University California, Santa Cruz

Younger Lagoon Reserve

Annual Report 2016-2017

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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 undergraduate course use. Most formal undergraduate education users were within the Environmental Studies and Ecology and Evolutionary Biology departments. Younger Lagoon Reserve-affiliated internships also supported over 70 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 working closely with faculty research projects on cost effective methods for native habitat restoration (PI, Karen Holl), evolution of the threespined stickleback (co-PIs Eric Palkovacs and Ben Wasserman), and grassland response to drought (co-PIs Michael Loik and Kathleen Kay), 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, local K-12 programs, and other community groups.

Restoration activities in FY 2016-2017 included weed control, planting of over 2 acres, seed collection, and preliminary wetlands work. 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 sixth year of CLRDP CCC compliance monitoring for restored Coastal Bluffs, Wetland Buffer, Coastal Scrub, 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 2016-2017 represented the seventh 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 2018 that summarizes the findings of the Beach Access Management Plan to date.

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 2016-2017 fiscal year (July 1, 2016 - June 30, 2017). 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 ninth 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 Coastal Science Campus (CSC).

CLRDP Activities

Overview

This year represented the ninth 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 Coastal Science Campus development.

The CLRDP requires that the entire Reserve be protected and used as a living laboratory and outdoor classroom 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 seventh 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 were to be compiled and included in a report that summarizes and assesses the effect of controlled beach access on flora and fauna. That report was submitted to the California Coastal Commission in 2016. The CLRDP requires that University submit a NOID to the CCC that summarizes findings of the Beach Access Management Plan every five years. That NOID (NOID 9) was initially submitted in the Fall of 2016; however, it was withdrawn due to CCC staff work load and was resubmitted in summer of 2017. Although CCC staff recommended approval of NOID 9 as submitted, CCC Commissioners raised questions regarding beach access at the July 2017 meeting, and YLR staff withdrew NOID 9 prior to the Commissioners vote in order to try and better address these questions. The University plans to resubmit NOID 9 in 2018.

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 continued to be offered twice a month throughout FY 2016-2017 and biological monitoring of the lagoon and adjacent beach was conducted quarterly in FY 2016-2017. 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 CSC 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, including the reconnection of upper terrace wetlands 1 and 2. Restoration of the Terrace lands continued throughout FY 2016-2017. Activities included weed control, planting, seed collection, and wetlands reconnection work.

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, 2013-2014, 2014-2015, and 2015-2017 Annual Reports). FY 2016-2017 marked the sixth year of compliance monitoring for restored Coastal Bluffs, Wetland Buffer, Coastal Scrub, and Grassland areas. A detailed compliance monitoring report is included in Appendix 2.

Monitoring efforts in 2017-2018

During the 2017-2018 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 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 included 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 storm water treatment and infiltration features. It also consisted of campus utility and circulation improvements to serve both the new lab building and future campus development under the CLRDP. The Project developed a complex of public access and interpretive facilities, including pedestrian access trails, interpretive program shelters, 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 initiated 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 and continued in FYs 2015-2016 and 2016-2017. Occupancy of the Coastal Biology Building took place in summer of 2017. The project is slated to be complete by the end of calendar year 2017.

In 1999, when the University purchased the land for the expanded CSC, 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 and continued in FY 2016-2017. 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. These trail signs were temporarily removed in 2017 to allow for construction of the new trails and are scheduled to be replaced by the end of calendar year 2017.

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 consulted with reserve staff on an as needed basis in FY 2016-2017. Discussion topics included 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 seventh year of data, which is reported in Lesage (2017). The main results and recommendations are listed below.

- Seven years after initial treatment, herbicide-treated plots continue to have the lowest cover of non-native grasses (35.5 ± 3.58%) compared with other treatments (54.3 ± 0.80% average across all treatments and control). Scraped plots have the lowest cover of non-native forb species (14.9 ± 1.48% vs. 18.2 ± 1.88% average across all treatments and control), though the variation in exotic forb cover is low across plots.
- Native grass cover has declined in all plots over time, from all treatments having above 25% native grass cover in 2015 to only herbicide treated (30.9 ± 2.7%) and scraped (26.4 ± 3.5%) plots having over 25% native grass cover by 2017.

- Mulched plots had significantly greater cover of non-native grasses this year (57.6 ± 2.7% non-native grass cover in mulched plots vs 50.9 ± 2.6% non-native grass cover in no mulched plots), though visual evidence of the mulch has long since disappeared. This contrasts with findings in prior years that mulching was effective in controlling exotic grasses initially, but had minimal effect on native grass cover.
- The plots with the highest cover in 2017 were the herbicide treatment plots that did not receive mulching, with an average native grass cover of 36.2 ± 4.1%. The lowest native cover was in the control and 1x tarping no-mulch treatments (16.5 ± 3.15% and 13.8 ± 3.31%, respectively).
- We recommend the use of herbicide for effective, if minor, reductions in exotic grass cover in California coastal prairies.

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. This year, Holl et al. collected the fifth year of data on the three remaining treatments; monitored cover all planted native species, as well as cover of exotic grasses and exotic forbs as a guild, which is reported in Snider (2017). The main results and recommendations are listed below and Snider's entire report is included in Appendix 3.

- Island and fully planted plots showed little difference in their cover of native and exotic species, suggesting that planting a 1/3rd of the area is as effective as planting the entire plot, several years after implementation.

- Wind-dispersed species, like *Achillea millefolium* and *Hordeum brachyantherum* appear to be most effective at spreading within the island planting plots. We found evidence that planted species continued to spread outside the planted areas.

- Mowing did not have a significant effect on exotic species cover six years into the treatment, despite differences between mowed and un-mowed plots in prior years.

- There continues to be no effect of mulching since the first two years of the study, given that wood mulch larger breaks down after two years in a coastal climate.

- Native cover declined across all plots to slightly below the native cover site restoration goal of 20%. Native grass cover has been declining since 2015 and native forb cover declined from 2016 to 2017.

- Holl et al. recommend that for small areas, planting patches or "islands" of native species may be as effective as planting the entire area after several years, especially if planted with native species that spread easily and/or are wind-dispersed.

A Comparison of Small-Scale Direct Seeding Methods to Restore California Coastal Prairie Cost effective methods to restore small areas of coastal prairie are needed. In FY 2016-2017, Professor Karen Holl, doctoral student Josie Lesage and undergraduate student Green Burns tested two methods of direct seeding adapted for use on a small scale: (1) single-row, walk-behind drill-seeder, and (2) hand broadcasting followed by tamping with a lawn roller. In fall 2015, Holl et al. set up ten, 10 × 10 m plots, five replicates of each seeding treatment; these were divided into two 5 × 10 m subplots. In one subplot, Holl et al. added wood mulch immediately after seeding and mowed three months later to control exotics; the other served as a control. Holl et al. seeded five grass species (*Danthonia californica*, *Elymus glaucus*, *Elymus triticoides*, *Hordeum brachyantherum*, and *Stipa pulchra*) and five forb species (*Achillea millefolium*, *Eschscholzia californica*, *Grindelia stricta*, *Sisyrinchium bellum*, and *Symphyotrichum chilense*) each in separate 1 × 10 m strips. Field germination was monitored in first in January 2016 and establishment was measured in April 2016, and students continued monitoring the project in April 2017 to determine the second-year success of the seeding techniques. The results of the second year of monitoring are presented in Nelson (2017). The main results and recommendations are listed below, and Nelson's entire report is included in Appendix 3.

- Direct seeding and hand broadcasting were not effective restoration methods for restoring most native coastal prairie species, as most planted species did not reappear in the second growing season.
  - Despite several species showing significantly higher establishment in the first year post-sowing (*Achillea millefolium*, *Grindelia stricta*, *Hordeum brachyantherum*, *Danthonia californica*, and *Elymus glaucus*), only *Hordeum brachyantherum* and *Achillea millefolium* were present at cover levels > 1% by the second growing season.
- In the second year, *Achillea millefolium* was more successful in the hand broadcasted plots (9.6%) than the drill-seeded plots (1.0%), whereas *Hordeum brachyanthreum* was more successful in the drill seeded plots (31.7%) than in the hand broadcast plots (19.3%).
- The weed-suppression effects of mulching and mowing were significantly dampened in the second year when compared with the results in year one, suggesting these management strategies have ephemeral effects on community composition.
- Direct seeding is not recommended as a restoration strategy for small areas where multiple species are desired. It may be an effective choice for some single-species restoration efforts.

Non-chemical methods of the reduction of exotic plant cover and facilitation of native coastal prairie and scrub restoration

Restoration of coastal scrub and coastal prairie habitat requires the effective suppression of exotic species, which can otherwise overwhelm native plantings. Non-chemical methods for the removal of exotic species are desired for projects where the use of chemical control methods is forbidden or avoided. This new study examined the effects of three methods of non-chemical weed control on the establishment and growth of planted native species and suppression of undesirable exotic species: covering plots with a layer of black plastic tarp, non-toxic carboard, or paper mulching. In the fall of 2016, four replicates of each of the three treatments were applied to a total of twelve 6.1 × 6.1 m plots, and each plot was then covered with wood chip mulch. In January 2017, seedlings of twelve native coastal prairie and scrub species (*Artemisia californica*, *Ericameria ericoides*, *Mimulus aurantiacus*, *Scrophularia californica*, *Clinopodium douglasii*, *Horkelia californica*, *Prunella vulgaris*, *Symphyothicum chilense*, *Elymus glaucus*, *Stipa pulchra*, *Danthonia californica*, and *Hordeum brachyantherum*) were planted in each plot. The plots were monitored for planted species survival and growth and exotic species cover in April-May 2017. The results from the first growing season following implementation are presented in Filous (2017) and Wertheimer (2017). The main results and recommendations are listed below, and Filous and Wertheimer's entire reports are included in Appendix 3.

- All three treatments (black plastic tarp, cardboard, and paper mulch) were effective at reducing exotic species cover in the first year following their application, and there was no difference in plot level soil moisture between the treatment types.

- Native plant species survival and establishment was high in the paper and cardboard treatments, but plastic tarp treated plots were less successful at establishing native grasses.

- Grasses had both lower survival rates and growth rates in the plastic tarp plots than the other species groups.

- Universal application of wood chip mulch to all treatments may have suppressed differences between the paper and cardboard treatment, and exceptionally heavy precipitation may also have washed out differences in survival and growth between them.

- We recommend the use of cardboard and paper mulching as alternative short-term weed suppression techniques to chemical methods in small scale coastal prairie and scrub restoration projects where the initial survival of native plantings is key.

Management Recommendations:

In FY 2016-2017 the SAC continued to discuss two ongoing management issues at YLR: 1) Domesticated Animals, specifically dogs, and 2) upper terrace wetland work, including and 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. In FY 2016-2017, 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.

Upper Terrace Wetland Work

CLRDP RMP MM 9 states that the University shall "*Restore, consolidate, expand, and enhance wetlands on the northern part of the site (i.e., north of the Campus access road) to restore historic functional values lost during decades of agricultural use. The restoration program will include integrating the hydrology of Wetlands W1 and W2 to create a consolidated north-south area for wildlife movement to YLR. Hydrological surveys will be conducted by a qualified hydrologist to establish the elevations appropriate for optimizing expected wetland functioning. The area will be graded to provide a natural channel profile and gradient between the culvert at the Union Pacific Railroad tracks and the culvert outlet to Younger Lagoon on the west property line. The area west of the combined W1/W2 hydrologic corridor shall be restored as functioning wetland* *upland/transitional habitat, as shall buffer areas to the east. Maintain the CRLF potential habitat at the northern end of W-2.*

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. This discussion included members of the Natural Reserves and Physical Planning and Construction. In April 2014, USFWS approved the University's project as proposed and 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.

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 the site within the permitting requirements and procedures for UC) 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. Subsequently, PP&C staff engaged additional outside hydrologic and biologic consultants to do a feasibility study in 2016. This study continued in 2017 and is is expected to be completed by the end of calendar year 2017. The results of this study will help inform future decisions regarding CRLF pond construction in the upper terrace.

The SAC is generally 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. However, 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.

SAC member and hydrologist Dr. Bryan Largay consulted with Reserve Manager Elizabeth Howard in the fall of 2016 to discuss plans for meeting the Reserve's obligations under RMP MM 9, while still leaving open the possibility of future CRLF ponds. Due to natural changes on the site (e.g. drought, sedimentation and subsequent changes in vegetation), the wetland 1 channel is no longer as pronounced as it was at the time of CLRDP certification, and Dr. Largay recommended that the reserve deploy brush packs in wetland 1 to reconnect wetlands 1 and 2. Initial brush packing activities began in the summer of 2016 and was completed in 2017.

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 April 22, 2016. 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 weed and water native planting.

Priority One Weed Removal

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 2016-2017, 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 2016-2017, 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 2016, 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 2016/2017.

Restoration Planting

In FY 2016-2017, approximately 2 acres of 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 2016-2017 the reserve hosted classes in Ecology, Entomology, Freshwater Ecology, Restoration Ecology, Ecological Field Methods, 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).

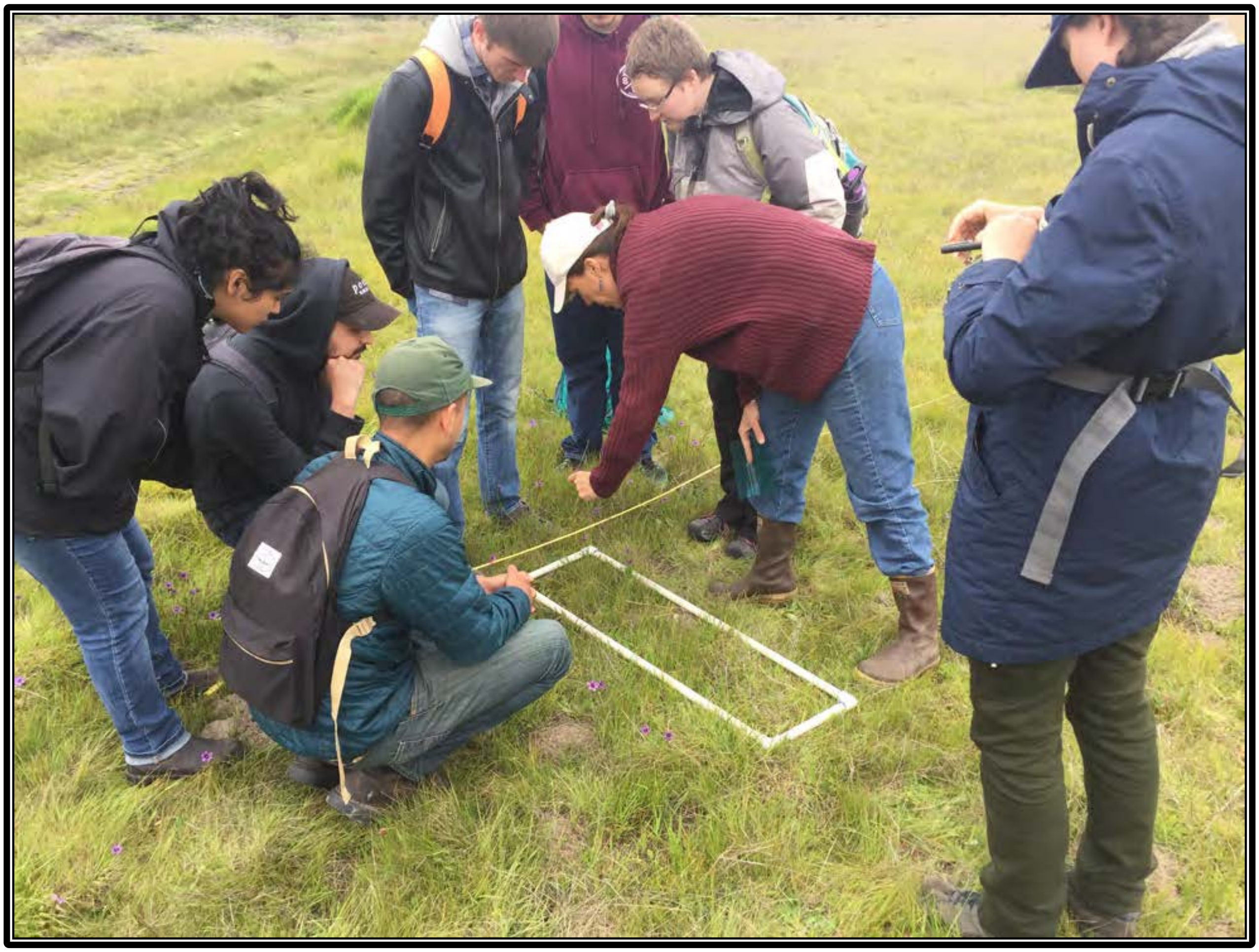

Figure 2. Dr. Karen Holl and students from ENVS 196 Senior Seminar *Field Research on Coastal Habitat Restoration* in the field.

Internships and Senior Theses

In FY2016-2017, YLR staff sponsored over 70 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 at the reserve.

Table 1. Younger Lagoon Courses

Course Title	Institution (Department)	Instructor's Name
BIO 11C - Ecology	Cabrillo Community College	Eva Salas
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 137 – Molecular Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Beth Shapiro

BIOE 151ABCD/ENVS109ABCD – Ecology and Conservation in Practice Supercourse	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology and Dept. of Environmental Studies)	Don Croll and Gage Dayton
BIOE 155 - Freshwater Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Eric Palkovacs
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)	Sara Baguskas
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 196 – Senior Seminar on Coastal Habitat Restoration	University of California, Santa Cruz (Dept. of Environmental Studies)	Karen Holl
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
OPERS Animal Tracking class	University of California, Santa Cruz (OPERS)	Chris M Lay
Dorris Duke Conservation Scholars Program	University of California, Santa Cruz (Dorris Duke Conservation Scholars Program at UCSC)	Erika Zavaleta

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 2016-2017 we approved 11 research applications. Examples and summaries of new and ongoing research are included below.

Faculty Research Highlight: Evolution of the Threespine Stickleback

Natural selection is important for organisms to adapt to their environment. When environments change, selection may also. Professor Eric Palkovacs and graduate student Ben Wasserman are exploring whether fluctuating selection can maintain genetic diversity, unlike directional selection, which reduces diversity but increases fitness using the threespine stickleback inhabiting Younger Lagoon.

Typically, anadromous populations of threespine stickleback are covered in a continuous row of bony armor plates (20 or more) but freshwater resident populations have few plates (10 or less). This phenotype is known to be determined primarily by which copy of a single gene *Ectodysplasin-A* (*Eda*) the individual has. In the ocean, marine predators select for high plate counts (and *C* alleles), whereas in freshwater it is believed that the energetic cost means that low plate counts (and *L* alleles) are selected for since the strength of selection from predators is less or absent.

In Younger Lagoon and other seasonally closed estuaries in California, stickleback may experience freshwater-style selection for low plate counts during the summer months when the estuary is separated from the ocean and there are no fish predators, but experience marine selection for high plate counts following the estuary breach, when their data show that most individuals are released into the ocean (Figure 4). Palkovacs and Wasserman have collected threespine stickleback from Younger Lagoon every month starting in February of 2014. By counting the plates and determining which copies of the *Eda* gene these individuals have, they can determine how the strength of selection changes over time, and whether both copies of the *Eda* gene can persist in the population over time.

Since their study includes both historic high- and low-rainfall years, they can determine the range of fluctuation over which persistence of allelic diversity is possible. As climate change alters the frequencies of different types of rain years, they might even be able to predict what type of climatic conditions would lead to the loss of genetic diversity.

Figure 4. Lagoon breach 2017.

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

Several UC Natural Reserve sites in California are participating in the International Drought Experiment. The experiment is compliant with the *DroughtNet* protocol for comparison to 100 other sites worldwide (drought-net.org). Effects of drought on plant growth and biodiversity are being measured at a number of grassland and shrubland sites along a north-south and coastal-inland gradient in California. At UCSC, professors Michael Loik, Kathleen Kay, and Karen Holl are collaborating with graduate student Justin Luong on this project.

The UCSC Drought Experiment was built with support from the Institute for the Study of Ecological and Evolutionary Climate Impacts (ISEECI) during 2015 at three sites including Younger Lagoon UC Natural Reserve, the UCSC Arboretum, and the UCSC Campus Natural Reserve. The main goal of the experiment is to better understand how long-term drought affects which plant species grow, and by how much, in California coastal prairie. The UCSC Drought Experiment sites span an elevation gradient of about 300 m with changes in rainfall, temperature, and fog. Fog-collectors are co-located with shelters at each site. Initial plot establishment made up the laboratory section activities for ENVS 162/L Plant Physiological Ecology at Younger Lagoon, the Arboretum, and the Campus Natural Reserve during Spring 2015.

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. Loik et al. also have water addition plots available for experiments. There are n = 5 plots per treatment. Size = 2 X 2 m, with a 1 m buffer around the 4 m^2 square plot.

Shelter construction commenced in July 2015. Plots were trenched to 50 cm deep and lined with 6 mil plastic to prevent lateral water flow and root encroachment. Shelters were initially constructed of lightweight metal and rainfall is intercepted using clear, v-shaped polycarbonate troughs. In 2017, the shelters were rebuilt using wooden posts. Rainfall interception commenced during the first significant rainfall between 2 -3 November 2015. With *ISEECI* support, Loik et al. began to automatically monitor soil moisture and temperature, as well as air temperature and relative humidity near the ground under the shelters in 2016.

Figure 5. Undergraduate student intern works on the experimental *DroughtNet* shelters.

During 2017, the drought experiment activities at YLR focused on: 1. Continued measurements and monitoring of plots in accordance with the International Drought Experiment protocol; 2. Continued deployment of the micrometeorological sensor measurement system; 3. Continued monitoring of survival and growth of California native plant seedlings under drought and watering treatments; and 4. Measurements of above-ground, non-drought related impacts of the drought infrastructure on photosynthesis and respiration of five native California plant species. Highlights for each are summarized below.

Measurements and monitoring of plots in accordance with the International Drought Experiment protocol

Loik et al. measured aboveground net primary productivity (ANPP) and plant diversity of IDE shelter and control plots at YLR, as well as at the UCSC Arboretum and UCSC Campus Reserve lands at Twin Gates. These data represent year two of the IDE treatment. Early analyses suggest a "reverse shelter" effect at YLR for winter 2017, for which plants under shelters grew more than plants in control plots. Loik et al. have not yet processed results for plant diversity. Likewise, Loik et al. completed similar measurements for the Arboretum and Twin Gates sites but results have not been analyzed yet.

Continued monitoring of the micrometeorological conditions on control and drought plots.

Loik et al. continued monitoring air and soil temperature (two depths), soil moisture (two depths), photosynthetically active radiation, solar radiation, relative humidity, and fog interception at 30 minute frequency. Loik et al. monitored conditions below rain interception shelters as well as on open control plots.

Some of these data will be used for the first manuscript from the drought project at YLR (see below.) Loik et al. also have sensors on plots with planted native seedlings under rain-out shelters and control (open) plots.

Continued monitoring of survival and growth of California native plant seedlings under drought and watering treatments.

This work is led by Prof. Kathleen Kay, Ecology & Evolutionary Biology, UC Santa Cruz. There was one round of seedling survival and growth measurements conducted after the end of the rainfall season of 2017.

Measurements of above-ground, non-drought related impacts of the drought infrastructure on photosynthesis and respiration of five native California plant species.

Loik et al. used potted, well-watered plants of *Elymus glaucus*, *E. triticoides*, (Poaceae), *Eriogonum latifolium* (Polygonaceae), *Mimulus aurantiacus* (Scrophulariaceae) and *Morella californica* (Myracaceae) placed under drought shelters and on control plots in 2016 and followed up with analyses in 2017. Loik et al. tested the hypothesis that the infrastructure affects photosynthesis, such as through shading, reflection, or infrared radiation emission at night by the posts, support troughs, and gutters of the drought shelters. Loik et al. measured impacts in terms of photosynthetic CO2 uptake, stomatal conductance, Photosystem II integrity within chloroplasts, and nighttime respiration.

Results show:

- Instantaneous light intensity under shelters can be as much as 20% of full sun.
- But integrated over the entire day, PAR is 20% lower on shelters compared to control plots.
- Air and soil temperatures are not different during the day on control and shelter plots.
- Air temperatures are a bit warmer (by 0.6 degrees) at night under shelters.
- Leaf temperatures and leaf-to-air water vapor deficits were not different on control and shelter plots.
- Stomatal conductance and photosynthesis were not different for four of the five species.
- For *Morella californica*, there was about 33% higher stomatal conductance on shelter plots.
- Despite slightly warmer temperatures, nighttime respiration and stomatal conductance do not differ on control and shelter plots.
- In summary, there are only minor aboveground, non-drought effects of the shelter infrastructure on micrometeorological conditions and photosynthesis for the California native species.

This work was presented at the Annual Meeting of the Ecological Society of America, August 2017, Portland, OR.

Numerous student internships and graduate theses are ongoing throughout the California Drought Experiment. At Younger Lagoon Reserve (YLR), over 30 students have been involved with construction and scientific experiments.

Undergraduate Research Highlights

Undergraduate Jay Luce Nelson completed a senior thesis with the UCSC Natural Reserves in June 2016. Nelson's thesis, entitled 'Direct Seeding Ineffective in Restoring Coastal Prairie' was a case study of seeding techniques for ecological restoration in coastal prairie systems. Nelson worked closely with Reserve Manager, Elizabeth Howard, Restoration Steward Tim Brown, Graduate Student Josie Lesage and Faculty Advisor Karen Holl to ensure that their results and recommendations would influence future restoration and management activities.

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 2016-2017 the reserve continued its 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 6. WATCH program participants explore the lagoon with science mentor Ben Wasserman.

Reserve Use

The greatest educational user group for YLR in FY 2016-2017 was once again undergraduate education, a breakdown of all user groups is included in Table 2. YLR was used by UC Santa Cruz, UC Davis, UC San Diego, Michigan State University, University of Utah, Aptos High School, Half Moon Bay High School, Pacific Collegiate School, Pajaro Valley High School, Watsonville High School, California Academy of Sciences, Land Trust of Santa Cruz County, Seymour Marine Discovery Center, Santa Cruz Bird Club, Audubon California, and several local and regional volunteer groups (Table 3).

Table 2. Younger Lagoon Total Use

RESERVE USE DATA
Period from July 1, 2016 to June 30, 2017

University of California, Santa Cruz
Younger Lagoon Reserve

	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																										
Faculty	5	58	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6	59
Research Scientist	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0	0	0	0	2	19
Research Assistant	1	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14
Graduate Student	4	85	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	91
Undergraduate Student	6	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	39
Volunteer	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
SUB-TOTALS	16	196	5	13	0	0	0	0	0	0	1	1	0	0	0	0	1	14	0	0	0	0	0	0	23	224
UNIVERSITY-LEVEL CLASSES																										
Faculty	13	34	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	37
Graduate Student	22	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	44
Undergraduate Student	535	9715	0	0	13	13	30	60	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	598	9828
Professional	2	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	254
SUB-TOTALS	572	10047	0	0	14	14	31	62	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	637	10163
PUBLIC SERVICE																										
Faculty	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Graduate Student	11	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	141
Undergraduate Student	25	125	0	0	0	0	0	0	0	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	36	136
K-12 Instructor	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	52	0	0	10	56
K-12 Student	13	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131	633	0	0	144	647
Professional	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	16	0	0	0	0	0	0	2	16
Other	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	52	766	0	0	0	0	13710	13710	13763	14477
Docent	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	40
Volunteer	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	330	330	333	333
SUB-TOTALS	97	328	0	0	0	0	0	0	0	0	12	12	0	0	0	0	55	783	0	0	137	685	14040	14040	14341	15848
TOTALS:	**685**	**10571**	**5**	**13**	**14**	**14**	**31**	**62**	**20**	**40**	**13**	**13**	**0**	**0**	**0**	**0**	**56**	**797**	**0**	**0**	**137**	**685**	**14040**	**14040**	**15001**	**26235**

*Other includes members of the public who took the SMDC's daily tour. All daily tours in FY 2016-2017 visited the Younger Lagoon Overlook.

Table 3. Younger Lagoon Group Affiliations

University of California Campus	**Non-governmental organizations**
University of California, Davis	Audubon Society
University of California, San Diego	California Academy of Sciences
University of California, Santa Cruz	Land Trust of Santa Cruz County
	Monterey Bay Aquarium WATCH Program
California State Universities	Santa Cruz Bird Club
California State University, Monterey Bay	Seymour Marine Discovery Center
California State University, San Jose	Watsonville Wetlands Watch
California Community College	**Governmental Agencies**
Cabrillo Community College	California State Parks
Universities outside California	
Michigan State University	
University of Utah	
	Volunteer Groups
K-12 system	UCSC Wilderness Orientation
Aptos High School	
Half Moon Bay High School	
Pacific Collegiate School	
Pajaro Valley High School	
Watsonville High School	

Summary

FY 2016-2017 was a successful year for YLR. The reserve continued to move forward with restoration, initiated new projects, strengthened collaborations, and developed new relationships. The increase in student and course use is a direct result of having superb staff on sight that are 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 the California Coastal Commission and the State of California in general. We look forward to continuing this exciting and important work in FY 2017-2018.

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
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7 Ex-Officio

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Alex Jones, MS – Manager
Campus Natural Reserve
Natural Sciences II, Rm 465

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 Santa 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, 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

Lesage, Josie, 2017. Compliance Monitoring Report for Coastal Prairie, Wetland Buffer, and Coastal Scrub Restoration Sites at Younger Lagoon Reserve, Spring 2017. Prepared for the California Coastal Commission and Younger Lagoon Reserve Scientific Advisory Committee, 2017.

Appendix 1. California Coastal Commission monitoring report

Younger Lagoon Reserve

Beach Monitoring Report

2017

***Watsonville Area Teens Conserving Habitats* (WATCH) *Program* Participants at Younger Lagoon**

Elizabeth Howard and Gage Dayton
Younger Lagoon 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 its 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 and submitted as a NOID to the CCC. That NOID was initially submitted to the CCC in the Fall of 2016; however, it was withdrawn due to CCC staff workload and was resubmitted in summer of 2017 as NOID 9 (17-1). Although CCC staff recommended approval of NOID 9 as submitted, CCC Commissioners raised questions regarding beach access at the July 2017 meeting, and YLR staff withdrew NOID 9 prior to the Commissioners vote in order to try and better address these questions. The University plans to resubmit NOID 9 in 2018.

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 2016 and a summary report for the entire 7-year monitoring program. All year's results are included. Data collected indicate that Younger Lagoon Reserve (YLR) supports a wide variety of native flora and fauna, provides habitat for sensitive and threatened species, supports a very unique beach dune community, and is extensively used for research and education. 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 its 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 first 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. As reported in the 2015 YLR Beach Monitoring Report, beginning in the summer of 2015 and 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 the previous 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 resubmit NOID 9 to the CCC in 2018.

Introduction

Over 50 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 its 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 that 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, results shouldn't necessarily be used to create strict prescriptions.

This report is a report for activities under NOID 10-1 during Fiscal Year (FY) 2016-2017 (July 1, 2016 – June 30, 2017) which surveyed YLR. In addition, because of the upcoming NOID resubmission, although we are no longer monitoring Natural Bridges and Sand Plant beaches, we have included all year's results from all sites in this report in order to show the entire effort to date. 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 2016-2017.

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 LML 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, educate the public about the closure, and use the site for research and education. 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 (Seymour Center).

Beach Access Tours

In 2017, beach access tours were offered two times per month (one tour on a weekday and one on a weekend) and were free with admission to the Seymour Center. In 2018, beach access tours will be offered two to four times per month depending on historic demand (e.g. more tours during the spring and summer months when visitation is high) and children will be free. 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 Seymour Center 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 Seymour Center docents during the regular winter docent training program in 2010. YLR Beach tours began in the spring of 2010 and are advertised via the Seymour Center website: https://seymourcenter.ucsc.edu/visit/behind-the-scenes-tours/, various social media, online media, print ads, and radio spots, and filled via phone reservation: (831) 459-3800. The Seymour Center 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.

Public Education and Outreach Programming on the Coastal Science Campus

The YLR beach access tours are part of broader public education and outreach programming on the Coastal Science Campus offered through the Seymour Center.

Every year, over 60,000 people visit the Seymour Center. The Seymour Center provides marine science education to hundreds of classes, comprised of thousands of students, teachers, and adult chaperones from across the country. Many of the classes served come from schools classified as Title 1—schools with high numbers of students from low-income families. Scholarships are made available to Title 1 schools, making it possible for students to participate who would not otherwise have the opportunity to experience a marine research center. Teachers often incorporate the Seymour Center into their weeklong marine science field study courses.

In FY 2016-2017, The Seymour Center, Younger Lagoon Reserve and the Monterey Bay Aquarium continued their partnership supporting high school students in the Watsonville Area Teens Conserving Habitats (WATCH) program. WATCH students from Aptos High School designed and carried out field-based research projects in Younger Lagoon Reserve on topics including endangered fish, aquatic invertebrates, and birds. These students made repeated visits to the Reserve throughout the year.

Every year, dozens of children ages 7-14, enroll in weeklong summer science sessions known as Ocean Explorers. Students actively learn about and participate in marine research at the Seymour Center, and our associated Long Marine Laboratory, where participants work alongside marine mammal researchers and trainers. Participants gain experience with the scientific process, focusing on honing their observation and questioning skills. Ocean Explorers also investigate the coastal environment at field sites around Monterey Bay, including rivers and watersheds, sandy beaches, rocky intertidal areas, and kelp forests by kayak. Young participants generally come from Santa Cruz, Santa Clara, and San Mateo Counties. Full and partial scholarships are extended to low-income participants.

The Seymour Center actively promotes its activities with press releases and calendar listings throughout the region. Every year, traditional print ads are placed in newspaper and magazines. The

Seymour Center's activities are also often covered in the local newspaper, the Santa Cruz Sentinel. Public radio ads run throughout the year on the NPR-affiliate, KAZU.

Coupons for discounted admissions are available in various formats. The most highly used program is through the many Bay Area municipal libraries. Called Discover and Go, hundreds of families from across the region utilize these discount coupons. The Seymour Center continued to connect with the public through Facebook, Twitter, Instagram, Pinterest, Flickr, and bi-monthly e-blasts.

While part of UC Santa Cruz, the Seymour Center must raise its ~$1.25 million budget annually (including all operating costs, salaries, and benefits). Earned revenue—admissions, program fees, facility rentals, and the Ocean Discovery Shop—makes up approximately half of its general operating requirements.

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 Reserve, and Little Wilder/Sand Plant Beach from 2010-2015 (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. Starting in FY 2015-2016 and moving forward, only Younger Lagoon Reserve has been and will continue to be monitored.

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. Several species or reptiles and amphibians, including the California Red-legged Frog, also are found in the Reserve. 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 quarterly througout the study peroiod. Cameras were placed along the eastern edge of Sand Plant Beach and Natural Bridges Beach from FY 2010-2011 – FY 2014-2015 and at the western edge of Younger Lagoon from FY 2010-2011 – present with each separate quarterly 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 quarterly throughout the study period. 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 placed for two nights every quarter of the study period - a total of 30 traps were placed used (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 quarterly throughout the study period. Survey locations were selected along one edge of the beach on the cliff. At Sand Plant Beach the entire beach area, fore portion of the lagoon, and western cliff were surveyed from the eastern edge of the lagoon (FY 2010-2011 – FY 2014-2015). At YLR the entire beach area, fore portion of the lagoon, and western cliff were surveyed from the eastern edge of the lagoon and the top and western face of the rock stack that is located at the beach/ocean edge was surveyed (FY 2010-2011 – present). 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 (FY 2010-2011 – FY 2014-2015). 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 reserve overlook during daily tours at the Seymour Center. Those users 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 16-17 fiscal year a total of 80 participants went on the Seymour Center docent led Younger Lagoon beach access tours. Since the start of the Seymour Center docent led beach access tours, nearly 139 tours have gone out and more than 621 visitors have participated. The beach access tours are part of a broad offering of public outreach and education programming on the Coastal Science Campus managed by the Seymour Center, including K-12 school visits to the Seymour Center, the Ocean Explorers Summer Camp, Bay Area Libraries Discover and Go Program, as well as print, web, social media, and radio campaigns.

Despite ongoing staff efforts towards public outreach and education, some unauthorized uses of Younger Lagoon Reserve, including trespass and vandalism occurred in FY 2016-2017. Thus far, no significant damage to ecologically sensitive habitat areas, research sites, research equipment, or facilities has occurred. Reserve staff will continue their public outreach and education efforts, and continue to partner with UCSC campus police to ensure the security of the reserve and protect sensitive resources and ongoing research.

Table 1. Younger Lagoon user affiliations.

University of California Campus	**Non-governmental organizations**
University of California, Davis	Audubon Society
University of California, San Diego	California Academy of Sciences
University of California, Santa Cruz	Land Trust of Santa Cruz County
	Monterey Bay Aquarium WATCH Program
California State Universities	Santa Cruz Bird Club
California State University, Monterey Bay	Seymour Marine Discovery Center
California State University, San Jose	Watsonville Wetlands Watch
California Community College	
Cabrillo Community College	**Governmental Agencies**
	California State Parks
Universities outside California	
Michigan State University	
University of Utah	
	Volunteer Groups
K-12 system	UCSC Wilderness Orientation
Aptos High School	
Half Moon Bay High School	
Pacific Collegiate School	
Pajaro Valley High School	
Watsonville High School	

Table 2. Younger Lagoon Total Use.

RESERVE USE DATA
Period from July 1, 2016 to June 30, 2017

University of California, Santa Cruz
Younger Lagoon Reserve

	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																										
Faculty	5	58	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6	59
Research Scientist	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0	0	0	0	2	19
Research Assistant	1	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14
Graduate Student	4	85	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	91
Undergraduate Student	6	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	39
Volunteer	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
SUB-TOTALS	16	196	5	13	0	0	0	0	0	0	1	1	0	0	0	0	1	14	0	0	0	0	0	0	23	224
UNIVERSITY-LEVEL CLASSES																										
Faculty	13	34	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	37
Graduate Student	22	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	44
Undergraduate Student	535	9715	0	0	13	13	30	60	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	598	9828
Professional	2	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	254
SUB-TOTALS	572	10047	0	0	14	14	31	62	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	637	10163
PUBLIC SERVICE																										
Faculty	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Graduate Student	11	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	141
Undergraduate Student	25	125	0	0	0	0	0	0	0	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	36	136
K-12 Instructor	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	52	0	0	10	56
K-12 Student	13	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131	633	0	0	144	647
Professional	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	16	0	0	0	0	0	0	2	16
Other	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	52	766	0	0	0	0	13710	13710	13763	14477
Docent	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	40
Volunteer	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	330	330	333	333
SUB-TOTALS	97	328	0	0	0	0	0	0	0	0	12	12	0	0	0	0	55	783	0	0	137	685	14040	14040	14341	15848
TOTALS:	**685**	**10571**	**5**	**13**	**14**	**14**	**31**	**62**	**20**	**40**	**13**	**13**	**0**	**0**	**0**	**0**	**56**	**797**	**0**	**0**	**137**	**685**	**14040**	**14040**	**15001**	**26235**

*Other includes members of the public who took the SMDC's daily tour. All daily tours in FY 2016-2017 visited the Younger Lagoon Overlook.

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. We surveyed Sand Plant Beach from FY10-11 – FY14-15.

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. We surveyed Natural Bridges Lagoon from FY10-11 – FY14-15.

Human Use During Survey Efforts

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. Number of users at YLR beach during the survey efforts varied among beach 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 consistent across sampling periods. 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

Site	Month	[1]Total # of people	[1]Ave # of People / 15 minute
Younger Lagoon	February, 2011	2	0.06
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

Site	Month	[1]Total # of people	[1]Ave # of People / 15 minute
Younger Lagoon	February, 2014	1	0.01
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
Younger Lagoon	July, 2015	6	0.02
Younger Lagoon	October, 2015	0	0
Younger Lagoon	February, 2016	0	0
Younger Lagoon	May, 2016	1	0.02
Younger Lagoon	July, 2016	0	0
Younger Lagoon	November, 2016	0	0
Younger Lagoon	February, 2017	0	0
Younger Lagoon	April, 2017	0	0

[1]Standardized by area surveyed.

Figure 4. 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 year's report are included as Appendix 1.

Tidewater Goby Surveys

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. Evidence of breeding (multiple size classes) continued to be observed at YLR during the reporting period (Table 4).

Table 4. Fish species encountered during sampling efforts.

	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
July 8, 2015							
Younger Lagoon	X	X					
November 4, 2015							
Younger Lagoon	X	X					
February 9, 2016							
Younger Lagoon	X	X					
May 13, 2016							
Younger Lagoon	X	X					
July 20, 2016							
Younger Lagoon	X	X					
November 17, 2016							
Younger Lagoon	X	X					
March 1, 2017							
Younger Lagoon							
May 3, 2017							
Younger Lagoon	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

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. 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 was consistently greatest at Natural Bridges and lowest at Sand Plant Beach 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 5).

Native plant species richness was consistently greatest at Younger Lagoon; however, it varied across sampling periods (Figure 6). Mean proportion of non-native species was greatest at Natural Bridges (53%) and least at Younger Lagoon (27%) (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	Summer, 15	Fall, 15	Winter, 16	Spring, 16
Younger Lagoon	21.4	10	26.4	19.5	19.3	20.5	31.4	42.8
Sand Plant Beach	27.5	31	24.5	29.2				
Natural Bridges	74.3	89.4	71	75.8				

Site	Summer, 16	Fall, 16	Winter, 17	Spring, 17
Younger Lagoon	36.6	46.3	19.5	37.3

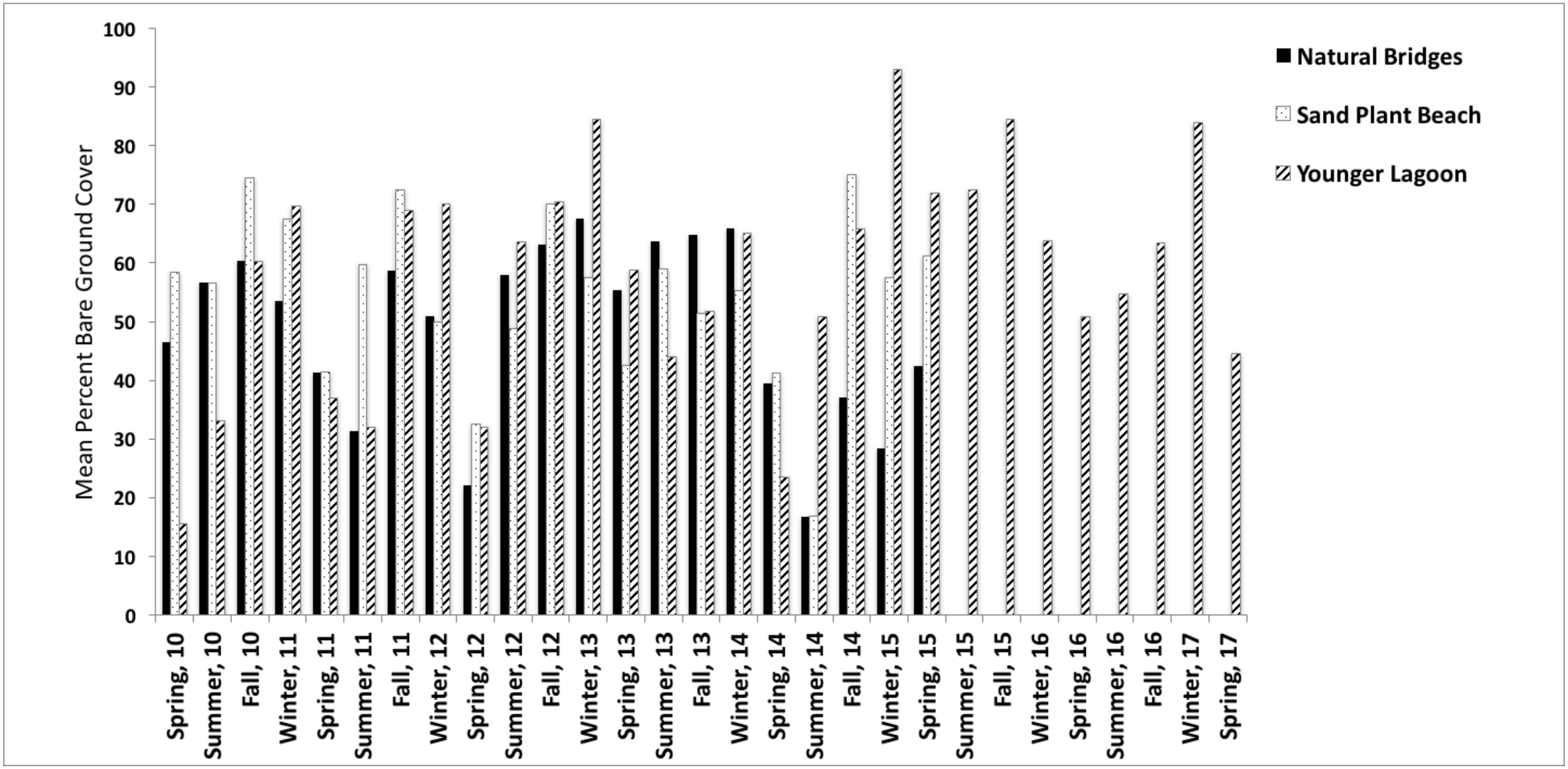


Figure 5. Mean percent bare ground encountered at each site.

Table 6. Number and proportion of native and non-native plant species encountered during surveys. Mean is calculated across all samples.

Site	Spring, 10	Summer, 10	Fall, 10	Winter, 11	Spring, 11	Summer, 11	Fall, 11	Winter, 12	Spring, 12
Natural Bridges									
Native	7 (41%)	8 (44%)	9 (60%)	8 (44%)	9 (43%)	6 (67%)	8 (62%)	9 (47%)	11 (48%)
Non-native	10 (59%)	10 (56%)	5 (40%)	10 (66%)	12 (57%)	9 (33%)	5 (38%)	10 (53%)	12 (52%)
Total	17	18	14	18	21	15	13	19	23
Younger Lagoon									
Native	11 (85%)	11 (85%)	11 (85%)	11 (73%)	12 (80%)	13 (81%)	9 (82%)	6 (50%)	6 (43%)
Non-native	2 (15%)	2 (15%)	2 (15%)	4 (27%)	3 (20%)	3 (19%)	2 (18%)	6 (50%)	8 (57%)
Total	13	13	13	15	15	16	11	12	14
Sand Plant Beach									
Native	7 (88%)	7 (63%)	7 (70%)	8 (80%)	7 (88%)	7 (88%)	9 (82%)	3 (33%)	4 (40%)
Non-native	1 (12%)	2 (37%)	3 (30%)	2 (20%)	1 (12%)	1 (12%)	2 (18%)	6 (67%)	6 (60%)
Total	8	9	10	10	8	8	11	9	10

Site	Summer, 12	Fall, 12	Winter, 13	Spring, 13	Summer, 13	Fall, 13	Winter, 14	Spring, 14
Natural Bridges								
Native	5 (35%)	10 (59%)	7 (88%)	9 (56%)	7 (37%)	6 (35%)	6 (43%)	10 (50%)
Non-native	9 (65%)	7 (41%)	8 (12%)	6 (44%)	12 (63%)	11 (65%)	8 (57%)	10 (50%)
Total	14	17	15	16	19	17	14	20
Younger Lagoon								
Native	12 (67%)	7 (88%)	9 (69%)	12 (75%)	13 (72%)	14 (74%)	10 (83%)	12 (67%)
Non-native	6 (33%)	1 (12%)	4 (31%)	4 (25%)	5 (28%)	5 (26%)	2 (17%)	6 (33%)
Total	18	8	13	16	18	19	12	18
Sand Plant Beach								
Native	2 (40%)	3 (50%)	4 (100%)	4 (67%)	6 (100%)	6 (100%)	5 (100%)	5 (83%)
Non-native	3 (60%)	3 (50%)	0 (0%)	2 (33%)	0 (0%)	0 (0%)	0 (0%)	1 (17%)

Total	5	6	4	6	6	6	5	6

Site	Summer, 14	Fall, 14	Winter, 15	Spring, 15	Summer, 15	Fall, 15	Winter, 16	Spring 16
Natural Bridges								
Native	5 (42%)	5 (45%)	4 (33%)	5 (31%)				
Non-native	7 (58%)	6 (55%)	8 (67%)	11 (69%)				
Total	12	11	12	16				
Younger Lagoon								
Native	9 (69%)	5 (62%	10 (67%)	10 (67%)	11 (73%)	2 (67%)	5 (100%)	10 (83%)
Non-native	4 (31%)	3 (38%)	5 (33%)	5 (33%)	4 (27%)	1 (33%)	0 (0%)	2 (17%)
Total	13	8	15	15	15	3	5	12
Sand Plant Beach								
Native	4 (50%)	4 (40%)	5 (50%)	4 (33%)				
Non-native	4 (50%)	6 (60%)	5 (50%	8 (67%)				
Total	8	10	10	12				

Site	Summer, 16	Fall, 16	Winter, 17	Spring, 17
Younger Lagoon				
Native	10 (83%)	8 (57%)	3 (60%)	13 (68%)
Non-native	2 (17%)	6 (43%)	2 (40%)	6 (32%)
Total	12	14	5	19

Site	Proportion of native and non-native species across all sample periods
Natural Bridges	
Native	**47%**
Non-native	**53%**
Total	
Younger Lagoon	

Native	**73%**
Non-native	**27%**
Total	
Sand Plant Beach	
Native	**68%**
Non-native	**31%**
Total	

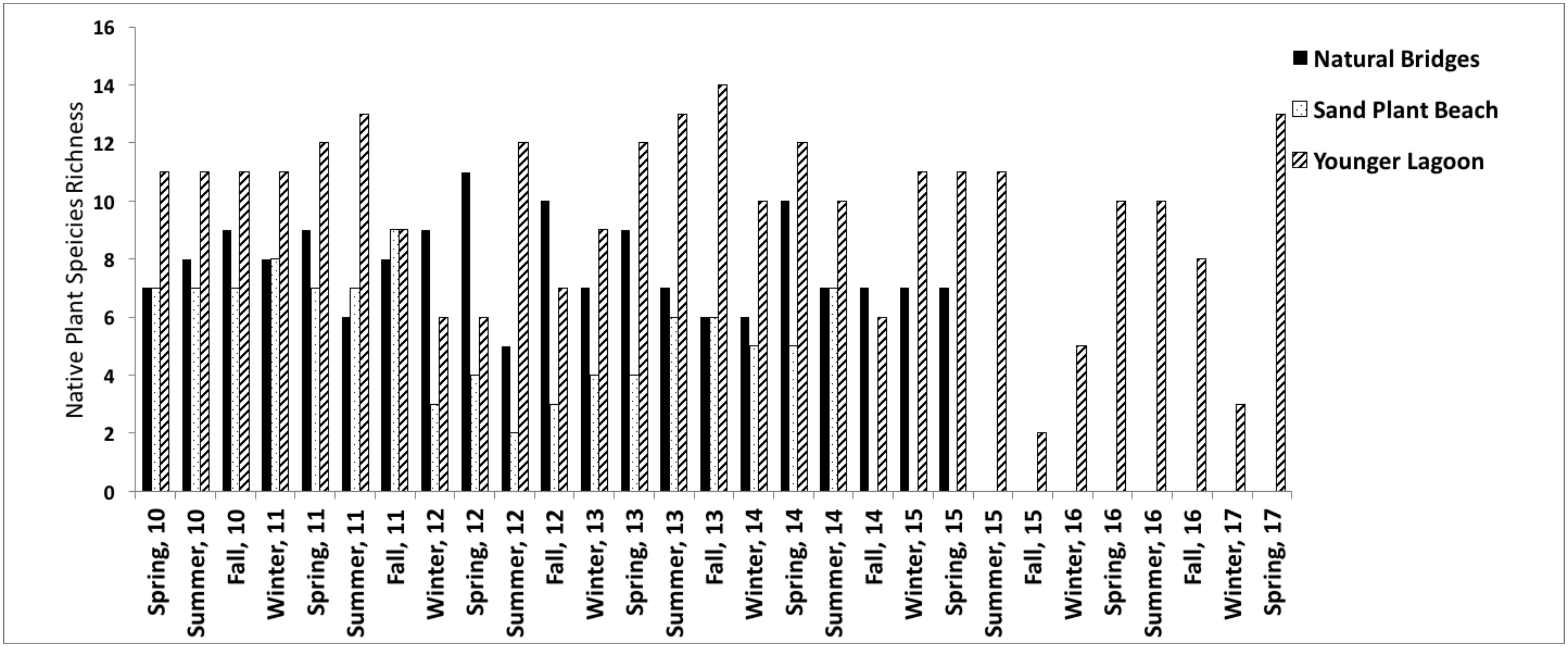


Figure 6. Number of native plant species encountered at each site.

Track Plate Monitoring

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. Native species richness of mammals detected in raked sand plots was across all three sites (n = 8). Ground squirrel were not detected at Natural Bridges and opossum have not been detected in our track surveys at Sand Plant Beach or Younger Lagoon Reserve (Table 7). It is likely that ground squirrels occur at Natural Bridges and opossum are likely using upland habitat at Sand Plant Beach and Younger Lagoon Reserve; 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.

Table 7. 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													

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
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													
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

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
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									
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

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
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
July 8-9, 2015													
Younger Lagoon	X			X	X								
									X				X
October 29-30, 2015													
Younger Lagoon		X		X									
February 2-3, 2016													
Younger Lagoon		X							X				
May3-4, 2016													
Younger Lagoon		X							X				
July 12-13, 2016													
Younger Lagoon		X		X									
November 9-10, 2016													
Younger Lagoon		X		X					X				
March 1-2, 2017													
Younger Lagoon	X	X		X									
April 25-26, 2017													
Younger Lagoon		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 through spring 2017 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	(15) 52%	(24) 83%	(2) 7%	(22) 76%	(7) 24%	(2) 7%	(3) 10%	0%	(18) 62%	0%	0%	0%	(10) 36%	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

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. A total of 272 individual small mammals representing four species have been captured during small mammal trapping efforts (Table 9).

Table 9. Summary of Sherman trapping efforts

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**

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
March 30, 2012					
Little Wilder	6				**6**
Younger Lagoon	1		1		**2**
Natural Bridges		5	2		**7**
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**

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
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**
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					
Younger Lagoon	7		1		**8**

Site	Pema[1]	Mica[1]	Reme[1]	Rara[1,2]	**TOTAL**
October 29-30, 2015					
Younger Lagoon	2		6		**8**
February 2-3, 2016					
Younger Lagoon			6		**6**
May 3-4, 2016					
Younger Lagoon			3	1	**4**
July 12-13, 2016					
Younger Lagoon			4		**4**
November 9-10, 2016					
Younger Lagoon	2		1		**3**
March 1-2, 2017					
Younger Lagoon	2		1		**3**
April 25-26, 2017					
Younger Lagoon			1		**1**
TOTAL	**138**	**55**	**76**	**3**	**272**

[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

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. 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

Although we are no longer monitoring Natural Bridges and Sand Plant beaches, we continue include results in order to have standalone reports that include all data going forward. Avian species varied among sites and sampling dates (Table 10); however, number of species and abundance were consistently greatest at Natural Bridges and Younger Lagoon.

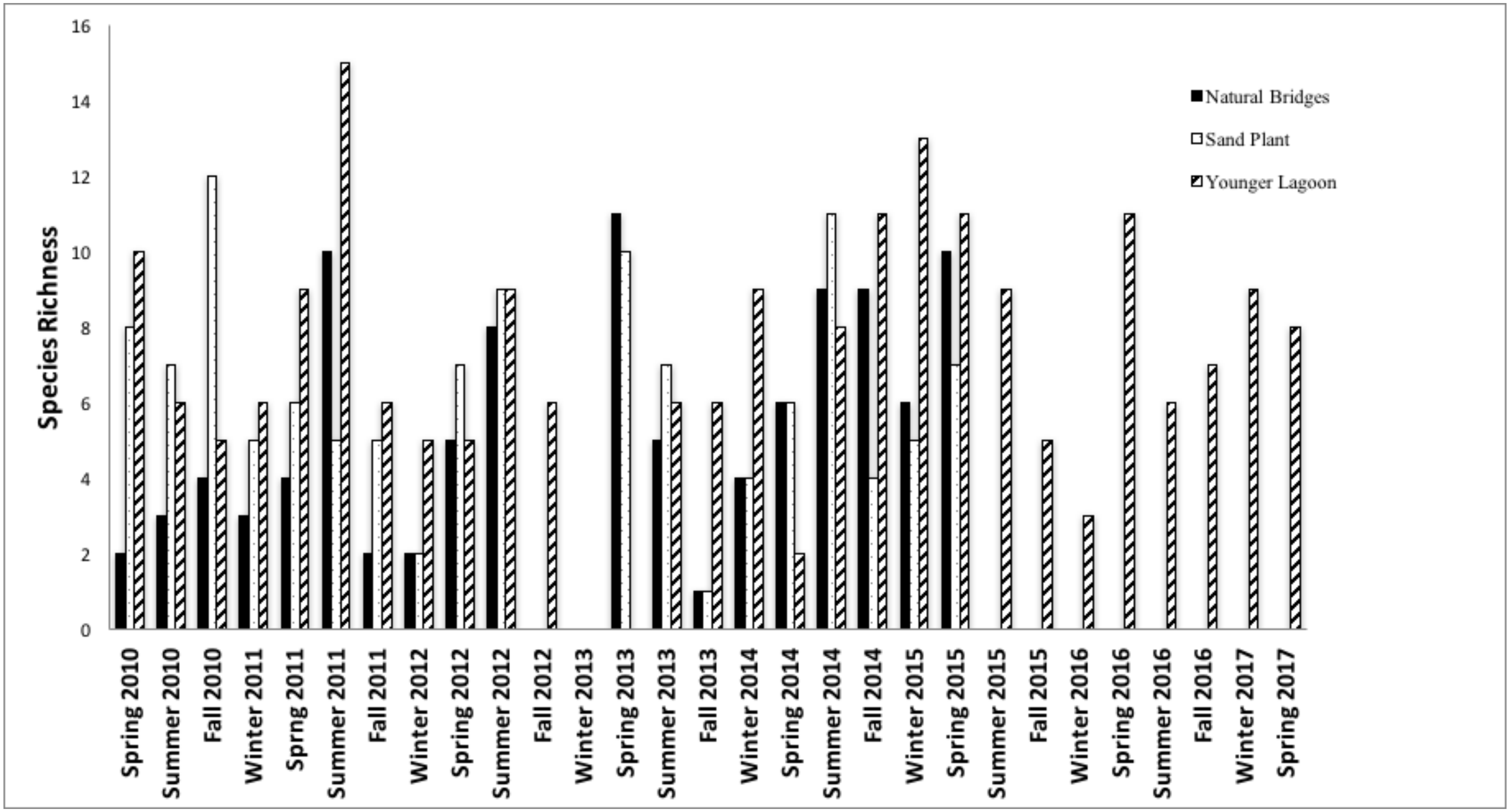


Figure 7. Species richness of invertebrates across all beaches

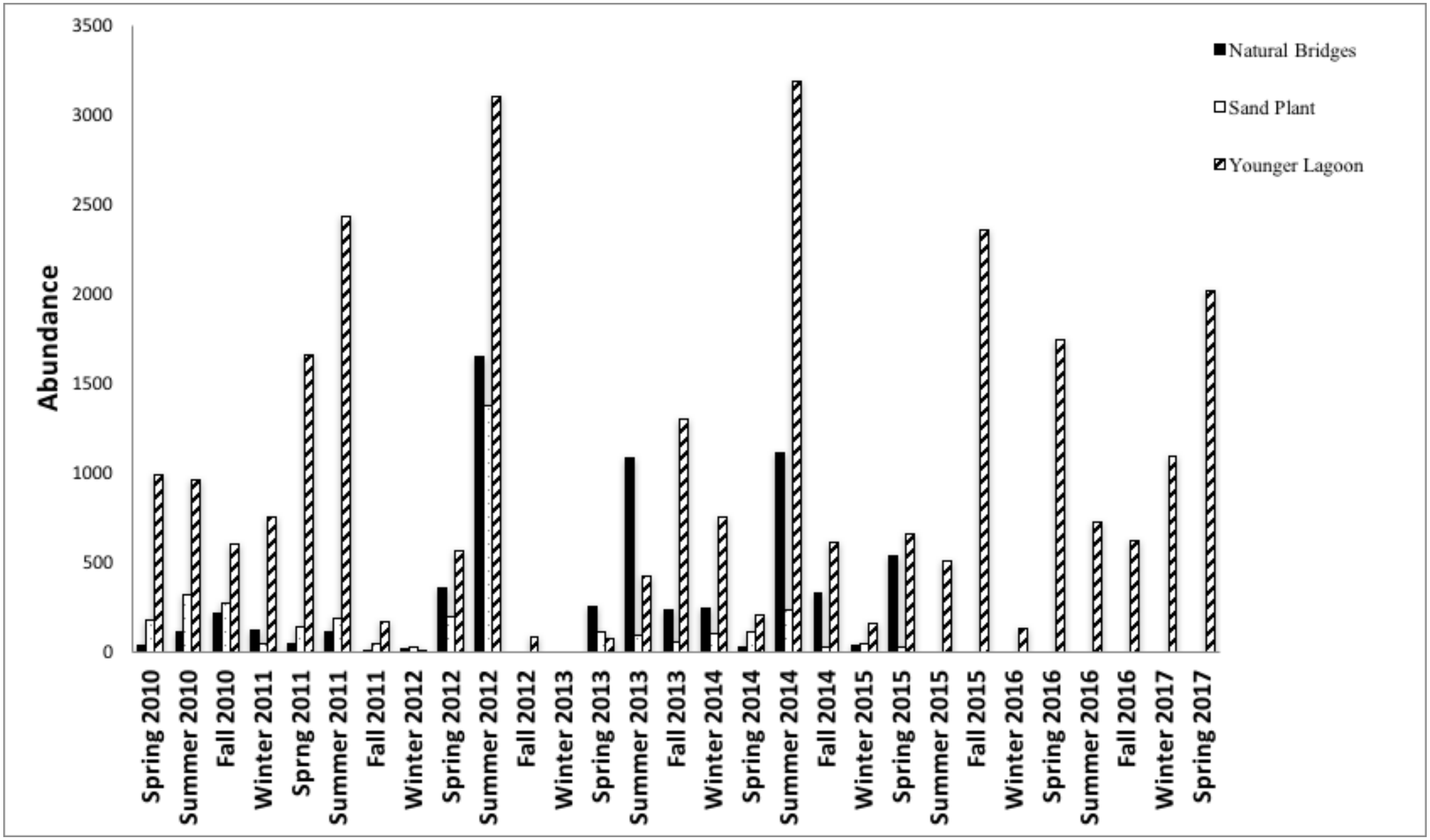


Figure 8. Total abundance of invertebrates at Natural Bridges, Sand Plant Beach, and Younger Lagoon beaches.

Table 10. Summary of bird surveys at Sand Plant Beach, Younger Lagoon, and Natural Bridges beaches.

Site	GREG	GRTE	HEGU	KILL	LOCU	MALL	MAGO	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG
April 24 & 26, 2010																				
Sand Plant						2														
Younger Lagoon						3														2
Natural Bridges				1											2					2
August 11-12, 2010																				
Sand Plant			1																	
Younger Lagoon			2	2	1	10														4
Natural Bridges				1																
November 15 & 16, 2010																				
Sand Plant																				
Younger Lagoon											15							11		
Natural Bridges	2		24	4				2										140		1
February 15 & 16, 2011																				
Sand Plant						2														
Younger Lagoon																			1	
Natural Bridges					3	4					47									18
May 3 & 4, 2011																				
Sand Plant						4				2			35							
Younger Lagoon																				
Natural Bridges	1			7	4	4	1										1			
July 22 & 23, 2011																				
Sand Plant			8										17							1
Younger Lagoon																				
Natural Bridges			48			7							3				2			2
March 29 & 30, 2012																				
Sand Plant						5														
Younger Lagoon				1		8					13									2
Natural Bridges		2				10	3						2					65		2
May 15 & 16, 2012																				
Sand Plant																				
Younger Lagoon				3		2					25		5				1			2
Natural Bridges						6														2
August 25 & 26, 2012																				
Sand Plant				3																
Younger Lagoon						4					35				8		1			1
Natural Bridges				5		1														
November 5& 6, 2012																				
Sand Plant																				
Younger Lagoon				5							14			1			4			2
Natural Bridges				4		9														2
January 13&14, 2013																				
Sand Plant																				
Younger Lagoon											3	1						38	1	1
Natural Bridges																				1
May 1 & 2, 2013																				
Sand Plant													8							
Younger Lagoon						3			2		9									
Natural Bridges	2					4														
July 16-17, 2013																				
Sand Plant													7							
Younger Lagoon				2		25					8		1							4
Natural Bridges			11	1																

Site	AMCR	AMPE	BBPL	BCNH	BASW	BLOY	BLPH	BLTU	BRBL	BRPE	BUHE	CAGO	CAGU	CLSW	CORA	COOT	DOCO	DUSP	EUST	GRHE
April 24 & 26, 2010																				
Sand Plant																				
Younger Lagoon																				
Natural Bridges									2											
August 11-12, 2010																				
Sand Plant																				
Younger Lagoon						2											1		1	
Natural Bridges	2								19											
November 15 & 16, 2010																				
Sand Plant																				3
Younger Lagoon								1		27						2		3	1	
Natural Bridges									1											2
February 15 & 16, 2011																				
Sand Plant																				
Younger Lagoon																	5			
Natural Bridges	3								2			1	58							
May 3 & 4, 2011																				
Sand Plant	2									8										
Younger Lagoon																				
Natural Bridges	1						1						3				6			
July 22 & 23, 2011																				
Sand Plant					4		1							4						
Younger Lagoon																				
Natural Bridges	9				4				6								10			
March 29 & 30, 2012																				
Sand Plant													1							
Younger Lagoon									5							3			2	
Natural Bridges								1												
May 15 & 16, 2012																				
Sand Plant																				
Younger Lagoon						3			2										2	
Natural Bridges	1								1											
August 25 & 26, 2012																				
Sand Plant													2		2					
Younger Lagoon		1				1	1						4							
Natural Bridges													1							
November 5& 6, 2012																				
Sand Plant																5				
Younger Lagoon									4							8				
Natural Bridges	2																			
January 13&14, 2013																				
Sand Plant																				
Younger Lagoon						1						1				5				
Natural Bridges															1					1
May 1 & 2, 2013																				
Sand Plant																				
Younger Lagoon									1			2							2	
Natural Bridges	2																			
July 16-17, 2013																				
Sand Plant				1									1		1					
Younger Lagoon				1			2		7				2							1
Natural Bridges							2		1				1							1

Site	SPSA	SURF	WEGU	WESA	WHIM	Richness
April 24 & 26, 2010						
Sand Plant			2			1
Younger Lagoon			2			3
Natural Bridges						2
August 11-12, 2010						
Sand Plant						1
Younger Lagoon			32			9
Natural Bridges			3			5
November 15 & 16, 2010						
Sand Plant			1			2
Younger Lagoon	1		4			9
Natural Bridges	1		17		1	11
February 15 & 16, 2011						
Sand Plant			6			2
Younger Lagoon						2
Natural Bridges			6		19	10
May 3 & 4, 2011						
Sand Plant			5		1	7
Younger Lagoon						0
Natural Bridges			16		7	12
July 22 & 23, 2011						
Sand Plant			1			7
Younger Lagoon						0
Natural Bridges			81		1	11
March 29 & 30, 2012						
Sand Plant						2
Younger Lagoon			16		2	9
Natural Bridges			10		5	9
May 15 & 16, 2012						
Sand Plant			4		5	2
Younger Lagoon			15			10
Natural Bridges						4
August 25 & 26, 2012						
Sand Plant						3
Younger Lagoon			7			10
Natural Bridges	1		5	1		6
November 5& 6, 2012						
Sand Plant			1			2
Younger Lagoon			3		10	9
Natural Bridges	1	2			12	7
January 13&14, 2013						
Sand Plant						0
Younger Lagoon						8
Natural Bridges			11			4
May 1 & 2, 2013						
Sand Plant			2			2
Younger Lagoon			11		2	8
Natural Bridges			23		2	5
July 16-17, 2013						
Sand Plant						4
Younger Lagoon						10
Natural Bridges			10			7

Site	AMCR	AMPE	BBPL	BCNH	BASW	BLOY	BLPH	BLTU	BRBL	BRPE	BUHE	CAGO	CAGU	CLSW	CORA	COOT	DOCO	DUSP	EUST	GRHE
October 22-23, 2013																				
Sand Plant													1		2					
Younger Lagoon			3				3						2				1		1	
Natural Bridges	2		1							1			3							
February 13-14, 2014																				
Sand Plant												6								
Younger Lagoon																				
Natural Bridges	1																			
April 27-28, 2014																				
Sand Plant	3									20										
Younger Lagoon						8				13		2								
Natural Bridges	3					2				11			7	2			8			
July 30-31, 2014																				
Sand Plant													10							
Younger Lagoon										18										
Natural Bridges										18										
November 4-5, 2014																				
Sand Plant																2				
Younger Lagoon							2			5						6				
Natural Bridges	11								2							10				
January 26-27, 2015																				
Sand Plant							2					2								
Younger Lagoon										6						9				
Natural Bridges	12						1			27					3					
April 14-15, 2015																				
Sand Plant							1					2				1				
Younger Lagoon							2									1				
Natural Bridges										6						7				
July 8-9, 2015																				
Younger Lagoon				2	4															
October 29-30, 2015																				
Younger Lagoon							1			4			2							
February 2-3, 2016																				
Younger Lagoon							1												2	
May 3-4, 2016																				
Younger Lagoon					4		2					2								
July 12, 2016																				
Younger Lagoon					3		1		12				2							
November 9-10, 2016																				
Younger Lagoon							2			1										
March 1-2, 2017																				
Younger Lagoon							1						3							
April 25-26, 2017																				
Younger Lagoon	1													6					2	

Site	GREG	GRTE	HEGU	KILL	LOCU	MALL	MAGO	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG
October 22-23, 2013																				
Sand Plant																				
Younger Lagoon			300	4			1				33									3
Natural Bridges			3			2														4
February 13-14, 2014																				
Sand Plant						2											1			
Younger Lagoon	1										8									4
Natural Bridges						2														1
April 27-28, 2014																				
Sand Plant						6							4							
Younger Lagoon				3		6							8			1				
Natural Bridges	1			1		4														
July 30-31, 2014																				
Sand Plant	1		10	4									3							
Younger Lagoon	4			2		2							3							3
Natural Bridges			15	3														7		
November 4-5, 2014																				
Sand Plant			6													2				
Younger Lagoon																		11		1
Natural Bridges	1		9	4														20		4
January 26-27, 2015																				
Sand Plant						2														
Younger Lagoon						4										10				
Natural Bridges	1					2										9				2
April 14-15, 2015																				
Sand Plant						2							3							
Younger Lagoon				1												5				2
Natural Bridges																4				3
July 8-9, 2015																				
Younger Lagoon				2		2							4							2
October 29-30, 2015																				
Younger Lagoon																				
February 2-3, 2016																				
Younger Lagoon						3							2							3
May 3-4, 2016																				
Younger Lagoon			1	1		3										1				
July 12, 2016																				
Younger Lagoon	1					3														1
November 9-10, 2016																				
Younger Lagoon	1			6												5				
March 1-2, 2017																				
Younger Lagoon	1										1					6				1
April 25-26, 2017																				
Younger Lagoon						4										2				

Site	SPSA	SURF	WEGU	WESA	WHIM	Richness
October 22-23, 2013						
Sand Plant						2
Younger Lagoon			150		26	13
Natural Bridges			110		24	8
February 13-14, 2014						
Sand Plant			103			4
Younger Lagoon			7		10	5
Natural Bridges			19		24	5
April 27-28, 2014						
Sand Plant			24		2	6
Younger Lagoon			2		2	9
Natural Bridges			18		7	11
July 30-31, 2014						
Sand Plant			25		2	8
Younger Lagoon			28		1	8
Natural Bridges			80		7	6
November 4-5, 2014						
Sand Plant			3			4
Younger Lagoon			10		8	7
Natural Bridges	1		18			10
January 26-27, 2015						
Sand Plant			25			4
Younger Lagoon			27		1	7
Natural Bridges			175		3	10
April 14-15, 2015						
Sand Plant			5			6
Younger Lagoon			5			6
Natural Bridges			21		9	7
July 8-9, 2015						
Younger Lagoon			31			7
October 29-30, 2015						
Younger Lagoon			6			4
February 2-3, 2016						
Younger Lagoon			9		4	7
May 3-4, 2016						
Younger Lagoon	1		8			10
July 12, 2016						
Younger Lagoon			2			7
November 9-10, 2016						
Younger Lagoon			6			8
March 1-2, 2017						
Younger Lagoon			2		1	10
April 25-26, 2017						
Younger Lagoon			2		4	8

Discussion

Data collected indicate that Younger Lagoon Reserve (YLR) supports a wide variety of native flora and fauna, provides habitat for sensitive and threatened species, supports a very unique beach dune community, and is extensively used for research and education.

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 small. 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.

Open access to the beach would likely result in the loss of the unique ecological characteristics of the site and certainly reduce its 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.

Figure 9. Younger Lagoon dune map. Survey data and resulting elevation model output shows topographic features on Younger Lagoon Beach.

Literature Cited

Friends of Santa Cruz State Parks. Natural Bridges. Retrieved from http://thatsmypark.org/naturalBridges.php. Accessed December 10, 2010.

Friends of Santa Cruz State Parks. Wilder Ranch. Retrieved from http://thatsmypark.org/wilderRanch.php. Accessed December 10, 2010.

Hyland, Tim. Personal communication December 22, 2010.

University of California at Santa Cruz. 2008. Final Compiled Coastal Long Range Development Plan. Prepared for California Coastal Commission, December 2008.

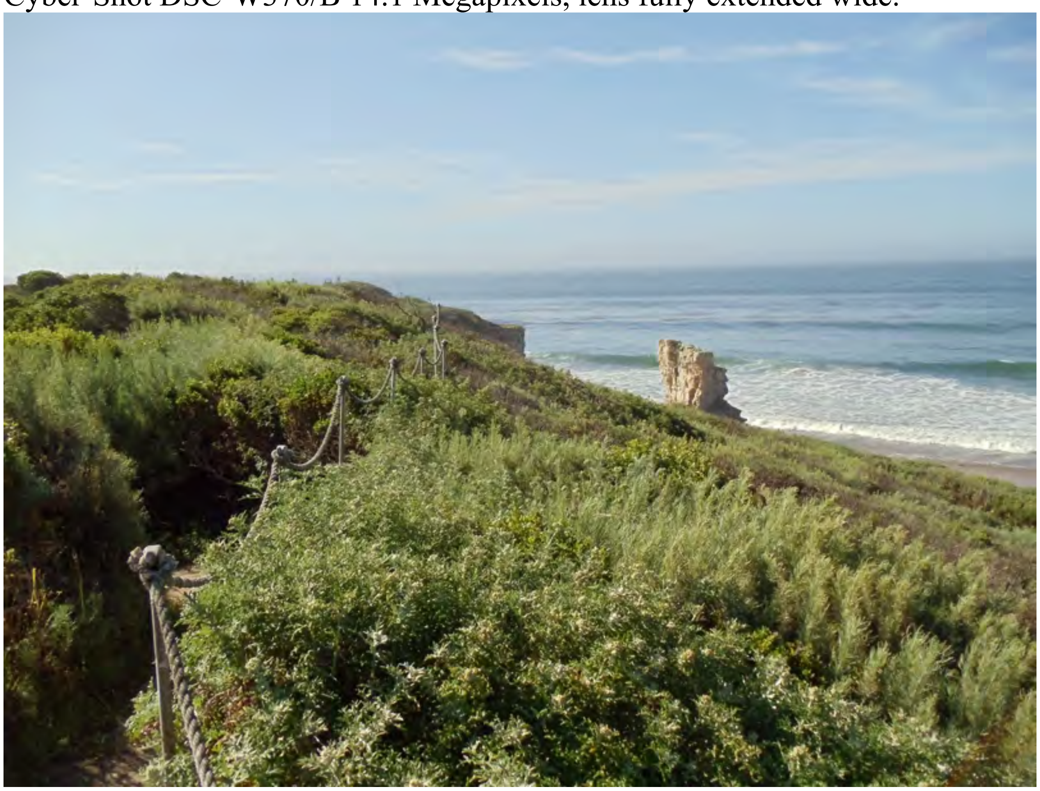
University of California at Santa Cruz. 2010. Notice of Impending Development 10-1, Beach Access Management Plan. Prepared for California Coastal Commission, March 2010.

Appendix 1. Younger Lagoon Photos.

YLR Beach Photopoint #1. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #1. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #1. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.



YLR Beach Photopoint #2. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.


YLR Beach Photopoint #2. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.


YLR Beach Photopoint #2. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #2. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.


YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.


YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #3. May 2, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide.

YLR Beach Photopoint #4. May 2, 2017. Photographer: Tim Brown. 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, Wetland Buffer, and Coastal Scrub Restoration Sites at Younger Lagoon Reserve
Spring 2017
J. Lesage

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 2017 monitoring of the lower terrace coastal prairie/grassland habitat plantings of 2010/2011 and 2014/2015, the wetland 6 buffer plantings of 2012/2013, and coastal scrub plantings of 2014/2015. Restoration efforts are within target richness and native cover goals for all planted areas described above except the 2011 grassland, which is slightly below the native cover goal.

Methods

Planting

Seeds for the coastal prairie and coastal scrub planting projects were primarily collected from local reference sites along coastal Santa Cruz and San Mateo Counties. The seeds were typically grown D7 conetainers^{TM} 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 m x 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 2m belt transect on either side of the 50 m transect tape to visually detect any species not measured in the cover quadrat sampling. Within the belt transects, visual surveys also looked for new recruitment of native species. Coastal scrub plantings were sampled by measuring the length of shrub cover beneath the transect tape to the nearest 0.1 m for each native species present.

In the lower terrace grassland, four 50 m transects were placed parallel to the coastal bluff, and were positioned to maximize coverage of the planted area while avoiding areas disturbed or destroyed by recent construction work (Figure 1). This yielded a total of 40 cover quadrats in the 2011 coastal prairie/grassland planting site. 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). The 2015 coastal prairie/grassland plantings were measured using three 50 m transects, for a total of 30 quadrats (Figure 1). The 2015 scrub plantings were measured using 2 transects, one of which was split, for a total of 20 quadrats. For all areas, cover and richness were averaged across transects and quadrats.

All sites but the 2015 scrub site are expected to meet the targets laid out for coastal prairie/grassland restoration. The 2011 site should meet 6 year post-planting targets, the 2013 wetland 6 buffer site is to meet the 4 year post-planting targets, and the 2015 coastal prairie/grassland site is expected to meet 2 year post-planting targets. The 2015 scrub planting site is expected to meet 2 year post-planting targets for coastal scrub restoration. Goals for all habitat types available in Appendix 1.

Results

Observed native cover surpassed target requirements in all but one of the sites (Table 1). In the 2011 grassland planting site, cover was 18.7% ± 3.5, below the goal of ≥ 25%. The 2013 Wetland 6 buffer planting site had a native cover value of 24.9% ± 6.4, which exceeds the ≥ 15% goal. Finally, the 2015 coastal prairie/grassland and scrub sites had native cover values of 31.8% ± 5.1 and 56.2% ± 9.6, exceeding their respective goals of ≥ 5% and ≥ 10% respectively.

Native species richness was above target levels in all four planted sites. The 2011 coastal prairie/grassland had a richness of 9.8 ± 0.8, the 2013 Wetland 6 buffer site had a richness of 8 species, the 2015 coastal prairie/grassland site had 14 ± 1.5 species, and the 2015 scrub site had a richness of 9 species. All sites exceeded the post-planting goal of ≥ 6 species, and all restoration sites had evidence of recruitment.

Discussion

All areas but the 2011 grassland/coastal prairie plantings have achieved their restoration goals during this monitoring period. Native cover in the 2011 coastal prairie/grassland planting area has declined since the last monitoring period, causing it to drop below the 6 year post-planting target set for the California Coastal Commission. Native cover was 28.1% ± 18.8 and 27.69% ± 3.80 in 2013 and 2015 respectively, but dropped to 18.7% ± 3.5 during the current monitoring period (Hammond 2013 Report, Lesage 2015 Report, Table 1). The decline in native cover in the 2011 grassland/prairie planting may be the result of nearby disturbance, as a portion of the site was destroyed in the last two years by construction work associated with the Marine Science Campus Coastal Biology Building Infrastructure Project. The restoration site destruction will be repaired using appropriate species by the construction in the future. An alternative cause for the decline in native cover in the 2011 plantings is that the exceptionally high precipitation this year benefitted invasive species to the detriment of native species. Unlike native species cover, native species richness has remained constant over the past two monitoring periods in the 2011 grassland/coastal prairie plantings, with 9.8 ± 0.6 species in 2015 and an average of 9.8 ± 0.75 species this spring (Hammond 2013 Report, Table 1).

The restoration of the wetland 6 buffer continues to achieve the targets laid out for the California Coastal Commission (UCNRS 2010) for coastal prairie/grassland restoration four years after implementation. In 2015, the wetland 6 buffer area had 29.5% ± 5.97 native cover, which dropped slightly to 24.9% ± 6.41 this monitoring period (Table 1, Lesage Report 2015). This still surpasses the 15% criteria set for 4-years post-planting in restored prairie/grassland. Native richness in the wetland 6 has improved since meeting the requirement with 6 species in 2015 – there were 8 species found during this monitoring period. Looking forward, the six year post-planting criteria will be 25% native cover, which will require that the current plantings recruit and spread successfully in the next two years. This will likely occur naturally, as recruitment was recorded for five of the eight species present (*Achillea millefolium*, *Baccharis pilularis*, *Hordeum brachyantherum*, *Juncus patens*, and *Rubus ursinus*).

This is the first year of monitoring for both the 2015 grassland/coastal prairie and 2015 scrub plantings, and both met or exceed their restoration goals. Native cover in the 2015 grassland/coastal prairie planting area was 31.8% ± 5.1, well above the 2-year criteria of ≥5%. The native species richness at this site was also impressive, with 14 ± 1.5 species. The 2015 scrub plantings are also exceeding their 2-year post-planting requirements. Overall native cover averaged 56.2% ± 9.56 in the 2017 monitoring season, well above the >10% cover goal. Additionally, there was an average 9 species present in each transect, with a total of 14 different species represented, also well exceeding the 6 species restoration criteria.

Overall, most of the restoration efforts at Younger Lagoon Reserve monitored this spring are meeting and exceeding 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. The 2011 restoration plantings may benefit from additional weeding, mowing, or herbicide application to reduce the cover of exotic weeds and allow native species to regain cover following destruction by construction crews.

Tables and Figures

Figure 1. Maps of transect locations in the 2011 grassland/coastal prairie (yellow), 2015 scrub (red), and 2015 grasslands/coastal prairie (blue) planting sites. Note that some transects are split to fit at the site.

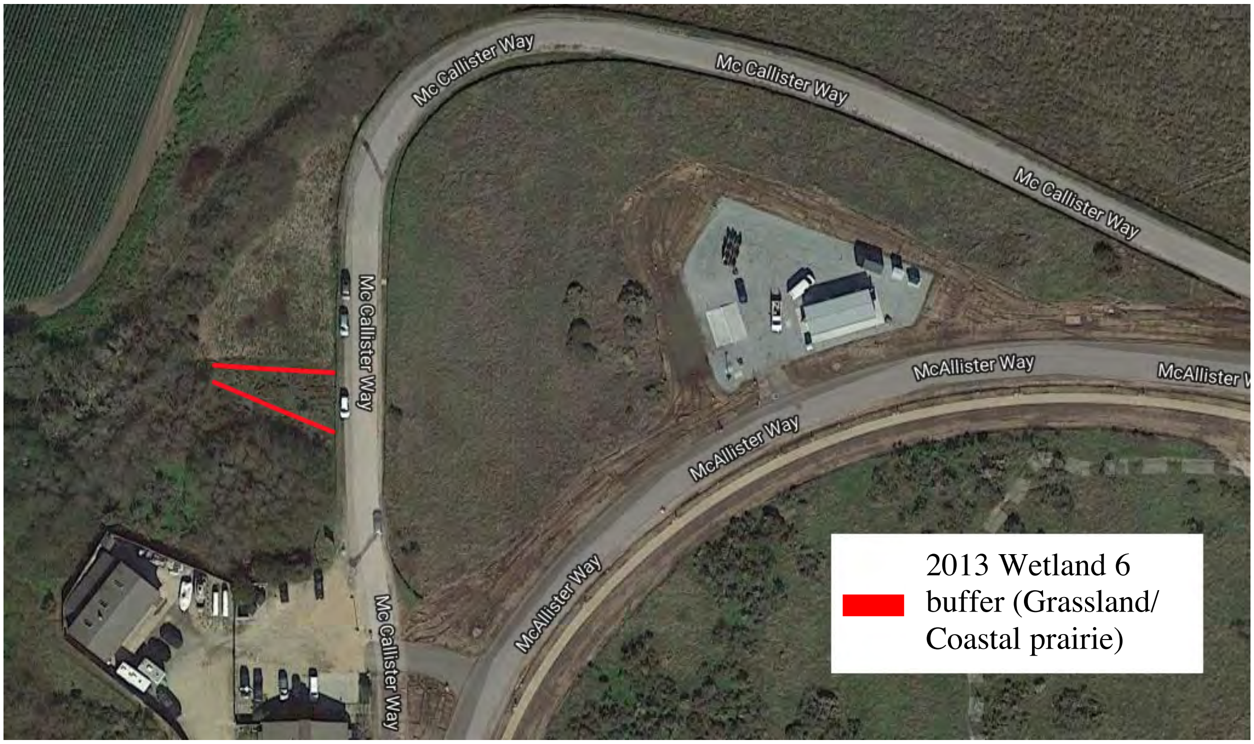


Figure 2. Map of transect locations (in red) in the 2013 Wetland 6 buffer planting site. Note that the transect is split to fit at the site.

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

	Restoration Site			
	2011 Grassland	**2013 Wetland 6 Buffer**	**2015 Grassland**	**2015 Scrub**
Observed Native Cover	18.7% ± 3.5	24.9% ± 6.4	31.8% ± 5.1	56.2% ± 9.6
Target Native Cover	≥ 25%	≥ 15%	≥ 5%	≥ 10%
Observed Native Richness	9.8 ± 0.8	8	14.0 ± 1.5	9
Target Native Richness	≥ 6 species	≥ 6 species	≥ 6 species	≥ 6 species

Table 2. Table of the native species observed in the 2011 and 2015 Grassland/Coastal Prairie sites, the 2013 Wetland 6 (W6) buffer site, and 2015 scrub restoration site 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 W6 Buffer	2015 Grassland	2015 Scrub
Erigeron canadensis	horseweed	AF	x			
Achillea millefolium	yarrow	PF	x	x	x	x
Baccharis glutinosa	marsh baccharis	PF	x		x	x

Chlorogalum pomeridianum	soaproot	PF	x		x	x
Epilobium spp.	willowherb	PF	x		x	x
Eriogonoum latifolium	coast buckwheat	PF				X
Eriophyllum staechadifolium	lizard tail	PF	x		x	X
Grindelia stricta	gumweed	PF	x			X
Horkelia californica	California horkelia	PF			x	
Prunella vulgaris	selfheal	PF		x	x	X
Pseudognaphalium californicum	Ladies' tobacco	PF	x			X
Ranunculus californica	California buttercup	PF				X
Scrophularia californica	bee plant	PF			x	X
Symphyotrichum chilense	Pacific aster	PF	x		x	
Agrostis pallens	leafy bent grass	PG			x	
Bromus carinatus	California brome	PG	x		x	X
Danthonia californica	California oatgrass	PG				
Elymus glaucus	blue wild rye	PG	x		x	X
Elymus triticoides	creeping wild rye	PG	x		x	X
Hordeum brachyantherum	meadow barley	PG	x	x	x	X
Carex harfordii	Monterey sedge	PGRM	x	x	x	
Juncus mexicanus	mexican rush	PGRM		x	x	X
Juncus patens	spreading rush	PGRM	x	x	x	
Artemisia californica	California sagebrush	S			x	X
Artemisia pyconocephala	coastal sagewort	S				X
Baccharis pilularis	coyote brush	S	x	x		
Frangula californica	coffeeberry	S			x	
Mimulus auranticus	sticky monkey flower	S			x	x
Rosa californica	California wild rose	S			x	x
Rubus ursinus	Pacific blackberry	S	x	x	x	x
	Total Observed Richness:		17	8	22	21

Works Cited

Lesage, J. 2015. Compliance Monitoring Report for the Coastal Bluff Grassland at Younger Lagoon Reserve, Spring 2015. Monitoring Report Prepared for the California Coastal Commission

Hammond, J. 2013. Compliance Monitoring Report for the Coastal Bluff Grassland at Younger Lagoon Reserve, Spring 2013. Monitoring Report Prepared for the California Coastal Commission.

Holl, K. D., and Reed, L. K. 2010. Reference and Baseline Vegetation Sampling for Younger Lagoon Natural Reserve. Report to the Coastal Commission.

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

Andrew Filous
Karen Holl
Research Paper
6/11/17

Non-chemical Methods to Reduce Exotic Cover and Facilitate Native Coastal Prairie and Scrub Plant Survival and Growth

Abstract

Coastal prairie and scrub habitats were once the dominant ecosystems lining the coast of California. Today land managers face the challenge of restoring these ecosystems often with diminished or limited budgets and in some cases constraints on use of herbicides. One of the many difficulties in restoring these ecosystems is managing to establish natives while suppressing exotic growth. I compared the efficacy of three non-chemical treatments (black plastic tarp, cardboard, and paper mulch) in facilitating the survival and growth of 12 native species spanning three guilds (shrubs, forbs, and grasses). Native plant survival was highest in paper and cardboard mulch treatments while tarp treatments were less effective in establishing native grasses. Mean growth was also lowest amongst native grasses in tarp treated plots, and were highest for grasses and forbs in paper treated plots. Costs for each treatment are nearly the same and soil moisture showed no significant differences across treatments. Continued study and long term monitoring will be necessary to determine which treatment methods are most effective.

Introduction

Past research has shown that native plant species richness and survival is often directly related to the presence and abundance of invasive species (Wood et al., 2017). Controlling competitive invasive species proves to be vitally important to the reestablishment of native plant species (McCary et al., 2016). Land managers in some areas (e.g. Younger Lagoon Reserve) are restricted in which methods they can use to control exotic species as herbicides are restricted. Alternative cost-effective methods, including different mulch treatments, are often used in place of herbicides to control background vegetation growth. Invasive species have been known to increase rates of herbivory which can be detrimental to the health of native plants. Studies have shown that choosing plants for restoration with similar traits to likely exotic species can hinder the establishment of exotics (Funk et al., 2008). These studies demonstrate clearly that the presence of exotic species is detrimental to native plants, making land managers control over them vitally important.

Adding various types of mulch (wood chip, cardboard, paper) to a restoration project can be important to reducing exotic cover as well as improving soil health and moisture content, and subsequently promoting plant health (Chalker-Scott, 2007). Reduced soil moisture content can result in reduced water uptake and leaf water potential in scrub ecosystems (Saha, 2007). While mulch can help with soil moisture retention in periods of low rainfall, mulch can also act as a rainfall barrier to prevent soils from becoming over-saturated during storm events (Cook et al., 2006). Mulch can also be critical to the suppression of light and space required for weed germination (Upadhyaya & Blackshaw, 2007). More recent studies have shown that cardboard mulch paired with wood chip mulch can increase plant survival and cover (Wood et al., 2017). Mulch treatments have also shown to increase microbial activity which can enhance plant growth and survival in native perennials (Zink & Allen, 1998).

Studies have shown that tarping can be effective in shading out recently germinated exotic seedlings (Holl et al., 2014). Destroying exotic species before planting natives gives the native plants the distinct advantage of decreased competition. With decreased competition for nutrients, native plant species have a much greater chance of establishing early on (Cushman et al., 2011). Other studies have shown that applying black plastic tarp helps with the establishment of native grasses while reducing exotic grass cover (Holl et al., 2014).

The goal of my study was to test the effects of different mulching treatments on native plant survival and growth. In a paired study my research partner analyzed the effects of the three mulching treatments on exotic growth and cover. Past research suggests that tarping is effective in reducing exotic forb and grass cover for a couple of years (Holl et al., 2014). Therefore, I expected that the tarped plots would have the lowest weed survival rates. This combined with the positive effects tarping can have on soil moisture lead me to believe it will also have the greatest native plant survival and growth rates as well. Cardboard remains underneath the wood chip mulch for months after planting. Due to its resilience, I believed the presence of cardboard would act as a physical barrier to weed growth, allowing for easier establishment of natives early on. I expected cardboard plots would follow closely behind tarped plots in native cover measurements and survival percentages. The paper treatment used in the project decomposed rather quickly (within 3 weeks); therefore the treatment was not expected to have a strong effect on the prevention of background vegetation growth.

Methods

Coastal prairie and scrub habitats were once the dominant ecosystem types lining the coasts of California. Beginning as early as the 1700s with the establishment of the mission system, coastal habitats began to dwindle as the Spanish cleared land for agricultural production (Stern, 2013). Agricultural practices as well as continued housing development went on to play a role in coastal habitat degradation for the next 200 plus years. Our study site at Younger Lagoon Reserve (YLR) was no exception to that fate. Coastal systems like YLR became dominated by exotic species. Due to those changes in land use practices, restoration work has been made exponentially more difficult. Therefore, restoring these habitats to a semblance of their native structure requires a multifaceted approach. The project was conducted on the 29-

hectare tract of land at YLR owned by the University of California, Santa Cruz. YLR is one of over 30 natural reserve lands under the stewardship of the UC system. There are three main habitat types that are the focus of restoration at YLR which are coastal prairie, northern coastal scrub, and seasonal freshwater wetlands (Stern, 2013). My study focuses on the restoration of coastal prairie and scrub species.

The seedlings used in the experiment were grown at the UCSC Greenhouses under the supervision of Director Jim Velzy. Student interns and my collaborator on the project were on site at the Greenhouse placing seeds collected from nearby reference sites into soil filled conetainers. After germination the seedlings remained on site at the Greenhouses for several weeks in order to undergo hardening. Once ready for the field, seedlings were then transferred to YLR for outplanting. The species studied (Table 1) are all natives to California coastal prairie and scrub habitat and can be found across many reference sites nearby.

In fall 2016 my project collaborator, YLR staff, and interns set out twelve 6.1 × 6.1m plots (Fig. 1) with four replicated plots of each treatment: tarp, cardboard and paper mulch. Four plots were covered with a black plastic tarp to shade out recently germinated exotic seedlings. The tarps were placed in early November 2016 following late October rains and were removed after six weeks in late December prior to planting. Four plots were treated with non-toxic cardboard obtained primarily from a local bike shop in Santa Cruz. Staples were removed from the cardboard and it was cut to size. The cardboard was then spread evenly atop the soil. The four remaining plots were treated with a black paper mulch, which covers the entirety of the plots and is 0.28 mm thick. The paper was purchased online from the Sunshine Paper Company based in Arora, Colorado. All 12 plots were then covered with a wood chip mulch immediately prior to planting. The wood chips are comprised of a mixture of mainly redwood, cypress, and bay laurel. The wood chip mulch is provided by the UCSC campus via the Grounds Department. The wood chips are free to UCSC but labor costs $50/hour to deliver.

Flags were placed at the ends of each row, indicating which species was planted in that given row. Bright red string was tied from the Northeast to Southwest and Northwest to Southeast corners of each plot to form an 'X' to keep birds from landing in the plots.

Beginning in mid-January, seedlings of the 12 different species were planted. Over the course of 2 weeks my collaborator and I led a group of student interns who assisted in the planting of all 1,728 plants. The planting matrix consists of 12 rows, each containing a different species. Each row was planted 45.72 cm apart with a buffer zone of 53.34 cm on each side. The rows of plants are oriented longitudinally running north to south. Also beginning in January, soil moisture has been monitored every two weeks with a Spectrum Field Scout TDR 100 soil moisture sensor that determines VWC% (volumetric water content).

Data Collection

My student collaborator and I conducted an initial plant survival count in early February Seedlings that died within the first two weeks were replaced. Between April and May of this year I measured survival and cover of each individual plant. Individual native species survival was recorded as alive or dead. I then measured plant cover to the nearest 0.5 dm^2 using cover squares. Percent cover of exotic grasses and forbs was estimated by a student collaborator using a 1m x 0.25 m quadrat and a 0.5 x 0.5 decimeter cover square. Sixteen points were designated at random for quadrat placement in each plot and percent exotic cover and species type were recorded.

Statistical Analysis

I used a one-way analysis of variance (ANOVA) to assess the effects each treatment (cardboard, tarp, and paper) had on native plant survival and cover. Data were analyzed using statistical analysis software JMP pro version 13.1. P values of < 0.05 are considered statistically significant. One of the cardboard treated plots suffered mass die off for all of the shrub species and was been removed from the data analysis as an outlier.

Cost Analysis

Costs of the tarp and paper treatments were determined by taking the entire cost of the product and dividing it by the total area in square meters. This calculation produced a cost per m^2 for both treatments. Although the cardboard was free, the labor put into collecting and preparing the treatment was not. Labor costs were divided by square meters of cardboard collected to determine the cost of the treatment.

Results

Survival

Survival of shrubs was highest in cardboard (outlier plot removed) and tarp treated plots and significantly lower in paper treated plots (Fig. 2). Forbs had highest survival in paper treatment, intermediate in cardboard, and lowest in tarp. The grasses guild had highest survival in cardboard and paper treatments, both of which were significantly higher than tarp (Fig. 2). For individual species results please refer to Table 1.

Cover

Cover amongst the shrub guild was significantly higher in tarp treated plots than in both paper and cardboard. Cover of forbs was significantly higher in paper treated plots than in both tarp and cardboard. Cover in the grass guild was highest in paper treatment, intermediate in cardboard, and significantly less in tarp treatment (Fig. 2). For individual species results please refer to Table 2.

Soil Moisture and Cost

An analysis of soil moisture readings from a date two weeks before data collection showed no significant results across treatments (21.05 ± 1.30). Cost of tarp treatment was 27¢ per m^2, paper was 54¢ per m^2, and cardboard was 43¢ per m^2.

Discussion

Overall survival and cover measurements were consistently high within all guilds and across treatments. The only exception was the grass guild, which had low survival and growth in tarp treated plots. *Danthonia californica* did well in most treatments and had its highest growth and survival measurements in paper treated plots. *Horkelia californica* displayed consistently high growth and survival measurements across all treatments. *Clinodopium douglasii* (Yerba Buena) struggled to establish in each treatment displaying low survival and growth measurements. The only species which displayed no significant differences in growth across treatments was *Ericameria ericoides*, with consistently moderate to low growth measurements.

Differences across treatments were not as strong as expected before planting. Native growth and survival were mostly similar across treatments. Soil moisture showed no significant differences across treatments. In a parallel study conducted by Wertheimer (2017), cover of background vegetation yielded no significant results either. The lack of variance in results may be attributed to two factors, the first of which is the wood chip mulch that was applied. It is possible that the universal application of the wood chip mulch may have ameliorated the effects of the treatments. Differences may have been more striking if treatments were left exposed. Another factor that may have played a role in the uniformity of results was the heavy rainfall the area experienced. The persistent storm events in the winter and spring months could be responsible for the lack of significance in the moisture data and background vegetation measurements. Additionally, the oversaturation of the soil could have contributed to the lack of differences in survival and growth measurements for native planted species.

There are pros and cons associated with associated with each of the treatments. Cardboard displayed the most consistently high survival of the three treatments, as well as steady growth measurements (Figure 2). An additional benefit of cardboard it that it is yet to fully break down, acting as a potential barrier to background vegetation growth. Studies have shown that cardboard can help promote growth by adding additional organic matter to the soil (Elliott et al., 2013). Some of the issues with cardboard are logistical. Although it was free, acquisition of the cardboard required hours of labor to source and transport. Additional labor had to be put into shaping and preparing the cardboard for application in the field. These negative factors make cardboard a more time consuming option.

Paper was effective in promoting growth of natives and produced high survival rates (Figure 2). Paper is also much easier to handle logistically. The treatment was easily purchasable online and was reasonably priced (54¢ per m2). Application requires simply rolling out the paper in rows and cutting it at the appropriate length. One con of the paper application is that it breaks down quickly (within 3 weeks). Once broken down, it will no longer act as a weed suppressor or provide a barrier to rainfall and prevent oversaturation of the soil.

Like the other treatments, there are both positive and negative aspects to tarping. The tarp treatment was effective in promoting growth and survival in the forb and grass guilds (Figure 2). The tarp was also easily accessible through online purchase. Another benefit of tarp is that it can be used multiple times, doubling its cost effectiveness. One negative aspect of the tarp treatment is that it did not do well in promoting growth and survival within the grass guild. Also, if unable to apply the tarp a second time (like in our study), background growth would be difficult to suppress.

Continued study will be necessary to determine long term efficacy of each treatment. As of yet there is no clear choice for a treatment strategy. Studies have shown that second and third year establishment of grasses tend to change over time (Holl et al., 2014). Due to the cardboard treatment's continued presence above the soil, I expect background vegetation growth to be significantly lower in that treatment next year. There will be no secondary applications of treatments, therefore the lack of presence of both paper and tarp may lead to higher measurements in background growth. Higher exotic cover could subsequently hinder native growth and survival. Based on current results, continued survival and growth of shrub and forb guilds are expected to be higher than that of grasses. Monitoring of the sites will continue through next year.

Acknowledgements

A special thank you to Dr. Karen Holl for being essential to the organization of the study as well as advising me throughout the project. Also to Tim Brown for helping design the experiments and for sourcing all of the materials used in the project along with leading a crew of interns in setting up the plots. Thank you to Delanie Wong for leading interns and assisting in the planting of our native species. Jim Velzy for helping grow and establish all of the seedlings used in the project. Kacie Ring and Josie Lesage for assistance in data collection. Lastly, the many interns who helped establish the plots and plant the plants.

Reference List

Cook, H. F., Valdes, G. S., & Lee, H. C. (2006). Mulch effects on rainfall interception, Soil physical characteristics and temperature under *Zea mays* L. *Soil and Tillage Research 91*, 227–235. http://doi.org/10.1016/j.still.2005.12.007

Cushman, J. H., Lortie, C. J., & Christian, C. E. (2011). Native herbivores and plant facilitation mediate the performance and distribution of an invasive exotic grass. *Journal of Ecology*., 99.2. http://doi.org/10.1111/j.1365-2745.2010.01776.x

Elliott, Stephen, David Blakesley, Kate Hardwick, Surat Plukham, Damrongchai Saengkam, and Joseph Nkongho Agbor. "Chapter 7.2 - Planting." *Restoring Tropical Forests: A Practical Guide*. London: Royal Botanic Gardens, Kew, 2013. 226. Print.

Funk, J. L., Cleland, E. E., Suding, K. N., & Zavaleta, E. S. (2008). Restoration through reassembly: plant traits and invasion resistance. *Trends in Ecology & Evolution*, *23*.12. 695–703. http://doi.org/10.1016/j.tree.2008.07.013

Holl, K. D., Howard, E. A., Brown, T. M., Chan, R. G., Silva, T. S. D., Mann, E. T., … Spangler, W. H. (2014). Efficacy of exotic control strategies for restoring coastal prairie grasses. *Invasive Plant Science and Management*, *7*, 590–598.

http://doi.org/10.1614/ipsm-d-14-00031.1

Chalker-Scott, L. (Washington State University), Puyallup Research and Extension Center, 7612 Pioneer Way E., Puyallup, WA 98371), *Journal of Environmental Horticulture* 25.4. December 2007, 239- 249, published by the Horticultural Research Institute, 1000 Vermont Ave., N.W., Suite 300, Washington, DC 20005.

Mccary, M. A., Mores, R., Farfan, M. A., & Wise, D. H. (2016). Invasive plants have different effects on trophic structure of green and brown food webs in terrestrial ecosystems: a meta-analysis. *Ecology Letters*, *19*.30. 328–335. http://doi.org/10.1111/ele.12562

Saha, S., Strazisar, T. M., Menges, E. S., Ellsworth, P., & Sternberg, L. (2008). Linking the patterns in soil moisture to leaf water potential, stomatal conductance, growth, and mortality of dominant shrubs in the Florida scrub ecosystem. *Plant and Soil*,313(1-2), 113–127. http://doi.org/10.1007/s11104-008-9684-3

Stapleton, J. J. (2000). Soil solarization in various agricultural production systems. *Crop Protection*, *19*(8-10), 837–841. http://doi.org/10.1016/s0261-2194(00)00111-3

Stern, N., Holl., K., & Howard, E. (2013). Habitat Types of Younger Lagoon Reserve. *UCSC*.

Taparauskiene, L., & Miseckaite, O. (2013). Effect of Mulch on Soil Moisture Depletion and Strawberry Yield in Sub-Humid Area. *Polish Journal of Environmental Studies*, *23*.2. 475–482. http://doi.org/10.1111/j.1365-2745.2010.01776.x

Upadhyaya, M. K., & Blackshaw, R. E. (2007). 9. In *Non-chemical Weed Management: Principles, Concepts and Technology* (pp. 135–149). essay, Wallingford, UK: CABI.

Wood, J. K., Gold, W. G., Fridley, J. L., Ewing, K., & Niyogi, D. K. (2017). An Analysis of Factors Driving Success in Ecological Restoration Projects by a University-Community Partnership. *Ecological Restoration*, *35*.1. 60–69. http://doi.org/10.3368/er.35.1.60

Zink, T. A., & Allen, M. F. (1998). The Effects of Organic Amendments on the Restoration of a Disturbed Coastal Sage Scrub Habitat. *Restoration Ecology*, *6*.1. 52–58. http://doi.org/10.1046/j.1526-100x.1998.00617.x

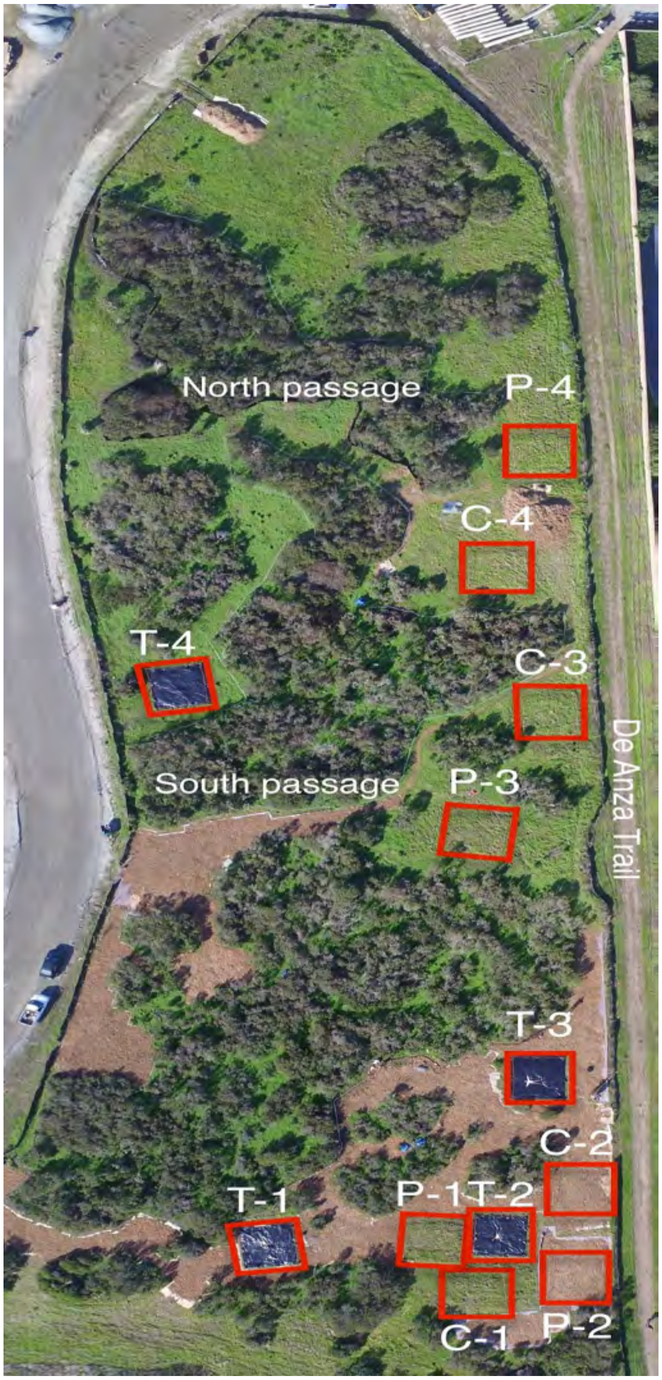


Fig 1. Aerial view of plots at Younger Lagoon Reserve. Red boxes indicate location of research plots. The letters ‘T’ ‘P’ and ‘C’ represent tarp, paper, and cardboard respectively.

Table 1. Mean survival percentage across species and guilds plus/minus standard error. F and P values taken from ANOVA testing significance of survival rates amongst species and across treatments. Numbers represent a mean survival percentage. Guilds represented next to species.

Native Mean Survival

Species	**Guild**	Tarp	Paper	Cardboard	F	P
Artemisia californica-ARCA	Shrub	96 ± 4	81 ± 4	100 ± 5	5.97	0.0033
Ericameria ericoides-ERER	Shrub	89 ± 4	83 ± 4	100 ± 5	3.32	0.0392
Mimulus aurantiacus-MIAU	Shrub	92 ± 3	98 ± 3	97 ± 4	1.25	0.2888
Scrophularia californica-SCCA	Shrub	92 ± 4	94 ± 4	97 ± 4	0.55	0.578
Clinopodium douglasii-CLDO	Forb	44 ± 7	58 ± 7	38 ± 7	2.23	0.1116
Horkelia californica-HOCA	Forb	98 ± 2	98 ± 2	98 ± 2	0.00	1.00
Prunella vulgaris-PRVU	Forb	77 ± 4	98 ± 4	92 ± 4	5.89	0.0035
Symphyotrichum chilense-SYCH	Forb	75 ± 4	98 ± 4	94 ± 4	7.88	0.0006
Elymus glaucus-ELGL	Grass	56 ± 5	94 ± 5	100 ± 5	25.91	<0.0001
Stipa pulchra-STPU	Grass	46 ± 5	90 ± 5	98 ± 6	30.49	<0.0001
Danthonia californica-DACA	Grass	42 ± 5	92 ± 5	92 ± 5	29.68	<0.0001
Hordeum brachyantherum-HOBR	Grass	65 ± 4	96 ± 4	100 ± 4	19.67	<0.0001

Table 2. Mean growth of native species across guilds plus/minus standard error. F and P values from ANOVA testing significance of treatments amongst species growth rates. All

measurements are in decimeters squared. Guilds represented next to species.

Species	**Guild**	**Tarp**	**Paper**	**Cardboard**	**F**	**P**
Artemisia californica-ARCA	Shrub	1.48 ± 0.12	1.14 ± 0.12	1.15 ± 0.13	2.79	0.065
Ericameria ericoides-ERER	Shrub	0.39 ± 0.04	0.28 ± 0.03	0.37 ± 0.05	1.98	0.141
Mimulus aurantiacus-MIAU	Shrub	0.86 ± 0.09	0.52 ± 0.07	0.69 ± 0.09	5.06	0.0077
Scrophularia californica-SCCA	Shrub	1.51 ± 0.13	1.26 ± 0.09	0.94 ± 0.13	5.52	0.005
Clinopodium douglasii-CLDO	Forb	0.14 ± 0.04	0.30 ± 0.06	0.14 ± 0.28	3.52	0.0326
Horkelia californica-HOCA	Forb	1.71 ± 0.10	1.78 ± 0.07	1.45 ± 0.10	3.46	0.0341
Prunella vulgaris-PRVU	Forb	1.43 ± 0.14	1.95 ± 0.09	1.33 ± 0.11	8.56	0.0003
Symphyotrichum chilense-SYCH	Forb	1.07 ± 0.12	1.67 ± 0.12	1.29 ± 0.11	6.79	0.0015
Elymus glaucus-ELGL	Grass	0.51 ± 0.08	1.28 ± 0.10	0.86 ± 0.05	24.01	<0.0001
Stipa pulchra- STPU	Grass	0.32 ± 0.06	0.80 ± 0.06	0.64 ± 0.04	18.11	<0.0001
Danthonia californica-DACA	Grass	0.20 ± 0.04	0.65 ± 0.06	0.47 ± 0.04	22.43	<0.0001
Hordeum brachyantherum-HOBR	Grass	0.78 ± 0.11	1.43 ± 0.08	1.08 ± 0.07	13.85	<0.0001

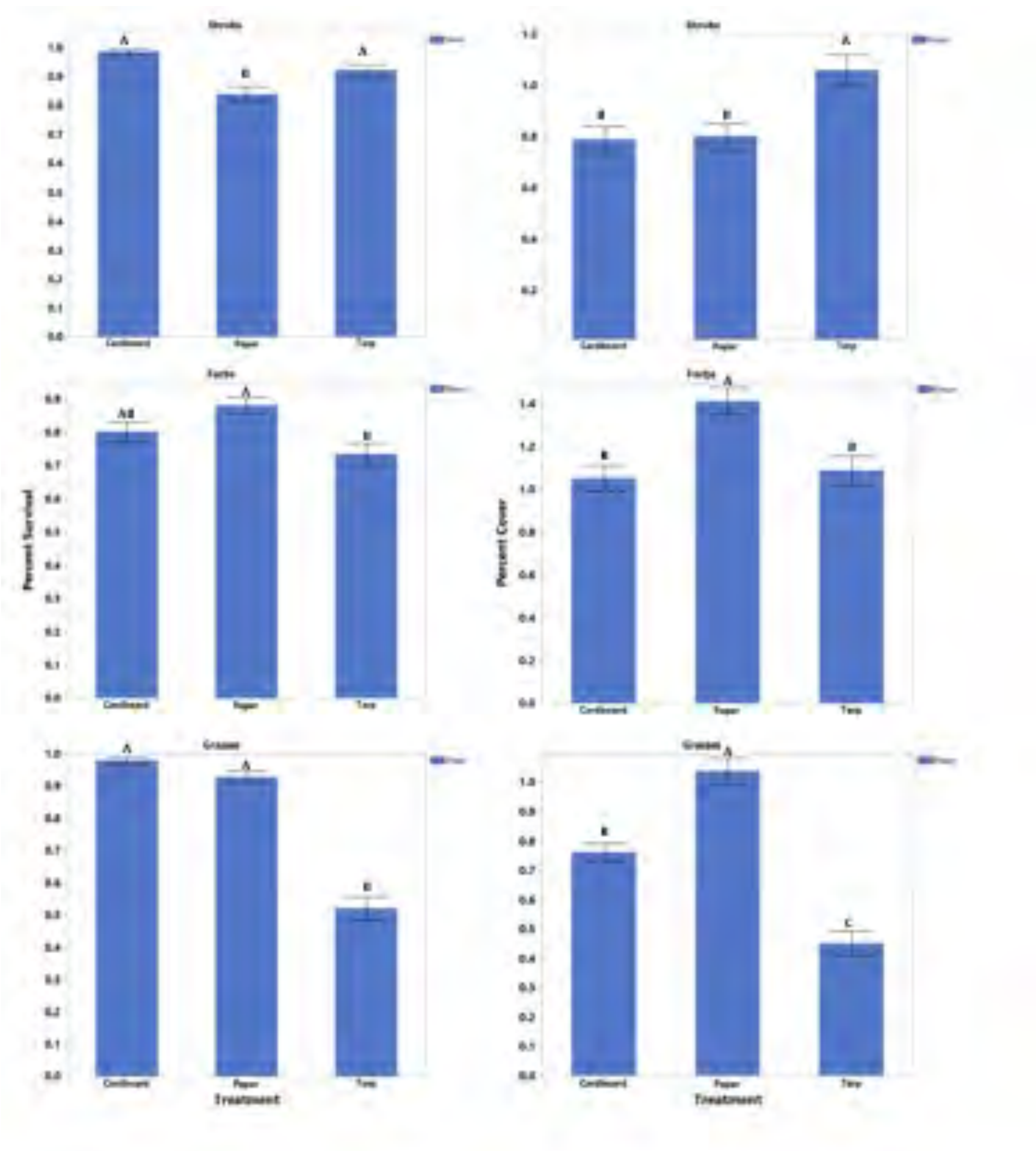


Figure 2. Survival (left) and growth (right)
across each treatment for shrubs (top), forbs (middle), and grasses (bottom) . Error bars represent one standard error.

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

Direct Seeding Ineffective in Restoring Coastal Prairie

by
Jay Luce Nelson

This thesis was submitted to the faculty of the Environmental Studies Department of the University of California, Santa Cruz in partial fulfillment of the requirements for the Bachelor of Arts degree

June 12, 2017

Advisor:
Dr. Karen Holl

Abstract California coastal prairie is a diverse but widely degraded habitat that is a common target for restoration efforts. Direct seeding is generally cheaper than planting seedlings for restoration, making it of interest to land managers. We assessed two methods of seeding, hand broadcasting and drill seeding, in the second growing season after sowing. We additionally assessed the efficacy of mulching and mowing as non-native grass management to increase native establishment. The average percent cover of all native species seeded except *Hordeum brachyantherum* and *Achillea millefolium* was less than one percent. In all cases in year two, broadcast seeding was more or equally effective when compared to drill seeding. Results in the first and second growing season differ in some aspects; mulch was less effective in the second growing season, and stands of only three sown native species remained despite five having established previously. One of species found in year two, *Sisyrinchium bellum*, was not found in the first year. Direct seeding is not recommended as a restoration method except for single-species restoration of selected species.

KEYWORDS: Coastal prairie restoration, broadcast seeding, drill seeding, mulch, mowing, non-native grass control

Introduction

Like other ecosystems within Mediterranean climate zones, California coastal prairies have high biodiversity with many rare, threatened, and endemic species, making them a popular target of restoration efforts (Ford and Hayes 2007, Stromberg et al. 2001). Over 80 species of plants are endemic to coastal prairies, some essential to the persistence of threatened and endangered species including the Ohlone tiger beetle (*Cicindela ohlone*) and various native butterflies (Ford and Hayes 2007). Much of this habitat in California has been previously converted to agricultural land or lost to urbanization; recent work has been done in the case of the former to functionally restore coastal prairies to pre-agricultural conditions (Holl et al. 2010).

Historically dominated by native perennial bunchgrasses, disturbed California coastal prairie is threatened and often successfully invaded by non-native species, particularly annual grasses from Mediterranean regions that compete with native species for nutrients, light, and space. Although native grasses have been able to outcompete non-native species over multiple years in some sites (Seabloom et al. 2003a, Seabloom et al. 2003b, Stromberg et al. 2007), many more regions are seed limited and lack native species in the standing vegetation or seed bank, requiring active restoration of grass and forb species through seeding or planting (DiVittorio et al. 2007, Seabloom et al. 2003a, Stromberg et al. 2007).

When choosing between seeding or planting, land managers look for cost-effective techniques for the reestablishment of native grass and forb populations (Holl et al. 2014). Concern regarding potential pathogen transmission by nurseries and higher costs of planting plugs to direct seeding, in terms of both purchasing and labor, have fostered interest in the potential of restoration using direct seeding (Desimone 2011). Seeding is considered to be a cheaper alternative to planting seedlings, but low success rates of establishment and survival until reproduction from seeds may incur labor costs nearly two times the cost of planting per established seedling (Moore et al. 2011).

Direct seeding has shown variable results in previous experiments, with failures typically accredited in part to weather, seed predation, herbivory, or competition with non-natives (Hamilton et al. 1999, Hayes and Holl 2003, Orrock et al. 2008). One experiment found that adding seed to plots with over 65% non-native cover resulted in successful establishment of native forbs. The same experiment found that recruitment was a more important limiting factor of native establishment than environmental conditions while acknowledging that precipitation affects the outcome of inter-guild competition between native forbs and non-native grasses (Seabloom et al. 2003a). Desiccation is problematic for direct seeding efforts in years of infrequent precipitation due to California's highly variable rainfall (DeFalco et al. 2012); a combination of germination failure and high mortality of newly-germinated plants decrease the success of seeding further (Clark et al. 2007, James et al. 2011).

Direct seeding may be accomplished by broadcasting seed by hand or machine or by using mechanical drilling; the method selected may affect efficacy of restoration projects. Drill seeding has been found to be effective on a case-by-case basis (Nyamai et al. 2011) and provides significant soil-seed contact, which increases seed germination rates (Rotundo and Aguiar 2005). However, drill seeding may require more time and effort when using seeds with chaff that may cause jamming and provide considerable difficulty for those not skilled with the equipment (Burns 2016). Broadcasting results in less soil-seed contact unless further action is taken after broadcasting; tamping soil following broadcasting (e.g. by using a lawn roller) increases establishment rates through improved soil-seed contact in coastal scrub restoration (Desimone 2011). Broadcast seeding with tamping may prove to be an efficient alternative to drill seeding, which may be inaccessible to non-agricultural areas, difficult, and expensive if equipment must be acquired. Additionally, drill seeding may be less efficient for small-seeded forbs, which may germinate less successfully when buried at lower depths, than for grasses (Traba et al. 2004, Burns 2016).

In addition to native establishment, management of non-native grasses is a necessary priority in restoration. Non-native annual grasses tend to germinate faster than native perennial grasses due to their short life cycle and allocation of resources to rapid growth rather than surviving summer droughts (Abraham et al. 2009, DiVittorio et al. 2007, Wainwright et al. 2012). In prior seeding experiments, coastal prairie restoration has been most successful where non-native species were removed prior to seeding, as non-native annuals may successfully compete with native perennials (Corbin and D'Antonio 2004). Mulch also improves native reestablishment by reducing evaporation of soil moisture, and the use of wood chips has been linked to increased native cover (DiTomaso 2000, Jodaugiene et al. 2006, Tang 2013). Mulching and mowing as post-seeding management may increase the sometimes-low success rate of direct seeding, but the extent to which this occurs in the first growing season is likely crucial, as mulch effects decrease in the second year (Holl et al. 2014).

Green Burns (2016) initiated an experiment assessing the efficacy of broadcast and drill seeding, additionally testing the potential of mulching and mowing as non-native grass control to increase establishment of five native forbs and five native grasses. Burns found that of the five species that successfully established with more than 25 individuals, two forb species (*Achillea millefolium* and *Grindelia stricta*) established more successfully in broadcast plots and that seeding method did not affect the establishment of the three grass species (*Hordeum brachyantherum*, *Danthonia californica*, and *Elymus tricoides*). Non-native grasses showed higher percent cover in broadcast plots than drill seeded plots. Wood mulch with mowing significantly increased the establishment of all sown species regardless of seeding method but also increased the percent cover of bare ground and non-native grasses. We continued the experiment in the second growing season to determine long-term effects of the treatments that may not arise in the first season.

Due to the importance of the order of emergence, we hypothesized that the five species that established a population of greater than 25 individuals in 2016 would retain significantly higher percent cover than the five lesser- and unestablished species. we hypothesized that relative non-native cover would increase in the 2017 growing season due to decreased necessary dispersal distance of non-native annuals (i.e. seeds will be readily available from 2016 annual growth and reproduction) and vegetative reproduction. I predicted that mulch would continue to have a positive effect on the native percent cover, but to a much weaker extent than in year one.

Methods

<u>Site</u>

The experiment was conducted on the first marine terrace of Younger Lagoon Reserve (YLR) in Santa Cruz, California (36°57’03”N, 122 °03’57”W). The reserve land was historically used for agricultural Brussels sprouts production until 1987 and laid fallow until the initiation of the experiment. The land is managed by the University of California Natural Reserve System and contains seasonal wetlands, coyote brush scrubland, and grassland dominated by non-native annuals. The University of California, Santa Cruz is required to restore coastal prairie at Younger Lagoon Reserve to mitigate for the development of the Coastal Science Campus. The site experiences wet cool winters and dry warm summers typical of a Mediterranean climate (Holl et al. 2010).

Experimental Design

The first stage of the experiment was performed by Green Burns (2016). Burns established ten 10 × 10 m plots at YLR (Appendix Fig. 1). The plots were tarped for approximately two years prior to the start of the experiment to decrease competition with non-native species. The seed bank was then allowed to germinate before the tarps were returned to shade out plants that germinated from the seed bank. Tarps were removed for the last time in October 2015. Plots were rototilled to approximate depths of 10-12 cm and raked using a stirrup hoe to disrupt the growth of remaining plants. In mid-November, five randomly-selected plots were broadcast seeded and the remaining five were drill seeded with a single-row walk-behind drill seeder. The western half of each plot was mulched prior to seeding and was mowed in the spring and fall. The eastern half acted as a control for non-native grass management. All subplots were mowed in August 2016.

Burns seeded one species among the five perennial forb and five perennial grass species in 1 × 10 m belt transects. Plants were seeded in alternate rows of forbs and grasses with some exceptions due to errors during seeding (Appendix Fig. 2). Burns seeded the perennial forbs *Achillea millefolium* (common yarrow), *Grindelia stricta* (coastal gumplant), *Sisyrinchum bellum* (western blue-eyed grass), *Symphyotrichum chilense* (common California aster), and *Eschscholzia californica* (California poppy). The seeded perennial grasses were *Danthonia californica* (California oatgrass), *Elymus glaucus* (blue wild rye), *Elymus triticoides* (creeping wild rye), *Hordeum brachyantherum* (meadow barley), and *Stipa pulchra* (purple needlegrass). Species were selected by seed availability.

Drill seeding encountered difficulties. Due to seeder jamming, some drill seeding was simulated by placing seed in a shallow furrow created with the handle of a hoe and covering the seeds using a rake. Drill seeding had to be simulated for *Danthonia californica* and *Elymus glaucus* in plots 2, 3, and 6. The seeder and simulated drill seeding were both used for *Hordeum brachyantherum* in plots 6 and 7. For more detailed methods regarding the seeds used and germination rates, see Burns 2016.

Data Collection

We used 0.25 m × 1 m quadrats to maintain the method used in the previous year for visually estimating percent cover using 5% and 10% cover references. Between 24 April and 07 May, we placed four quadrats in each subplot of a species row using randomly generated distances along the transect. One of the quadrats was assigned to be a full measurement, including percent cover estimations of the seeded species, thatch, bare ground, non-native forb, non-native grass, and other native species. We estimated percent cover of only the seeded species in the remaining three quadrats per subplot. We measured percent cover of each species within the quadrats in intervals of 5 percent (i.e. 0-5% cover, 5-10% cover, etc.) and recorded the median value of the interval (i.e. 2.5%, 7.5%, etc.). Due to the density of grasses in the experimental area, individual native plants were not counted as they were in the first growing year. Rainfall data were collected from a NOAA cooperative station located near the site in Santa Cruz, California.

Data Analysis

The effects of seeding method, non-native management (mulch and mowing), and the interaction between the two were assessed using ANOVA. Data were analyzed using JMP Pro 13 with $P < 0.05$ considered as significant.

Results

Of the ten seeded species, only *A. millefolium*, *S. bellum*, and *H. brachyantherum* were present in more than two quadrats in the second year. *S. bellum* did not establish in year one but was found in numerous plots with low cover. *A. millefolium* and *H. brachyantherum* established in the first year, with the latter increasing substantially in mean percent cover in the second growing season. *Eschscholzia californica* and *Elymus glaucus* were not present despite field establishment in the first growing season; the remaining species had low or no cover in both years (Table 1).

A. millefolium and *G. stricta* achieved higher establishment in broadcast plots in the first growing season; *G. stricta* was only present in one quadrat in year two, but *A. millefolium* continued to show higher cover from broadcast seeding in the second growing season (Table 2, Fig. 1a). *S. bellum* did not establish in year one and had similar establishment between the primary treatments in year two (Table 2, Fig. 1b). *H. brachyantherum* had comparable establishment between the two seeding methods in both years (Table 2, Fig. 1c).

Mulch and mowing increased the percent cover of all sown species in year one; in year two, only *A. millefolium* showed significantly more establishment in mulch and mowing subplots, with significant interaction between seeding and non-native management treatments showing the highest establishment in broadcast seeded plots with non-native control (Table 2, Fig. 1a). *S.*

bellum showed no significant difference in cover between the non-native control treatments in year two (Table 2, Fig. 1b). *H. brachyantherum* showed similar establishment between non-native management treatments for both years (Table 2, Fig. 1c).

In year one, non-native grasses had higher establishment in broadcast seeded plots. This relationship was not observed in year two, but the combination of seeding and non-native management treatments was significant, displaying the greatest non-native grass cover in drill seeded plots without non-native control (Fig. 2a, Table 2). In year two, bare ground was significantly higher in drill seeded plots and non-native forb cover showed an interaction between the two treatment levels (Fig. 2a, Table 2). The unsown native *J. bufonius* had greater percent cover in drill seeded plots in year two. *Erigeron canadensis,* an unsown native forb not recorded in year one, had higher establishment in broadcast seeded plots (Fig. 2b, Table 2).

Discussion

Direct seeding is not an effective restoration method for most coastal prairie plant species. Native diversity decreased in the second growing season following seeding, and only three of the ten species maintained stands of more than two individuals within the surveyed area and only two species, *H. brachyantherum* and *A. millefolium*, had mean vegetative cover of more than one percent. Although seeding may be used to restore specific target species, it is inefficient in restoration projects using an array of native species. The lesser cost of seed is offset by the unpredictability and low long-term success of seeding efforts.

Although seeding is not recommended for most coastal prairie species tested, *Sisyrinchium bellum* has been shown to establish populations from seed successfully after a period of stratification; *Stipa pulchra* established successfully and persisted in the same experiment 2-4 years after seeding (Holl et al. 2014). In systems that initially contained the native plants to be repopulated, *S. bellum* and *S. pulchra* benefitted from additional seeding while *D. californica* did not at any point, and *E. californica* did not after an initial increase in cover (Hayes and Holl 2011). Seeding seems to be an effective restoration method for *S. bellum* and potentially *S. pulchra* in the long term depending on other environmental conditions, but not for *D. californica* and *E. californica*, consistent with our findings. Our data suggest that *G. stricta*, the species with the highest field establishment in the first growing season, does not necessarily persist when grown from seed in the field; only two individuals were observed in the second year.

Although *A. millefolium* establishment was poor in a previous study, the low success was likely a result of the experiment using simulated drill seeding (Holl et al. 2014), which is consistent with small-seeded forbs establishing more successfully from shallow seed depths (Traba et al. 2004). Data from the first growing season indicate that the forb is more successful in broadcast-seeded plots, likely due to the shallow seed depth. If seeding *A. millefolium*, it is critical that the seed is broadcast, preferably with mulch and mowing.

The native forb *J. bufonius* grows in disturbed soil (Baldwin et al., 2012), explaining its greater presence in the more disturbed drill seeded plots. *J. bufonius* seeds remaining in the soil were exposed and allowed to germinate after drilling. The species was successful in establishing stands despite not being seeded; the same is true of *Erigeron canadensis* in broadcast seeded plots. It is unknown if seeding would be effective for these species, but they indicate an ability to spread once established in the area.

These results highlight the importance of monitoring for multiple years, as coastal prairie ecosystems are dynamic and highly dependent on abiotic and biotic interactions. Rainfall may be one such abiotic factor that dramatically alters coastal prairie plant communities (Hobbs et al. 2007). In the first year of the experiment, some mulch was washed away by the high levels of rain in January. The second growing season had similarly high rainfall with the peak occurring later in the year (Fig. 3). Mean annual rainfall for the region from 1989 to 2017 was 744.98 mm. Rainfall reached 1227.56 mm in the 2015-2016 rainfall year and 1238.00 mm in 2016-2017 as of May 2017, as reported by the Santa Cruz NOAA cooperative station. Interestingly, wet years are typically associated with high native diversity (Seabloom et al. 2003a), but both growing seasons were wet and displayed decreasing native presence. Increased grass seed availability and grass establishment following the first year may have hindered the persistence of forbs (Levine and Rees 2004). This only adds to the uncertainty surrounding the risk of direct seeding. As with other seeding studies, our data add to the body of works documenting the varied results of direct seeding depending on yearly conditions that must be considered. Data collection for this experiment should continue into the following years and monitor trends in population size to determine if the outcomes were primarily a result of species' physiological traits or the specific environmental conditions.

Acknowledgements

This study would not have been possible without the guidance and feedback of Dr. Karen Holl. I would also like to thank my research partner Jorge Amar for his time, effort, and cooperation; Tim Brown for his aid in plant identification and data collection; Green Burns for information regarding the original experimental design; and Younger Lagoon Reserve interns for their help with data collection.

References

Abraham, J.K., J.D. Corbin, and C.M. D'Antonio. 2009. California native and non-native perennial grasses differ in their response to soil nitrogen, non-native annual grass density, and order of emergence. *Plant Ecology* 201:445-456.

Baldwin, B.G., D.H. Goldman, D.J. Keil, R. Patterson, T.J. Rosatti, and D.H. Wilken (Eds.). 2012. The Jepson Manual, Vascular Plants of California, Rev. 2, 2nd edition. University of California Press, Berkeley, California.

Burns, G.L. 2016. A comparison of small-scale direct seeding methods to restore California coastal prairie. B.A. Thesis: University of California, Santa Cruz, Santa Cruz, CA.

Clark, C.J., J.R. Poulsen, D.J. Levey, and C.W. Osenberg. 2007. Are plant populations seed limited? A critique and meta-analysis of seed addition experiments. *The American Naturalist* 170:128-142.

Corbin, J.D. and C.M. D'Antonio. 2004. Competition between native perennial and non-native annual grasses: implications for an historical invasion. *Ecology* 85:1273-1283.

DeFalco, L.A., T.C. Esque, M.B. Nicklas, M.B. and J.M. Kane. 2012. Supplementing seed banks to rehabilitate disturbed Mojave Desert shrublands: Where do all the seeds go?. *Restoration Ecology* 20:85-94.

Desimone, S. 2011. Balancing Active and Passive Restoration in a Nonchemical, Research-Based Approach to Coastal Sage Scrub Restoration in Southern California. *Ecological Restoration* 29:45-51.

DiTomaso, J.M. 2000. Invasive weeds in rangelands: species, impacts, and management. *Weed Science* 48:255-265.

DiVittorio, C.T., J.D. Corbin, and C.M. D'Antonio. 2007. Spatial and temporal patterns of seed dispersal: an important determinant of grassland invasion. *Ecological Applications* 17:311-316.

Ford, L.D. and G.F. Hayes. 2007. Northern coastal scrub and coastal prairie. Pages 180-207 in Barbour M., T. Keeler-Wolf, and A.A. Schoenherr (Eds.) Terrestrial Vegetation of California. University of California Press, Berkeley.

Hamilton, J.G., C. Holzapfel, and B.E. Mahall. 1999. Coexistence and interference between a native perennial grass and non-native annual grasses in California. *Oecologia* 121:518-526.

Hayes, G.F. and K.D. Holl. 2003. Site-specific responses of native and non-native species to disturbances in a mesic grassland community. *Applied Vegetation Science* 6:235-244.

Hobbs, R.J., S. Yates, and H.A. Mooney. 2007. Lont-term data reveal complex dynamics in grassland in relation to climate and disturbance. *Ecological Monographs* 77:545-568.

Holl, K.D., T. Hyland, B. Largay, L. Stratton. 2010. Enhancement and Protection of Terrace Lands at Younger Lagoon Reserve. Prepared by UCSC Staff and the Younger Lagoon Reserve Scientific Advisory Committee on behalf of Younger Lagoon Reserve.

Holl, K.D., G.F.Hayes, C. Brunet, E.A. Howard, L.K. Reed, M. Tang, and M.C. Vasey. 2014. Constraints on Direct Seeding of Coastal Prairie Species: Lessons Learned for Restoration. *Grasslands* 24:8-12.

James, J.J., T.J. Svejcar, and M.J. Rinella. 2011. Demographic processes limiting seedling recruitment in arid grassland restoration. *Journal of Applied Ecology* 48:961-969.

Levine, J. M. and M. Rees. 2004. Effects of temporal variability on rare plant persistence in annual systems. American Naturalist 164:350-363.

Moore, P.L., K.D. Holl, and D.M. Wood. 2011. Strategies for Restoring Native Riparian Understory Plants Along the Sacramento River: Timing, Shade, Non-Native Control, and Planting Method. *San Francisco Estuary and Watershed Science 9*.

Nyamai, P.A., T.S. Prather, and J.M. Wallace. 2011. Evaluating restoration methods across a range of plant communities dominated by invasive annual grasses to native perennial grasses. *Invasive Plant Science and Management* 4:306-316.

Orrock, J.L., M.S. Witter, and O.J. Reichman. 2008. Apparent competition with a non-native plant reduces native plant establishment. *Ecology* 89:1168-1174.

Rotundo, J.L. and M.R. Aguiar. 2005. Litter effects on plant regeneration in arid lands: a complex balance between seed retention, seed longevity and soil–seed contact. *Journal of Ecology* 93:829-838.

Seabloom, E.W., E,T, Borer, V.L. Boucher, R.S. Burton, K.L. Cottingham, L. Goldwasser, W.K. Gram, B.E. Kendall, and F. Micheli. 2003a. Competition, seed limitation, disturbance, and reestablishment of California native annual forbs. *Ecological Applications* 13:575-592.

Seabloom, E.W., W.S. Harpole, O.J. Reichman, and D. Tilman. 2003b. Invasion, competitive dominance, and resource use by non-native and native California grassland species. *Proceedings of the National Academy of Sciences* 100:13384-13389.

Stromberg, M.R., P. Kephart, and V. Yadon. 2001. Composition, invasibility, and diversity in coastal California grasslands. *Madroño*, 48:236-252.

Stromberg, M.R., C.M. D'Antonio, T.P. Young, J. Wirka, and P.R. Kephart. 2007. California grassland restoration. Pages 254-280 in Stromberg, M.R., J.D. Corbin, and C.M. D'Antonio (Eds.) *California Grasslands: Ecology and Management*. University of California Press, Berkeley.

Tang, M., 2013. Effects of mulch, planting design, and mowing on native plant restoration in a California coastal prairie. B.S. Thesis: University of California, Santa Cruz.

Traba, J., F.M. Azcárate, and B. Peco. 2004. From what depth do seeds emerge? A soil seed bank experiment with Mediterranean grassland species. *Seed Science Research* 14:297-303.

Wainwright, C.E., E.M. Wolkovich, and E.E. Cleland. 2012. Seasonal priority effects: implications for invasion and restoration in a semi-arid system. *Journal of Applied Ecology* 49:234-241.

Tables and Figures

Table 1. Mean percent cover of seeded species in the first two growing seasons following sowing, 2016 and 2017, by seeding method.

	2016		2017	
	Hand Broadcasted	Drill Seeded	Hand Broadcasted	Drill Seeded
Forbs				
Achillea millefolium	7.8	0.8	9.6	1.0
Eschscholzia californica	0.2	0.3	0	0
Grindelia stricta	2.2	0.4	0	0.1
Sisyrinchium bellum	0	0	0.8	0.5
Symphyotrichum chilense	0.3	0.3	0	0
Grasses				
Danthonia californica	1.2	1.4	0.1	0
Elymus glaucus	0.6	0.8	0	0
Elymus triticoides	0	0	0	0
Hordeum brachyantherum	8.6	8.6	19.3	31.7
Stipa pulchra	0	0	0.1	0.1

Table 2. ANOVA showing the effects of direct seeding method, mulch and mowing as a non-native control method, and their interaction on percent cover of the three established sown species, key guilds, and the unsown native species *Juncus bufonius* and *Erigeron canadensis*. Asterisks indicate significance.

Variable	**Seeding Method**		**Mulch and Mowing**		**Seeding Method * Mulch/Mowing**	
	F	P	F	P	F	P
Sown Species						
Achillea millefolium	20.2	<0.0001*	11.4	0.0012*	5.4	0.0222*
Hordeum brachyantherum	3.9	0.0521	1.6	0.2135	0.2	0.6618
Sisyrinchium bellum	0.6	0.4460	1.3	0.2541	1.3	0.2541
Percent Cover of Key Guilds						
Bare ground	12.5	0.0005*	0.4	0.5389	0.3	0.5824
Thatch	0.8	0.3785	0.0	0.8435	0.2	0.6612
Non-native forbs	2.6	0.1101	0.8	0.3863	7.2	0.0079*
Non-native grasses	0.0	0.9786	3.4	0.0678	4.7	0.0311*
Unsown Native						
Juncus bufonius	7.2	0.0078*	2.1	0.1533	2.6	0.1084
Erigeron canadensis	5.5	0.0197*	0.0	0.8466	0.0	0.8683

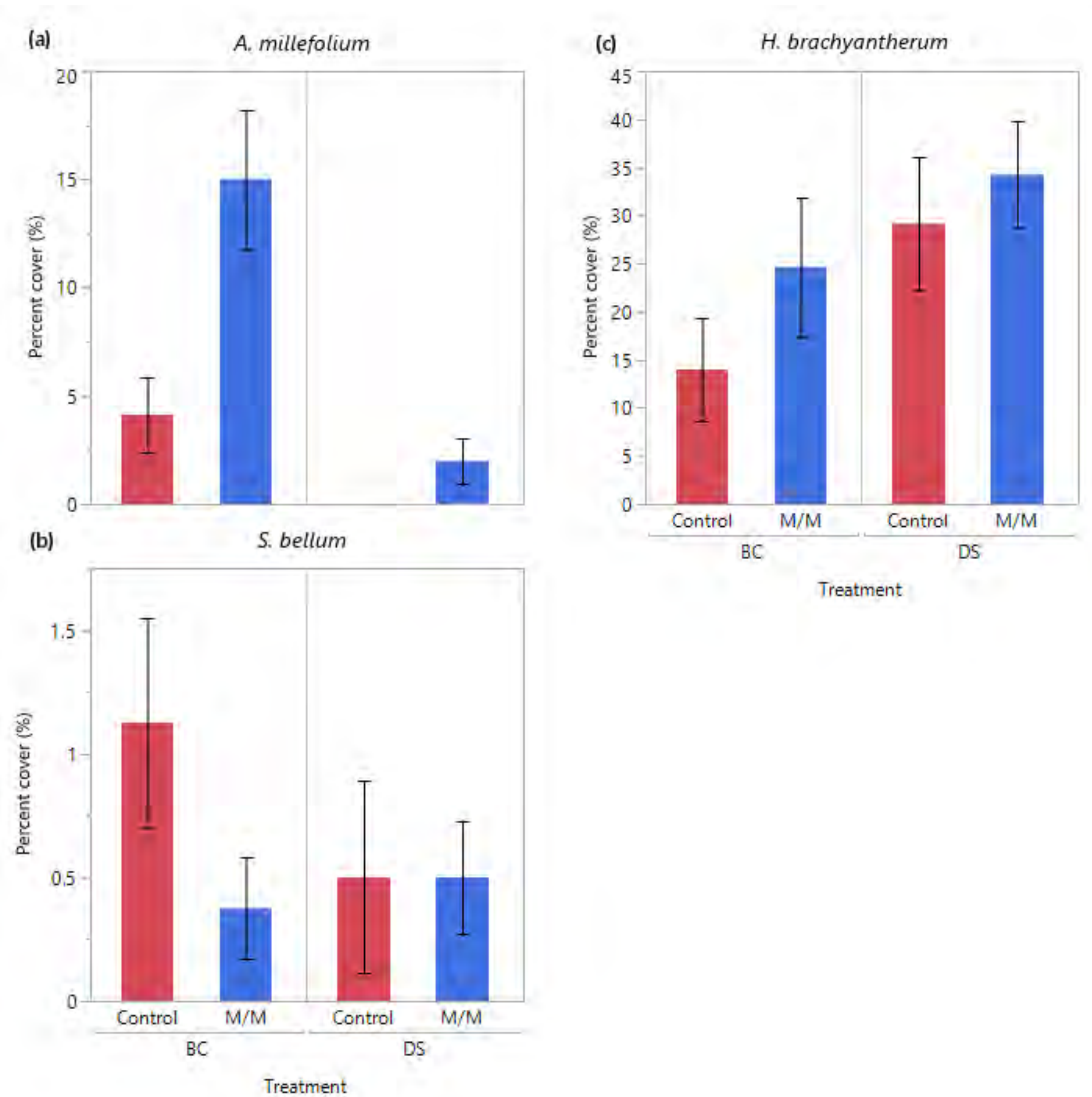


Figure 1. Percent cover of the seeded native forbs *Achillea millefolium* (a) and *Sisyrinchium bellum* (b) and the native grass *Hordeum brachyantherum* (c) in broadcast seeded (BC) and drill seeded (DS) treatments. Treatments were split into control and mulched and mowed (M/M) subplots. Bars represent one standard error. Note differences in Y axis scales.

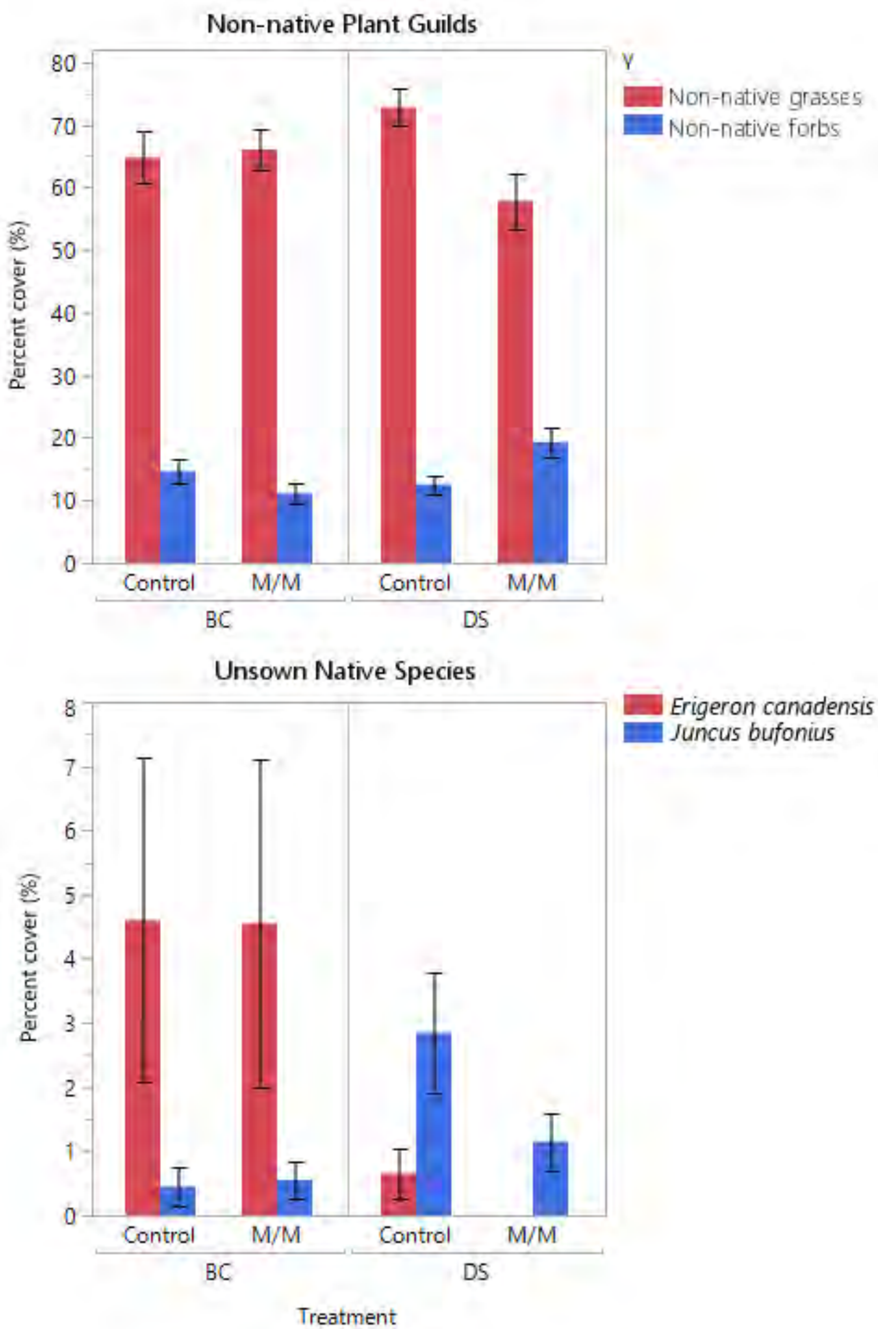


Figure 2. Mean percent cover of major non-native plant guilds (a) and the unsown native forb species *Erigeron canadensis* and *Juncus bufonius* (b). Bars represent one standard error. Note differences in Y axis scales.

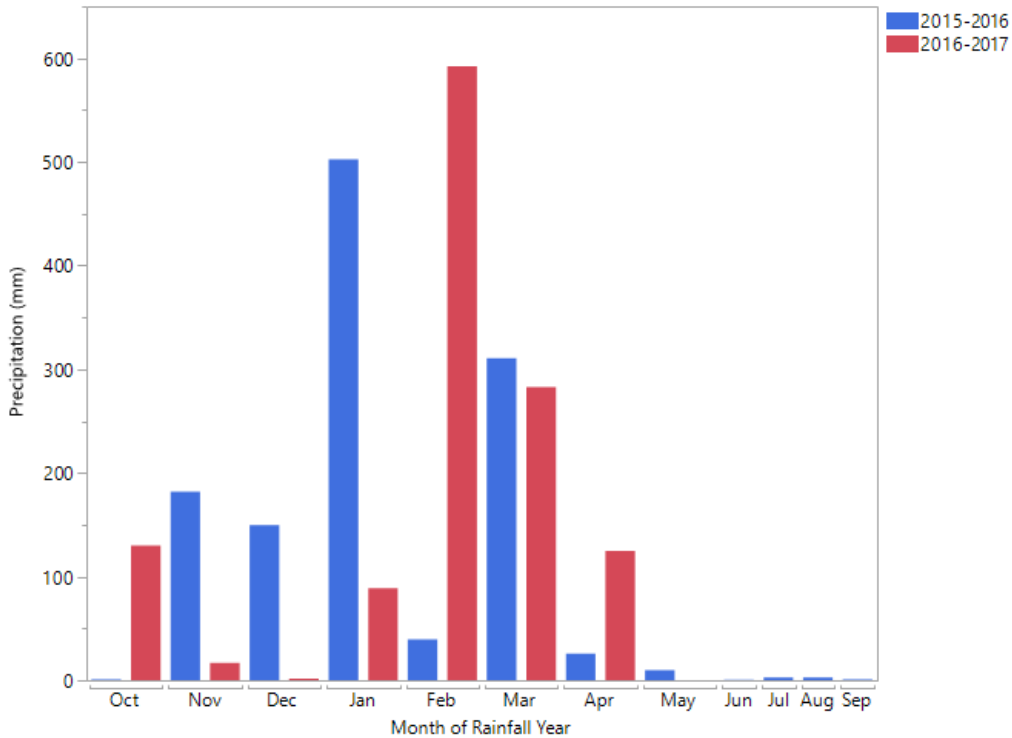


Figure 3. Rainfall at Younger Lagoon Reserve throughout the 2015-2016 and 2016-2017 rainfall years as of vegetative data collection in May 2017. Data were collected from a NOAA cooperative station located near the site in Santa Cruz, California.

Appendix

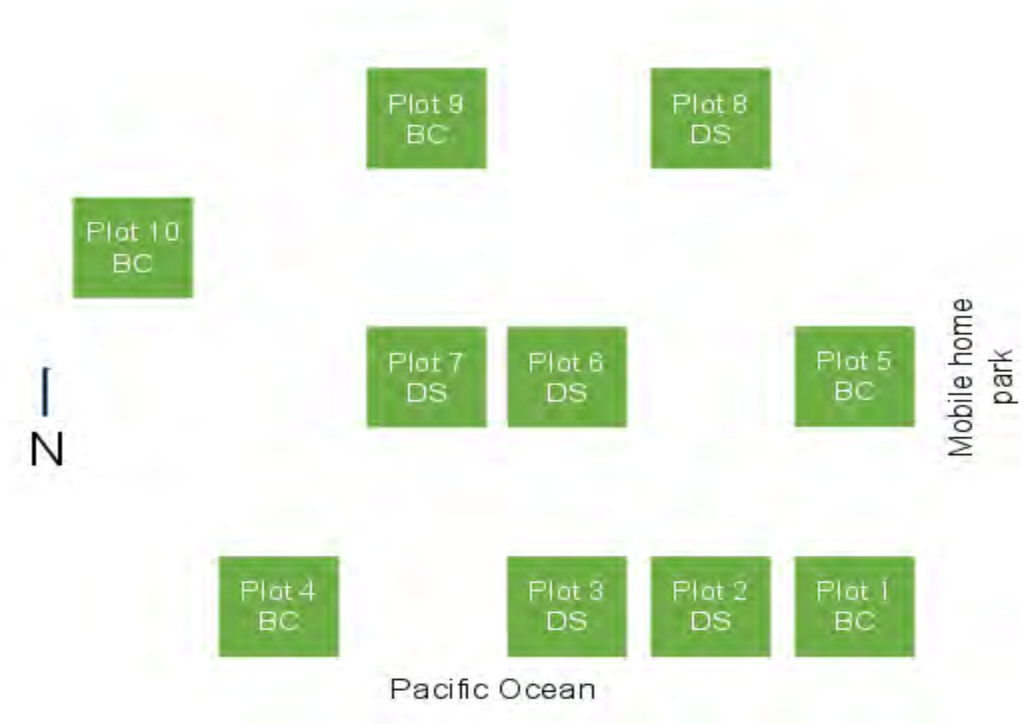


Figure 1. Plot locations within the experimental site, indicating randomly chosen broadcast (BC) and drill seeded (DS) treatments. Corrected from the site map originally used in Burns 2016.

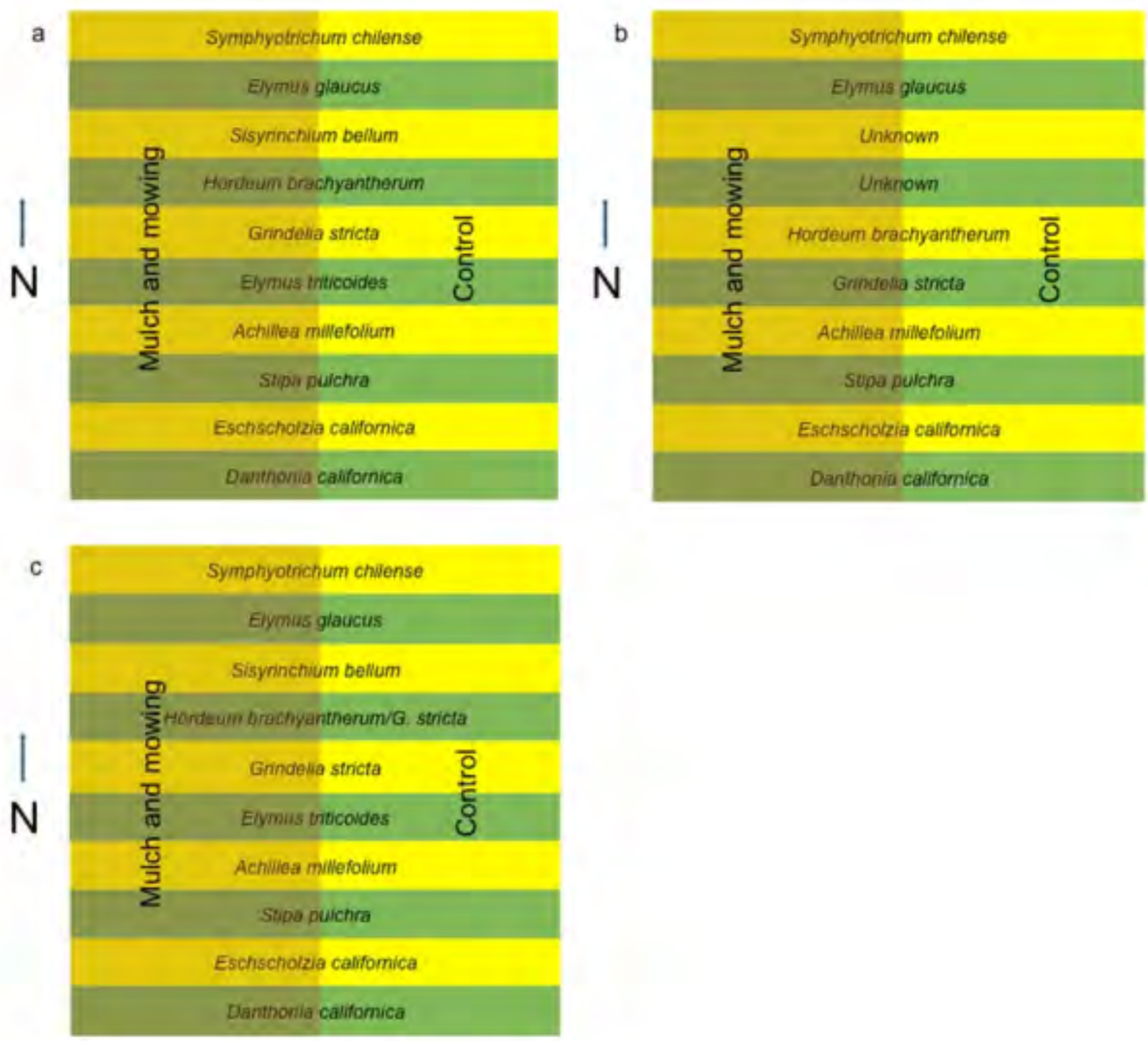


Figure 2. Plot species layouts for (a) plots 1-5 and 8-9; (b) plot 10, in which the seeded species in rows 3-4 are unknown due to seeding error; and (c) plots 6 and 7, in which *G. stricta* was inadvertently sown in row 4 with *H. brachyantherum*. Figure originally used in Burns 2016.

Christina Snider

Planting in islands vs. homogeneous plantations to restore native coastal grassland

Abstract

This is a continuation of the study being done at Younger Lagoon Reserve to determine whether “applied nucleation” is a viable technique to restore coastal grasslands. This technique has been used in forest restoration as a less resource intensive technique compared to a traditional plantation technique that plants homogeneous rows of trees. It utilizes natural succession of species by planting heterogeneous early successional micro communities in patches to facilitate establishment of later successional species. Three techniques were compared in five replicate plots; fully planted plots with wood mulch, fully planted plots without mulch, and island planted plots with mulch. We monitored the plots for native and exotic grasses and forbs with 16 quadrats in fully planted plots and 24 quadrats in island planted plots. Overall, island planted plots and fully planted plots were not significantly different in native and exotic species cover. *Hordeum brachyantherum* and *Achillea millefolium*, were the two native species that showed the highest cover and the most migration into unplanted areas in island plots. Mowing did not have a significant effect on exotic species cover, and full mulched plots showed no significant difference from not mulched plots in native species cover. This means that island planting for coastal grassland restoration is as effective as fully planting plots and allows land managers to get similar results without having to invest in as many seedlings. *H. brachyantherum* and *A. millefolium*, two native species which are both wind dispersers, showed a strong ability to spread and should be considered in coastal grassland restoration. Mowing and mulch can be used to reduce exotic cover early on but will diminish over time. Land managers should look toward adaptive management to find seasons of the year most effective for mowing certain exotic species and new ways to curb exotic species as time goes on.

Introduction

Restoration of native habitats has been growing with increasing awareness of habitat degradation due to anthropogenic land uses and exotic species invasions. People have been conducting many restoration studies to see what methods, conditions, species, and monitoring plans best suit the restoration they are trying to accomplish. Each site seems to be specific to how it reacts to different restoration strategies. In California, coastal grasslands and prairies have become threatened ecosystems due to land use changes, including agriculture and urban development, lack of disturbance that allows woody succession to coastal scrub, and exotic invasions (Ford and Hayes, 2007). In addition to removal of invasive exotic plants, methods for re-populating the areas with native grasses and forbs at a low cost is necessary to accomplish restoration of California coastal grassland ecosystems.

Typically, large areas of grassland are planted with native grasses and forbs for restoration. People have tested the idea of planting in patches or creating micro communities of native species, often referred to as "applied nucleation" to see if this planting method could be an effective way to restore native grasslands that uses less resources than planting giant areas that require lots of labor and time. Grygiel et al. (2009) performed a study on whether or not small amounts of disturbance would be as effective as full rototill and broadcasting of seeds to establish species richness. They found that small-scale disturbances (SSD) over 25% of the area were not significantly different from a full disturbance and seeding of the plot in restoring native forb species richness and density. Robinson and Handel (2000) explored the method of applied nucleation to attract animal dispersers such as birds to help recruitment of woody plant species and found that this method was successful. Corbin et al. (2016) measured the same site as Robinson and Handel (2000) 19 years after planting and found that there was significant improvement to forest habitat and there was recruitment occurring outside of the nuclei. The majority (58%) of recruits were wind dispersed (Corbin et al., 2016) which shows that wind dispersed seeds tend to have a high recolonization outside of a nucleus. The applied nucleation restoration method focuses on trying to attract animal dispersers to the area and it has mostly been studied in forest ecosystems, while only Grygiel et al. (2009) performed their study in grassland. More studies for patch planting or "applied nucleation" in the coastal grassland habitats should be conducted to see if this technique is viable across different habitats with different species compositions. If applied nucleation is seen as a way to recreate natural succession, it could be utilized in many future restoration efforts to come.

Grasslands require disturbance regimes to keep coastal scrub from encroaching, so a technique used to replicate disturbance is mowing. Mowing has been proposed to favor native forbs over exotic grasses (Maron and Jeffries, 2001), but multiple studies have shown that the main effect is to benefit short species with high specific leaf area regardless of whether they are exotic or native (Hayes and Holl, 2011; Sandel et al., 2011). A treatment done by Cox et al. (2008) controlled grasses by mowing for three years and showed lower exotic species numbers but for only two years. While mowing and clipping exotic species is a management tool used throughout, it is not as effective in containing exotic species while letting natives grow. Mowing alone has been inadequate to curb unwanted species, but with adaptive management and good timing, it could keep diversity high in grasslands (Dee et al., 2016).

I conducted a follow up on a long-term study looking at the effects of different planting methods which are planting an entire area with native grasses and forbs versus planting in "islands" which uses the idea of applied nucleation in forest restoration. The study also tests the effect of wood mulch and mowing. I hypothesized that native cover in the island plots that are mowed would be similar to native cover in fully planted plots that are mowed because past results from the same study (Tang 2013, Rusk 2016) showed evidence to support this. Mowed and mulched fully planted and mowed and mulched island planted plots had similar native cover with grasses around 5-7% cover and forbs around 15-20% cover (Rusk, 2016). I expected to see more native forbs spreading out from the nuclei of the island plots over the native grasses because Rusk (2016) showed that the forbs had much higher percentage of cover in the edges and on the outside of the islands when compared to the native grass cover. The forbs recolonized in the mowed and unmowed parts of the plot while grasses seemed to show little to no cover outside of the islands with a maximum less than 10% cover in the mowed plot on the edge of the island (Rusk, 2016). Through this study, restoration at Younger Lagoon and other coastal grassland sites can be better implemented by determining effective techniques for native grasses and forbs recolonization with ongoing monitoring to evaluate their success.

Materials and Methods

Site Description and Experimental Design:

Draws heavily from Tang (2013) and Rusk (2016):

This study takes place in the city of Santa Cruz at the Younger Lagoon Reserve. This reserve has been under stewardship of University of California, Santa Cruz (UCSC) through the University of California Natural Reserve System. Originally, this land was used as agricultural fields to farm for Brussels sprouts, and has been under restoration efforts since UCSC has had stewardship over it. This study is an extension of an experiment that started in fall 2010 to compare planting in islands versus planting full coverage of a plot. The plots were mowed and sprayed with a glyphosate herbicide in October 2011 and right before planting in January 2012 to reduce exotic species cover. Wood mulch, collected from fallen trees on the UCSC main campus, was added to assigned plots to see if mulch would have an effect on the experiment.

The experiment was a split-plot design with four treatments crossed with a mowing treatment (Fig. 1). Twenty 10 × 10 m plots were created to allow for five replicates of each treatment. The plots were separated from each other on all sides by 1 m. Each plot was randomly assigned one of the four treatments that include: full cover planting with mulch (F-M), Full cover planting without mulch (F-NM), island planting with mulch (I-M), and island planting without mulch (I-NM). However, the five plots with the island planting without mulch (I-NM) treatment were removed in the second year of the study due to low native cover. The species that were planted included three native perennial grasses--*Stipa pulchra, Hordeum brachyantherum,* and *Bromus carinatus--,* five forbs--*Achillea millefolium, Clarkia davyi, Grindelia stricta, Trifolium willdenovii,* and *Symphyotrichum chilense,* and one rush, *Juncus patens*, but it has been excluded from results in the past due to low establishment. Native seeds were collected in 2011 from sites close to and with similar characteristics to Younger Lagoon Reserve. These seeds were processed and propagated as seedling plugs at the UCSC Greenhouses and Central Coast Wilds, a native plant nursery. By the time planting began in January 2012, seedlings were three months old except for one species, *Symphyotrichum chilense*. This species was delayed and planted later that year in May.

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. The plugs were planted at a distance of 45.45 cm from each other and plot boundaries, and each row had a single species. 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. willdenovii, J. patens;* one row of *S. 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.

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. Each island had 6 rows of 6 plants, for a total of 144 plants per plot. 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, four months into the experiment, half of all the plots were mowed. Plots were mowed perpendicular to planted rows, so half of the forbs/rushes and grasses were mowed. This mowing was repeated every year in May instead of an herbicide management technique because Younger Lagoon no longer can have permits to use herbicides on location.

Data Collection:

I collected data between April 25th and May 4th, 2017. I monitored and measured native plant cover, exotic plant cover, and bare ground. Two transects were placed in each fully planted plot perpendicular to each other to divide each plot into four subplots (Fig. 1) Each subplot represents a combination of the different mowing treatments with each guild and resulted in grasses*mowed, grasses*unmowed, forbs*mowed, and fobs*unmowed. Each subplot had four randomly located 0.25-m^2 quadrats placed inside, totaling to 16 quadrats.

Island plots were also divided into four subplots using two perpendicular transects (Fig. 1). Just as for the full plots, these subplots represent the mowing treatment with each guild. The island plots had two randomly placed quadrats inside each island, on the edges of each island, and on the outside of each island to determine if plants are spreading outside of the nuclei. This resulted in 24 quadrats for each island plot.

Native species cover was estimated in 5% cover classes (e.g., 0-5%, 5-10%) in a 0.25 m^2 quadrat since it is impossible to measure more precisely. When a measurement was, for example, between 10 and 15%, the median, 12.5%, was entered for the amount of cover for a species in the quadrat. Due to canopy overlap of different species in some quadrats, percent cover could be >100%.

Data Analysis:

Data were analyzed using JMP Pro 13 statistical software. A two-way ANOVA was conducted with treatment (full mulched, full no mulch, and island mulched) and mowing and the interaction between the two factors. Percent coverage for bare ground, thatch, *J. patens, C. davyi,* and *B. carinatus* were not included due to either not being present or too low of cover. For island plot recruitment, only three species, *H. brachyantherum, A. millefolium* and *S. chilense*, were used because other species were not found to be recruiting well. A two-way ANOVA was done for each species based on location in the island (In, Edge, Out) and which guild subplots each species was found in (Forbs, Grasses).

<u>Results</u>

Over all the plots, average native grass cover was 5.9% (±1.2 SE) and average native forb cover was 12.3% (±2.6 SE) (Fig. 2). There was no effect of mowing or planting treatment (island plot or full plot) on exotic grass and forb cover or the cover of any of the native species (Fig. 2, Table 1). The mean for all exotic species cover in unmowed subplots was 70.4% (±4.3 SE) and the mean for exotic species cover in mowed subplots was 73% (±4.6 SE). *H. brachyantherum*, *S. chilense,* and *A. millefolium* were the most abundant native species and the only three natives to show recruitment outside of their respective nuclei (Fig. 3). *J. patens, G. stricta, S. pulchra,* and *B. carinatus* each had <1.4% average cover across plots. Native plant cover was statistically similar between mulched and not mulched plots (Fig. 4). Native forb cover has diminished since last year and native grass cover has been decreasing since 2015 (Fig. 5).

Discussion

My results showed no difference between the island and the full planted treatment with respect to native cover and exotic cover (Fig. 2). This is consistent with prior results (Tang 2013, Arneson 2014, Schreiber 2015, Rusk 2016) that applied nucleation planting in coastal grasslands is just as effective as full plantation planting for restoration. This is important because land managers can get similar results with using less seeds and seedlings to restore a coastal grassland. Younger Lagoon, for example, is seed limited due to invasion of exotics so being able to plant less area with less seedlings means lower cost of finding seeds and labor goes down to one third of full planting (Tang 2013).

The mowing sub-treatment showed no difference in percent cover between exotic species and native species in either full or island plots (Table 1). Although this study showed no significant difference between mowing and not mowing, it could be because of the time of year mowing occurs. Each site is specific and determining which exotics are prevalent could be useful in determining when mowing would be most helpful to deter exotic recruitment (Dee et al., 2016). As shown in previous papers for this study and other studies such as Prevey et al. (2014), Maron and Jeffries (2001) and Hayes and Holl (2011), mowing had an effect on changing the dynamics from exotic annual grasses to more of an exotic/native forbs dynamic in the plots (Schreiber, 2015). Mowing can still be used as a management tool for land managers when properly implemented at times of the year that will benefit the natives and exclude the exotics.

While only looking at the island plots to see if recruitment is occurring, only one grass and two forb species were found to be mimicking natural succession and moving away from the nuclei (Fig. 3). While Schreiber (2015) found multiple native species growing outside of the original planted island, this year shows that many of these species were not able to propagate against the competition of exotic species. I found *H. brachyantherum, S. chilense* and *A. millefolium* growing on the edge and outer rim of their respective guild islands, as well as recruiting in the opposite guild's plots. Two of the promising species, *A. millefolium* and *H. brachyantherum,* are both wind dispersers and may be well suited for future coastal grassland restoration sites. While nine native species were planted at the beginning of this experiment, after six growing seasons only three of the natives have shown to be persisting for the long term. This reflects how difficult it is to restore coastal grassland.

Early results from this study (Arneson 2014, Schreiber 2015, and Rusk 2016) showed a higher percent coverage for native forbs in mulched plots, but this year there was no difference of native species cover between mulched and not mulched plots (Fig. 4). This replicates results according to Holl et al. (2014) that the effect of mulch diminishes over time.

Over the last three years, native grass cover has declined (Fig. 5). There is no definite evidence for what the cause could be, but one change that occurred before collecting results this year was the amount of rainfall. There was an increase of rain compared to the years of drought that California had been experiencing. This could have led to giving the exotic species an advantage to propagate more since native species perform well in dry seasons. This is only a hypothesis that can be looked into further with the years to come for this ongoing monitoring.

While native cover has decreased, compliance with the Coastal Long Range Development Plan (CLRDP) is still attainable. Native cover in both the full and island plots has almost reached 20% and this is only the first part of the 20 year plan (Fig. 2). With island plots showing similar results to fully planted plots, land managers can take this information to utilize less resources and labor to achieve the same amount of coverage as a traditional plantation design.

Literature Cited

Arneson, E. (2014). The effects of applied nucleation, mulch and mowing on a California Coastal prairie restoration. B.A. Thesis: University of California, Santa Cruz

Corbin, J. D. and D'Antonio, C. M. (2004). Can Carbon addition increase competitiveness of native grasses? A case study from California. Restoration Ecology, 12:1, 36-43. DOI: 10.1111/j.1061-2971.2004.00299.x

Corbin, J. D., Robinson, G. R., Hafkemeyer, L. M., and Handel, S. D. (2016). A long-term evaluation of applied nucleation as a strategy to facilitate forest restoration. Ecological Applications. 26:1, 104-114. DOI: 10.1890/15-0075

Cox, R. D. and Allen, E. B. (2008). Stability of exotic annual grasses following restoration efforts in southern California sage scrub. Journal of Applied Ecology, 45:2, 495-504. DOI: 10.1111/j.1365-2664.2007.01437.x

Dee, J. R., Thomas, S. M., Thompson, S. D., et al. (2016). Long-term late season mowing maintains diversity in southern US tallgrass prairie invaded by *Bothriochloa ischaemum*. Applied Vegetation Science. 19:3, 442-453. DOI: 10.1111/avsc.12227

Eliason, S. A. and Allen, E. B. (1997). Exotic grass competition in suppressing shrubland re-establishment. Restoration Ecology, 5:3, 245-255. DOI: 10.1046/j.1526-100X.1997.09729.x

Ford, L. D. and Hayes, G. F. (2007). Northern Coastal Scrub and Coastal Prairie. In: Barbour, M. G., Keeler-Wolf, T., & Schoenherr, A. A. (Eds.), Terrestrial Vegetation of California. University of California Press, Berkeley, pp 180-207.

Grygiel, C. E., Norland, J. E., and Biondini, M. E. (2009). Precision Prairie Reconstruction (PPR): A Technique for Increasing Native Forb Species Richness in an Established Grass Matix. Ecological Restoration, 27:4, 458-466.

Hayes, G. F. and Holl, K. D. (2011). Manipulating disturbance regimes and seeding to restore mesic Mediterranean grasslands. Applied Vegetation Science. 14:3, 304-315. DOI: 10.1111/j.1654-109X.2011.01127.x

Holl, K. D., Howard, E. A., Brown, T. M., Chan, R. G., de Silva, T. S., Mann, E. T., Russell, J. A., and Spangler, W. H. (2014). Efficacy of Exotic Control Strategies for Restoring Coastal Prairie Grasses. Invasive Plant Science and Management. 7:4, 590-598. DOI: 10.1614/IPSM-D-14-00031.1

Maron, J. L. and Jeffries, R. L. (2001). Restoring enriched grasslands: Effects of mowing on species richness, productivity, and nitrogen retention. Ecological Applications, 11:4, 1088-1100. DOI: 10.2307/3061014

Prevey, J. S., Knochel, D. G., and Seastedt, T. R. (2014). Mowing Reduces Exotic Annual Grasses but Increases Exotic Forbs in a Semiarid Grassland. Restoration Ecology. 22:6. 774-781. DOI: 10.1111/rec.12140

Robinson, G. R., and S. N. Handel. (2000). Directing spatial patterns of recruitment during an experimental urban woodland reclamation. Ecological Applications 10:174–188.

Rusk, J. (2016). Efficacy of restoration treatments in California’s coastal grassland influenced by variability in rainfall. University of California, Santa Cruz

Sandel, B., Corbin, J. D., and Krupa, M. (2011). Using plant functional traits to guide restoration: A case study in California coastal grassland. Ecosphere 2:2, art. 23. DOI: 10.1890/ES10-00175.1

Schreiber, R. (2015). Effect of Planting Design, Mulching and Mowing on Coastal Prairie Restoration. University of California, Santa Cruz

Tang, M. (2013). Effects of mulch, planting design, and mowing on native plant restoration in a California coastal prairie. B. A. Thesis: University of California, Santa Cruz

Figures and Tables

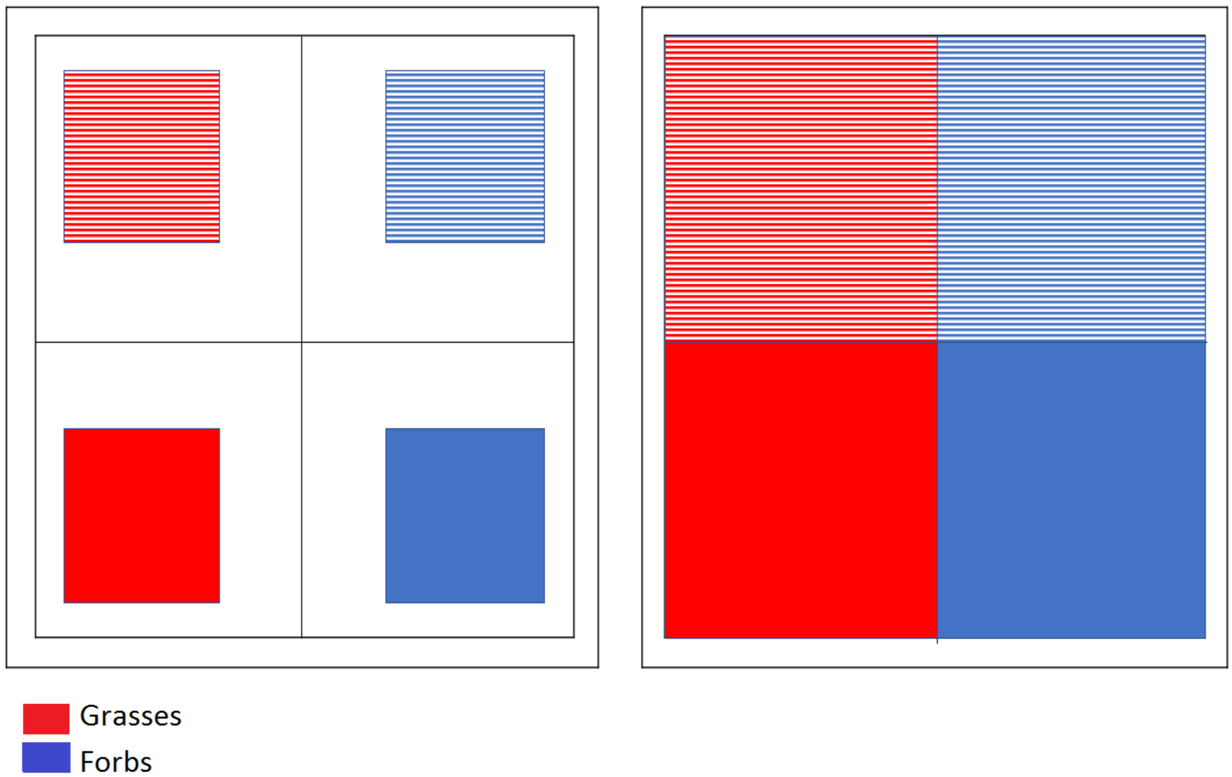


Fig. 1

Schematic of the island plots and full plots. Stripes represent mowed subplots.

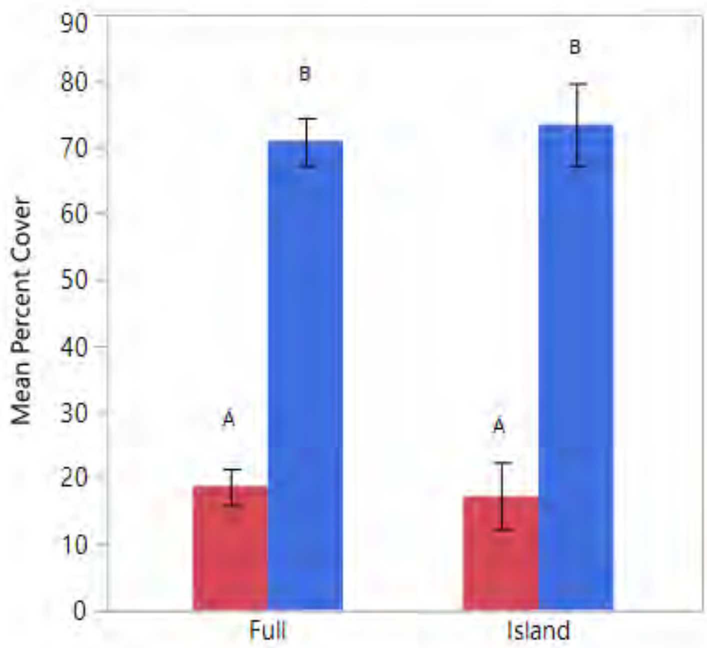


Fig. 2

The mean percent cover of native species (RED) and exotic species (BLUE) across all the full plots and all the island plots. Native species and exotic species cover in both full and island plots are not statistically different (Table 1). Error bars represent 1±standard error from the mean. Means with same letter do not differ significantly ($p<0.5$).

	Treatment	**Mowed**	**Treatment*Mowed**
Exotic Grasses	F=0.4 (p=0.6796)	F=0.58 (p=0.4486)	F=0.011 (p=0.9889)
Exotic Forbs	F=1.3 (p=0.2780)	F=2.2 (p=0.1412)	F=0.99 (p=0.3773)
Hordeum brachyantherum	F=2.4 (p=0.0970)	F=1.4 (p=0.2492)	F=1.3 (p=0.2883)
Stipa pulchra	F=1.9 (p=0.1598)	F=2.0 (p=0.1664)	F=0.92 (p=0.4048)
Achillea millefolium	F=0.83 (p=0.4421)	F=0.076 (p=0.7842)	F=0.32 (p=0.7311)
Grindelia stricta	F=1.7 (p=0.1867)	F=0.046 (p=0.8318)	F=0.38 (p=0.6854)
Symphyotrichum chilense	F=2.2 (p=0.1187)	F=0.42 (p=0.5186)	F=0.12 (p=0.8986)

Table 1
F- and p-values for the ANOVAs testing the effect of treatments, mowing, and the interaction between the two on exotic grass cover, exotic forb cover and each native species that was originally planted in 2010 that was found this season. Values were calculated using JMP Pro 13.

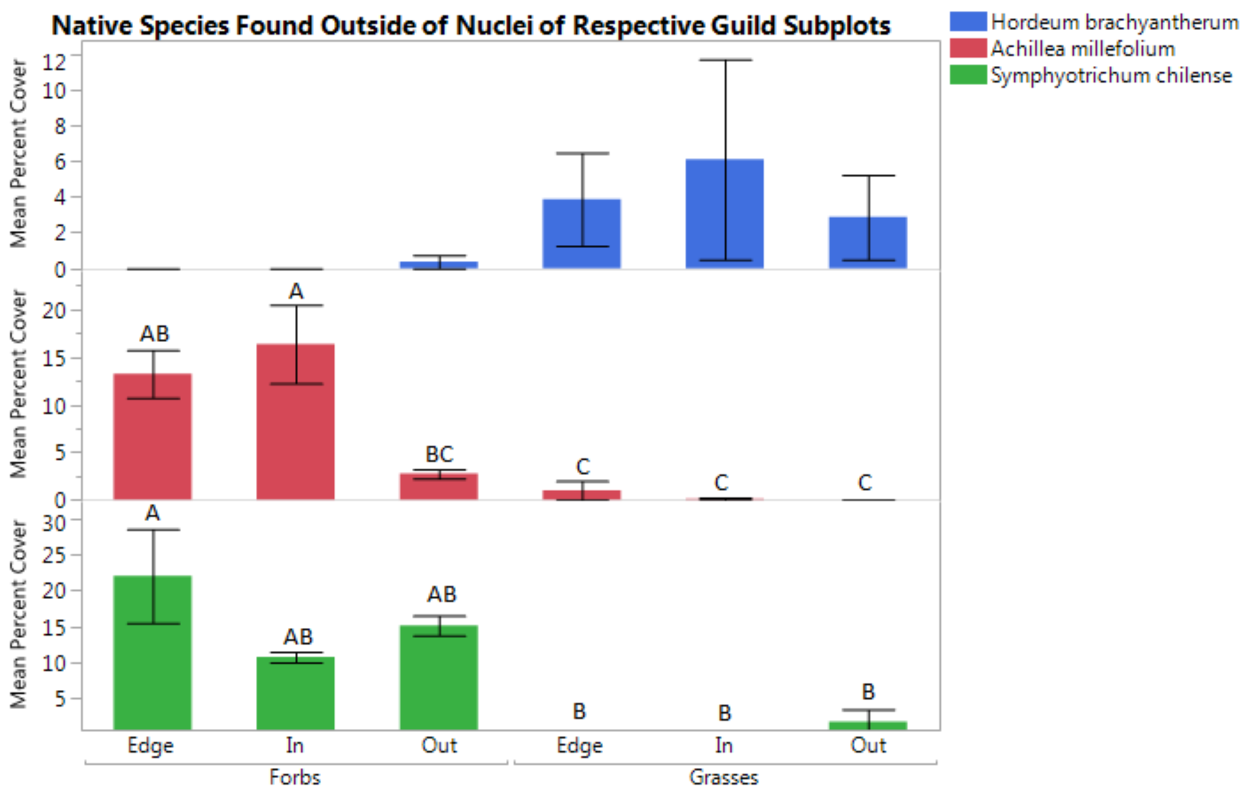


Fig. 3

The mean percent cover of *Hordeum brachyantherum* (top) and *Achillea millefolium* (middle) and *Symphyotrichum chilense* (bottom) in the island plots. For each species, the mean percent cover is largest in their respective guild islands and decreases as they move away from where they were planted. Each species is found outside of their respective islands and inside the subplot of the other guild. Error bars represent 1± standard error from the mean. Means with same letter do not differ significantly ($p<0.5$).

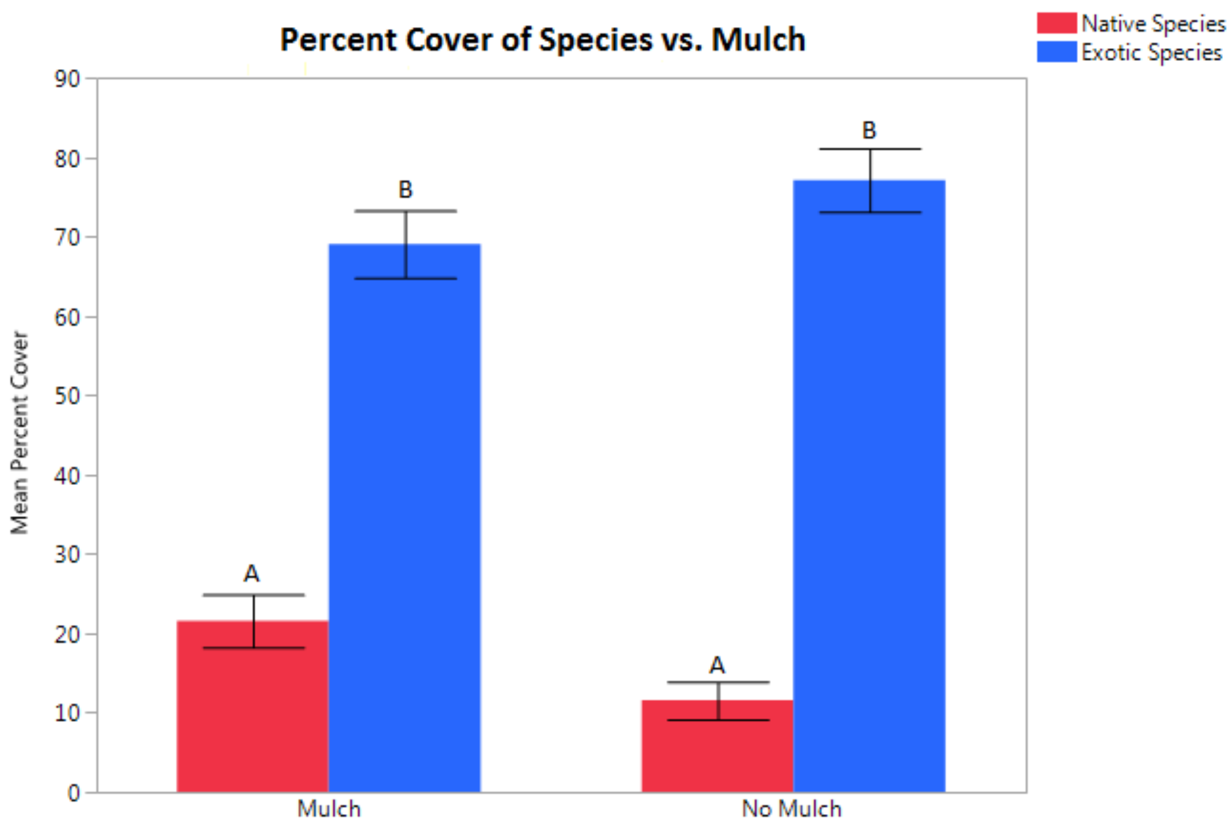


Fig. 4

The mean percent cover of native species and exotic species across mulched and not mulched plots. Error bars represent 1±standard error from the mean. Means with same letter do not differ significantly ($p<0.5$).

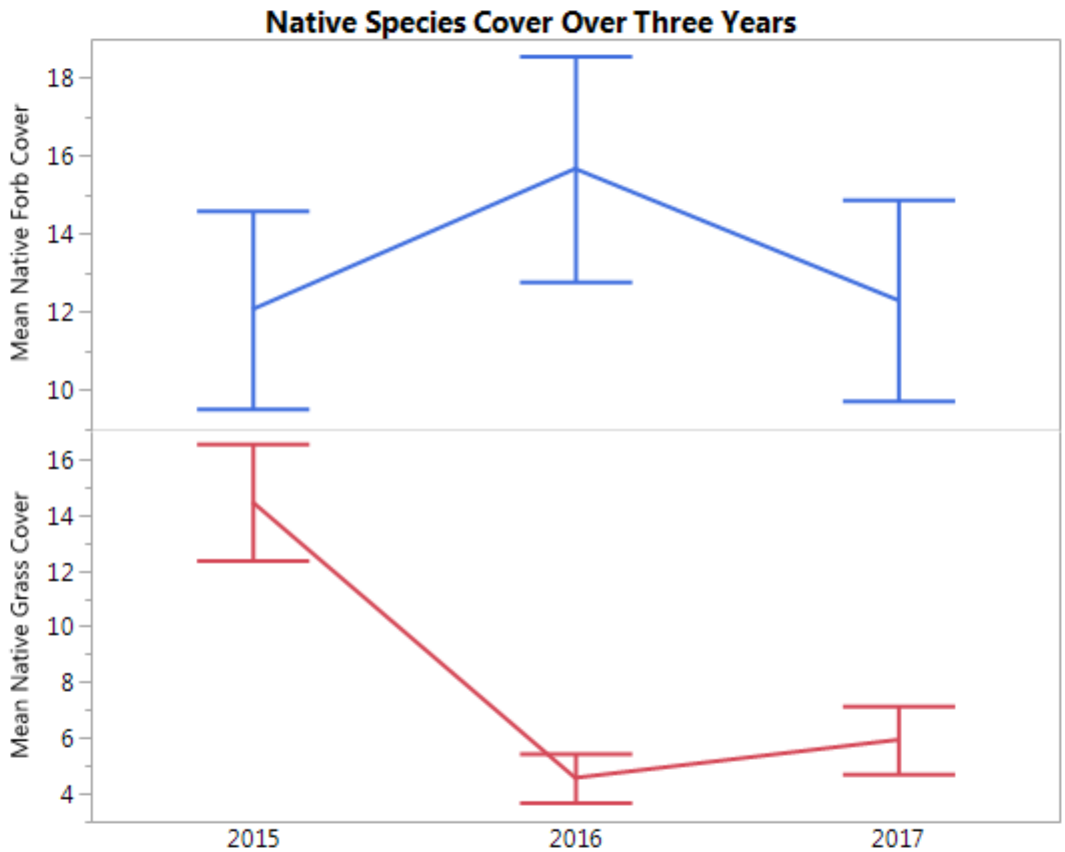


Fig. 5
Data from Schreiber (2015), Rusk (2016) and this year showing the trends of native forbs and grasses from the past three years. Error bars represent 1± standard error from the mean.

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Effectiveness of Tarp and Mulch on Exotic Plant Suppression To Restore Coastal Grassland

Abstract

Many of California's coastal scrub and grasslands have been overtaken by exotic plant species due to invasive flora proliferation and ecosystem-degrading land usage practices. Herbicides have become the standard for suppressing exotic plant populations due to low costs and ease of accessibility, however they have shown to be damaging to surrounding ecosystems and unsafe regarding human exposure. In this study, I observed the effectiveness of three non-chemical approaches to exotic plant control (wood mulch applied after black plastic tarping, cardboard over wood mulch, and paper over wood mulch) in a coastal scrub and grassland ecosystem. I measured exotic grass and forb cover on all plots and concluded that all three treatments were almost equally effective in invasive plant suppression. Considering labor and sourcing costs, I recommended paper mulch as the most efficient and cost-effective method for exotic plant control in a coastal shrub and grassland setting. Given the abnormal rainfall patterns and short time allotment for this study, future data may reveal a more distinct trend for treatment effectiveness.

Introduction

Coastal grassland and scrub restoration efforts have shown promising but inconsistent results for offsetting the drastic loss and degradation of these important ecosystems. Restoration methods such as controlled burning, cattle grazing, and use of herbicides are not always feasible due to economic viability and potential dangers to nearby human populations and the surrounding ecosystems (Holl et al. 2014). Non-chemical methods of controlling exotic and invasive flora need to be developed, given growing concerns about potential negative effects of widespread herbicide use for restoration.

Anthropogenic influences on California's native ecosystems (especially land conversion for agriculture) have altered soil profiles and nutrient availability, setting grounds for invasive and exotic flora populations to flourish and ultimately reduce native biodiversity (Kotze et al. 2012). Unlike California's more inland grasslands that are dominated by Mediterranean annual grasses, coastal California grasslands have retained a more diverse and prominent native grass profile that must be preserved (Heady 1988). The ability of many exotic plants to thrive in a variety of soil conditions directly leads to outcompeting of specialist native plant communities (Yepsen et al. 2014). The displacement of California's coastal grassland native flora by exotic annuals and forbs can be amplified in lands that have been previously used for agriculture. Intensive agricultural practices consistently lead to changes in physical soil structures from tilling, and changes in the nitrogen cycle due to pollution from fertilizers, which ultimately impacts soil microbial community interactions (Bozzolo, 2013). Many exotic plants have shown to be indifferent to soil microbe communities while many California coastal native plants have shown to be reliant specific soil microbial facilitation for more vigorous growth (Bozzolo 2013). Similarly, changes in mycorrhizal fungi dynamics from improper land management can affect the competitive success of invasive species over natives (Stinson et al. 2006). The influx of exotic plant invasions on California coastal grassland and scrubland is responsible for the decrease in species richness and biodiversity of native grasses, shrubs, and forbs. C

The application of organic materials and mulch coverings prior to planting native species have shown to be effective methods in preparing coastal grasslands for the establishment of sustaining populations of native flora populations and diminishing prevalence of exotic and invasive flora (Wood et al., 2017). In addition to exotic and invasive plant control, organic mulches and coverings can have positive benefits on soil biota, soil moisture retention, increased organic material, stabilization of soil temperature depending on cover material, and an overall stability of topsoil physical conditions (Cook et al. 2006). These soil-enhancing traits can further help with the establishment of native plantings especially when restoring a land previously used for agriculture.

The use of black plastic tarp weed barriers has shown to be an effective method for invasive weed control, even more so than use of herbicides and burning (Holl et al., 2014). The black tarp smothers germinating seeds and effectively reduces unwanted seed banks and overall invasive plant populations through lack of UV penetration following a rainfall event (Holl et al., 2014). Plastic tarp application can be expensive, however it can be reused for multiple treatments and has shown to be cost-effective considering lower future land management expenses regarding exotic plant abatement (Markus 2011).

Considering the variability of biotic and abiotic factors in a given plot, it is important to use a variety of methods when restoring a large site. The goal of intensive active management treatments in restoration projects is to begin a solid trajectory of less resource and labor-intensive maintenance regimes, leading to an increasingly passive management plan. With proper land management (reducing anthropogenic disturbances), annual native grasses in California coastal grassland habitats can begin to significantly reduce the productivity of exotic grasses by crowding out and shading exotic grass seedlings (Corbin, 2004). By initially reducing exotic flora establishments, a jump-start can be given to efficient native plant colonization.

This study looks at the effectiveness of black plastic tarp covering prior to restoration, and applications of corrugated cardboard and paper mulch ground coverings at the time of planting on coastal grassland plots regarding native plant community restoration at a site in the Younger Lagoon Reserve. Due to the temporary nature of the plastic tarp treatment, and the rapid biodegradation of the paper mulch treatment, I predict that cardboard treatment would be more effective in a more long-term invasive and exotic plant deterrent (Zhang et al. 2008). In addition to the wood mulch, the corrugated cardboard cover creates a more durable and insulative barrier that should smother invasive and exotic plants from lack of UV penetration while supporting a healthy soil biome, soil moisture retention, and stabilized soil temperatures. With increased soil moisture stabilization and diminished competition of exotic and invasive plant populations, the native plantings should have a better chance to establish.

Methods

Site description

The restoration experiment is located at the Younger Lagoon Reserve (YLR) in Santa Cruz CA. The YLR consists of a 29-hectare parcel of land that is part of a larger parcel donated by Santa Cruz residents Donald and Marian Younger to UCSC for the development of a natural reserve. The University of California has implemented a Coastal Long Range Development Plan (CLRDP) in this territory with plans to develop space and offer resources for teaching, research, and public access opportunities. The CLDRP includes a protection and restoration program for land that makes up the YLR (Stern 2013). The YLR is currently managed by the University of California Natural Reserve System (NRS) as of 2008, with intentions of contributing to ecological restoration and management research (Stern 2013). The site was previously used for agriculture (predominately Brussels sprouts) and cattle grazing up until the early 1980s. The site is composed of coastal wetlands, grasslands, and coastal scrub, many areas of which are dominated by invasive shrubs, forbs, and grasses. Our 12 plots are predominately coastal grassland areas, close to existing coyote brush dominated scrubland. (Figure 1)

Figure 1. (Plot locations are outlined in red squares, "T" is tarp treatment, "C" is cardboard treatment, and "P" is paper treatment).

Data collection

Two UCSC students, Andrew Filous and Taylor Ramos set up an experiment with three treatments before planting native seedlings: black plastic tarp was implemented before application of wood mulch, paper overlaid with wood mulch, and cardboard overlaid with wood mulch. Each treatment was replicated on four 6.1 x 6.1 m plots for a total of 12 plots. All plots did not receive any prior plant removal or preparation before treatments were implemented. Black plastic tarp was placed on four plots in November 2016 a couple weeks following germinating rains, then removed in January 2017, and finally covered with wood mulch before planting. The cardboard and paper treatments were applied and covered in wood mulch (January 2017) just before natives were planted. The wood mulch was a mixture of redwood, cypress, and bay laurel provided by the UCSC Grounds Department. The plastic tarp was 0.15 mm thick and purchased from Home Depot. Corrugated cardboard was sourced from a local bike company and stripped of all metal staples and tape. 0.28mm thick Paper rolls were purchased from Sunshine Paper Company in Aurora, CO. The 12 selected planted native species include four species of native coastal grasses: (*Danthonia californica, Elymus glaucus, Hordeum brachyantherum, Stipa pulchra),* four species of forbs: *(Horkelia californica, Clinopodium douglasii, Prunella vulgaris, Symphyotrichum chilense),* and four species of shrubs: *(Artemisia californica, Ericameria ericoides, Mimulus arianticus, Scrophularia californica)*. Plantings were established with ten individuals in ten parallel rows spaced 47.2 cm apart, with a 53.3 cm buffer between the rows and plot perimeter for each plot. Native seedlings were propagated in Santa Cruz, CA in UCSC's greenhouses, and underwent hardening for weather acclimation before planting

After a timespan of 6 months (late April 2017) I identified species and measured percent exotic and native plant cover in each of the 12 plots. Rectangular quadrats (0.25x 1m) composed of PVC were used to assess plant cover in 5% cover classes (e.g. 0-5, 5-10, 10-15). Each plot was split into a grid consisting of 6 (1-m) vertical rows by 24 (0.25-m) horizontal rows. A random number generator was used to select two quadrat locations to be measured for each of the 6 vertical rows for a total of 12 quadrats per plot. Percent cover of wood mulch and exotic plant species was recorded within each quadrat. A soil hydrometer was used to record soil moisture readings every two weeks in set locations throughout each plot. Four measurements readings were taken for each plot and averaged. Moisture data was recorded starting from the beginning of the application of wood mulch in January until data collection in late April.

Data analysis

One-way ANOVA's at the p<.05 level and Tukey's HSD tests were used to compare variables between treatments, percent exotic cover, plant guild, and plant species. A One-way ANOVA at the p<.05 level and Tukey's HSD was used to compare soil moisture data (collected on April 20, 2017) with total percent exotic cover. A regression curve was used to compare the same soil moisture data with treatment type. The "four most prevalent species versus treatment" data were acquired through one-way ANOVA. All data was transcribe onto excel and processed through JMP.

Costs for material per plot for each treatment type were calculated from wholesale bulk pricing or estimated labor costs for material retrieval. Cardboard treatment costs are somewhat arbitrary considering sourcing, labor, and preparation.

Results

There was no significant difference in the effectiveness of the three treatments in suppressing exotic grass cover: ($F(2,9)=0.10$, $p=0.90$, Figure 2A) or total exotic cover ($F(2,9)=1.45$, $p=.29$). Exotic forb cover was marginally higher in the tarp treatment than the other two treatments: ($F(2,9)=3.48$, $p=0.076$, Figure 2B).

The four exotic species with the highest percent cover were: *Avena barbata* (grass), *Bromus diandrus* (grass), *Oxalis pes-caprae* (forb), and *Raphinus sativa* (forb). (Table 1)

There was also not a significant correlation between higher percent exotic plant cover with native plant survival based on a regression test: (Rsquare=0.040, p=0.53) (Native plant survival data from Andrew Filous, UCSC Student).

Soil moisture recordings did not differ across treatments: ($F(2,9)=0.078$, $p=0.34$, Figure 4) Total exotic percent cover was not correlated with the same soil moisture data: ($R^2=0.00072$, $p=0.93$).

The cost of cardboard treatment per plot for our particular application standards was slightly lower ($16.02) than either paper ($20.03) or tarp ($20.03).

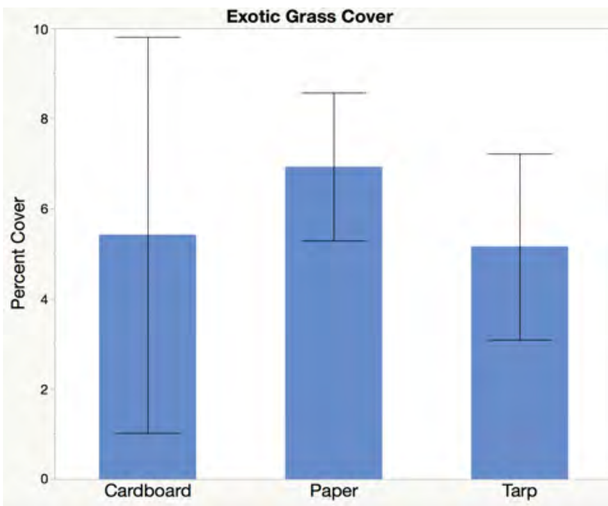

Figure 2A.

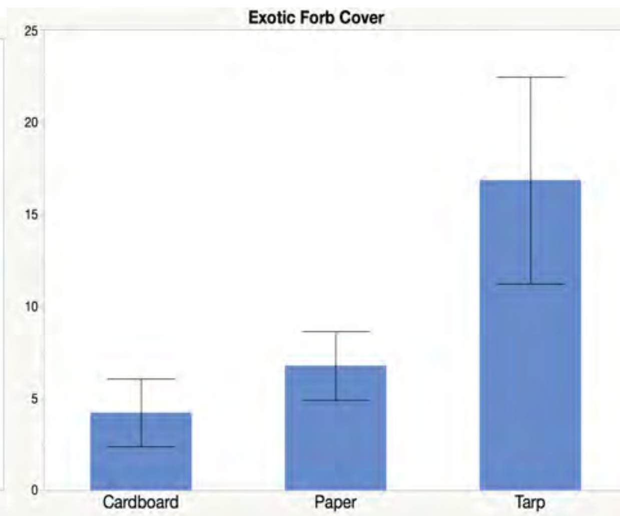

Figure 2B.

(Figure 2A/2B): Mean percent exotic grass and forb cover vs. treatment type. Error bars are ±1 standard error.

Species	Guild	Cardboard	SD	Paper	SD	Tarp	SD	F	P
(AveBar)	Grass	4.53	±7.82	5.52	±2.79	1.41	±1.72	0.77	0.49
(BroDia)	Grass	0.83	±1	1.41	±1.31	3.59	±4.62	1.05	0.39
(OxaPes)	Forb	3.02	±3.99	5.16	±1.99	3.75	±2.65	0.52	0.61
(RapSat)	Forb	1.15	±1.37	1.15	±1.75	9.79	±13.51	1.59	0.26

Table 1. Species categorized by guild and treatment type: *Avena barbata* (AveBar), *Bromus diandrus* (BroDia), *Oxalis pes-caprae*, and *Raphinus sativa* (RapSat).

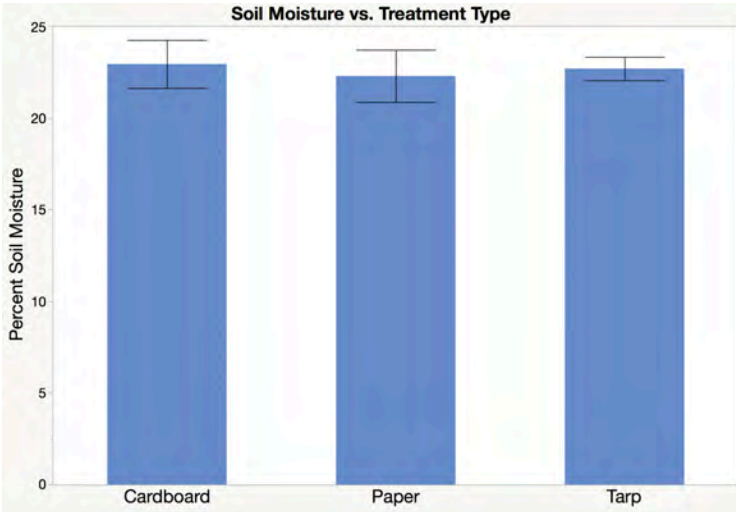

Figure 3. Average percent soil moisture (collected on April 20, 2017) vs. treatment type. Error bars are ±1 standard error.

Conclusion

The three treatments seemed to be equally effective in suppressing both exotic grasses and forbs, disregarding the marginal influx of exotic forb cover for the tarp treatment (Figure 2A/2B). Soil moisture content had little to no effect on exotic plant cover, and did not vary across the three treatments (Figure 3).

Cardboard was the most cost effective treatment, however labor for preparation of cardboard (pulling tacks and stripping tape) and the difficulty in application due to weight and dimensions are not entirely accounted for. Considering that both cardboard and paper have similar effectiveness in exotic plant suppression, paper may be the better treatment considering ease of application. Paper treatment also showed to be more effective in the facilitation of native planting establishment across the same 12 plots (Native plant survival and growth data from Andrew Filous, UCSC Student). According to my research, paper barrier with wood mulch would be the most efficient (and most likely cost-effective) way to implement a non-toxic exotic and invasive abatement regime in a coastal grassland and scrubland setting. I hope that this study will help facilitate more effective strategies for future coastal scrub and grassland restoration efforts.

Discussion

Given the location of some of the plots, there could have been unaccounted for factors that lead to inconsistencies in data. Plots were situated in locations that varied in surrounding exotic plant species richness and diversity that could be responsible for influxes of specific exotic plant prevalence. Specific locations could affect existing seed banks that survived after treatment. Variable in plot location could affect soil moisture levels as well: three plots in particular were bordering a compacted dirt road that could account for a decrease in water drainage (Figure1). Given the prior agricultural usage of the experimental site, inconsistencies in soil nutrient and physiology profiles could reflect exotic plant prevalence and vigor as well. With a larger sample size to work with, perhaps there would be more significant trends regarding effectiveness of treatment types.

Soil moisture levels have shown to be fairly consistent in regards to exotic plant cover and treatment types across the plots (Figure 3). Given the abnormal abundance of rainfall during the experiment, soil moisture results based on this data can be regarded as situational based on the typical climate of Santa Cruz County CA. However, applications of paper and other organic mulching have shown to effectively conserve soil moisture in agriculture settings (Schonbeck 1999). Coastal grasslands have shown resilience to short-term and long-term rainfall changes pertaining to predictions for the region (Fry et al., 2014). The increased rainfall in our site of study could have been in favor of exotic plant establishment for all treatments. The frequent rainfalls could have acted as a buffer for typical reduced seasonal rainfall.

Considering that all three treatments resulted in similar effectiveness in exotic plant abatement, it is possible that the application of wood mulch equalized the treatment effects. Wood mulch on its own has shown to be an effective exotic plant abatement treatment by reducing the germination of exotic plants as well as enhancing soil moisture retention, leading to favorable conditions for native plant competition (Holl et al., 2014). Organic mulch has also shown to immobilize soil nitrogen, allowing native plants to outcompete exotic plants for water and nutrients (Zink & Allen 1998). Agricultural land conversion alters preexisting soil microbe populations and diversity setting grounds for invasive plant establishment. Native microbial diversity frequently correlates with native flora vigor. (Kotze et al., 2012) These observations are especially relevant considering previous agricultural land usage at YLR. Wood mulch on its own may prove to be just as effective as when adding paper and cardboard layers or after plastic tarp treatment.

Ecological restoration is the process of changing a degraded ecosystem to a state in which it becomes able to withstand periodic environmental stressors and to recover from disturbance (Wood 2011). Relatively few restoration sites are thoroughly evaluated or monitored for an appropriate length of time due to lack of funding or resources. (Wood 2011) Given the short amount of time between treatment implementation and data recording, the scope of this project does not accurately reflect the potential long-term resiliency of exotic plant establishment with the paper, cardboard, and plastic tarping in a coastal shrub and grassland ecosystem. I hope to follow up on future data regarding the plots and observe data for the possibility of more distinct trends regarding effectiveness of exotic plant suppression across the three treatments.

Literature Cited

Bozzolo, F., & Lipson, D. (2013). Differential responses of native and exotic coastal sage scrub plant species to N additions and the soil microbial community. *Plant & Soil*. 371, 37-51.

Cook, H. F., Valdes, G. S., & Lee, H. C. (2006). Mulch effects on rainfall interception, soil physical characteristics and temperature under zea mays l. *Soil and Tillage*. 80, 23-40.

Corbin, J. D. (2004). Competition between native perennial and exotic annual grasses: implications for a historical invasion. *Ecology*. 85, 1273-1283.

Fry, E., Manning, P., Power, S. (2014). Ecosystem functions are resistant to extreme changes to rainfall regimes in mesotrophic grassland. *Plant and Soil.* 381, 351-365.

Grose, P. J. (2012). Restoring a seasonal wetland using woven black plastic weed mat to overcome a weed threshold. *Ecological Management & Restoration*. *13*, 191-195.

Haubensak, K. A., & D'Antonio, C. M. (2006). Restoration of a coastal California grassland after invasion by nitrogen-fixing shrubs, French Broom and Scotch Broom. *Ecological Restoration*. 24, 93-99.

Heady, H. F. (1958). Vegetational changes in the California annual type. *Ecology.* 39, 402-415.

Holl, K. D., Howard, E. A., Brown, T. M., Chan, R. G., de Silva, T. S., Mann, T., Russell, J. A., Spangler, W. H. (2014). Efficacy of exotic control strategies for restoring coastal prairie grasslands. *Invasive Plant Science and Management*. 7, 590-598.

Irvine, I. C., Witter, M. S., Brigham, C. A., & Martiny, J. H. (2013). Relationships between methylobacteria and glyphosate with native and Invasive plant species: implications for restoration. *Restoration Ecology*. 21, 105-113.

Kotze, D., Ellery, W., Macfarlane, D., & Jewitt, G. (2012). A rapid assessment method for coupling anthropogenic stressors and wetland ecological condition. *Ecological Indicators*. *13*, 284-293.

Markus, D. J. (2011). Use of synthetic ground covers to control weeds in blackberries. *International Journal of Fruit Science*. 11, 286-298.

Schonbeck, M. W. (1999) Weed suppression and labor costs associated with organic plastic, and paper mulches in small0scale vegetable production. *Journal of Sustainable Agriculture*. 13, 13-33.

Stinson, K. A., S. A. Campbell, J. R. Powell, B. E. Wolfe, R. M. Callaway, G. C. Thelen, S. G. Hallett, D. Prati, and J. N. Klironomos. 2006. Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualisms. *PLoS Biology*. 4, 140.

Wood, J. K. (2011). Evaluating and monitoring the success of ecological restoration*. Capstone Project: University of Washington Restoration Ecology Network.*

Wood, J. K., Gold, W. G., Fridley, J. L., Ewing, K., Niyogi, D. K. (2017). An analysis of factors driving success in ecological restoration projects by a university-community partnership. *Ecological Restoration*, 35, 60-69.

Yepsen, M., Baldwin, A. H., Whigham, D. F., McFarland, E., LaForgia, M., & Lang, M. (2014). Agricultural wetland restorations on the USA Atlantic Coastal Plain achieve diverse native wetland plant communities but differ from natural wetlands. *Agriculture, Ecosystems & Environment*. 197, 11-20.

Zhang, Y., Han, J., Kim, G. (2008). Biodegradable mulch film made of starch-coated paper and its effectiveness on temperature and moisture content of soil. *Communications In Soil Science & Plant Analysis*. 39, 1026-1040.

Zink, T. A., Allen, M. F. (1998), The effects of organic amendments on the restoration of a disturbed coastal sage scrub habitat. *Restoration Ecology*. 6, 52–58.

Appendix 4. Photo monitoring

YLR Terrace Photopoint #1. April 27, 2017. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

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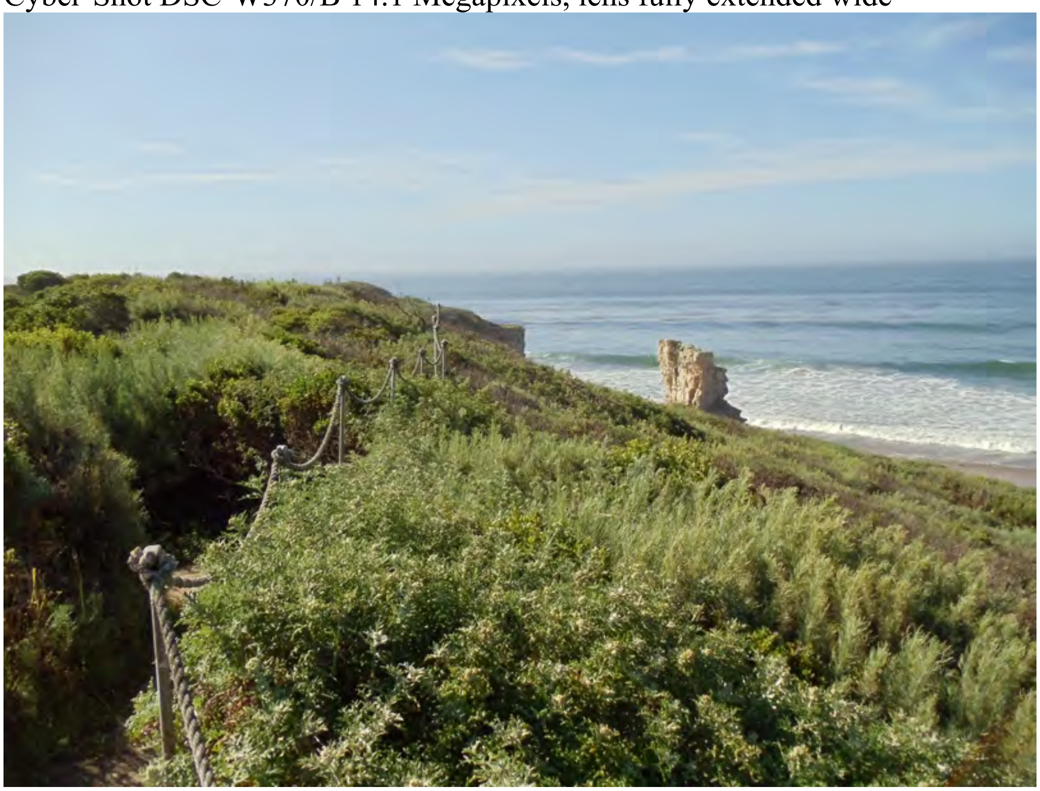
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YLR Beach Photopoint #4. May 2, 2017. Photographer: Tim Brown. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide