement.

Policy 3.3 Use and Protection of Coastal Waters and Wetlands

IM 3.3.1 Pre-development Evaluation of Wetland Conditions.

A wetland evaluation for the entire campus was completed in 2011. The CLRDP land use designations were amended accordingly as part of CLRDP Amendment #1 in 2013. The Project is consistent with the revised designations.

~~IM 3.3.2 Update CLRDP With Respect to Wetlands.~~

Policy 3.4 Protection of Environmentally Sensitive Areas (ESHAs)

IM 3.4.1 Additional Measures to Protect Habitat Areas.

Project conforms to policies and programs of the CLRDP that buffer sensitive habitats.

IM 3.4.2 Noise Intrusion into Terrace ESHA.

Project would is not within 100 feet of a designated Resource Protection area in the terrace portion of the campus.

IM 3.4.3 Noise Intrusion into YLR.

A noise technical study determined that project operational noise would not result in noise levels in excess of 60 dBA CNEL at the Reserve boundary

IM 3.4.4 Pre-development Evaluation of ESHA Conditions.

A wetland evaluation for the entire campus was completed in 2011. The CLRDP land use designations were amended accordingly as part of CLRDP Amendment #1 in 2013. The Project is consistent with the revised designations.

~~IM 3.4.5 Update CLRDP With Respect to ESHA.~~

Younger Lagoon Reserve

Policy 3.5 Special Protection for Younger Lagoon Reserve

~~IM 3.5.1 Protection and Enhancement of YLR Habitats.~~

~~IM 3.5.2 Protection of Special Status Species in YLR.~~

~~IM 3.5.3 Protection of YLR Resources.~~

~~IM 3.5.4 Development of Monitoring and Maintenance Program.~~

~~IM 3.5.5 Siting of Windbreak/Screening Trees.~~

IM 3.5.6 YLR Manager Consultation.
The Administrative Director of the UCSC Natural Reserves and the Manager of the Younger Lagoon Natural Reserve have been consulted on the scope of the Project (NOID 7 (14-1)) and concur that the Project would not result in significant impacts to the Reserve.

4/10/14

Gage Dayton, Administrative Director, UCSC Natural Reserves Date

IM 3.5.7 Movement Not Visible From YLR (original YLR).
The existing berm will maintain visual separation of mammal pool facility from the original YLR.
~~IM 3.5.8 Protective Measures for YLR (original YLR) in Middle Terrace.~~
Policy 3.6 Public Access to and within YLR (Original YLR)
~~IM 3.6.1 Provision of Controlled Access within YLR.~~
~~IM 3.6.2 Visual Access to YLR.~~
~~IM 3.6.3 Public Beach Access within YLR.~~
Coastal Bluffs and Blufftops
Policy 3.7 Protection of Coastal Bluff and Bluff top Areas
IM 3.7.1 Bluff Setbacks.
Expansion of the marine mammal pool within 100 feet of bluff is consistent with this measure.
~~IM 3.7.2 Coastal Bluff and Bluff top Area Protection and Enhancement Measures.~~
~~IM 3.7.3 Protecting Existing Development from Coastal Erosion.~~
Agricultural Resources
Policy 3.8 Protection of Adjacent Agricultural Resources
~~IM 3.8.1 Cooperation.~~
~~IM 3.8.2 Agreement to Indemnify and Hold Harmless.~~
Cultural Resources
Policy 3.9 Conservation of Cultural Resources
IM 3.9.1 Construction Monitoring.
This requirement is included in Campus construction contract template.
Hazardous Materials Management
Policy 3.10 Hazardous Materials Management
IM 3.10.1 Hazardous Materials Management.
No new hazardous materials storage or use is proposed.
~~IM 3.10.2 Protective Measures for Laydown Yard.~~
Air Quality and Energy Consumption
Policy 3.11 Energy Efficiency in New Construction
IM 3.11.1 Energy Efficiency in New Construction.
Project includes a system to recover heat from pool overflows to eliminate need for additional boiler capacity.
~~IM 3.11.2 Energy Efficiency in Use.~~
Policy 3.12 Air Quality and Energy Conservation through Land Use and Transportation Controls
~~IM 3.12.1 Air Quality and Energy Conservation through On-Campus Short-Term Accommodations.~~
~~IM 3.12.2 Air Quality and Energy Conservation through Controlling Travel Mode Split.~~
~~IM 3.12.3 Air Quality and Energy Conservation through Parking Control.~~
~~IM 3.12.4 Air Quality and Energy Conservation through Alternative Transportation.~~
~~IM 3.12.5 Air Quality and Energy Conservation through Transportation Demand Management.~~
Natural Resource Protection Analysis
Policy 3.13 Natural Resource Protection Analysis Required
Policy 3.14 Permanent Protection
~~IM 3.14.1 Natural Areas Protection.~~

5.4. Scenic and Visual Qualities
Figure 5.4 Development Subareas
Project is in Development Subareas 12 and 13, and is consistent with Figure 5.4
Policy 4.1 Protection of Scenic Views
IM 4.1.1 Location of Development.
Project location is consistent with Figures 5.2. and 5.4.
Policy 4.2 Protection of Scenic Quality
IM 4.2.1 Design Standards and Illustrative Campus Build out Site Plan.
New fencing around the expanded mammal pool facility would be no more than 8 feet tall, in compliance with the fencing/barrier design guidelines in the CLRDP.
IM 4.2.2 Alteration of Natural Landforms.
Project would increase depth of mammal pool to 30 feet but would not alter surface landforms
IM 4.2.3 Building and Other Structure Heights.
New fencing around the expanded mammal pool facility would be no more than 8 feet tall, in compliance with the fencing/barrier design guidelines in the CLRDP.

~~IM 4.2.4 Laboratory Buildings.~~
~~IM 4.2.5 Maximum Building Gross Square Footage.~~
~~IM 4.2.6 Maximum Additional Gross Square Footage in Lower Terrace.~~
~~IM 4.2.7 Construction Materials.~~
~~IM 4.2.8 Building Setbacks.~~
~~IM 4.2.9 Building Length Limitations.~~
IM 4.2.10 Placement of Utility Lines Underground.
All utilities would be underground.
~~IM 4.2.11 Windbreak/Screening Trees.~~
~~IM 4.2.12 Development in Northernmost Portion of Middle Terrace.~~
IM 4.2.13 Development Along Edge of Lower Terrace.
Area of mammal pool facility expansion is in Subarea #13, and will not be taller than the top of the berm
IM 4.2.14 Building Development West of McAllister Way in Lower Terrace.
Mammal pool facility is in Lower Terrace west of McAllister Way. The project would not develop any buildings, and the mammal pool expansion is integrally related to existing research activities in that area.
~~IM 4.2.15 Building Development West of McAllister Way in Middle Terrace.~~
~~IM 4.2.16 Building Development Outside of Subareas Prohibited.~~

Policy 4.3 Visual Intrusion and Lighting

IM 4.3.1 Visual Intrusion into YLR (Original YLR).
With existing berm, activity and light will not be visible from with the original YLR.
IM 4.3.2 Visual Intrusion into YLR (Terrace Lands).
Existing and new fencing would screen the expanded mammal pool facility from other ESHA.
IM 4.3.3 All Lighting.
Low-level LED pathway lighting will be provided along the new ramp to the underground observation room, replacing existing large area flood lights New pole-mounted lighting at the dolphin pool would be designed to limit light spillage. If feasible, switches will be designed to allow staff to turn on only those lights that are needed.
~~IM 4.3.4 Building Lighting.~~
~~IM 4.3.5 Street and Trail Lighting.~~
~~IM 4.3.6 Parking Lot and Maintenance Yard Lighting.~~
~~IM 4.3.7 Sign Lighting.~~
~~IM 4.3.8 Lighting Plan Required.~~

5.5. Circulation and Parking

Figure 5.5 Circulation and Parking Diagram

Auto Circulation

Policy 5.1 Vehicular Access

~~IM 5.1.1 New Circulation System.~~
~~IM 5.1.2 Improve Shaffer Road / Delaware Avenue Intersection~~
~~IM 5.1.3 Shaffer Road Improvements.~~
~~IM 5.1.4 Access for Wildlife Across Shaffer Road (Upper Wildlife Corridor).~~
~~IM 5.1.5 Access for Wildlife Across Shaffer Road (Lower Wildlife Corridor).~~
~~IM 5.1.6 Use of Former Access Road.~~
~~IM 5.1.7 Emergency Access.~~

Travel Mode Split

Policy 5.2 Travel Mode Split

~~IM 5.2.1 Encourage Alternatives to Single-Occupant Vehicle.~~
~~IM 5.2.2 Alternatives to the Single-Occupant Vehicle.~~

Parking

Policy 5.3 Parking for Campus Use and Public Coastal Access

~~IM 5.3.1 All Campus Users Off-Hour Parking.~~
~~IM 5.3.2 Public Coastal Access Parking.~~
~~IM 5.3.3 Campus Entrance Public Coastal Access Parking.~~
~~IM 5.3.4 Middle Terrace Public Coastal Access Parking.~~
~~IM 5.3.5 Lower Terrace Dual Use Parking (Public Coastal Access Parking and Discovery Center Parking).~~
~~IM 5.3.6 Lower Terrace Public Coastal Access Parking.~~
~~IM 5.3.7 Parking Demand Satisfied On-Campus.~~
~~IM 5.3.8 Free and/or Low Cost Public Coastal Access Parking.~~

Parking Supply

Policy 5.4 Parking Supply

~~IM 5.4.1 Development of New Parking~~
~~IM 5.4.2 Lease Agreements~~
~~IM 5.4.3 Distribution and Intensity of Parking~~

Parking Management

Policy 5.5 Parking Management

~~IM 5.5.1 Permits Required.~~
~~IM 5.5.2 Public Coastal Access Parking.~~

IM 5.5.3 Carpools and Vanpools.
IM 5.5.4 Parking Management Strategy for Special and/or Temporary Events.
IM 5.5.5 Entrance Kiosk.
IM 5.5.6 Parking Limitation Seaward of Whale Skeleton.
IM 5.5.7 Parking Enforcement.

Pedestrian and Bicycle Facilities

Policy 5.6 Promotion of Bicycle Use and Walking

IM 5.6.1 Sheltered and Secured Bike Parking.
IM 5.6.2 Bike Parking Outside Buildings.
IM 5.6.3 Personal Lockers and Showers.
IM 5.6.4 Coordinated Marketing with City of Santa Cruz.
IM 5.6.5 Crosswalk Design.
IM 5.6.6 Siting Buildings for Ease of Access.

Transit

Policy 5.7 Promotion of Transit Use

IM 5.7.1 Extension of Santa Cruz Municipal Transit District Transit Services.
IM 5.7.2 Expansion of Shuttle Services.
IM 5.7.3 Physical Infrastructure for Transit.

Transportation Demand Management (TDM) Coordination

Policy 5.8 TDM Coordination

IM 5.8.1 Carpool and Vanpool Services.
IM 5.8.2 TDM Coordination.
IM 5.8.3 Transportation Information.

Traffic Impacts on City Streets

Policy 5.9 Impacts Offset

Circulation and Parking Plan

Project will not generate new vehicle trips or parking demand.

5.6. Public Access and Recreation

Figure 5.6 Coastal Access and Recreation Diagram

Policy 6.1 Public Access to the Marine Science Campus

IM 6.1.1 Free Public Access for Visitors.
IM 6.1.2 Public Access Parking.
IM 6.1.3 Public Access Trails.
IM 6.1.4 Public Access Overlooks.
IM 6.1.5 Docent-Led Tours and Education Programs for the Public.
IM 6.1.6 Educational Programs for Pre-College Students.
IM 6.1.7 Interpretive Information.

Policy 6.2 Management of Public Areas

IM 6.2.1 Public Use Hours for the Marine Science Campus.
IM 6.2.2 Public Trail Continuity.
IM 6.2.3 Access to Resource Protection Areas.
IM 6.2.4 Access to Resource Protection Buffer Areas.
IM 6.2.5 Access to Coastal Bluffs.
IM 6.2.6 Access to Laboratories and Research Areas.
IM 6.2.7 Caretaker Residence and Lab Security.
IM 6.2.8 Bicycles on the Marine Science Campus.
IM 6.2.9 Domestic Pets.
IM 6.2.10 Public Access Signage.
IM 6.2.11 Off-Campus Trail Connectivity.
IM 6.2.12 Maintenance of Existing Public Access.
IM 6.2.13 Public Access to Younger Lagoon Beach.

5.7. Hydrology and Water Quality

Figure 5.7 Utilities Diagram

Policy 7.1 Productivity and Quality of Coastal Waters

IM 7.1.1 Management of Storm water and Other Runoff.
Project includes a new infiltration basin the filter and treat runoff.
IM 7.1.2 Water Quality Standards.
Project includes a new infiltration basin the filter and treat runoff.
IM 7.1.3 Pre- and Post-Development Flows.
Project includes a new infiltration basin the filter and treat runoff.
IM 7.1.4 Pre-Development Drainage Patterns Defined.
IM 7.1.5 Pre-Development Drainage Peak Flow Rates Defined.
IM 7.1.6 Groundwater Recharge.
New infiltration basin will be constructed to meet this requirement.

IM 7.1.7 Seawater System (Seawater Containment)
Project site is served by seawater system. Discharges from the system and overflows from the pools would continue to flow to the seawater system discharge.
~~IM 7.1.8 Irrigation and Use of Chemicals for Landscaping.~~
IM 7.1.9 Wastewater.
Project will not generate additional wastewater.
IM 7.1.10 Elements of the Storm water Treatment Train.
A new infiltration basin will be constructed.
~~IM 7.1.11 Runoff Containment for Laydown Yard and Food Service Washdown Areas.~~
IM 7.1.12 Location of Treatment Train Components.
New infiltration basin will be constructed within the Lower Terrace development Zone.
IM 7.1.13 Permeable Hardscape.
Project would not construct new parking areas, paths or roads.
IM 7.1.14 Ocean Discharge.
Site discharges to seawater system, which is covered under the NPDES General Permit for Discharges from Aquaculture and Aquariums (NPDES Permit No. CAG993003)
~~IM 7.1.15 Drainage System Interpretive Signs.~~
IM 7.1.16 Design of Vegetated Storm water Basins.
New infiltration basin will be within the Lower Terrace development zone and will be planted with native vegetation.
IM 7.1.17 Designation of Treatment Train.
New infiltration basin will be constructed to meet this standard
Policy 7.2 Long-Term Maintenance and Monitoring
IM 7.2.1 Drainage System Monitoring and Maintenance.
New infiltration basin will be incorporated into maintenance program.
~~IM 7.2.2 Storm water System Natural Features Maintenance.~~
IM 7.2.3 Drainage System Sampling.
Site discharges to seawater system, which is covered under the NPDES General Permit for Discharges from Aquaculture and Aquariums (NPDES Permit No. CAG993003),which includes sampling requirements.
~~IM 7.2.4 Long-Term Maintenance of Storm water System.~~
Policy 7.3 Drainage Discharge Points
~~IM 7.3.1 Discharge to Younger Lagoon Reserve.~~
IM 7.3.2 Discharge Siting and Design.
New impervious surface will discharge to existing seawater return outfall.
Policy 7.4 Drainage Plan Required

5.8 Utilities
Policy 8.1 Provision of Public Works Facilities
IM 8.1.1 Sizing of Utilities.
No new utility lines other than connecting new pools to existing utilities, moving existing utility lines outside of footprint of pool expansion area, and connection to new PV or solar thermal systems.
IM 8.1.2 Seawater System.
Project will not expand seawater system.
Policy 8.2 Protection of Biological Productivity and Quality of Coastal Waters When Providing Public Works Facilities
IM 8.2.1 Installation of New Utility Lines and Related Facilities.
All new utility lines would be within CLRDP development zones.
~~IM 8.2.2 Seawater System.~~

IM 8.2.3 Evaluation of Western Utility Corridor.
Policy 8.3 Water Conservation Required
Project will not increase campus water use.
Policy 8.4 Impacts to City Water and Sewer Systems Offset
Project will not increase campus water use or discharge to sewer system.
Policy 8.5 Utility Plan Required

CHAPTER 6 Design Guidelines

6.1 Building Design
6.2 Campus Street Design
6.3 Parking Design
6.5 Landscape Design
6.6 Lighting Design
6.7 Signage Design
6.8 Fence / Barrier Design

CHAPTER 7 Illustrative Campus Buildout Site Plan and Preliminary Designs

CHAPTER 8 Development Procedures

This NOID and the public notification process is submitted in conformance with the requirements of the CLRDP.

CHAPTER 9 Capital Improvement Program

APPENDIX A Resource Management Plan

APPENDIX B Drainage Concept Plan

1c. Environmental Compliance Documentation

See Section 3

1d. Technical Reports

NA

1e. Consultation Documentation with other Agencies

UC Santa Cruz Mail - Re: UCSC Marine Science Campus: Mammal Pool... https://mail.google.com/mail/u/0/?ui=2&ik=cac2c222b6&view=pt&searc...

Google @ UCSC

Alisa Klaus <aklaus@ucsc.edu>

Re: UCSC Marine Science Campus: Mammal Pool Renovation and Expansion Project

1 message

Mitcham, Chad <chad_mitcham@fws.gov> Fri, Oct 25, 2013 at 3:45 PM

To: Alisa Klaus <aklaus@ucsc.edu>

Alisa,

We've reviewed your request for concurrence for the UCSC Marine Science Campus Expansion Project. It appears that the possibility of California red-legged frogs (CRLF) occurring at the project site is low; however, we recommend the implementation of the proposed measures (1a - 1d) that are contained in the biological assessment (attached) to ensure no take of CRLF. With the implementation of the proposed measures consider this email our authorization to conduct the proposed project. Keep in mind that this authorization does not allow for take of federally listed species. If a CRLF is observed onsite in an area to be impacted work must cease and the Service notified. Thank you for your coordination and feel free to contact me if you have any questions.

Chad Mitcham
Fish and Wildlife Biologist
US Fish and Wildlife Service
Ventura FWO, Santa Cruz sub-office
1100 Fiesta Way, Watsonville 95076
Tel: 805-512-6805

On Thu, Oct 10, 2013 at 10:16 AM, Alisa Klaus <aklaus@ucsc.edu> wrote:

Dear Chad--

We are preparing a Draft Initial Study/Mitigated Negative Declaration for a project at the UCSC Marine Science Campus that would renovate and expand the existing marine mammal pool facility on the lower terrace and, and install some temporary mammal pool tanks within the CDFW mammal tank yard in the middle terrace. For the most part, construction will within existing developed and fenced research yards, but the project also includes expansion of the yard on the lower terrace. This will require excavation into the vegetated berm that separates the Long Marine Lab development from Younger Lagoon Reserve.

Mark Allaback (Biosearch Associates) and Tom Mahoney (Coast Range Biological) have prepared a biotic assessment for the Project (attached). Their report concluded that the probability of CRLF is present is low, but recommends mitigation measures to address potential construction impacts.

This email is to request your concurrence with the determination that, with implementation of these mitigation measures, the Project would not result in take of CRLF. I am attaching the biotic assessment report, which includes a brief project description and maps showing the project areas, as well as the biologists' findings and recommended mitigation measures.

Please let me know if you have any comments or questions, and if you would like to visit the site.

Thank you---Alisa

--
Alisa Klaus
Senior Environmental Planner
UCSC Physical Planning and Construction
(831) 459-3732

1 of 1 11/12/2013 9:11 AM

1f. Implementing Mechanisms

1g. Correspondence Received

1h. Project Manager

Christy Ishimine Hatfield, 831.459.2170

2. University Approval Documentation

Drafted by: A. Klaus
Reviewed by: D. Fitch

March 5, 2014

ITEM FOR ACTION

FOR VICE CHANCELLOR APPROVAL

DESIGN APPROVAL, MARINE MAMMAL POOL EXPANSION AND RENOVATION PROJECT

The Campus Architect, UC Santa Cruz Physical Planning and Construction recommends that, upon review and consideration of the potential for environmental consequences of the proposed Marine Mammal Pool Expansion and Renovation Project as described in the Initial Study/Mitigated Negative Declaration that was prepared for the Project, and in accordance with the Regents Delegation of Authority DA 2575 delegates to Chancellors, "the authority to approve design for projects with a total individual project cost not exceeding $10,000,000." Projects over $10,000,000 require design approval by the Committee on Grounds and Buildings of The Regents. On February 28, 2014, the Chancellor re-delegated to the Vice Chancellor – Business and Administrative Services authority to approve design of projects with costs not exceeding $10,000,000, the Vice Chancellor – Business and Administrative Services hereby takes the following actions:

1. Review and consider the Initial Study/Mitigated Negative Declaration (Attachment #2) and the Final Environmental Impact Report prepared for the Marine Science Campus Coastal Long Range Development Plan (Attachment #3), from which the Initial Study/Mitigated Negative Declaration is tiered.
2. Adopt the Mitigated Negative Declaration and Initial Study and Mitigation Monitoring and Reporting Program (Appendix C to the Initial Study).
3. Adopt the Findings set forth in Attachment #4 hereto.
4. Approve the design and construction of the Marine Mammal Pool Expansion and Renovation Project.

The Marine Mammal Pool Expansion and Renovation Project falls within the authority of the Vice Chancellor – Business and Administrative Services for approval.

Enclosed for the Vice Chancellor's consideration and approval are the following documents, all of which have been prepared in consultation with the Office of the President and the Office of General Counsel:

Marine Mammal Pool Expansion and Renovation Project

- Attachment 1. Project Graphics
- Attachment 2. Mammal Pool Expansion and Renovation Project Final Tiered Initial Study/Mitigated Negative Declaration
- Attachment 3. Marine Science Campus Coastal Long Range Development Plan EIR (on CD)
- Attachment 4. Mammal Pool Expansion and Renovation Project CEQA Findings

I recommend approval of this project. Physical Planning and Construction staff are available to answer any questions that you have. Please return the signed documents to PP&C for appropriate distribution and filing.

RECOMMENDED

John Barnes 3.18.14

John Barnes, Campus Architect Date

APPROVED

Sarah C. Latham 3/19/14

Sarah C. Latham, Vice Chancellor, Business and Administrative Services Date

ATTACHMENTS:

Attachment 1. Project Graphics

Attachment 2. Mammal Pool Expansion and Renovation Project Final Tiered Initial Study/Mitigated Negative

Attachment 3. Marine Science Campus Coastal Long Range Development Plan EIR (on CD)

Attachment 4. Mammal Pool Expansion and Renovation Project CEQA Findings

3. Environmental Compliance Documentation

Attached Final Initial Study – Mitigated Negative Declaration

Notice of Determination Appendix D

To: ☒ Office of Planning and Research
PO Box 3044, 1400 Tenth Street, Room 222
Sacramento, CA 95812-3044
☐ County Clerk County of ________

From: University of California Santa Cruz
Physical Planning and Construction
1156 High Street
Santa Cruz, California 95064

Subject: Filing of Notice of Determination
in Compliance with Section 21108 or 21152 of the Public Resource Code.

State Clearinghouse Number:	2013112013
Project Title:	Mammal Pool Renovation and Expansion Project
Project Location:	UC Santa Cruz Marine Science Campus, 100 Shaffer Rd., Santa Cruz
County:	Santa Cruz

Project Description: The Project would renovate and expand the existing 20,200-sf outdoor marine mammal pool facility. The Project would expand the facility by about 2,894 sf to accommodate enlargement of the largest pool up to 25 feet in length. The expansion would involve removing an existing fence, excavation of a portion of a berm, excavation to increase the maximum depth of the expanded pool to 30 feet, construction of a new retaining wall, and new fencing. The Project also includes improvements to existing above-ground tanks and the installation of new tanks at the California Department of Fish and Wildlife facility at the Marine Science Campus, to provide temporary accommodation of the animals that would be displaced by construction.

This is to advise that the University of California (☒ Lead Agency ☐ Responsible Agency) has approved the above-described project on March 19, 2014 and has made the following determinations regarding the above-described project:

1. The project ☐ will ☒ will not have a significant effect on the environment.
2. ☐ An Environmental Impact Report was prepared for this project pursuant to the provisions of CEQA.
   ☒ A Negative Declaration was prepared for this project pursuant to the provisions of CEQA.
3. Mitigation measures [☒ were ☐were not] made a condition of the approval of the project.
4. A mitigation reporting or monitoring plan [[☒ was ☐ was not] adopted for this project.
5. A statement of Overriding Considerations [☐ was ☒was not] adopted for this project.
6. Findings [☒ were ☐ were not] made pursuant to the provisions of CEQA.

This is to certify that the final Initial Study with comments and responses, , and record of project approval are available to the general public at the office of Physical Planning and Construction, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA.

Signature: Alisa Klaus
Title: Senior Environmental Planner
Date: March 20, 2014

RECEIVED
MAR 21 2014
STATE CLEARING HOUSE

Dated Received for filing at OPR:

Authority cited: Sections 21083 and 21087, Public Resources Code.
Reference: Sections 21000-21174, Public Resources Code. Revised 2004

4. Plans, Specifications, etc.

(this section used if project documentation is large format or extensive)

Attached Design Graphics

5. Technical Reports

NA

Appendix 6. Publications

Invasive Plant Science and Management 2014 7:590–598

Efficacy of Exotic Control Strategies for Restoring Coastal Prairie Grasses

Karen D. Holl, Elizabeth A. Howard, Timothy M. Brown, Robert G. Chan, Tara S. de Silva, E. Tyler Mann, Jamie A. Russell, and William H. Spangler*

Restoration in Mediterranean-climate grasslands is strongly impeded by lack of native propagules and competition with exotic grasses and forbs. We report on a study testing several methods for exotic plant control combined with planting native grasses to restore prairies in former agricultural land in coastal California. Specifically we compared tarping (shading out recently germinated seedlings with black plastic) once, tarping twice, topsoil removal, herbicide (glyphosate), and a control treatment in factorial combinations with or without wood mulch. Into each treatment we planted three native grass species (*Elymus glaucus, Hordeum brachyantherum,* and *Stipa pulchra*) and monitored plant survival and cover for three growing seasons. Survival of native grass species was high in all treatments, but was slightly lower in unmulched soil removal and control treatments in the first 2 yr. Mulching, tarping, and herbicide were all effective in reducing exotic grass cover and enhancing native grass cover for the first 2 yr, but by the third growing season cover of the plant guilds and bare ground had mostly converged, primarily because of the declining effects of the initial treatments. Mulching and tarping were both considerably more expensive than herbicide treatment. Topsoil removal was less effective in increasing native grass cover likely because soil removal altered the surface hydrology in this system. Our results show that several treatments were effective in enhancing native grass establishment, but that longer term monitoring is needed to evaluate the efficacy of restoration efforts. The most appropriate approach to controlling exotics to restore specific grassland sites will depend not only on the effectiveness, but also on relative costs and site constraints.

Nomenclature: Glyphosate; blue wild rye, *Elymus glaucus* Buckley; meadow barley, *Hordeum brachyantherum* Nevski; purple needlegrass, *Stipa pulchra* Hitchc.

Key words: Cost of restoration, grassland, herbicide, mulch, solarization, tarping, topsoil removal.

Temperate and Mediterranean grasslands worldwide, and in California in particular, are highly threatened ecosystems that are the focus of extensive restoration efforts (Hoekstra et al. 2005; Stromberg et al. 2007). Recovery of Mediterranean grasslands is limited both by competition from numerous exotic grasses and forbs and a lack of native propagules (Corbin et al. 2004; Gaertner et al. 2009; Seabloom et al. 2003). Therefore, restoration strategies typically include efforts to both reduce exotic plant cover and reintroduce native species (Corbin et al. 2004; Stromberg et al. 2007). While many different strategies are used to control exotic species and tip the balance toward natives, some are not feasible in the remaining habitat fragments bordered by human developments that characterize most coastal systems. For example, burning often is highly restricted because of concerns regarding air quality and risk to nearby properties (Keeley 2002), and cattle grazing may not be economically profitable (Huntsinger et al. 2010). Land managers commonly use herbicides for exotic control given their cost effectiveness, but their use may be limited because of concerns about their effects on nearby human populations and ecosystems (Cornish and Burgin 2005), which have resulted in some local ordinances constraining their use (e.g., City of Sebastopol 2000).

Therefore, research is needed on non-chemical exotic management strategies, among which are mulching, tarping, and topsoil removal. Wood mulch is commonly used in restoration to reduce germination of and competition with exotic plants, as well as to ameliorate temperature extremes, enhance soil moisture retention, and increase the accumulation of organic matter (Biederman

DOI: 10.1614/IPSM-D-14-00031.1

* First, fourth, fifth, and seventh authors: Professor (ORCID: 0000-0003-2893-6161) and Undergraduate Students, Environmental Studies Department, University of California, Santa Cruz, CA 95064; second, third, and eighth authors: Manager, Restoration Steward, and Restoration Steward, Natural Reserves System, University of California, Santa Cruz, CA 95064; sixth author: Undergraduate Student, Ecology and Evolutionary Biology Department, University of California, Santa Cruz, CA 95064. Corresponding author's E-mail: kholl@ucsc.edu

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Constraints on Direct Seeding of Coastal Prairie Species: Lessons Learned for Restoration

by Karen D. Holl[1], Grey F. Hayes[2], Coral Brunet[3], Elizabeth A. Howard[4], Lewis K. Reed[5], Mickie Tang[6], and Michael C. Vasey[7]

Introduction

California coastal prairies have been adversely affected by agriculture, development, and changing disturbance regimes, and they are the focus of extensive restoration efforts given the high number of species of concern they host (Stromberg et al. 2001, Ford and Hayes 2007). Grassland restoration throughout California generally involves reducing exotic cover and reintroducing native species, given that many native grasses and forbs are absent from both the seed bank and standing vegetation community and dispersal is limited (Seabloom et al. 2003, DiVittorio et al. 2007, Stromberg et al. 2007). One frequently suggested and implemented strategy for reintroducing native propagules is seeding, as the associated costs are often less than planting seedlings (Moore et al. 2011). Some past studies in both interior and coastal California grasslands have suggested that seeded grasses can establish (Buisson et al. 2008) and outcompete exotics over a period of a few years (Kephart 2001, Seabloom et al. 2003, Stromberg et al. 2007). A much larger number of studies, however, suggests that establishment from seed is highly unpredictable (Dyer et al. 1996, Hamilton et al. 1999, Orrock et al. 2008, Hayes and Holl 2011, Seabloom 2011), which the authors attribute to variable rainfall, competition with exotic species, and seed predation.

Here, we summarize results from three studies in the vicinity of Santa Cruz, California, that tested seeding of native grass and forb species into weed-dominated coastal prairies combined with different management regimes designed to reduce exotic grass and forb cover. Our results show low rates of establishment for most species seeded into existing weedy coastal prairie, which suggests that this approach has limited utility for coastal prairie restoration. All study sites were located in coastal terrace prairies within 2 km of the ocean that were dominated by exotic grasses and forbs. Seeds were collected locally when possible or obtained from commercial suppliers of seed from the closest available source population. Seeding rates varied across studies based on seed availability, viability (percent pure live seed or germination), and size (fewer seeds of larger-seeded species), and all fell in the middle to high end of the range of seeding rates typically used for California grasslands (Stromberg et al. 2007).

Case Study 1

We seeded a number of grass and forb species as part of a study designed to test the effect of mowing on the balance between native and exotic vegetation (Hayes and Holl 2011). The study was conducted at three sites: UC Santa Cruz (UCSC) campus (36° 59' 5.5" N, 122° 3' 0.9" W), Swanton Pacific Ranch (37° 4' 13.4" N; 122° 15' 0.0" W), and land owned by the Elkhorn Slough Foundation (36° 52' 4.3" N, 121° 44' 23.8" W). All sites had sandy loam soils >1 m deep and slopes of <10°. All sites were likely lightly surface tilled (<5 cm) in the early 1900s and grazed periodically between the 1950s and the start of the study. The sites were dominated by exotic grasses (primarily *Brachypodium distachyon, Bromus* spp., *Festuca myuros,* and *Festuca perenne*) and exotic forbs (largely *Erodium* spp., *Geranium dissectum, Plantago lanceolata,* and *Trifolium* spp.). See Hayes and Holl (2011) for a detailed description of site conditions and species composition.

We manually broadcasted seeds in nine 3 × 3 m plots at Swanton and UCSC without removing the existing vegetation cover or taking any additional management actions (e.g., raking in seeds or providing supplemental watering). In fall 2003, we seeded 500 seeds m^{-2} of each of five species: *Danthonia californica* and *Stipa pulchra* (native perennial grasses), *Castilleja exserta* spp. *exserta* and *Gilia capitata* (native annual forbs), and *Sisyrinchium bellum* (native perennial forb). In fall 2004, we reseeded the same species, as well as *Calandrinia ciliata, Eschscholzia californica,* and *Lupinus nanus* (native forbs), at a density of 500 seeds m^{-2} per species. Since most species seeded in 2003 and 2004 had very low or no establishment, we tried again to enhance species richness in these plots by seeding five annual and one perennial (*Achillea millefolium*) forb species in fall 2009 and 2010 at one to three sites (Table 1); some species were not seeded at all sites due to the presence of existing populations of the species or limited seed. We recorded the number and cover of seedlings beginning the spring following seeding through spring 2012 for all species. We also conducted greenhouse germination tests for seeds used in 2009 and 2010 to assess viability.

We recorded no establishment of seedlings in the first growing season following the 2003 seeding, during which annual rainfall was

continued next page

[1]Karen D. Holl is Professor, Environmental Studies Department, UC Santa Cruz. [2]Grey F. Hayes is Director, Elkhorn Slough Coastal Training Program, Watsonville. [3]Coral Brunet is a teacher in the El Dorado County Department of Education. [4]Elizabeth A. Howard is Reserve Manager at the Younger Lagoon Natural Reserve, UC Santa Cruz Natural Reserve System. [5]Lewis K. Reed is Reserve Steward, Bodega Marine Reserve, UC Davis. [6]Mickie Tang is Research Assistant, Audubon California Starr Ranch Sanctuary, Orange County. [7]Michael C. Vasey is Interim Director, San Francisco Bay National Estuarine Research Reserve, Tiburon.

Table 1. Seeding and germination rates in the greenhouse and field for forb seedlings in fall 2009 and 2010 in Case Study 1. All species are annuals except *A. millefolium*. Values are means ± 1 SE. Seedling density in the field is reported for the growing season after seeding (either spring 2010 or 2011) and spring 2012.

Species	Year Seeded	No. of sites	Seeds m^{-2}	Greenhouse germination (%)	Seedlings m^{-2} in spring following seeding	% yield	Seedlings m^{-2} in spring 2012
Achillea millefolium	2009	2	65	66.0 ± 4.9	0	0	0
Clarkia davyi	2010	3	700	26.8 ± 8.4	1.7 ± 0.7	0.1	0.6 ± 0.3
Deinandra corymbosa	2009	1	245	33.3 ± 0.6	0	0	0
	2010	1	60	11.0 ± 6.4	0	0	0
Madia sativa	2009	1	75	30.5 ± 0.7	1.8 ± 1.2	2.4	1 seedling*
Navarretia squarrosa	2009	2	500	81.8 ± 8.4	0.3 ± 0.3	<0.1	1 seedling*
Trifolium willdenovii	2009	3	200	no data	0	0	0
	2010	3	500	49.2 ± 8.1	0	0	0
TOTAL	2009		585				
	2010		1260				

*Only 1 seedling was observed in all the quadrats surveyed.

Direct Seeding *continued*

close to average (Hayes and Holl 2011). Two species (*Stipa pulchra* and *Sisyrinchium bellum*) had higher cover in seeded vs. non-seeded plots at one or both of the sites 2–4 years following the 2004 seeding, during which rainfall was above average (Hayes and Holl 2011). Two species (*Eschscholzia californica* and *Gilia capitata*) had higher establishment in seeded plots in the first growing season, but not thereafter. The remaining four species showed little (<4 seedlings total at all sites) or no establishment in seeded plots. There was no difference in exotic species composition in seeded vs. unseeded plots, and inter-annual variation in vegetation composition is described in detail in Hayes and Holl (2011). In 2012 (7.5 years after seeding), both *Stipa pulchra* and *Sisyrinchium bellum* cover remained higher in seeded vs. unseeded plots (*Stipa*—seeded: 11.4 ± 2.5%, unseeded: 1.9 ± 2.5, F = 11.0, p = 0.0022; *Sisyrinchium*—seeded: 2.2 ± 0.7%, unseeded: 0.0 ± 0.0, F = 7.4, p = 0.0107, Fig. 1), which shows that these two species were able to establish successfully from seed.

Of the six species seeded in 2009 and 2010, only half established in the field experiments (Table 1) and only one (*Madia sativa*) had a yield rate (number of seedlings per number of seeds) of >0.1%. Viability was not likely to be the limiting factor in this case, as 11–82% of the seeds germinated in the greenhouse (Table 1). Rainfall was below average in fall 2009, whereas rainfall was well above average throughout the 2010–2011 growing season.

Figure 1. UCSC experimental plots from Case Study 1. Note *Stipa pulchra*, one of the few species that established from seed. *Photo: Lewis Reed*

Case Study 2

In a second study, we either used controlled burns (conducted in late September 2007 using a burn box) to reduce above-ground vegetation or scraped off the top 5 cm of soil to reduce competition by removing vegetation and the exotic annual forb and grass seed bank (Buisson et al. 2006), as well as to create optimal habitat for recruitment of the endangered Ohlone tiger beetle (*Cicindela ohlone*). Each treatment was replicated in two blocks of ten 2 × 2 m plots in two different areas of coastal prairie with sandy loam soils on the UCSC campus (n = 40 per treatment). Vegetation prior to treatments and in control plots consisted of a dense cover (~90%) of exotic grasses (primarily *Avena barbata, Briza maxima, Bromus hordaceous,* and *Festuca myuros*) and forbs (mostly *Medicago polymorpha, Plantago lanceolata,* and *Erodium botrys*). Native perennial grasses and forbs made up ~10% of the cover and consisted of species such as *Danthonia californica, Ranunculus californicus, Stipa pulchra, Chlorogalum pomeridianum, Eschscholzia californica,* and *Sisyrinchium bellum*. The plots were seeded at a rate of 1,150 seeds m^{-2} with seven native annual forbs in fall 2007 (Table 2) to try to enhance the diversity of this guild, and no supplemental water was provided. We monitored establishment of seeded species for the two subsequent growing seasons (spring 2008 and 2009). Seed viability was not tested in the greenhouse, so it is possible that low viability may have affected establishment.

continued next page

Table 2. Seeding rate and annual forb seedling density in scraped plots for the first growing season following seeding for Case Study 2. Values are means ± 1 SE.

Species	Seeds m^{-2}	Seedlings m^{-2}	% yield
Castilleja densiflora	113	0.0 ± 0.0	0.0
Clarkia rubicunda	465	1.9 ± 0.6	0.4
Lasthenia californica	276	1.2 ± 0.4	0.4
Layia platyglossa	41	0.7 ± 0.2	1.7
Lepidium nitidum	32	0.5 ± 0.2	1.4
Lupinus nanus	15	0.4 ± 0.2	2.5
Triphysaria eriantha	212	0.4 ± 0.1	0.2
TOTAL	1154	5.0 ± 1.2	0.4

Direct Seeding *continued*

One individual of *Lasthenia californica* was the only seedling from seeded species observed in burned plots in the first growing season when annual rainfall was close to average, and no seeded individuals were observed in burned plots in the second growing season. Only a few individuals of six of the seven species were observed in scraped plots in the first growing season (Table 2), despite the fact that scraping substantially reduced exotic cover and increased bare ground in scraped plots (46.5 ± 2.4%), as compared with burn (9.4 ± 0.9%). By the second growing season, there were only a few individuals of *Layia platyglossa, Lasthenia californica,* and *Lupinus nanus* in some scraped plots, at which time approximately half of these plots were still ~25% bare of vegetation.

Case Study 3

The third study was conducted in a weedy, moist, formerly coastal prairie site that had been used for several decades for agriculture and then had been abandoned for over 20 years at the UC Younger Lagoon Reserve located in Santa Cruz, California (+36° 57' 00.75", -122° 03' 47.80"). At the time of the study site initiation, it was covered by nearly 100% exotic species, dominated by exotic grasses (primarily *Festuca perenne* and *Bromus diandrus*) and exotic forbs (such as *Raphanus sativus, Medicago polymorpha,* and *Helminthotheca echioides*). In summer 2011, plots were mowed to reduce the cover of standing thatch and fenced to minimize herbivory from rabbits. During October 2011 following the first rain and emergence of annual weeds, the site was treated with a broad-spectrum herbicide (2.5% glyphosate). Immediately prior to seeding in November 2011, any exotic regrowth was treated with herbicide and then the thatch was raked off the plots. In five 10 × 10 m plots, we seeded each of eight coastal prairie grasses and forbs (Table 3) into a single, 10-m long row consisting of two hand-cut furrows. Seeds were hand-buried to a depth of 7–10 mm to simulate drill seeding and manually tamped to improve seed–soil contact. Given the small size of the plots, a regular drill seeder was not used. Due to unusually dry conditions, the plots received supplementary water in December to help ensure germination and survival of germinated seedlings. We planted the same species as plugs in rows in five additional 10 × 10 m plots in January 2012. In April–May 2012 and 2013, each seeded row was surveyed for planted seedlings, and plant survival was recorded in planted plots. We also conducted greenhouse germination studies to assess seed viability.

In the greenhouse, most species had germination rates >50%; however, *Symphyotrichum chilense* and *Juncus patens* had very low germination (Table 3). Two forb species, *Trifolium willdenovii* and *S. chilense*, were not observed in the field during the first year. For the remaining three forb species (*Achillea millefolium, Clarkia davyi,* and *Grindelia stricta*), percent yield (seedlings/live seed planted ×100) was 1–2% in Year 1 (Table 3), but no individuals of the two perennial species survived until the second year. In the field, the grasses and one rush species planted could not be distinguished from the large number of exotic grass seedlings (Fig. 2) and, therefore, were not quantified; but even by the second year we did not record identifiable individuals of those species, and the sites retained a dense cover of the exotic grasses and forbs present prior to the initiation of the experiment. As a comparison, 72% of planted plugs survived in Year 1 and 40% in Year 2, ranging in survival from 64% for *Hordeum brachyantherum* to 13% for *S. chilense* in Year 2 (Tang 2013).

Figure 2. Recently germinated *Clarkia davyi* seedling underneath dense exotic grass cover at Younger Lagoon Reserve (Case Study 3). *Photo: Lewis Reed*

Discussion and Conclusions

The results of the three case studies presented, as well as Buisson et al. (2006), show extremely low establishment rates in coastal prairie from seed with yields of 1–2% at best in the first year and numbers

continued next page

Table 3. Seeding and germination rates in the greenhouse and the first year in the field for Case Study 3.* Values are means ± 1 SE. Note that units of germination in the field are per meter of drill-seeded row.

Species	Growth form	Seeds m^{-2}	Greenhouse germination (%)	Mean ± seedlings m^{-1}	SE % yield
Clarkia davyi	Annual forb	135	50 ± 4.5	3.0 ± 1.1	2.1
Trifolium willdenovii	Annual forb	90	36 ± 4.9	0	0
Symphyotrichum chilense	Perennial forb	180	10 ± 0.4	0	0
Achillea millefolium	Perennial forb	180	76 ± 4.7	2.6 ± 0.7	1.4
Grindelia stricta	Perennial forb	135	85 ± 2.4	1.7 ± 0.6	1.2
Bromus carinatus	Perennial grass	135	61 ± 3.7	no data	
Hordeum brachyantherum	Perennial grass	135	65 ± 2.7	no data	
Stipa pulchra	Perennial grass	135	46 ± 3.8	no data	
Juncus patens	Perennial sedge	180	<2	no data	
TOTAL		1305			

*It was impossible to reliably identify recently germinated native grass and rush seedlings in the field from the huge number of recently germinated exotic grass seedlings; no native grass and rush seedlings were observed in larger size classes.

Direct Seeding *continued*

declining in subsequent years. Of the many species we seeded, only *Stipa pulchra* and *Sisyrinchium bellum* established populations (and only at one site) that were observed in any abundance after the first 2 years. We reiterate, however, that we were unable to reliably identify native grass seedlings in the third Case Study, and some seed may have germinated after the second year of Case Studies 2 and 3. There are several reasons for such low yield rates: highly variable rainfall typical of California, which often results in seedling desiccation (Hamilton et al. 1999, DeFalco et al. 2012); competition with abundant exotic grasses, the seeds of which often outnumber and germinate before natives (DiVittorio et al. 2007, Abraham et al. 2009, Wainwright et al. 2012); and high levels of herbivory (Orrock et al. 2008, Maze 2009, DeFalco et al. 2012). These factors also present challenges to restoring coastal prairies by planting seedlings, but outplanting larger seedlings overcomes losses due to seed predation, failed germination, and mortality of recently germinated seedlings, which are typically quite high (Clark et al. 2007, James et al. 2011).

We note that results of direct seed-sowing may be more favorable when seeds are 1) drill seeded into recently abandoned agricultural lands where weeds have been controlled for many years, thereby reducing the exotic seed bank and competition, and/or 2) extensive exotic control measures are undertaken after seeding (Lulow 2008, Nyamai et al. 2011, Watsonville Wetland Watch 2013). Typically, efforts to improve seed–soil contact, such as drill seeding, tamping, or using a heavy roller, improve establishment from seed (Rotundo and Aguiar 2005, Desimone 2011, DeFalco et al. 2012). The low establishment from our simulated drill seeding likely resulted from a low rainfall year combined with high cover of exotic grasses (particularly *Festuca perennis*), although it is important to note that we found low establishment from seed in years that annual rainfall spanned from below to well above the average.

One important consideration is the relative cost of seeding vs. other revegetation methods. Typically, seeding is much less expensive than planting seedlings, due to nursery propagation and outplanting costs for seedlings (Moore et al. 2011). Relative costs, however, vary greatly depending on 1) whether seed is purchased from a seed supplier with propagation fields or locally hand collected, 2) germination rates, and 3) labor costs, particularly if volunteer labor is available for small restoration planting efforts. For example, in our third Case Study, the contract for collecting and processing seed was double that for producing plugs for a similar area of land, and the project had substantial volunteer labor support to reduce the cost of planting plugs. Moreover, plug planting resulted in much higher cover of native grasses and forbs than did seeding (Tang 2013).

In summary, our results from multiple studies demonstrate that sowing seeds into weed-dominated coastal prairies, where exotic plant competition is high and rainfall is unpredictable, is likely to have a low success rate. Further research on the prospective value of direct seeding in coastal prairies should focus on pre-planting site preparation and post-planting weed control, which ameliorates exotic plant competition and methods for overcoming drought stress during initial years of establishment.

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Management Implications

Restoring California grasslands requires extensive efforts to reduce competition with exotic grasses and forbs and reintroduction of native species. Herbicides are frequently used to control exotic species, but given various concerns about their negative effects, cost-effective non-chemical strategies are needed. We compared five strategies for controlling exotic species in former agricultural lands to restore California coastal prairie species: tarping (shading out recently germinated seedlings with black plastic) once, tarping twice, topsoil removal, glyphosate herbicide, and wood mulch. Into each treatment we planted three native perennial grass species (blue wild rye, meadow barley, and purple needlegrass) and monitored plant survival and cover for three growing seasons. Our results show that using black plastic tarps to shade out recently germinated seedlings and applying wood mulch are both effective non-herbicide methods for reducing exotic grass cover and enhancing native grass cover in the initial stage of grassland restoration. Both approaches, however, are considerably more expensive than using herbicides unless they can be done with volunteer labor. Overall, tarping twice was no more effective than tarping once, so we do not recommend a second tarping. Removing topsoil resulted in a sufficient change in hydrology that the sites experienced extended flooding in the first year which reducing native grass survival, but this approach may be more effective in sites with different topography. The effectiveness of our restoration treatments declined substantially by the third year, highlighting the importance of ongoing monitoring to compare the efficacy of restoration strategies, combined with continued exotic control. Herbicide, tarping, and mulch were all effective in reducing exotic grasses for the first 2 yr of restoration. The most cost-effective strategy for reducing exotic cover and restoring native grasses will depend on project-specific factors, including cost of labor and supplies, as well as local herbicide use constraints.

and Whisenant 2009; Chalker-Scott 2007; Concilio 2013). Solarization is another potential exotic control strategy in which a clear or black plastic tarp is placed on bare ground to sterilize the soil. This strategy is primarily used in hot, arid conditions which result in sufficiently high soil temperatures that kill the seed bank and/or recently germinated seedlings (Concilio 2013; El-Keblawy and Al-Hamadi 2009; Lambrecht and D'Amore 2010; Moyes et al. 2005), but may be less effective close to the coast where summer temperatures are moderated by the ocean and fog (Stapleton 2000). A related, but less commonly used, alternative is to cover the soil with black plastic tarps to shade out recently-germinated exotic seedlings (hereafter referred to as tarping); this method has been successful in less extreme climatic conditions (Marushia and Allen 2011; Stapleton 2000). Another possible, non-chemical approach to controlling exotic plants is removing the top layer (5 to 10 cm (2 to 4 in) of soil which can serve to reduce the exotic seed bank and decrease soil nitrogen (Buisson et al. 2008; Buisson et al. 2006; Olsson and Ödman 2014).

We report on an experiment testing the efficacy of several methods to both reduce cover of exotic grasses and forbs and enhance the survival and cover of native grasses planted into former agricultural lands to restore California coastal prairie. We compared tarping once, tarping twice, herbicide, topsoil removal, and mulching through three growing seasons, as past research shows that while restoration treatments may have distinct differences in the first year or two following implementation, the effects often diminish over time (e.g., Rein et al. 2007; Rinella et al. 2012; Seabloom 2011).

Materials and Methods

Site Description. The research was conducted on a post-agricultural marine terrace at the University of California, Santa Cruz (UCSC) Younger Lagoon Reserve adjacent to the Long Marine Laboratory (36°57′11.59″N, 122°3′55.46″W). The land was used for over 50 yr for a mixture of dairy cattle followed by growing Brussels sprouts until agricultural activities ceased in the 1980s. The land transferred to the UCSC in 1999 and was later mandated for restoration of the original habitat types, a mixture of coastal prairie, scrub, and freshwater wet meadow, as part of mitigation for campus development.

The land has $<2°$ slope and the soils are mix of poorly drained loams and sandy loams which experience hydric conditions following normal to heavy rainfall periods. The climate is Mediterranean with rainfall falling during the winter mo (primarily November through April) and an extended dry season (May–October) during which temperatures are moderated by coastal fog (maximum daily temperatures rarely are >22 C (71 F), as the site is located <100 m (109 yd) from the Pacific Ocean. Average annual rainfall between 1993 and 2013 was 434.7 mm (17.1 in); the first year of the study (2010 to 2011) had above-average rainfall (720.2 mm (28.3 in)), whereas the subsequent 2 yr received less than average rainfall: 367.5 mm (14.5 in) (2011 to 2012) and 288.60 mm (11.4 in) (2012 to 2013).

California coastal prairies were probably once dominated by native bunch grasses and often host a high diversity of annual and perennial forbs (Ford and Hayes 2007; Stromberg et al. 2001). However, prior to the start of the experiment the above-ground vegetation in the study area consisted entirely of a mixture of exotic grasses and forbs.

Experimental Design. In late August 2010, the entire site was mowed and fenced to exclude large herbivores, primarily rabbits. Five 5 by 5-m plots in each of five randomized blocks were randomly assigned to one of five treatments: tarping once (1×), tarping twice (2×), topsoil removal, herbicide, and control (no treatment except mowing immediately prior to planting). The blocks run perpendicular to the coastal bluff edge to control for microclimatic variation because of this gradient. A 0.5-m buffer separates adjacent plots.

Treatments were initiated at different times so that they would be completed by the same planting date. In mid-August 2010, 2× tarping plots were irrigated for 10 min d^{-1} for 18 d. After allowing seeds to germinate, 10-mil black, polyethylene tarps were laid over each plot with corners weighed down by sandbags to prevent winds from disrupting the experiment. The tarps were removed after 6.5 wk immediately prior to the onset of fall rains. Both 1× and 2× tarping plots were left uncovered after the first rains in the third week of October to allow seed germination. In early November 1× and 2× tarping plots were covered with black tarps for 8 wk, and tarps were removed in early January, prior to planting.

In soil removal plots, a bulldozer scraped off the top 5 cm (2 in) of soil in October 2010. In herbicide plots, a solution of glyphosate (Round-up Pro®), water, and blue dye was sprayed in mid-November 2010 and again in early January 2011. Approximately 3,785 ml (1 gal) of water, 89 ml (3 oz) of glyphosate, and 47 ml (1.6 oz) of blue dye were manually sprayed on each plot. The second treatment was timed to allow the solution to immobilize before planting natives.

Immediately prior to planting, all plots (including controls) were clipped to ground level with a mechanical trimmer to facilitate planting seedlings. Plots were divided into two halves (2.5 by 5 m) and ~3 cm of wood mulch was applied to half of each plot. The mulch was a mixture of *Sequoia sempervirens* (D. Don) Endl. (coast redwood), *Quercus agrifolia* Née (coast live oak), and *Umbellularia californica* (Hook & Arn.) Nutt. (California bay laurel). Nomenclature throughout follows Baldwin et al. (2012).

Plant Materials and Planting. We planted three species of native, perennial coastal prairie grasses: *Elymus glaucus* Buckley (blue wild rye), *Hordeum brachyantherum* Nevski (meadow barley), and *Stipa pulchra* Hitchc. (purple needlegrass; *Nassella pulchra* (Hitchc.) Barkworth). Seeds were collected from within Younger Lagoon Natural Reserve or from Franklin Point in Año Nuevo State Park, approximately 40 km (25 mi) from the Reserve. *S. pulchra* and *E. glaucus* seeds were germinated and grown in greenhouses at the main UCSC campus (approximately 6 km from the study site) beginning in early September 2010. Seedlings were transferred into Ray Leach SC7 Stubby Conetainers (3.8 by 14 cm) to promote root-growth. Because of experimental difficulties, *H. brachyantherum* seeds were germinated in mid-November, approximately 10 wk after the other species. *E. glaucus* and *S. pulchra* seedlings were moved to the research site in early January 2011 to allow acclimation prior to planting. *H. brachyantherum* seedlings were moved to the site in early February and were only acclimated for 1 to 3 d prior to planting.

Elymus glaucus, S. pulchra, and *H. brachyantherum* seedlings were planted on January 14, January 21, and February 6, 2011, respectively. In each sub-plot there was an 8 by 15 grid of plants, each separated by 30 cm: seedlings were planted in five alternating rows of 8 seedlings of each species.

Data Collection. At the peak of the growing season (late-April/early-May) in 2011 (first growing season) and 2012 (second growing season), we recorded survival and estimated cover (to the nearest 0.25 square decimeter ($dm^2 = 100\ cm^2$)) of all planted grass seedlings. By 2013 (third growing season) it was impossible to distinguish separate grass seedlings, so we estimated relative cover of each species as part of guild cover measurements. To quantify overall vegetation composition, in late-April/early-May of 2011, 2012, and 2013, we estimated the percent cover of native grasses, exotic grasses, exotic forbs, and bare ground (including bare soil and mulch) in 5% cover classes (i.e. 0 to 5%, 5 to 10%, 10 to 15%) in four 0.25 by 1.0-m quadrats in each sub-plot. There were no native forbs recorded in experimental plots.

Data Analysis. Prior to analysis, measurements from individual plants or quadrats within a given sub-plot were averaged to obtain a single value. We used a mixed effects model (using the lme function in the lmer package in R) to analyze the effect of the whole-plot treatment (control, topsoil removal, herbicide, 1× tarping, or 2× tarping), mulch (the sub-plot treatment), and their interaction on survival and cover of each species of grass seedlings and cover of the different vegetation guilds (native grasses, exotic forbs, exotic grasses) and bare ground. Block was included as a random factor. We used Tukey's multiple comparison procedure to test for differences between whole-plot treatments when there was a significant treatment effect but not a significant treatment by mulch interaction. We conducted separate Tukey's multiple comparison procedures for mulched and unmulched sub-plots of the whole-plot treatments when there was a significant treatment by mulch interaction.

We present results of individual native grass plant survival and cover in April 2012, second growing season. Results from April 2011 (first growing season) were similar but less pronounced as measurements were taken only 3 mo after planting. We calculated relative cover of the vegetation guilds as the percentage cover of the target guild divided by total live vegetation cover. We report relative vegetation cover given that our goal was to test the effects of the different restoration strategies on increasing the relative cover of native compared to exotic guilds and total cover varied strongly interannually, largely in response to rainfall differences (Hobbs et al. 2007). Initial repeated measures analyses of cover guilds showed that there were strong treatment by time interactions so we report the results of the 3 yr separately. Percentage values were arcsine transformed and individual seedling cover values logtransformed when necessary to meet assumptions of normality and homogeneity of variance.

Cost Comparison. We estimated costs of both labor and supplies for the three most promising methods for exotic control: tarping 1×, herbicide, and mulching. We calculated labor time from work time logs maintained by UC Natural Reserves staff and supplies based on bulk prices in our region.

Results and Discussion

Survival and Individual Cover of Native Grasses. Overall seedling survival was high: 95% and 88% for all species across all treatments in the first (April 2011) and second (April 2012) growing seasons respectively, showing their promise for restoration in this system. Survival values were similar for all species in the second year (*E. glaucus*: 91%, *H. brachyantherum*: 87%, *S. pulchra*: 86%), whereas cover of individual plants of *E. glaucus* (1.5 dm^2) was greater than *H. brachyantherum* (1.0 dm^2) or *S. pulchra* (0.9 dm^2).

Seedling establishment and survival in Mediterranean systems is notoriously variable largely in response to large interannual differences in rainfall (Hobbs et al. 2007; Seabloom 2011), and the first year of our study coincided with an above-average rainfall year, which likely positively affected our high native grass seedling survival rates. Corbin and D'Antonio (2004) reported similarly high survival rates in mesic California coastal prairies, but others have reported lower survival in drier years with high variation across species (Buisson et al. 2006; Farrell et al. 2007; Tang 2013).

Second-year seedling survival was ≥84% in all mulched treatments, but was more variable across treatments in unmulched plots (Figure 1). The interaction between treatment and mulching was significant for *H. brachyantherum* and marginally significant for *S. pulchra*, as survival was lower in unmulched control and soil removal plots (Figure 1, Table 1). There was also a significant interaction term for *E. glaucus* for which survival was lowest in the unmulched herbicide treatment.

Cover of individual grass seedlings showed a similar, but stronger, pattern (Figure 1). For *S. pulchra*, cover was higher in mulched plots across all treatments with no significant interaction term (Table 1); cover was lower in control and soil removal compared to the other treatments. For both *E. glaucus* and *H. brachyantherum,* there was a significant treatment by mulch interaction; cover was lower in unmulched control and soil removal plots for both species, whereas mulching did not have as strong an effect in tarping 1× or 2× plots (Figure 1, Table 1).

Overall Vegetation Composition. In the first growing season, relative native grass cover was greater in mulched than unmulched plots and was greater in herbicide and both tarping treatments than in control and soil removal plots (Figure 2, Table 1), consistent with patterns of survival and cover of individual species. Results from the second year were identical except that cover in the tarping 1× treatment did not differ significantly from any other whole-plot treatments. By the third growing season, treatment differences had decreased; the positive effect of mulching was observed only in control, soil removal, and herbicide plots (treatment by mulching effect) and the treatment effect was only significant in unmulched plots (Figure 2, Table 1). Experiment-wide native grass cover in the third year was comprised of approximately half *E. glaucus* and a quarter each of *H. brachyantherum* and *S. pulchra*. No recruitment of native grasses was observed, so all the cover was comprised of planted individuals.

Relative exotic grass cover (mostly *Bromus diandrus* Roth (ripgut brome), *Festuca myuros* L. (rattail fescue), *Festuca perennis* (L.) Columbus & J.P. Sm. (Italian rye grass)) showed the opposite pattern as native grasses, with higher cover in unmulched plots in the first 2 yr and no effect by the third year (Figure 2, Table 1). Exotic grass cover was lowest in herbicide treatments in the first year, but did not vary across whole-plot treatments thereafter (Table 1).

Relative exotic forb cover was dominated by *Raphanus sativus* L. (radish), *Carduus pycnocephalus* L. (Italian thistle), *Cirsium vulgare* (Savi) Ten. (bull thistle), *Helminthotheca echioides* (L.) Holub (bristly ox-tongue) and *Medicago polymorpha* L. (California burclover) and did not differ across treatments in the first growing season (Figure 2). In the second year, there was a significant treatment by mulch interaction with greater cover in unmulched control, soil removal and herbicide plots (Table 1). There was greater cover in the control and soil removal treatments, primarily in unmulched plots, in the third year.

Bare ground (both bare soil and wood mulch) was much higher in all mulched plots and unmulched herbicide plots in the first year (Figure 3). Bare ground in mulched plots dropped substantially (<10% in all treatments) in the second year, but the mulching effect remained significant (Table 1). By the third year, there was no significant effect of the mulching treatment on bare ground (Table 1), although overall bare ground was higher than the preceding year likely because of dry conditions. By this time, wood mulch only covered 0.9% of mulched plots.

Cost Comparison. Costs for mulching and tarping were an order of magnitude higher than herbiciding (complete cost estimates are detailed in Table S1). At our site, herbiciding twice prior to planting cost US\$1,440 ha^{-1} (\$600 for herbicides and \$840 for labor). Tarping once would cost US\$14,040 ha^{-1} (\$5,400 for plastic and \$8,640 for labor) if all labor were paid, although we were

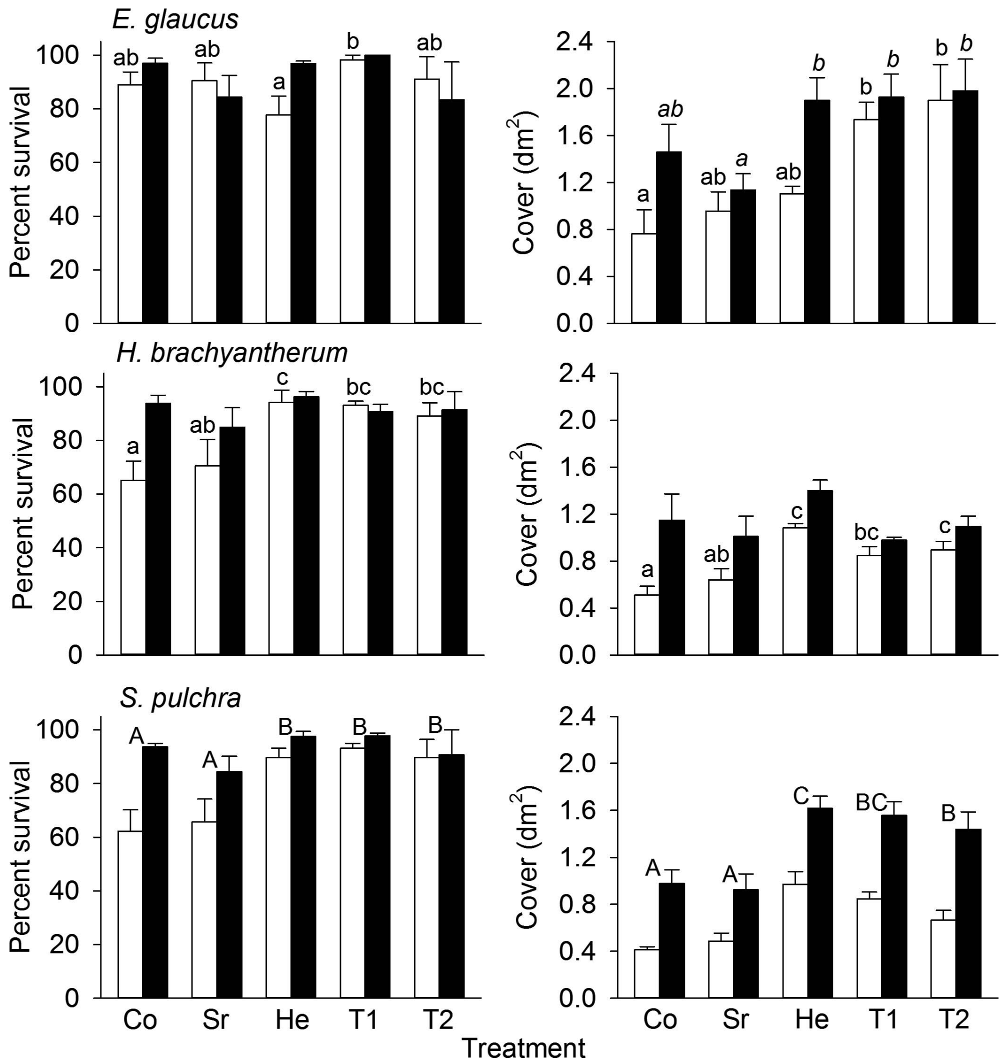

Figure 1. Percent survival and cover of individual grass seedlings in control (Co), soil removal (Sr), herbicide (He), tarping 1× (T1) and tarping 2× (T2) treatments crossed with no mulch (white bars) and mulching (black bars) in second growing season (April 2012). Error bars indicate 1 SE. When ANOVA (Table 1) indicated a significant treatment effect ($P < 0.05$) but no treatment by mulch interaction, differences in whole-plot treatment means using Tukey's mean separation procedure are indicated with capital letters. When ANOVA (Table 1) showed a significant treatment by mulch interaction, differences across sub-plot treatment means are illustrated with lower case letters separately for unmulched (nonitalic) and mulched (italic) sub-plots. No letters are shown when no treatments differed significantly.

able to utilize some volunteer labor to reduce costs. The cost of mulching is highly variable depending on whether a free source of mulch is available and whether it is spread manually or with machinery; a considerable amount of mulch is needed (300 m^3 ha^{-1}) resulting in an estimated total cost of US$18,190 ha^{-1} ($11,790 for mulch and $6,400 for labor).

Evaluation of Short-Term Treatment Efficacy. Our results are consistent with many previous studies showing that both herbicides and mulch are effective in reducing exotic grass competition and favoring native grasses (e.g., Cox and Allen 2008; Huddleston and Young 2005; Irvine et al. 2013; Kettenring and Adams 2011; Nyamai et al. 2011). Exotic control treatments had much weaker and less consistent effects on cover of exotic forbs, which likely reflects the fact that cover of exotics forbs, many of which are low-stature and/or have basal rosettes, is strongly influenced by competition with taller-stature grasses, both native and exotic (Cox and Allen 2011; Hayes and Holl 2011).

While herbicides are commonly the most effective exotic control strategy and much cheaper than alternatives (Kephart 2001; Kettenring and Adams 2011), they are

Table 1. Results of mixed effects models of treatment, mulch and treatment by mulch interaction on vegetation variables.

	Growing	Treatment		Mulch		Treat. × Mulch	
Variable	season	*F*	P	*F*	P	*F*	P
Individual plants (Figure 1)							
E. glaucus survival	2	2.4	0.0956	2.2	0.1559	4.0	0.0149
E. glaucus cover	2	4.3	0.0148	56.9	<0.0001	8.2	0.0004
H. brachyantherum survival	2	3.8	0.0238	20.9	0.0002	6.5	0.0016
H. brachyantherum cover	2	5.6	0.0051	81.3	<0.0001	7.9	0.0005
S. pulchra survival	2	7.0	0.0018	46.7	<0.0001	2.4	0.0878
S. pulchra cover	2	18.1	<0.0001	166.4	<0.0001	1.2	0.3366
Guild cover (Figure 2)							
Native grass	1	14.8	<0.0001	102.0	<0.0001	0.8	0.5666
	2	6.2	0.0034	79.2	<0.0001	1.4	0.2850
	3	2.3	0.1024	16.1	0.0007	4.0	0.0160
Exotic grass	1	15.4	<0.0001	132.3	<0.0001	1.3	0.3034
	2	3.3	0.0686	29.5	<0.0001	0.9	0.4849
	3	0.8	0.5292	0.5	0.4965	0.8	0.5601
Exotic forb	1	1.7	0.2049	<0.0	0.9247	0.8	0.5328
	2	3.4	0.0328	4.4	0.0479	3.8	0.0191
	3	3.5	0.0318	3.9	0.0612	2.0	0.1294
Bare ground (Figure 3)	1	10.5	0.0002	84.5	<0.0001	2.0	0.1363
	2	0.9	0.4622	35.4	<0.0001	0.4	0.8191
	3	9.2	0.0005	0.1	0.7714	1.4	0.2676

increasingly difficult to use because of popular sentiment. Herbicides may have negative effects on native species (Cornish and Burgin 2005; Rinella et al. 2009; Rodriguez and Jacobo 2013), but in systems such as California grasslands, where exotic species exert a strong competitive effect on native survival, the net effect of herbicides is usually positive (Corbin et al. 2004).

Mulching reduces exotic cover, which in part may be because of increased microbial activity reducing high N availability, which is especially important in former agricultural soils (Zink and Allen 1998) or in areas with high atmospheric N deposition (Weiss 1999). Mulch also increases soil moisture, which can enhance seed germination and seedling survival in arid systems (Biederman and Whisenant 2009; Nyamai et al. 2011). The vast majority of wood mulch breaks down within 2 yr in our study system, so in turn these effects are expected to decrease. A major obstacle to using mulch is the high cost if a free or low cost source is not available.

There has been much less study of using tarps to shade out exotic seedlings prior to seedling planting. Results from our study and others (Marushia and Allen 2011) suggest that a single tarping immediately after the first rainfall in a Mediterranean region can be similarly effective to herbicides in reducing exotic cover. Hutchinson and Viers (2011) found that tarping once, along with tilling to break up roots, was effective for control of a perennial invasive herb. Our results showed that a second tarping following irrigation during the Mediterranean dry season had minimal additional benefits for exotic control. Moreover, this approach requires irrigation, which adds costs and is not feasible in systems far from water sources. Tarping is used at a large scale in agriculture, suggesting it could be used in restoration settings. We estimate, however, that tarping is an order of magnitude more expensive than two herbicide applications, although these costs will vary depending on local supply and labor costs. Moreover, tarping can be challenging when there are existing woody plants interspersed throughout the grasslands.

Past research suggests that topsoil removal can be effective to reduce exotic competition and restore grassland habitats in upland conditions or to restore wet meadows in combination with introduction of native wetland plant propagules (Buisson et al. 2006; Farrell et al. 2007; Klimkowska et al. 2010; Pfeifer-Meister et al. 2012). Topsoil removal, however, causes extensive damage to the ecosystem, including removing the native seed bank and microbial communities (Diaz et al. 2008; Pfeifer-Meister et al. 2012), and requires somewhere to dispose of the soil. In our experiment, removing the top layer of soil was not effective in reducing exotic cover at our study site, which is flat, deep soiled, and includes small patches of herbaceous freshwater wetlands. Removing 5 cm of soil appeared to change the hydrological conditions; we

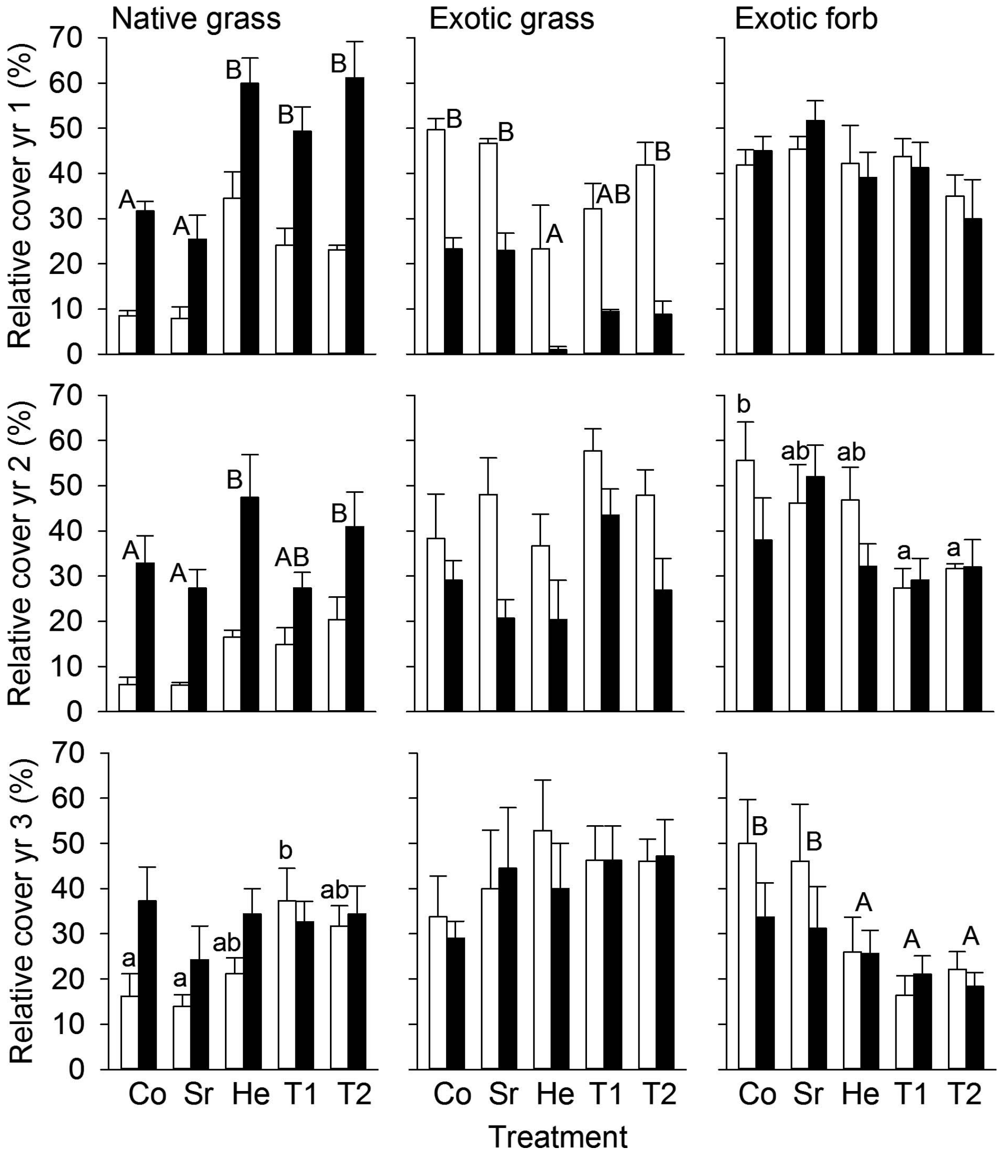

Figure 2. Relative cover of vegetation guilds in control (Co), soil removal (Sr), herbicide (He), tarping 1× (T1) and tarping 2× (T2) treatments crossed with no mulch (white bars) and mulching (black bars) over the 3 yr of the study. Error bars indicate 1 SE. When ANOVA (Table 1) indicated a significant treatment effect ($p < 0.05$) but no treatment by mulch interaction, differences in whole-plot treatment means using Tukey's mean separation procedure are indicated with capital letters. When ANOVA (Table 1) showed a significant treatment by mulch interaction, differences across sub-plot treatment means are illustrated with lower case letters separately for unmulched (non-italic) and mulched (italic) sub-plots. No letters are shown when no treatments differed significantly.

observed that soil removal plots had standing water for a longer time period than the other treatments following high rainfall events in the first year, which likely facilitated the recolonization of exotic seeds and reduced seedling survival of the planted native grasses. Interestingly, we also observed establishment of *Juncus bufonius* L. (toad rush), a native, annual rush commonly associated with freshwater wetlands (Lichvar 2013), primarily in soil removal plots, in the summer following the first sampling (Mann 2012), although the species was not recorded during our annual spring surveys perhaps because of its small size and late flowering period.

Convergence of Treatment Methods. Our results show that both mulching and tarping are non-chemical exotic control methods that reduce exotic grass cover and enhance the success of native grass planting efforts over the first 2 yr. The effects of the restoration methods, however, converged substantially within 3 yr after treatments congruent with a large body of past literature showing that the effect of

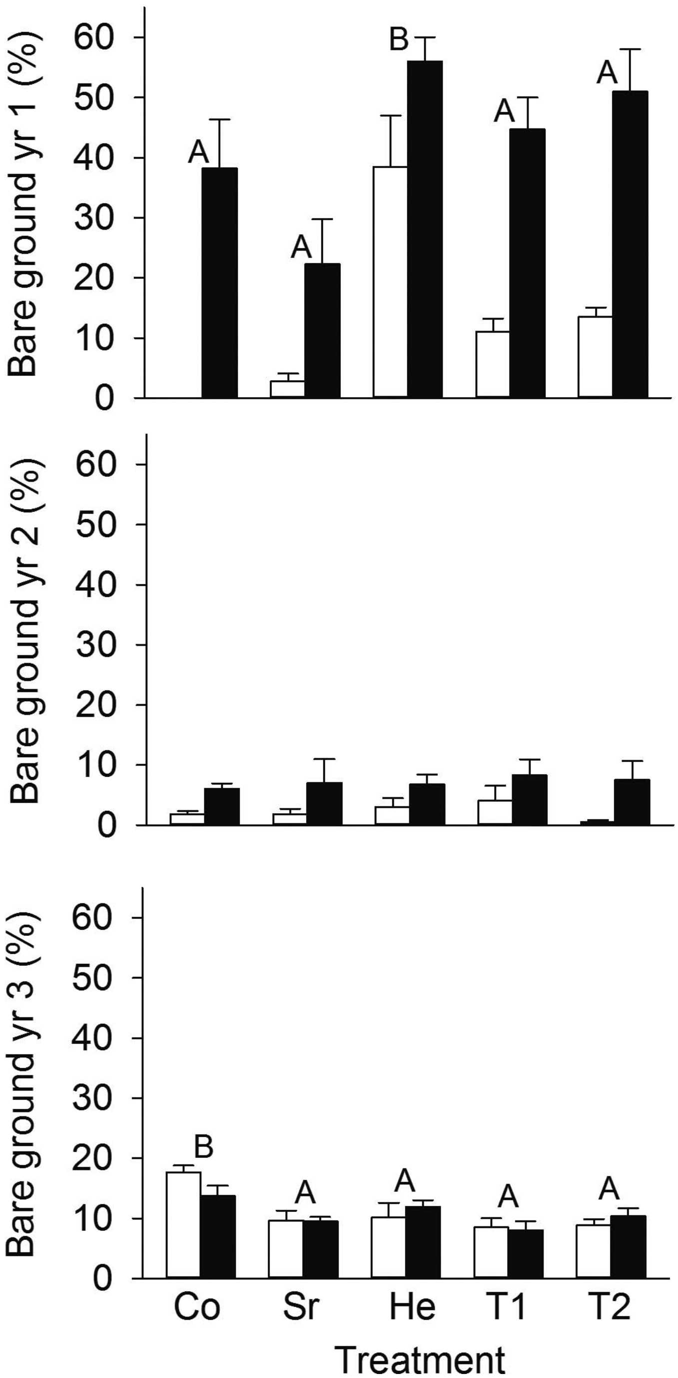

Figure 3. Bare ground in control (Co), soil removal (Sr), herbicide (He), tarping 1× (T1) and tarping 2× (T2) treatments crossed with no mulch (white bars) and mulching (black bars) over the 3 yr of the study. Error bars indicate 1 SE. Whole-plot treatment means with the same capital letters are not significantly different ($P < 0.05$) using Tukey's mean separation procedure. See Table 1 for ANOVA statistics.

restoration actions may be short-lived (Matthews and Spyreas 2010; Rinella et al. 2012; Seabloom 2011). By the third year, there were minimal effects of treatment on bare ground and exotic grasses, which raises the question of whether expensive exotic control techniques are justified. Treatment effects on native grasses declined although native cover remained lower in the control, soil removal, and herbicide plots that were unmulched.

Other studies have suggested that interannual climatic variation, which is beyond the control of practitioners, may be more important than the restoration method used (Cox and Allen 2011; Wilson et al. 2004), so that investing resources in multiple years of seeding or planting may enhance restoration success more than expensive efforts to control exotic competition. What is clear is that long-term monitoring is needed to evaluate the efficacy of different restoration treatments, a call that has been made repeatedly in the academic literature (Matthews and Spyreas 2010; Rinella et al. 2012), but is less commonly implemented (Kettenring and Adams 2011). Clearly, selecting among the options of no treatment, mulching, herbicide, and tarping will require balancing long-term efficacy with costs and logistical constraints at specific sites, as well as considering the effect of the treatments on any extant native vegetation and seed bank.

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