University California, Santa Cruz

Younger Lagoon Reserve

Annual Report 2015-2016

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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 75 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 (PI Eric Palkovacs), 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 2015-2016 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 fifth year of CLRDP CCC compliance monitoring for restored Coastal Bluffs and Grassland areas. YLR is meeting or exceeding restoration targets for all monitored sites and is on track to meet the restoration goals for Phase 1. FY 2015-2016 represented the sixth full year of implementation of the CLRDP CCC Beach Access Management Plan related activities at Younger Lagoon Reserve. The University plans to submit a NOID to the CCC in summer 2017 that summarizes 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 2015-2016 fiscal year (July 1, 2015 - June 30, 2016). 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 eighth year we had fulltime staff on site managing the Reserve. As a direct result, the level of academic and public engagement increased and the Reserve is on target for implementing its obligations required under the Coastal Long Range Development Plan (CLRDP).

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

CLRDP Activities

Overview

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

The CLRDP requires that the entire Reserve be protected and 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 sixth 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 was initially submitted in the Fall of 2016; however, it was withdrawn due to CCC staff work load and will be resubmitted in summer of 2017.

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 2015-2016 and biological monitoring of the lagoon and adjacent beach was conducted quarterly in FY 2015-2016. A detailed report on activities under the Beach Access Management Plan is included as Appendix 1.

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

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

The SRP for Phase 1A and 1B of restoration (first 7 years) was approved by the CCC in September 2010. Phase 1A projects include Priority 1 weed removal, re-vegetation, baseline monitoring and selection of reference systems. Phase 1B projects include work in wetland areas, including the reconnection of upper terrace wetlands 1 and 2. Restoration of the Terrace lands continued throughout FY 2015-2016. Activities included weed control, planting, seed collection, and preliminary 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, and 2013-2015 Annual

Reports). FY 2015-2016 marked the fifth year of compliance monitoring for restored Coastal Bluffs and Grassland areas. A detailed compliance monitoring report is included in Appendix 2.

Monitoring efforts in 2016-2017

During the 2016-2017 field season, UCSC graduate student Josie Lesage and professor Dr. Karen Holl will conduct restoration compliance monitoring at restoration sites 2, 4 and 6 years post planting as per CLRDP requirements.

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

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

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

In August 2013, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development NOID 6 (13-1) Coastal Biology Building and Associated Greenhouses; Site Improvements Including Road, Infrastructure and Service Yards; Public Access Trails and Interpretative Panels; Wetland Connection in Specific Resource Plan Phase 1b; Sign Program; Parking Program; Lighting Plan. This project includes development of a new seawater lab building, three new parking lots along with a parking management program, a research greenhouse complex, and associated site work including proposed storm water treatment and infiltration features. It also consists of campus utility and circulation improvements to serve both the new lab building and future campus development under the CLRDP. The Project will develop a complex of public access and interpretive facilities, including pedestrian access trails, an interpretive program shelter, educational signage, and outdoor exhibits. This project includes mandated wetland restoration and habitat improvements as described in the Specific Resource Plan Phase 1b. This project also initiates campus wide parking, sign, and lighting programs.

In February and March of 2015, goats were brought to the site to clear the grub from areas that were being prepared for construction. In April, 2015, additional site prep work occurred, including final site clearing for the start of construction. Construction of the Coastal Biology Building and Infrastructure Projects began in May 2015 and continued in FY 2015-2016. The project is slated to be completed in 2017.

In 1999, when the University purchased the land for the expanded MSC, a special exception was made in the campus code to allow leashed dogs on the bluff top trail that rings the YLR Terrace Lands. Since that time, the site had become popular with dog owners, many of whom do not obey the leash law. The CLRDP requires that all domesticated animals be eliminated from the campus. Parallel to the start of construction, implementation of the campus "no dog" policy began in May 2015 and continued in FY 2015-2016. New signage and other activities were implemented to educate the community and the public about the policy change. Student Ambassadors from the campus Police Department were brought on site to help inform the public about the new "no dog" policy. In addition, a new temporary sign was installed at the CSC entrance about the new policy, and existing trail signs were modified to reflect the change as well.

Scientific Advisory Committee (SAC) Meetings / Recommendations

A critical component of the CLRDP was the creation of a Specific Restoration Plan (SRP) guided by a Scientific Advisory Committee (SAC). The SAC is comprised of four members: Dr. Karen Holl (SAC chair) Professor and Chair of the Department of Environmental Studies at UCSC; Tim Hyland, Environmental Scientist, State Parks, Santa Cruz District; Bryan Largay, Conservation Director, Land Trust of Santa Cruz County; and Dr. Lisa Stratton, Director of Ecosystem Management, Cheadle Center for Biodiversity and Ecological Restoration, University of California, Santa Barbara (UCSB). SAC members consulted with reserve staff on an as needed basis in FY 2015-2016. Discussion topics included current and future projects under the CLRDP, as well as restoration, research, and teaching activities at YLR.

<u>Research Recommendations:</u>

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 sixth year of data, which is reported in Kircher (2016). The main results and recommendations are listed below and Kircher's entire report is included in Appendix 3.

- Over the years native grass cover in the treatments has converged so there are few treatment differences in either native or exotic species.
- *Hordeum brachyantherum* cover was higher in herbicide than control plots in 2016. Herbicide has been the exotic control method that has most consistently reduced non-native forb and grass cover and enhanced native grass cover over the six years of the study.
- The most striking difference this year was the increase in exotic forb cover between 2015 (40.3%) and 2016 (88.7%) and the simultaneously decline in native grass cover (34.1% in 2015 and 18.3% in 2016). Native grass cover dropped slightly below the 20% native cover restoration target. This was likely due to the higher rainfall during the 2015-2016 rainfall year and plot mowing in January 2016.
- Mowing in January 2016 did not favor native species, as anticipated, and rather seemed to favor short stature exotic forbs. Hence, different management methods should be considered for these plots in the future.

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 Rusk (2016). The main results and recommendations are listed below and Rusk's entire report is included in Appendix 3.

- The island planting treatment shows promise as a restoration treatment. Cover of native species was generally similar in island planting plots compared to full planting plots.

- Moreover, Holl et al. found evidence that planted species continue to spread outside the planted areas due to a mix of growth of existing plants and new recruitment. The native forbs in particular (primarily *Achillea millefollium* and *Grindelia stricta*) had substantial cover outside planted areas.

- Native grasses and forbs were patchily distributed in all treatments with the majority of quadrats having no native cover and small number of plots having very high cover.

- Mowing had mixed effects, as mowed plots had greater cover of both native and exotic grasses. The cover of native grasses was strong negatively correlated with thatch cover but not with exotic grass cover suggesting that a thick layer of thatch inhibits native grasses.

- Holl et al. had not seen effects of mulching since the first two years of the study, given that wood mulch larger breaks down after two years in a coastal climate. However, this year native forb cover was higher in full-planted mulched than unmulched plots.

- Overall native cover was lower and exotic forb cover higher than in previous years, which likely reflects higher rainfall this year compared to preceding years. Overall native cover was slight greater than the 20% cover target, but ongoing monitoring is needed to determine whether the decline in native cover continues.

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 2015-2016, 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 January 2016, establishment was measured in April 2016, and reported in Green (2016). The main results and recommendations are listed below and Green's entire report is included in Appendix 3.

- *Achillea millefolium* and *Grindelia stricta* showed significantly higher establishment in broadcast plots, whereas the three native grass species (*Hordeum brachyantherum*, *Danthonia californica*, and *Elymus triticoides*) had similar establishment in both seeding treatments.

- Although exotic growth was high across all treatments, mulching and mowing considerably improved establishment of both native forbs and native grasses.

- *Eschscholzia californica* had higher germination in the greenhouse and in the field in January, but few seedlings were observed in April.

- The remaining four species had extremely low establishment in all treatments.

- Drill seeding had the lowest establishment of all species and involved more time, equipment, and effort than broadcasting. Broadcast seeding followed by tamping with a lawn-roller combined with aggressive exotic control may be an effective management strategy for small-scale restoration of California coastal prairie, but continued monitoring is needed before drawing conclusions.

- *Grindelia stricta*, *Achillea millefolium* and *Hordeum brachyantherum* are recommended for direct seeding in coastal prairie restoration, as they showed a relatively high rate of establishment, particularly when combined with mulch and mowing.

<u>Management Recommendations:</u>
In FY 2015-2016 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 2015-2016, 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, which is expected to be completed in 2017. The results of this study will help inform future decisions regarding CRLF pond construction in the upper terrace.

The SAC discussed the CRLF pond idea at its 2015 meeting, and 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 met with Reserve Manager Elizabeth Howard on-site in the summer 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 will be 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 prepare for 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 2015-2016, 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 2015, 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 2015/2016.

Restoration Planting

In FY 2015-2016, 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 2015-2016 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. Kathleen Kay and students from BIOE 117/L Systematic Botany of Flowering Plants in the field

Internships and Senior Theses

In FY2015-2016, YLR staff sponsored over 50 undergraduate interns through the UCSC Environmental Studies Internship Office (Figure 3). The students ranged from entering freshman to graduating seniors and spent between 6 and 15 hours a week working on on-going restoration projects at the reserve. These projects included invasive species removal, re-vegetation with native species, seed collection, and propagation. Student-interns report a deep appreciation for the opportunity to obtain hands-on experience in their field of study.

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

Table 1. Younger Lagoon Courses

Course Title	Institution (Department)	Instructor's Name
BIO 11C - Ecology	Cabrillo Community College	Allison Gong
BIOE 85 – Natural History of the UCSC Natural Reserves	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Lewis Reed
BIOE 107 - Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	James Estes
BIOE 122/L - Invertebrate Zoology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Baldo Marinovic
BIOE 150 – Ecological Field Methods	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Don Croll,
BIOE 155 - Freshwater Ecology	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Joe Merz
BIOE 295 - Advanced Ecology and Evolutionary Biology Seminar	University of California, Santa Cruz (Dept. of Ecology and Evolutionary Biology)	Beth Shapiro
CLEI 55 - College Eight: Service Learning Practicum	University of California, Santa Cruz (College Eight)	Susan Watrus
CLEI 55 - Sustainability Internship	University of California, Santa Cruz (College Eight)	Susan Watrus
ENVS 104A/L - Environmental Field Methods (Summer)	University of California, Santa Cruz (Dept. of Environmental Studies)	Dan Brumbaugh
ENVS 160 - Restoration Ecology	University of California, Santa Cruz (Dept. of Environmental Studies)	Karen Holl
ENVS 162/L - Plant Physiological Ecology/Lab	University of California, Santa Cruz (Dept. of Environmental Studies)	Michael Loik

ENVS 167 - Freshwater / Wetland Ecology	University of California, Santa Cruz (Dept. of Environmental Studies)	Katie L Monsen
ENVS 83 / 183 - Younger Lagoon Reserve Stewardship Interns	University of California, Santa Cruz (Dept. of Environmental Studies)	Tim Brown
ENVS 84 / 184 - Younger Lagoon Reserve Stewardship Interns	University of California, Santa Cruz (Dept. of Environmental Studies)	Tim Brown
OPERS Animal Tracking class	University of California, Santa Cruz (OPERS)	Chris M Lay

Research

Due in part to its relatively small size and lack of facilities, YLR is unlikely to host many single-site research projects in biology or ecology. However, as one of the few remaining coastal lagoons in California, YLR is well suited to act as one of many research sites in a multi-sited project. Additionally, the close proximity to campus makes it an ideal place for faculty to conduct pilot and our small-scale studies as well as for undergraduate research opportunities. In FY 2015-2016 we approved 9 additional research applications. Examples and summaries of new and ongoing research are included below.

Faculty Research Highlight: Evolution of the Threespine Stickleback

Professor Erik Palkovacs and graduate student Ben Wasserman conducted an experiment in Younger Lagoon during the summer of 2015 to test for interactions between ongoing evolution occurring in a small fish species and the ecology of the lagoon environment. Younger Lagoon is inhabited by threespine stickleback – a fish that grows to about 2 inches. Like fruit flies, threespine stickleback have been the subject of many evolution studies. Scientists know that ancestral stickleback lived in saltwater, but over time they have repeatedly colonized freshwater. Marine stickleback are covered in a continuous row of bony plates that serve as armor, while freshwater stickleback usually have only a few plates. This change from completely plated to only a few plates is a genetic adaptation to freshwater environments, where there are fewer predators but also less Calcium, an important component of the plates.

In California's bar-built estuaries like Younger Lagoon, we find different types of threespine stickleback: some with the complete row of plates like marine fish, some with the low plate counts of freshwater fish, and everything in between. The variation suggests ongoing (or stop and start) evolution towards the freshwater state.

Using plastic enclosures (mesocosms) suspended in the lagoon (Figure 4), researchers in the Palkovacs lab created miniature ecosystems containing either completely plated, low plated, or partially plated stickleback. The researchers are measuring the invertebrates, plankton, and physical ecosystem properties inside the enclosures in order to determine the impacts, or "niche construction" of each plate type.

Figure 4. Palkovacs lab intern observes threespine sticklebacks in the lagoon mesocosms.

Once the miniature ecosystem in each enclosure has changed in response to the presence of the plated, low-plated, or partially-plated stickleback, researchers added groups of juvenile stickleback of mixed plate types to each enclosure and observe whether some types are better adapted to the "constructed" environment. Results from this experiment will let researchers observe the feedback between ecological and evolutionary processes.

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.

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. Over 20 Internship students helped build the experimental structures between July and November 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 we 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. We 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 are constructed of lightweight metal and rainfall is intercepted using clear, v-shaped polycarbonate troughs. Rainfall interception commenced during the first significant rainfall between 2 -3 November 2015. With *ISEECI* support, we will soon begin to automatically monitor soil moisture and temperature, as well as air temperature and relative humidity near the ground under the shelters.

Figure 5. Experimental *DroughtNet* shelters on the reserve terrace lands.

Fall 2015 – Spring 2016 was Year Two of the experiment, and the first year of the interception treatment. Highlights of 2016 results include:

- Interception worked as designed.
- Soil moisture differences were equivocal. Weekly measurements of gravimetric soil moisture at 15 cm depth, or weekly surface measurements of soil water content by shown by permanent planted soil moisture probes. Measurements need to be made at 30 to 60

minute frequencies. Installation of permanent TDR probes at 15 and 50 cm depth in the soil is ongoing.

- Net Primary Production did not differ between watered and control plots, likely due to small sample size and large variance among samples. These results are in contrast to Photosynthetically Active Radiation (PAR; 400 to 700 nm) within the plant canopies under shelters compared to control plant canopies, which suggest less of a canopy under shelters. We are yet to compare results in the dry year 2015 *vs.* the wetter year of 2016.
- Species composition appears to differ between 2015 and 2016 and between the Twin Gates site compared to YLR and the UCSC Arboretum. These data are yet to be fully analyzed.
- Plant water potential (Ψ) varied among treatments, days, and species in 2016. For example, Ψ did not differ for *Raphanus sativa*, but was lower on drought compared to control plots for *Avena barbata*.
- Stomatal conductance to water vapor flux from leaves (a measure of stomatal opening for photosynthesis) was significantly lower for both *A. barbata* and *R. sativa* on drought compared to control plots. However, there were no significant differences in photosynthetic rates (*i.e.*, CO_2 assimilation into sugars) for either species.

During summer 2016, Loik et al. will complete the installation of TDR soil moisture sensors at 15 and 50 cm soil depths; install air temperature, solar radiation, PAR, and relative humidity sensors; install and program Campbell Scientific CR206X data loggers; and install solar panels, waterproof instrument enclosures, radio communications, etc. These instruments will allow us to better quantify soil moisture differences between treatments and depths, as well as better understand the effects of the shelters on micrometeorology near the ground.

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 Green Burns completed a senior thesis with the UCSC Natural Reserves in June 2016. His thesis, entitled ‘A comparison of small-scale direct seeding methods to restore California coastal prairie’ was a case study of seeding techniques for ecological restoration in coastal prairie systems. Burns worked closely with Reserve Manager, Elizabeth Howard, Restoration Steward Tim Brown, Graduate Student Josie Lesage and Faculty Advisor Karen Holl to ensure that his results and recommendations would influence future restoration and management activities.

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 2015-2016 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 at work on the reserve.

Reserve Use

The greatest educational user group for YLR in FY 2015-2016 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 Santa Barbara, University of Utah, Aptos High School, Pacific Collegiate School, Pajaro Valley High School, Watsonville High School, 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, 2015 to June 30, 2016

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	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	59
Research Scientist	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10
Graduate Student	5	71	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	84
Undergraduate Student	13	188	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	188
Other	0	0	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15
SUB-TOTALS	23	318	4	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	356
UNIVERSITY-LEVEL CLASSES																										
Faculty	13	35	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	36
Graduate Student	31	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	47
Undergraduate Student	546	1706	0	0	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	596	1756
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
SUB-TOTALS	590	1788	0	0	0	0	51	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	642	1840
PUBLIC SERVICE																										
Faculty	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Research Scientist	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Graduate Student	6	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	60
Undergraduate Student	100	370	0	0	0	0	0	0	0	0	12	12	0	0	0	0	0	0	0	0	0	0	0	0	112	382
K-12 Instructor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	0	2	6
K-12 Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71	131	0	0	71	131
Professional	2	11	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	4	13
Other	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	52	766	0	0	0	0	2465	2465	2518	3232
Docent	283	283	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	284	284
Volunteer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5	50	6	51
SUB-TOTALS	395	728	1	1	0	0	0	0	0	0	13	13	0	0	1	1	55	769	0	0	73	137	2470	2515	3008	4164
TOTALS:	**1008**	**2834**	**5**	**39**	**0**	**0**	**51**	**51**	**0**	**0**	**13**	**13**	**0**	**0**	**1**	**1**	**55**	**769**	**0**	**0**	**73**	**137**	**2471**	**2516**	**3677**	**6360**

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

Table 3. Younger Lagoon Group Affiliations

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

Summary

FY 2015-2016 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 2016-2017.

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
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Año Nuevo Reserve Faculty Advisor	Daniel Costa Professor, Ecology & Evolutionary Biology

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Fort Ord Reserve Faculty Advisor	Laurel Fox Professor, Ecology & Evolutionary Biology EE Biology/Earth & Marine Sciences (831) 459-2533 – fox@biology.ucsc.edu
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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, 2016. Compliance Monitoring Report for the Coastal Bluff Grassland at Younger Lagoon Reserve, Spring 2016. Prepared for the California Coastal Commission and Younger Lagoon Reserve Scientific Advisory Committee, 2016.

Appendix 1. California Coastal Commission monitoring report

Appendix 2. Compliance monitoring report

Appendix 3. Student intern reports

Appendix 4. Photo monitoring

Younger Lagoon Natural Reserve

Beach Monitoring Report

2016

Younger Lagoon Fish Research

Elizabeth Howard and Gage Dayton
Younger Lagoon Natural Reserve

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Overview and Executive Summary

In March 2010, the California Coastal Commission (CCC) approved the University of California's Notice of Impending Development Implementation for Implementation Measure 3.6.3 of the CLRDP (NOID 10-1). NOID 10-1 requires that (through controlled visits) the public have access to Younger Lagoon Reserve beach and that a monitoring program be created and implemented to document the condition of native flora and fauna within Younger Lagoon and 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 will be resubmitted in summer of 2017.

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 2015 and a summary report for the entire 6-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 submit a NOID to the CCC in 2017.

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) 2015 (July 1, 2015 – June 30, 2016) which surveyed YLR. In addition, because of the upcoming NOID submission, 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 2015-2016.

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 (SMDC).

Beach Access Tours

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

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 Marine Discovery Center (Seymour Center).

In FY 2015-16, 64,856 people visited the Seymour Center. The Seymour Center provided marine science education to 285 classes, comprised of 8,550 students, teachers, and adult chaperones. Of the 285 classes served, 85 came from schools classified as Title 1—schools with high numbers of students from low-income families. Scholarships were made available to Title 1 schools, making it possible for 730 students to participate who would not otherwise have had the opportunity to experience a marine research center.

Approximately 55 percent of visiting schools came from Santa Cruz County, including Davenport, the San Lorenzo Valley, and Watsonville. Classes from Santa Clara and San Mateo Counties made up 30 percent. The balance was comprised of students from inland counties, traveling here to learn about their connection to the ocean. Students visited from Contra Costa, San Joaquin, Tuolumne, and San Benito Counties. Teachers often incorporate the Seymour Center into their weeklong marine science field study courses, including a high school class from Wisconsin that has made the Seymour Center a part of their curriculum for the past three years. The Seymour Center, Younger Lagoon Reserve and the Monterey Bay Aquarium continued our partnership supporting high school students in the Watsonville Area Teens Conserving Habitats (WATCH) program. Twenty-four 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.

With nearly as many on the wait list, 108 children ages 7-14, enrolled in nine, weeklong summer science sessions known as Ocean Explorers. Students actively learned about and participated in marine research at the Seymour Center, and our associated Long Marine Laboratory, where participants worked alongside marine mammal researchers and trainers. Participants gained experience with the scientific process, focusing on honing their observation and questioning skills. Ocean Explorers also investigated 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—however, nearly 10 percent traveled from areas as far away as Arizona, Oregon, Washington, Massachusetts, New York, and the

Philippines for this unique experience. Full and partial scholarships were extended to low-income participants.

The Seymour Center actively promotes its activities with press releases and calendar listings throughout the region. Last year, traditional print ads were placed in Good Times (and their annual Visitor Guide), Monterey Bay Travel Adventures, Summer Magazine, Bookshop Santa Cruz's Reader's Guide, Visit Santa Cruz County's Traveler's Guide, Wildlife Viewing Guide, and Visitor Map, plus the wedding-focused publications Coastal Wedding and Here Comes the Guide. The Seymour Center's activities are also often covered in the local newspaper, the Santa Cruz Sentinel. Online campaigns running throughout the year included SantaCruz.com and SantaCruzParent.com. Public radio ads ran two weeks every month on the NPR-affiliate, KAZU. The Seymour Center continued its long-time contract with Certified Folder, placing rack cards at lodging and attractions throughout the region, as well as the San Jose Airport. Coupons for discounted admissions were available in various formats. The most highly used program is through the many Bay Area municipal libraries. Called Discover and Go, more than 450 families from across the region utilized these discount coupons. The Seymour Center continued to connect with the public through Facebook, Twitter, Instagram, Pinterest, Flickr, and bi-monthly e-blasts. Their most active accounts are Facebook with ~3,500 followers, Twitter with ~600 followers, and Instagram with ~450 followers. Monthly e-blasts reached 5,800 people. The Seymour Center website continues to be strongly used—a sample month during the past year: 8,200 sessions; 6,200 users; 22,800 page views.

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 20010-2015 (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 marine mammal overlook during marine mammal tours at the Seymour Center. Those users (represent 10% of the individuals that attended SMDC tours outside of the YLR beach tours) were provided an overlook of the lagoon, interpretive information via docent led tours, and opportunities to read interpretive material presented on signs about the reserve; however, did not access the beach. During the 15-16 fiscal year a total of 105 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 117 tours have gone out and more than 541 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 2015-2016. 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, Santa Barbara	Land Trust of Santa Cruz County
University of California, Santa Cruz	Monterey Bay Aquarium WATCH Program
California State Universities	Santa Cruz Bird Club
California State University, Monterey Bay	Seymour Marine Discovery Center
	Watsonville Wetlands Watch
California Community College	
Cabrillo Community College	**Governmental Agencies**
	California State Parks
Universities outside California	
University of Utah	
	Volunteer Groups
K-12 system	UCSC Wilderness Orientation
Aptos High School	
Pacific Collegiate School	
Pajaro Valley High School	
Yerba Buena High School	

Table 2. Younger Lagoon Total Use.

RESERVE USE DATA
Period from July 1, 2015 to June 30, 2016

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	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	59
Research Scientist	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10
Graduate Student	5	71	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	84
Undergraduate Student	13	188	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	188
Other	0	0	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15
SUB-TOTALS	23	318	4	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	356
UNIVERSITY-LEVEL CLASSES																										
Faculty	13	35	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	36
Graduate Student	31	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	47
Undergraduate Student	546	1706	0	0	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	596	1756
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
SUB-TOTALS	590	1788	0	0	0	0	51	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	642	1840
PUBLIC SERVICE																										
Faculty	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Research Scientist	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Graduate Student	6	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	60
Undergraduate Student	100	370	0	0	0	0	0	0	0	0	12	12	0	0	0	0	0	0	0	0	0	0	0	0	112	382
K-12 Instructor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	0	2	6
K-12 Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71	131	0	0	71	131
Professional	2	11	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	4	13
Other	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	52	766	0	0	0	0	2465	2465	2518	3232
Docent	283	283	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	284	284
Volunteer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5	50	6	51
SUB-TOTALS	395	728	1	1	0	0	0	0	0	0	13	13	0	0	1	1	55	769	0	0	73	137	2470	2515	3008	4164
TOTALS:	**1008**	**2834**	**5**	**39**	**0**	**0**	**51**	**51**	**0**	**0**	**13**	**13**	**0**	**0**	**1**	**1**	**55**	**769**	**0**	**0**	**73**	**137**	**2471**	**2516**	**3677**	**6360**

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

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 – FY15-16.

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 – FY15-16.

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

[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					
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 (26%) (Table 6).

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

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

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

Site	Summer, 14	Fall, 14	Winter, 15	Spring, 15	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				

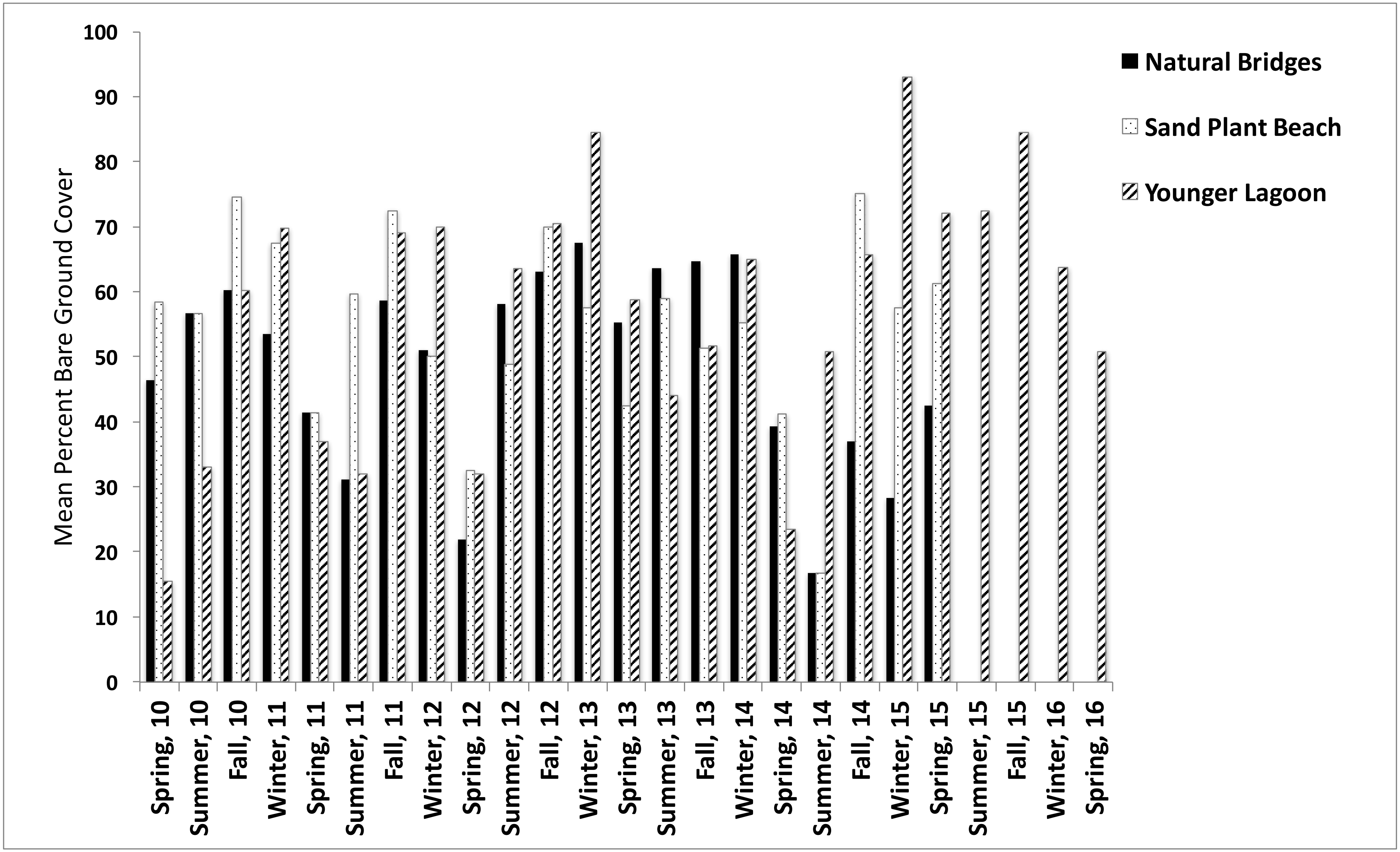

Figure 5. Mean percent bare ground encountered at each site.

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	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	**26%**
Total	
Sand Plant Beach	
Native	**68%**
Non-native	**31%**
Total	

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

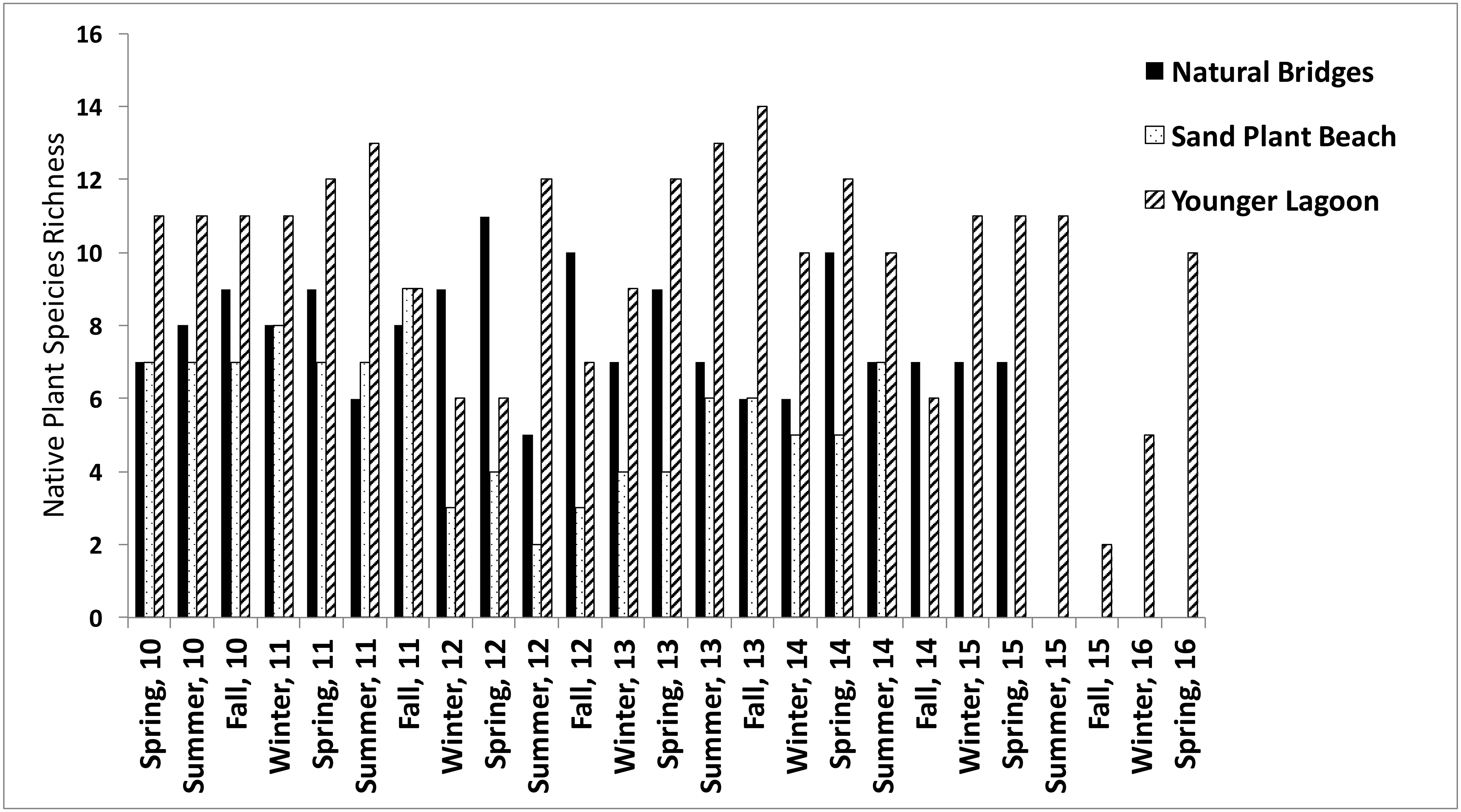

Figure 6. Number of native plant species encountered at each site.

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													
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

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

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

	Rodent[1]	Raccoon	Cottontail	Bobcat	Skunk	Squirrel	Deer	Opossum	Coyote	Bicycle	Vehicle	Dog	Human
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				
	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 2016 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	(14) 56%	(21) 84%	(2) 8%	(19) 76%	(7) 28%	(2) 8%	(2) 8%	0%	(16) 64%	0%	0%	0%	(9) 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 261 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**
	2		6		**8**
October 29-30, 2015					
Younger Lagoon					
			6		**6**
February 2-3, 2016			3	1	**4**
Younger Lagoon					
May3-4, 2016					
Younger Lagoon					
TOTAL	**134**	**55**	**69**	**3**	**261**

[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.

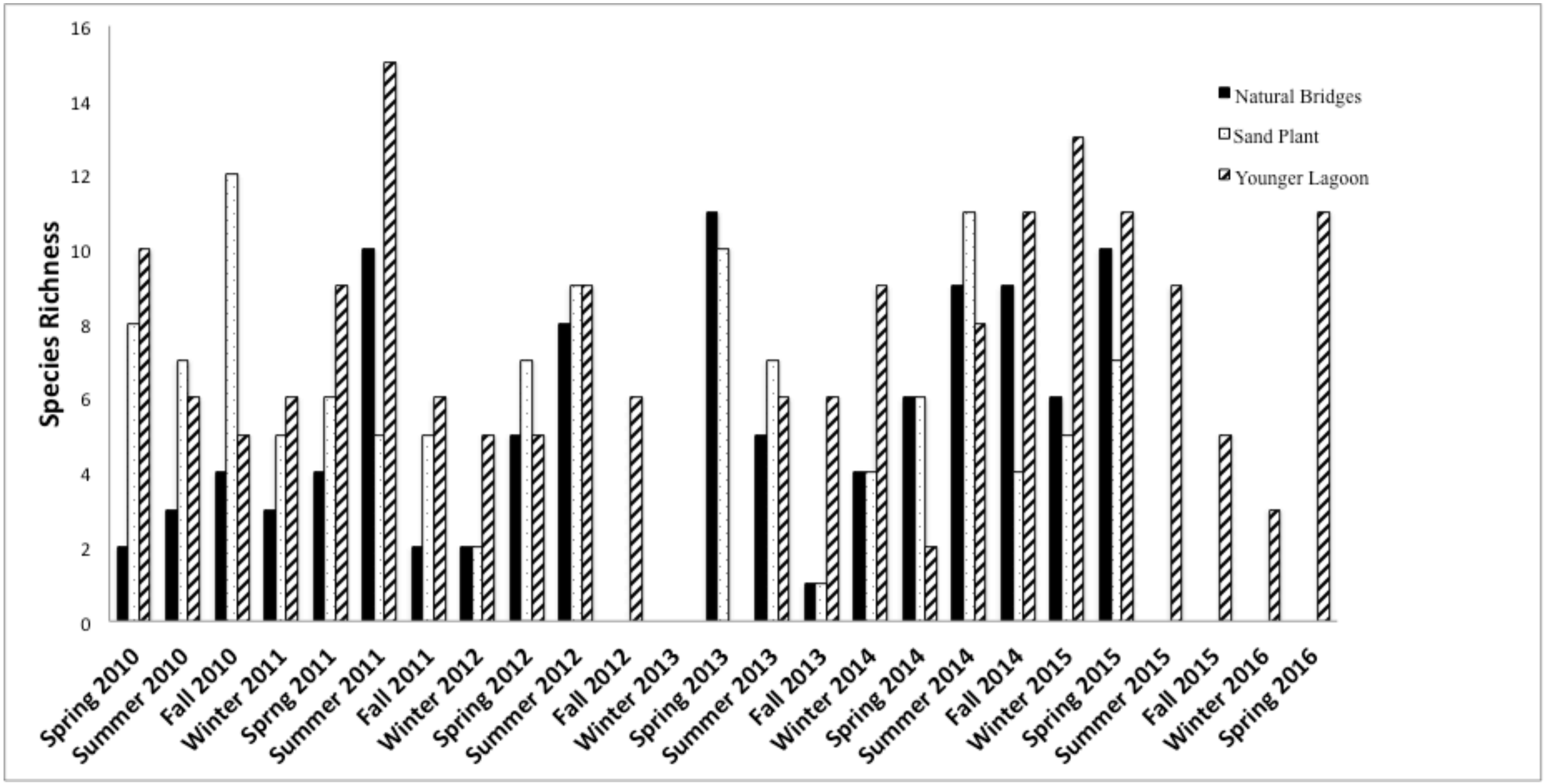

Figure 7. Species richness of invertebrates across all beaches

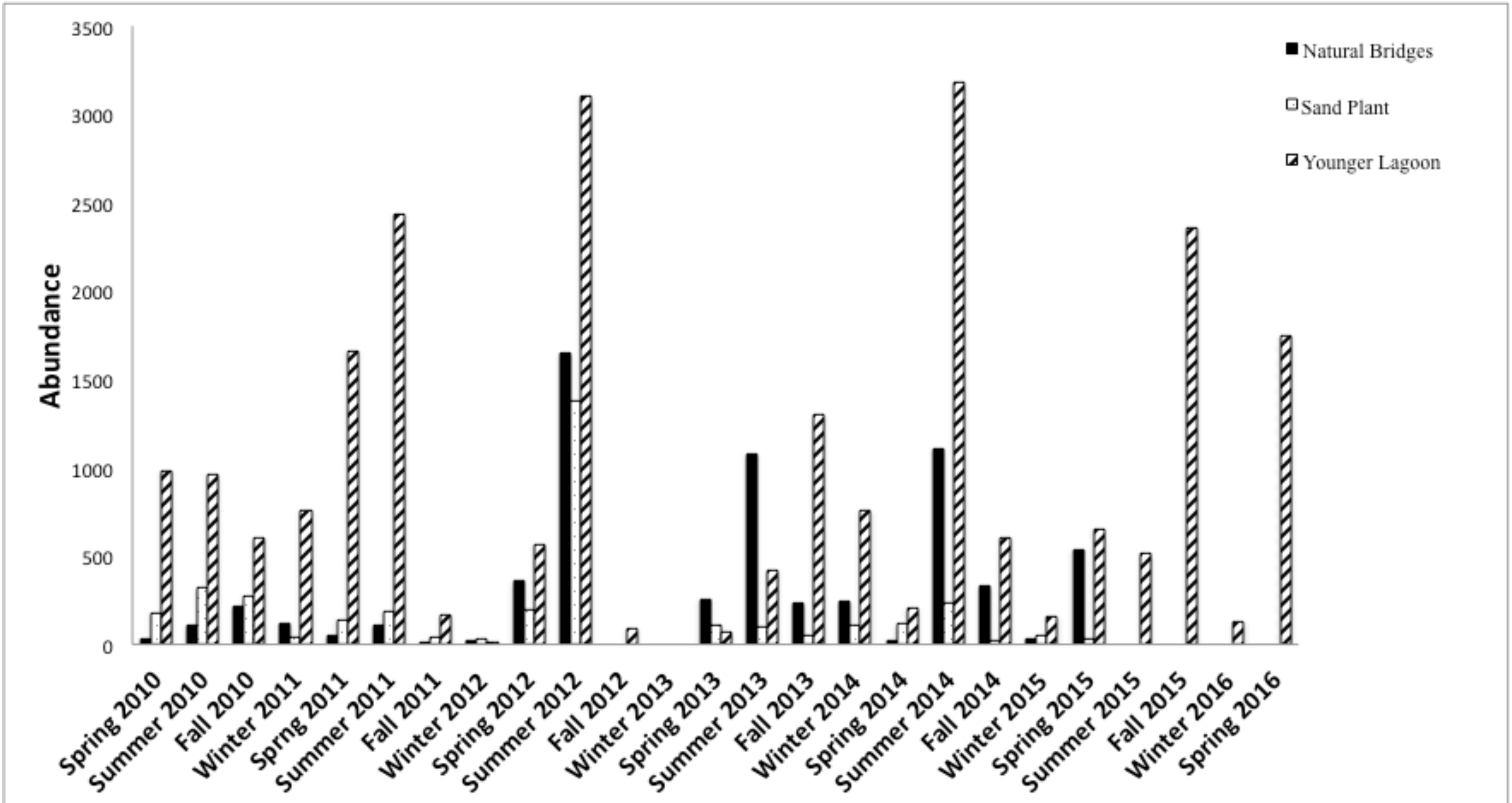

Figure 8. Total abundance of invertebrates at Natural Bridges, Sand Plant Beach, and Younger Lagoon beaches.

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

Site	AMCR	AMPE	BBPL	BCNH	BASW	BLOY	BLPH	BLTU	BRBL	BRPE	BUHE	CAGO	CAGU	CLSW	CORA	COOT	DOC
August 25 & 26, 2012																	
Little Wilder													2		2		
Younger Lagoon		1				1	1						4				
Natural Bridges													1				
November 5& 6, 2012																	
Little Wilder																5	
Younger Lagoon									4							8	
Natural Bridges	2																
January 13&14, 2013																	
Little Wilder																	
Younger Lagoon						1					1					5	
Natural Bridges															1		
May 1 & 2, 2013																	
Little Wilder																	
Younger Lagoon									1			2					
Natural Bridges	2																
July 16-17, 2013																	
Little Wilder				1									1		1		
Younger Lagoon				1			2		7				2				
Natural Bridges							2		1				1				
October 22-23, 2013																	
Little Wilder													1		2		
Younger Lagoon			3				3						2				1
Natural Bridges	2		1							1			3				
February 13-14, 2014																	
Little Wilder												6					
Younger Lagoon																	
Natural Bridges	1																
April 27-28, 2014																	
Little Wilder	3									20							
Younger Lagoon						8				13		2					

July 30-31, 2014																	
Little Wilder												10					
Younger Lagoon									18								
Natural Bridges									18								
November 4-5, 2014																	
Little Wilder															2		
Younger Lagoon						2			5						6		
Natural Bridges	11							2							10		
January 26-27, 2015																	
Little Wilder						2					2						
Younger Lagoon									6						9		
Natural Bridges	12					1			27					3			
April 14-15, 2015																	
Little Wilder						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											
May 3-4, 2016																	
Younger Lagoon					4		2				2						

Site	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG	SPSA	SURF	WEG
April 24 & 26, 2010																
Little Wilder																2
Younger Lagoon													2			2
Natural Bridges								2					2			
August 11-12, 2010																
Little Wilder																
Younger Lagoon													4			32
Natural Bridges																3
November 15 & 16, 2010																
Little Wilder																1
Younger Lagoon				15							11			1		4
Natural Bridges	2										140		1	1		17
February 15 & 16, 2011																
Little Wilder																6
Younger Lagoon												1				
Natural Bridges				47									18			6
May 3 & 4, 2011																
Little Wilder			2			35										5
Younger Lagoon																
Natural Bridges										1						16
July 22 & 23, 2011																
Little Wilder						17							1			1
Younger Lagoon																
Natural Bridges						3				2			2			81
March 29 & 30, 2012																
Little Wilder																
Younger Lagoon				13									2			16
Natural Bridges						2					65		2			10
May 15 & 16, 2012																
Little Wilder																4
Younger Lagoon				25		5				1			2			15
Natural Bridges													2			

August 25 & 26, 2012																
Little Wilder																
Younger Lagoon				35				8		1			1			7
Natural Bridges														1		5
November 5& 6, 2012																
Little Wilder																1
Younger Lagoon				14			1			4			2			3
Natural Bridges													2	1	2	
January 13&14, 2013																
Little Wilder																
Younger Lagoon				3	1						38	1	1			
Natural Bridges													1			11
May 1 & 2, 2013																
Little Wilder						8										2
Younger Lagoon		2		9												11
Natural Bridges																23
July 16-17, 2013																
Little Wilder						7										
Younger Lagoon				8		1							4			
Natural Bridges																10
October 22-23, 2013																
Little Wilder																
Younger Lagoon				33									3			150
Natural Bridges													4			110
February 13-14, 2014																
Little Wilder										1						103
Younger Lagoon				8									4			7
Natural Bridges													1			19
April 27-28, 2014																
Little Wilder						4										24
Younger Lagoon						8			1							2
Natural Bridges																18

Site	MEGU	MODO	NOHA	PECO	PIGR	PIGU	REHA	REPH	RWBB	RODO	SAND	SAPH	SNEG	SPSA	SURF	WE
July 30-31, 2014																
Little Wilder						3										25
Younger Lagoon						3							3			28
Natural Bridges											7					80
November 4-5, 2014																
Little Wilder									2							3
Younger Lagoon											11		1			10
Natural Bridges											20		4	1		18
January 26-27, 2015																
Little Wilder																25
Younger Lagoon									10							27
Natural Bridges									9				2			175
April 14-15, 2015																
Little Wilder						3										5
Younger Lagoon									5				2			5
Natural Bridges									4				3			21
July 8-9, 2015																
Younger Lagoon						4							2			31
October 29-30, 2015																
Younger Lagoon																6
February 2-3, 2016																
Younger Lagoon						2							3			9
May 3-4, 2016																
Younger Lagoon									1					1		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.

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Appendix 1. Younger Lagoon Photos.


YLR Beach Photopoint #1. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide


YLR Beach Photopoint #1. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide


YLR Beach Photopoint #1. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide


YLR Beach Photopoint #2. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

YLR Beach Photopoint #2. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

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YLR Beach Photopoint #3. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

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YLR Beach Photopoint #3. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide


YLR Beach Photopoint #4. April 20, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

Compliance Monitoring Report for Coastal Prairie, Coastal Bluffs, and Coastal Scrub Restoration Sites at Younger Lagoon Reserve
Spring 2016
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), reserve employees, interns, and volunteers have continued to perform native plant community restoration activities. This report presents the results of the 2016 monitoring of the 2010 coastal prairie/grassland habitat plantings and coastal bluff plantings, and the 2014 coastal prairie/grassland and coastal scrub plantings. Restoration efforts are within target richness and native cover goals for all of the restored habitat areas described above.

Methods

Planting

Seeds for the coastal prairie planting projects were primarily collected from local reference sites along coastal Santa Cruz and San Mateo Counties. The seeds were typically grown in Ray Leach stubby (SC7) conetainers™ for several weeks in the UCSC greenhouses before being introduced to the site. Site preparation prior to planting typically involved 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 applied to all restoration 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. Sites received supplemental irrigation during the first year following planting to help ensure establishment of the new plants. After the first year, no supplemental irrigation was done, and plantings received only natural rainfall.

Follow up management included hand-pulling and spot spraying of herbicide for emerging weeds during the first 18-24 months following planting. All sites were mowed twice annually. Fall mowing was intended to reduce thatch, and spring mowing was intended to reduce weed seed set while allowing native perennial species to drop seed.

Sampling

Vegetation sampling of the 2010 coastal prairie/grassland, 2010 coastal bluff, 2014 coastal prairie/grassland, and 2014 coastal scrub habitats follow the protocols described in Holl and Reed (2010). To measure cover, a 0.25 × 1-m quadrat was placed on alternating sides of a 50 m transect tape every 5 m, for a total of ten quadrats per 50-m transect. In some areas, restoration took place over a smaller distance than 50 m, so transects were split and divided into sections to better fit the site. Cover was measured using a modified Braun-Blanquet class system within each quadrat, with increases in 5% intervals, starting with 0-5%. The midpoint each cover class was used for data analysis (e.g. 2.5%, 7.5%, etc.). Richness was measured using a 2-m belt transect on either side of the 50-m transect tape to visually detect any species not measured in the cover quadrat sampling.

Of the two areas planted in the 2010 coastal prairie/grassland plantings, the southern site was damaged by construction crews this year, and therefore not sampled (Figure 1). The northern area of the 2010 coastal prairie/grassland habitat was monitored using one 35-m transect that was broken into three segments, yielding a total of 7 cover quadrats. The 2010 coastal bluff planting were measured using two 50-m transects and one 45-m transect, for a total of 29 cover measurements. All three transects were divided and/or angled to best follow the bluff coastline (Figure 1). The 2014 coastal prairie/grassland was measured using three transects of 45, 30, and

25 m, for a total of 20 quadrats (Figure 2). The 2014 coastal scrub area was measured using two transects of 30 m and one of 25 m, for a total of 17 quadrats (Figure 2). One transect in the coastal scrub habitat was split to better fit the site. For each planted area, cover and richness were averaged across transects/quadrats.

All sites are expected to meet the targets laid out for the California Coastal Commission (UCNRS 2010), with the 2010 coastal prairie/grassland and coastal bluff sites expected to meet six-year post-planting targets. and the 2014 coastal prairie/grassland and coastal scrub sites expected to meet two-year post-planting targets. Goals for all habitat types are available in Appendix 1.

Results

Observed native cover surpassed target requirements in all habitats (Table 1). The 2010 coastal prairie/grassland had a native cover of 25.7 ± 6.6%, which is exceeds the goal of ≥ 25% native cover. In the 2010 coastal bluff habitat, native cover was 68.8 ± 5.2%, exceeding the goal of ≥ 40% native cover. In the 2014 coastal prairie/grassland, native cover was 42.3 ± 5.9%, exceeding the goal of ≥ 5% native cover. In the 2014 coastal scrub habitat, native cover was 59.4 ± 7.2%, exceeding the goal of ≥ 10% native cover.

Native species richness was also at or above target levels in all three planted sites (Table 1, Table 2). The 2010 coastal prairie/grassland had a richness of 10 species, exceeding the goal of ≥ 6 native species. The 2010 coastal bluffs habitat transects had an average of 8.0 ± 0.0 species per transect and an overall richness of 11 species, surpassing the ≥ 8 native species goal. The 2014 coastal prairie/grassland site had a native richness of 9.3 ± 0.8 per transect and an overall richness of 15 species. The 2014 coastal scrub site had a native richness of 7.0 ± 0.58

species and an overall richness of 10 species. Both 2014 sites surpassed the two-year target of ≥ 6 native species.

All planted areas showed evidence of recruitment for multiple species.

Discussion

The restoration of the 2010 coastal prairie/grassland, 2010 coastal bluffs, 2014 coastal prairie/grassland, and 2014 coastal scrub have been successful to date. All sites have achieved the native species cover and native species richness targets laid out for the California Coastal Commission (UCNRS 2010) for their respective habitats. Construction related the Marine Science Campus Coastal Biology Building Infrastructure Project destroyed the southernmost portion of the 2010 coastal prairie/grassland plantings (Figure 1), and as a result, this portion of the site was not monitored. Construction crews will be required to replant the site with appropriate native species in the future.

The northern portion of the 2010 coastal prairie/grassland planting met the 25% native cover goal, but native cover in this location has declined steadily since the first monitoring period. Native cover was 57.6 ± 33.5% in 2012, which dropped to 39.0 ± 5.2% in 2014, and is now 25.7 ± 6.6% (Reed 2012, Hammond 2014). Drought conditions, which persisted from 2011 to 2015, may have contributed to the declining cover of native species over the last six years. Average annual rainfall in Santa Cruz is 75.8 cm per water year (California Department of Water Resources 2016). A water year is the period from October to the following September. Water years since 2011 have been lower than average (Table 1), and these drought conditions during the early years of habitat establishment likely reduced the growth, reproductive output, and overall success of native species planted at the site, resulting in the consistently declining cover that was measured. Decreased precipitation did not appear to have affected native species richness, which remained relatively constant through time: 12 native species were recorded in 2012, 8 native species were recorded in 2014, and 10 native species were recorded in 2016 (Reed 2012, Hammond 2014). The drought appears to have diminished as of the 2015-2016 rain year, but the trend of declining cover is concerning if the site is to maintain long-term restoration success. Additional monitoring in 2018 may elucidate whether the low precipitation hypothesis is correct, or may indicate that additional actions (such as supplemental planting or weed management) are necessary to reach long-term native restoration goals at this site. Nonetheless it is recommended that this area be watched closely over the next couple of years with possibly additional weeding or planting efforts undertaken if needed.

The 2010 coastal bluff restoration has been successful in meeting both native cover and native species richness goals despite low precipitation in the last five years. The native cover in this habitat has remained high, with an average native cover of 68.8% ± 5.2 in 2016 (Table 2; Reed 2012, Hammond 2014). Native cover in this habitat has likely remained high due to the competitive ability of native woody shrubs to access water and light as compared with herbaceous species. This is reflected in the native richness at the site over the last six years. While the richness of native species in the bluffs habitat dropped between 2012 and 2014 from 22 total species to 10, it has remained constant since 2014, with a total richness of 11 native species recorded this year (Reed 2012, Hammond 2014). The decrease in species richness from 2012 to 2014 was primarily attributable to the loss of native herbaceous species, which have not reappeared at the site following this year's greater precipitation. Despite the reduction in native species richness, the restoration of the coastal bluffs continues to be a success.

This was the first year of monitoring for both the 2014 coastal prairie/grassland and 2014 coastal scrub restoration plantings and both sites exceeded their two-year post-planting native cover and native richness goals (Figure 1). Furthermore, because these sites will likely experience greater precipitation in their establishment years than the 2010 plantings did, they may maintain higher cover and native richness over their first six years of monitoring.

Overall, the restoration efforts at Younger Lagoon Reserve are meeting their target goals. Management strategies, such as irrigation during the first year, hand-weeding of sites, and seasonal mowing, are maintaining native cover and richness in restored coastal prairie/grassland, coastal bluff, and coastal scrub habitats. The 2010 coastal prairie/grassland restoration has been successful, but the trend of declining native cover suggests that one additional monitoring period in 2018 may be necessary to ensure that cover does not drop below the ≥ 25% goal. Long-term habitat restoration has been successful for the 2010 coastal bluffs site, despite historic drought.

Tables and Figures

Figure 1. Map of transect locations for the 2010 coastal prairie/grassland (in red) and 2010 coastal bluff planting sites (in blue). The location of the 2010 coastal prairie/grassland planting that was disturbed by construction is shown in purple. Note that some transects are split to fit the sites.

Figure 2. Map of transect locations for the 2014 coastal prairie/grassland (in red) and 2014 coastal scrub (in blue) planting sites. Note that some transects are split to fit the sites.

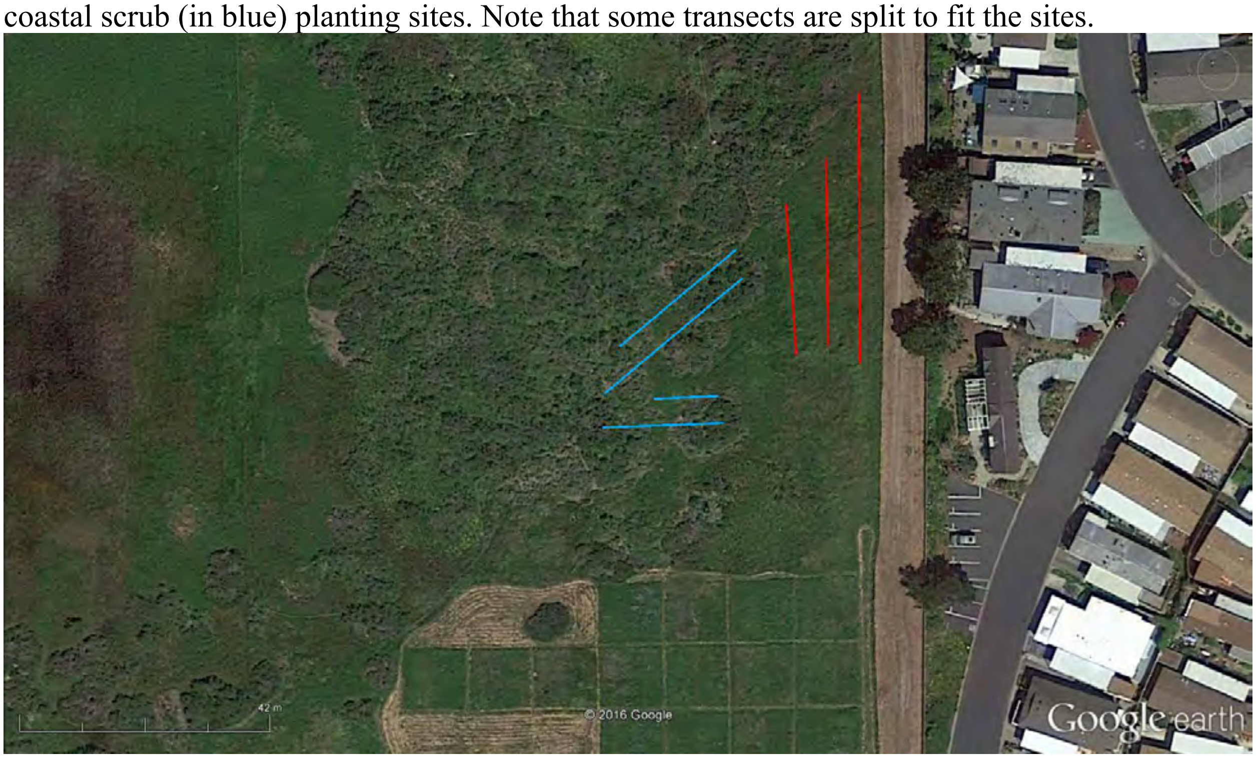

Table 1. Table of native species cover and richness targets and observed values (± SE) in the 2010 Coastal prairie/grassland, 2010 Coastal Bluffs, 2014 Coastal prairie/grassland, and 2014 Coastal Scrub restoration sites at Younger Lagoon Reserve.

	Restoration Site			
	2010 Grassland	**2010 Coastal Bluff**	**2014 Grassland**	**2014 Coastal Scrub**
Observed Native Cover (%)	25.7 ± 6.6	68.8 ± 5.2	42.3 ± 5.9	59.4 ± 7.2
Target Native Cover (%)	≥ 25	≥ 40	≥ 5	≥ 10
Observed Native Richness (# species per transect)	10	8	9.3 ± 0.9	7.0 ± 0.6
Target Native Richness (# species)	≥ 6	≥ 8	≥ 6	≥ 6

Table 2. Table of the native species observed in the 2010 Coastal Grassland/Prairie, 2010 Coastal Bluffs, 2014 Coastal prairie/grassland, and 2014 Coastal Scrub restoration sites at Younger Lagoon Reserve. 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**	**2010 Grassland**	**2010 Coastal Bluffs**	**2014 Grassland**	**2014 Scrub**
Lupinus nanus	sky lupine	AF			x	
Achillea millefolium	yarrow	PF	x	x	x	x
Artemisia pyncnocephala	beach sagewort	PF		x		
Baccharis glutinosa	marsh baccharis	PF	x			
Chlorogalum pomeridianum	soaproot	PF				x
Erigeron glaucus	seaside daisy	PF		x		
Eriogonum latifolium	coast buckwheat	PF		x	x	
Eriophyllum staechadifolium	lizard tail	PF	x	x		x
Eschscholzia californica	California poppy	PF			x	
Grindelia stricta	gumweed	PF	x			
Prunella vulgaris	selfheal	PF			x	
Pseudognaphalium sp.		PF				x
Ranunculus californica	California buttercup	PF			x	

Scrophularia californica	California bee plant	PF		x	x	x

Table 2, continued.

Scientific Name	Common name	Growth Form	2010 Grassland	2010 Coastal Bluffs	2014 Grassland	2014 Scrub
Sisyrinchium bellum	western blue eyed grass	PF			x	
Symphyotrichum chilense	Pacific aster	PF			x	x
Bromus carinatus	California brome	PG	x	x	x	
Danthonia californica	California oatgrass	PG				
Elymus glaucus	blue wild rye	PG	x		x	
Elymus triticoides	creeping wild rye	PG			x	
Hordeum brachyantherum	meadow barley	PG	x		x	
Stipa pulchra	purple needle grass	PG	x		x	
Carex spp.		PGRM	x			
Juncus patens	spreading rush	PGRM	x		x	
Artemisia californica	California sagebrush	S		x		x
Baccharis pilularis	coyote brush	S		x		x
Lupinus arboreus	yellow bush lupine	S		x		
Mimulus aurantiacus	sticky monkey flower	S		x		x
Rubus ursinus	pacific blackberry	S				x
		Observed Native Richness:	10 species	11 species	15 species	10 species
		Target Native Richness:	≥ 6 species	≥ 8 species	≥ 6 species	≥ 6 species

Table 3. Rainfall for Santa Cruz for rainfall years starting with plantings in 2010. Rainfall years are measured from October to September of the following year. Data from the California Department of Water Resources.

Rainfall Year	Total Precipitation
100 Year Average	75.8 cm
2010-2011	101.6 cm
2011-2012	52.6 cm
2012-2013	45.8 cm

2013-2014	36.6 cm
2014-2015	55.1 cm
2015-2016	82.7 cm

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Hammond, Jessi. 2014. Compliance Monitoring Report for Five Restored Habitat Patches at Younger Lagoon Reserve, Spring 2014. Monitoring Report 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

June 2016

International drought experiment: The effect of drought on plant photosynthesis and water relations in grassland ecosystems

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Abstract

An experiment is being conducted at the Younger Lagoon Natural Reserve in Santa Cruz, California, as well as 88 other sites around the world. The overall goal of this study is to assess the drought sensitivity and responses of a wide range of ecosystems. The focus of this paper is on the preliminary data collected at the Younger Lagoon site. Treatment plots were constructed to reduce rainfall infiltration by 60% in order to simulate drought conditions. Surface soil moisture, photosynthesis, water potential, Net Primary Productivity (NPP), and Photosynthetically Active Radiation (PAR) were measured as proxies for drought sensitivity. No statistically significant correlation was observed between the shelter plots and reduced soil surface moisture. *Avena barabta* (a C3 monocot) demonstrated reduced stomatal conductance in the shelter plots compared to the control plots. *Raphanus sativus* (a C3 dicot) demonstrated reduced stomatal conductance and carbon dioxide assimilation in the shelter plots compared to the control plots. No statistically significant difference in water potential was observed between the control and shelter plots for either *Avena barbata* or *Raphanus sativus*. No statistically significant correlation was observed between the shelter plots and reduced NPP. PAR above the canopy (60cm) was 19.4% lower in the shelter plots compared to the control plots, 20.0 % lower in the control plots compared to the shelter plots at the mid canopy level (30 cm), and 56.3% lower in the control plots compared to the shelter plots at ground level (0 cm).

Introduction

Over the course of recent years (2012-2015), California has been in the midst of an extraordinary drought. Average rainfall in the state fell to its lowest levels in the last century according to modern instrumental observations (Griffin and Anchukaitis, 2014). Furthermore, National Oceanic and Atmospheric Administration (NOAA) climate data and North American Drought Atlas (NADA) tree ring chronologies, indicate that these drought conditions have been the most severe to occur in the previous 1,200 years (Griffin and Anchukaitis, 2014). The Intergovernmental Panel on Climate Change (IPPC) has predicted that drought conditions will become more frequent and intense in the future due to anthropogenically influenced climate change (IPCC 2012).

Extreme dry years are predicted to be increasingly defined by an absence of large precipitation events and an increase in the average time between large precipitation events (Knapp et al., 2015). Prolonged drought may affect species composition and ecosystem dynamics, and may reduce the resistance and resiliency of ecosystems to future perturbations caused by more frequent episodes of drought (McNaughton & Frank 1991; Tilman & Downing, 1996). Ecosystems have varying degrees of sensitivity to drought conditions, leaving some systems more vulnerable (for example to incursion by invasive species) and others capable of persisting (Stampfli & Zeiter, 2004). Continuous drought conditions can have severe effects on natural ecosystems, not to mention wide-scale economic, societal, and even political impacts.

The goal of this study, the International Drought Experiment (IDE), is to assess the drought sensitivity of a wide range of ecosystems and identify the biotic and abiotic factors affecting this sensitivity. We tested hypotheses to better understand ecosystem sensitivity to drought in central coastal California, a hotspot of biodiversity, which can be compared to similar results found in other parts of California and internationally. Specifically, we hypothesized that

1). Surface soil moisture will be higher in the control plots than in the sheltered plots because the shelters in the shelter plots will reduce the amount of water infiltrating the soil (simulating drought conditions).

2). Less moisture under the drought shelters will affect the Net Primary Productivity, plant water relations, leaf-level photosynthesis, and canopy gas exchange of the treatment plants.

3). Certain native plant species may be better adapted to drought conditions

4). Photosynthetically Active Radiation (PAR) measurements will be lower above the canopy in the drought shelter plots due to shading from the troughs, however within the canopy there should be an increase in the amount of PAR due to a decrease in overall plant biomass.

Methods

Experiments were conducted in highly-invaded coastal prairie grassland at Younger Lagoon Natural Reserve in Santa Cruz, California (36.952904, -122.066581). The site is managed for biodiversity and ecosystem functions, and composed of a mix of native and non-native vegetation. Treatment plots contain shelters comprised of angled transparent troughs that remove a portion of rainfall away from the plots in order to simulate drought conditions. Control plots do not contain these shelters and are completely open to the elements. There are five treatment plots and five control plots for a total of ten plots. Plot size is 2m × 2m with a 1 m buffer surrounding the plot. The plots were trenched to a depth of 0.5 meters around their border and filled with an impermeable layer (0.6-mil plastic) to prevent the lateral flow of subsurface water into the plots. The drought treatments exist year-round and will proceed for a total of four years. Various data were collected and used as proxies for ecosystem drought sensitivity. These data include, but are not limited to: photosynthetic gas exchange, surface soil moisture, gravimetric water content, Photosynthetically Active Radiation, water potential, species composition, photosynthesis (which includes, stomatal conductance, internal leaf carbon dioxide concentration, transpiration, and vapor pressure deficit). Statistical analysis was done through an analysis of variance (ANOVA) calculation for some of these data.

Photosynthetic Gas Exchange

Photosynthetic gas exchange was compared for distal leaves (representing 2 × 3 cm of leaf area) of *Avena barbata* and *Raphanus sativus*. Leaves were spread out to minimize overlap, but measurements represent projected area. When *Avena* leaves did not fill the chamber, leaf area was computed based on the width and length of the leaf section in the chamber. Measurements occurred at the same time of day, as for water potential measurements (ca. 09:00 – 11:30 h), but on different leaves to minimize potential effects of stem removal on stomatal conductance and photosynthesis.

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Carbon dioxide assimilation, and stomatal conductance to water vapor were measured using a LI-6400 open-mode portable photosynthesis system (Li-Cor, Inc., Lincoln, NE, USA). Vapor pressure deficit within the chamber was maintained at pre-measurement ambient levels. The CO_2 concentration within the leaf measurement chamber was maintained at a constant level (380 µmol mol^{-1}) by scrubbing the incoming airstream with soda lime, and the subsequent addition of a precise amount of CO_2 via injection from an external cartridge. Photosynthetically Active Radiation (PAR; 400-700 nm) within the chamber was maintained at 1500 µmol m^{-2} s^{-1} using Li-Cor red-blue LEDs in the 2 × 3 cm rectangular chamber. Leaf temperatures were recorded with a copper-constantan thermocouple pressed to the abaxial (bottom) surface of the leaf within the cuvette. Distal, fully mature leaves were inserted into the cuvette at their natural branch orientation, and photosynthetic measurements were recorded when all stability criteria were met and the coefficient of variation for A and g_s combined was below 0.5%.

Surface Soil Moisture

Soil moisture was measured using a TDR soil moisture meter. Four measurements were recorded in each plot; one on each side corresponding to the cardinal direction. The metal probes of the TDR meter were pushed into the soil until completely submerged and the plastic meter was level with the soil surface. The soil moisture measurement was then determined from the reading displayed on the TDR meter's screen after pressing the "Read" button. These measurements were recorded for every plot.

Gravimetric Water Content

Soil moisture was quantified as gravimetric water content (%soil moisture = 100 * [(Fresh weight – dry weight)/dry weight]). After collecting soil samples from all ten plots, the sample's wet weight were measured and then re-weighed after spending on average 5 days in a drying oven at 40°C until fully dry. Soil moisture was monitored with Decagon Devices (Pullman, WA) soil aquameters (Model EC5) and an EM50 data logger. The Decagon soil moisture sensors are connected to the logger with one in an IDE control plot and the other in an IDE sheltered plot. The Decagon EM50 logger records the soil moisture in the control plot while recording the soil moisture and temperature in the sheltered plot every 30 minutes.

Photosynthetically Active Radiation

Photosynthetically Active Radiation (PAR; 400 – 700 nm) was measured at heights of 60 cm, 30 cm, and 0 cm above the soil surface of each plot using a light meter (Model Li-1400, LICOR, Lincoln, NE, USA) and quantum sensor (Model Li-190R, LICOR). Samples were collected Thursdays 09:00 – 12:00 h local time between March and April, 2016. PAR was recorded once at each height for each plot. Specific heights off the ground were kept consistent by using 2 pieces of PVC tubing of lengths 60 cm and 30 cm. The light sensor was placed on top of the tubing so as to not reflect sunlight from the tubing on to the sensor. The measurements were all taken on the northwest corner of each plot.

Water Potential

Among all plots, two species were chosen to measure stem water potential, *Avena barbata* and *Raphanus sativus.* These were gathered from both the control and shelter plots. Leaves from *Raphanus* were cut with approximately 4 cm of stem remaining. *Avena* blades were cut about 10 cm in length. The stem or blade was placed into the center hole of a rubber stopper in the direction that would place the stem upwards to be viewed through the chamber cap. Nitrogen gas was applied until water exuded from the cut petiole or blade surface; at this moment, stem water potential was recorded in MegaPascals. Leaves and stems were cut as straight and flush as possible in order to avoid uneven liquid discharge.

Net Primary Productivity (NPP)

Vegetation from both the treatment and control plots was cut and collected within a 20 x 100 cm PVC quadrat, sorted (grass, forb, thatch, etc.), and placed into labelled paper bags. The vegetation was dried in drying ovens. After desiccation, the biomass was weighed in order to determine the NPP of each plot. To correct for area, we multiplied all samples by five to scale to g/m2.

Results

Surface Soil Moisture

The observed surface soil moisture readings were slightly lower in the treatment (sheltered) plots than in the control plots. Four measurements were recorded from each control plot and each treatment plot. There are five control plots and five treatment plots combining for a total of twenty surface soil measurements.

<u>Table 1:</u> Contains the average surface soil measurements from five control plots and five shelter plots. Four samples were taken in each plot and then were averaged to obtain the computed values in the table below. The overall average for all twenty measurements can also be viewed below in green.

Plot (Control)	Soil Moist.	Plot (Shelter)	Soil Moist.
IC1	16.675	IS1	19.025
IC2	13.875	IS2	19.325
IC3	19.575	IS3	10.175
IC4	17.05	IS4	11.625
IC5	10.9	IS5	16.35
Mean	**15.615**	**Mean**	**15.3**

A single factor ANOVA was calculated and the computed P-value was 0.90. Because the P-value was greater than the critical value of 0.05, the data cannot be considered statistically significant. We fail to reject the null hypothesis in this case. The statistical outcome from this data can be expected about 90% of the time if the null hypothesis is true.

Photosynthesis

Photosynthesis measurements were, on average, slightly higher for *Avena barbata* in the shelter plots compared to the control plots (Table 2). However, these data were not significant (p-value = 0.270). The stomatal conductance for *Avena* was on average higher in the control plots compared to the shelter plots, with these data demonstrating a significant trend (p-value = 0.005). Finally, the carbon dioxide within leaves was also on average higher in the control plots compared to the shelter plots; however these data were not significant (p-value = 0.131).

For *Raphanus sativus*, photosynthesis, stomatal conductance, and carbon dioxide concentration within leaves were all higher in the control plots compared to the shelter plots. However, only the stomatal conductance and carbon dioxide concentration within leaves trends were significant with p-values of 0.000005 and 0.006, respectively.

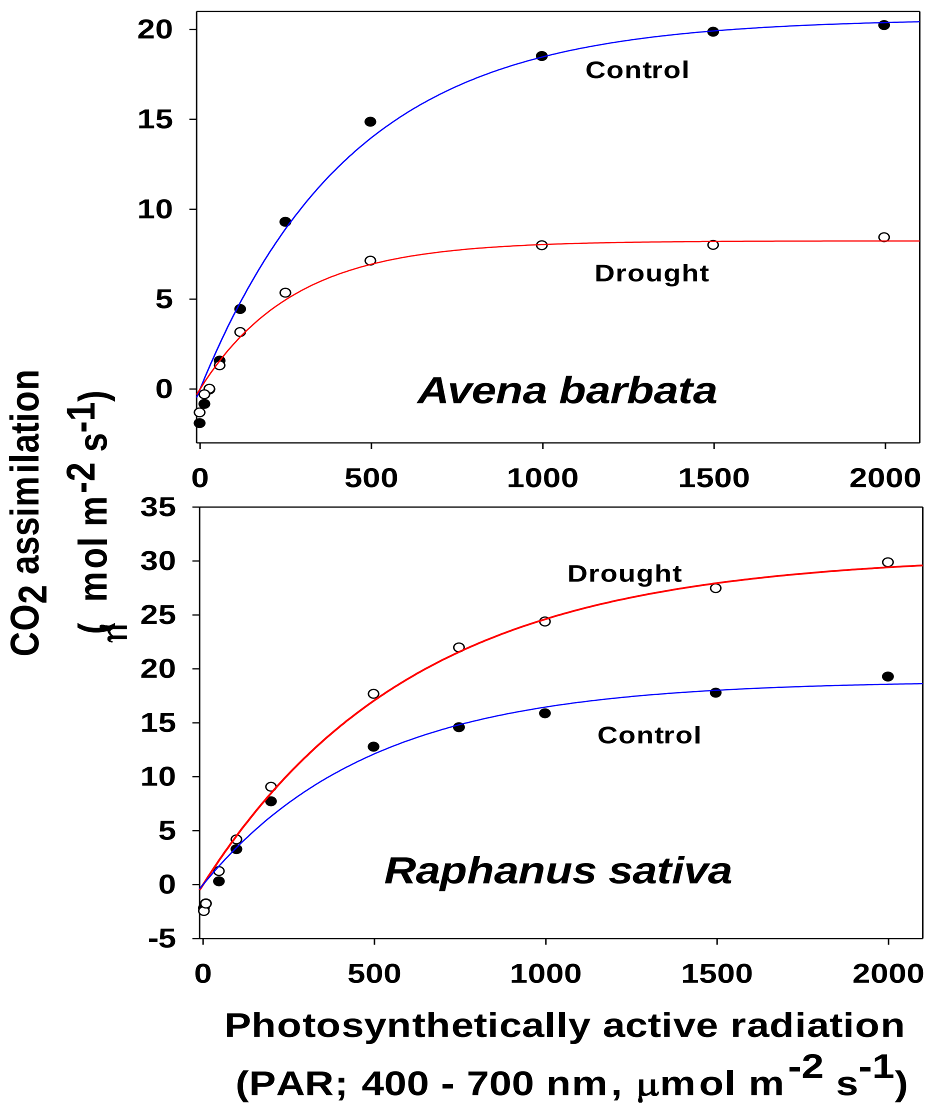
<u>Table 2:</u> Photosynthesis, stomatal conductance, and carbon dioxide assimilation averages for *Avena barbata* and *Raphanus sativus* in both control and shelter plots. *Denotes separate column.

*Avena** (Control)	**Photo**	**Cond**	**Ci**		*Raphanus** *(Control)*	**Photo**	**Cond**	**Ci**
Mean	20.35	0.586	295		**Mean**	23.94	0.912	311
SD	5.788	0.157	17.539		**SD**	3.713	0.130	15.288
se	1.745	0.047	5.288		**se**	1.120	0.039	4.609
*Avena** (Shelter)	**Photo**	**Cond**	**Ci**		*Raphanus** *(Shelter)*	**Photo**	**Cond**	**Ci**
Mean	22.45	0.413	277		**Mean**	23.61	0.643	250
SD	3.873	0.138	35.476		**SD**	7.352	0.112	68.257
se	1.035	0.037	9.481		**se**	1.965	0.030	18.243

When compared across a range of light levels, *Avena* plants on the control plots exhibited higher photosynthesis measurements compared to those on the shelter plots (Figure 1). For

Raphanus, photosynthesis was lower on the control plots versus the shelter plots. However, these results are in contrast to the trends seen in the overall averages in Table 2.

<u>Figure 1:</u> Light response curves for *Avena barbata* and *Raphanus sativus.*



Water Potential

Water potentials for *Raphanus* were not affected by the shelter drought effects, as the average water potentials for *Raphanus* were the same in the shelter plots and the control plots at -1.28 MPa (Table 3) and the data were not significant (p-value = 1). *Avena* exhibited a lower average water potential (-2.84 MPa) in the shelter plots compared to the control plots (-2.02 MPa). However, these are not significantly different (p-value=0.142).

Table 3: Average water potentials for *Avena barbata* and *Raphanus sativus* in the control and shelter plots. *Denotes separated column.

*Avena** (Control)	**Water Pot.***		*Raphanus** *(Control)*	**Water Pot.***
Mean	-2.02		**Mean**	-1.28
SD	0.48		**SD**	0.16
se	0.24		**se**	0.08
*Avena** (Shelter)	**Water Pot.***		*Raphanus** *(Shelter)*	**Water Pot.***
Mean	-2.84		**Mean**	-1.28
SD	1.02		**SD**	0.26
se	0.51		**se**	0.13

Photosynthetically Active Radiation (PAR)

The shelter plots recorded lower average PAR at the 60 cm canopy height compared to the control plots at that same height (Table 4). Interestingly, the control plots recorded lower average PAR readings at the 30 cm and 0 cm heights compared to the shelter plots. The data between the control and shelter plots at each sampling level (60cm, 30cm, 0cm) were statistically significant. Comparing the 60 cm control data to the 60 cm shelter data using an ANOVA calculation, produced a p-value of 0.0073. Doing the same at the 30 cm canopy level and the 0 cm canopy level also produced p-values of 0.0073, respectively. Thus, the shelters had a statistically significant effect on the amount of PAR reaching the canopy overall.

<u>Table 4:</u> Photosynthetically Active Radiation (PAR) at canopy heights 60 cm, 30 cm, and 0 cm. *Denotes separated column.

Shelter*	60 cm	30 cm	0 cm		Control*	60 cm	30 cm	0 cm
IS5	1042	143.4	9.81		IC5	1300	161	10.8
IS4	1019	1239	858.8		IC4	1349	569	17.2
IS3	1191	901	341.9		IC3	1531	541.7	303.7
IS2	1135	1400	200.1		IC2	1520	1344	55.33
IS1	1371	1520	851		IC1	1450	1550	600
Mean	1152	1041	452.3		**Mean**	1430	833.1	197.4
SD	141	552.9	385.9		**SD**	102.67	587.7	255.4
se	70.5	276.5	193		**se**	51.333	293.8	127.7

Net Primary Productivity (NPP)

NPP data from this year (2016) was not statistically significant (p-value of 0.81), with a relatively large standard deviation and standard error (Table 5). There was a high degree of variation within each dataset with NPP numbers ranging from as high as 773.90 g/m2 in the control and 686.25 g/m2 in the shelter to as low as 364.50 g/m2 in the control and 387.40 g/m2 in the shelter. There was no discernable trend between the NPP seen in the shelters and the NPP seen in the control plots.

<u>Table 5:</u> Area corrected NPP in g/m2. *Denotes separated column.

Shelter*	NPP		Control*	NPP
S1	686.25		C1	364.50
S2	387.40		C2	404.25
S3	559.15		C3	421.50
S4	449.10		C4	773.90
S5	494.40		C5	503.50
Mean	515.26		**Mean**	493.53
SD	114.373		**SD**	164.708
se	57.1863		**se**	82.3539

Discussion

Surface Soil Moisture

As surface soil moisture measurements were almost identical between the shelter plots and the control plots, no statistically significant correlation was observed between the shelter plots and reduced soil surface moisture. Decreased soil surface moisture was hypothesized to occur under the shelter plots, and further measurements of soil moisture at different depths throughout the rainfall season at a high time resolution are required to determine the statistical impact of the shelters on soil moisture. Only a small sample of data was included in this report and we expect to detect some observable trend in future soil surface moisture data once the permanent sensors are installed in spring 2016.

As anthropogenically accelerated climate change increases the variability of climatic patterns across the globe, surface soil moisture has been shown to fluctuate regionally depending on whether precipitation amounts increase or decrease (Sheffield and Wood, 2008). Globally, variations in soil moisture have been predominately and historically caused by El Niño Southern Oscillation (ENSO) affecting precipitation patterns, but with increasingly variable precipitation trends and steadily rising global temperatures due to climate change, drought conditions should become more frequent overall regardless of ENSO patterns (Sheffield & Wood, 2008). This should negatively affect surface soil moisture globally, however, with high regional variation, as precipitation is expected to increase in some areas and decrease in others as temperature influenced changes in drought affect precipitation patterns (Sheffield & Wood, 2008). In sum, it is expected that with escalating changes to Earth's climate, precipitation and temperature variations will negatively affect surface soil moisture globally as droughts become more frequent.

At the plant level, surface soil moisture can have an effect on plant response to water stress. Soil drying causes reduced water uptake by plant roots, which leads to water deficits within the plant. This phenomenon signals the plant to upregulate the hormone abscisic acid (ABA), which is then transported throughout the plant via a concentration gradient, reaching leaves and inducing stomatal closure in order to prevent further water loss (Farquhar and Sharkey, 1982; Davies and Zhang, 1991). This response has direct implications for plant productivity, as stomatal closure reduces photosynthetic capacity (Sharkey, 1990).

As this experiment is a subset of a much larger international endeavor, surface soil moisture measurements taken at the various study sites around California will help "connect the dots" of the changing global patterns observed in surface soil moisture when combined with the other results from the study sites around the globe. The soil moisture data collected at this research site is just one puzzle piece to a continually evolving puzzle that spans globally. At a more refined scale, this data can be used to better understand surface soil moisture variations and changes throughout Santa Cruz and California and how it affects plant responses to drought conditions. As drought may become ever more prevalent throughout California, it is important to analyze how soil moisture levels are affected, as moisture can be a key limiting factor to plant growth and ecosystem structure.

Photosynthesis

Avena barabta demonstrated reduced stomatal conductance in the shelter plots compared to the control plots. As the shelter plots are designed to simulate drought, the stress of reduced water may have affected canopy-level gas exchange; the sheltered *Avena* plants may have struggled to remain as turgid as the control plants, thus negatively affecting their stomatal conductance and leading to reduced gas exchange. *Raphanus sativus* demonstrated reduced stomatal conductance and carbon dioxide assimilation in the shelter plots compared to the control plots. Reduced photosynthesis was also observed in these plots; however, the data were not statistically significant. Similar to *Avena*, drought stress may have played a role in reducing the observed stomatal conductance and carbon dioxide concentration within the leaves of *Raphanus*. Plant water deficit induced by drought conditions has been shown to cause a decline in stomatal conductance, carbon dioxide assimilation, electron transport (under more extreme water stress), and net photosynthesis (Boyer, 1976; Cornic, 1994; Flexas et al., 2002). Stomatal closure is the main process leading to the reduction of photosynthesis under mild drought conditions (Sharkey, 1990; Chaves, 1991; Ort et al., 1994). But leaf-level photosynthesis can also be limited by drought impacts on biochemistry (Reed & Loik, 2016). Stomatal closure is induced by the upregulation of ABA in the plant in response to reduced soil moisture in the root zone; the production of ABA is responsible for the quick response of stomatal closure to plant water deficit/stress, which ultimately causes a decline in conductance and carbon dioxide assimilation (Farquhar and Sharkey, 1982; Davies and Zhang, 1991).

Additionally, it is a possibility that the drought shelters caused shading of the *Raphanus* plants and reduced the amount of PAR reaching the canopy, thus negatively affecting and reducing the photosynthetic capacity and efficiency of these plants. In our preliminary PAR data collection, we found that the drought shelters were responsible for shading and reducing incoming PAR at the 60 cm canopy level (see subsequent section on PAR). Further data collection is in progress to determine the effect of the drought shelters have on increased shading. When compared over a range of light levels, *Avena* plants displayed higher photosynthesis measurements in the control plots, which could indicate that the stomata on *Avena* are controlling photosynthesis, while photosynthesis measurements for *Raphanus* were lower in the control plots, which could indicate that *Raphanus* has physiologically adjusted to the increased shading caused by the shelters. However, these results are in contrast to the instantaneous photosynthetic rates measured for these species in previous weeks.

Water Potential

No statistically significant difference in water potential was determined between the control and shelter plots for either *Avena* or *Raphanus*. Water potential samples were recorded recently after late spring rain storms and during early morning conditions when condensation was abundant, which may have slightly affected the readings. Additional water potential data collection and analysis is required in order to determine if a trend exists between water potential and the shelter plots. We hypothesized that the shelter plots would produce plants with lower overall mid-morning water potentials compared to the control plants, as less water should be available in these plots, but this was not supported. We now hypothesize that pre-dawn water potential will show significant differences in water potential when plant roots are assumed to be in equilibrium with soil water content in the rooting zone. Additionally, we hypothesized that *Avena* should display lower overall water potentials compared to *Raphanus*, as *Avena* is a grass with a higher water-use efficiency and appears to survive and photosynthesize at lower water potentials.

Photosynthetically Active Radiation (PAR)

As expected, PAR above the canopy (60 cm) was 19.4% lower in the shelter plots compared to the control plots. This was most likely due to shading effect that we predicted would occur due to the troughs intercepting portions of incoming PAR. When focusing on the 30 cm and 0 cm sampling heights, the control plots recorded lower PAR readings compared to the shelter plots. This could be due to greater vegetative biomass production in the control plots at these heights absorbing and shading out PAR, by comparison to lower biomass on shelter plots presumably due to lower soil water content. Drought stress has been shown to decrease biomass production and yield by reducing the canopy absorption of PAR (Earl and Davis, 2003). This could have occurred in the shelter plots, as less biomass may have been produced due to the drought effects of the shelters, increasing PAR measurements at the 30 cm and 0 cm canopy levels. We hypothesized that there would be greater biomass in the control plots due to higher moisture levels, as the control plots lack troughs that simulate drought. The greater moisture levels in the control plots could have led to greater biomass production, which in turn could have increased shading and reduced PAR measurements lower in the canopy, however, this was not supported (see subsequent section).

Net Primary Productivity (NPP)

NPP data was not statistically significant and there was no correlation between a decrease in biomass and the shelter plots. We hypothesized that the shelters would cause a reduction in the biomass produced in the treatment plots. As this experiment is in its early stages, it is possible that there has not been sufficient time for the drought shelters to have caused a discernable effect on the biomass production of the existing plant species. Another possibility is that the existing plant species may have already adapted to drought conditions, as this experiment was constructed after one of the most severe droughts in California history. Further biomass collection and analysis is required as this long-term study moves forward in order to determine if a statistically significant trend exists.

Conclusion

The study sites in Santa Cruz County and California as a whole are part of a much larger international drought experiment that spans 88 sites around the world determined to understand the ecosystem responses to drought conditions at the regional level, and link these responses from an assortment of ecosystem types to those seen globally. Our site and data is just one facet of a multifaceted network of data collection that includes the hard work of countless researchers, students, and volunteers. We showed differences in stomatal conductance to water vapor and internal leaf CO_2 concentrations, and differences in PAR within the plant canopy, that are consistent with lower soil moisture under the shelters. Broad conclusions are premature at this juncture, as data collection and data abundance are in early stages. The full spectrum of data, once collected and analyzed at the end of the five year study, will be used to better understand how ecosystems are affected by and rebound from drought. All ecosystems have different responses and fully understanding the mechanisms behind these responses will help to better project the impacts of drought at a regional and global scale.

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UNIVERSITY OF CALIFORNIA, SANTA CRUZ

COMPARING MULCH, SCRAPING, TARPING, AND HERBICIDES IN COASTAL CALIFORNIA GRASSLAND RESTORATION.

A Senior Thesis submitted in partial satisfaction
of the requirements for the degree of

BACHELOR OF ARTS

in

ENVIRONMENTAL STUDIES

by

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ABSTRACT: Coastal California grasslands have experienced a major reduction due to habitat conversion and introduction of exotic species. An experiment was initiated in 2010-2011 at Younger Lagoon Reserve, located in Santa Cruz, CA to evaluate the effectiveness of herbicide, tarping, scraping, and wood mulch for the purpose of controlling exotic species and restoring native grasses. Over time, the influence of treatments has decreased. As a result, in 2016 only the native grass *Hordeum brachyantherum* and the exotic thistle species *Cirsium vulgare* and *Carduus pycnocephalus* experienced statistically significant treatment effects. *Hordeum brachyantherum* had highest cover in herbicide treatments and lowest in control. In contrast, control and herbicide treatments were the most effective at controlling thistle cover, while tarping twice was the least. Exotic forb cover was much higher in 2016 than previous years, which was likely due to high rainfall this year and the addition of a maintenance mowing in February 2016. This year's data suggest that herbicide has the longest lasting influence on community composition, and that variation in interannual rainfall may have a stronger influence on the plant community than restoration treatments.

KEYWORDS: California grassland, restoration, interannual rain, herbicide, mowing, topsoil removal, tarping

Student Signature   Date

Introduction

Following European colonization in the early 1700s, California's coastal grasslands have experienced major shifts in composition caused by habitat alteration and introductions of exotic species (Evett and Bartolome 2013). A study on phytolith content in California soils showed that the current distribution of exotic grass species mirrors where native grasslands were historically located (Evett and Bartolome 2013). Additionally, exotic and imperiled native populations are predominantly found in low-lying coastal areas, which are often targeted for habitat conversion (Seabloom 2006). These data show the trend that human development opens the doorway for exotic species establishment, which reduces native grass cover.

A transition to agriculture is one of the main causes of grassland alteration. Stromberg et al. (1996) reported a strong correlation between cultivation and decreased native perennial grasses. Even fields that had been abandoned since 1937 had not shifted back to their native perennial composition (Stromberg et al. 1996). In a study focused in a coastal Mediterranean climate, exotic species showed greater success and speed in germination than natives (Wainwright 2013).

Restoring native species to coastal grasslands is important because invasive exotic species create problems both environmentally and economically. In 1994, the United States lost $13 billion because of exotic weeds (Seabloom et al. 2006). Exotic species can reduce biodiversity, cause declines in native populations, homogenize the world's ecosystems, drive rare and endemic species to extinction, change disturbance regimes, and increase native pathogens (Seabloom 2006). Any of these components have the ability to lead to larger effects on the ecosystems involved, as organisms and processes influence and rely on each other. Biodiversity and ecosystem services are thus inhibited by human disturbance and exotic species.

There are many methods used to restore native coastal grasslands. Staff at Younger Lagoon Reserve, a coastal UC reserve, are simultaneously restoring habitats and conducting research experiments to test and improve restoration methodologies. One such study began in 2010 and is being monitored annually to compare the effectiveness of wood mulch, herbicide, tarping, and topsoil removal as methods supporting native establishment.

Herbicide plus wood mulch was one of the most effective treatments in the first four years of study (Angulo 2013, Holl et al. 2014). Wood mulch can provide protection for seeds, lessen temperature extremes, increase the moisture retention of soil, and decrease the abundance of exotic annual grasses, while supporting the establishment of native perennial species (Priscilla 2011, Holl et al. 2014). While mulch reduced competition in the first two years, it shows a diminishing effect over time (Holl et al. 2014), as it decomposes. Upon decomposition, it provides more organic matter for the soil (Holl et al 2014).

Herbicides are commonly used to control exotic plants. Herbicide provides the ability to treat large plots of land, has less monetary and labor requirements than many of the other methods, and is effective (Holl et al. 2014). The herbicide used most commonly for restoration purposes is glyphosate, because it breaks down quickly in the soil and has traditionally been considered to have little risk of toxicity to mammals (Irvine et al. 2013). However, there is recent controversy over the chemical's carcinogenic properties. In 2015, California Environmental Protection Agency's Office of Environmental Health Hazard Assessment submitted intent to add glyphosate to Prob 65, which requires a warning label and stricter regulations on the chemical (Haroff and Cassio 2016). The agency's evaluation of glyphosate states that there is significant evidence for carcinogenicity in experimental animals and probably evidence for carcinogenicity in humans (Haroff and Cassio 2016). This evidence has been legally questioned by Monsanto and as of 2016, final action has not been taken (Haroff and Cassio 2016). There are also concerns over the potential effects on other species, especially microbial communities. Glyphosate has been proven to reduce photosymbiotic pink-pigmented facultative methylotrophic bacteria, which can aid native plant growth (Irvine 2013).

Tarping is utilized to cause plant mortality at young life stages. Clear plastic tarps may be used to induce solar radiation, which raises soil temperatures to levels capable of killing the seed bank (Hutchinson 2011). This is often used in hot, arid climates (Holl et al. 2014). Since this study was conducted in a cooler coastal climate, the method used black plastic tarps to kill recently germinated seedlings by light exclusion (Holl et al. 2014). The first four years of data favored a single session of tarping, in the fall, prior to planting (Angulo 2013, Holl et al. 2014). Although two sessions of tarping were also effective, the differences in percentage of native cover were statistically insignificant, making it an uneconomical choice. The cost of one session of tarping, including labor, is estimated at nine to ten times the cost of two sprayings of herbicide (Holl et al. 2014).

Topsoil removal, also known as scraping, controls exotic populations by reducing their seed banks. Scraping removes the top 5 to 10 cm of the soil, which is the nitrogen rich layer. This process returns the soil conditions to a lower nutrient state that gives slow growing native perennials a competitive edge (Buisson et al. 2006). However, scraping can also reduce the native seed bank and microbial communities, which may have negative effects on plant growth (Holl et al. 2013). Scraping was not very effective for the first four years, but in spring 2015, results suggested that scraping had a favorable influence on canopy composition (Souri 2015). Percent of native cover in scraped plots was similar to the tarping and herbicide plots, and percent of exotic cover was less than that of all the other treatments (Souri 2015). Other studies also suggest that scraping is a useful tool for decreasing exotic annual plants (Niederer et al. 2014).

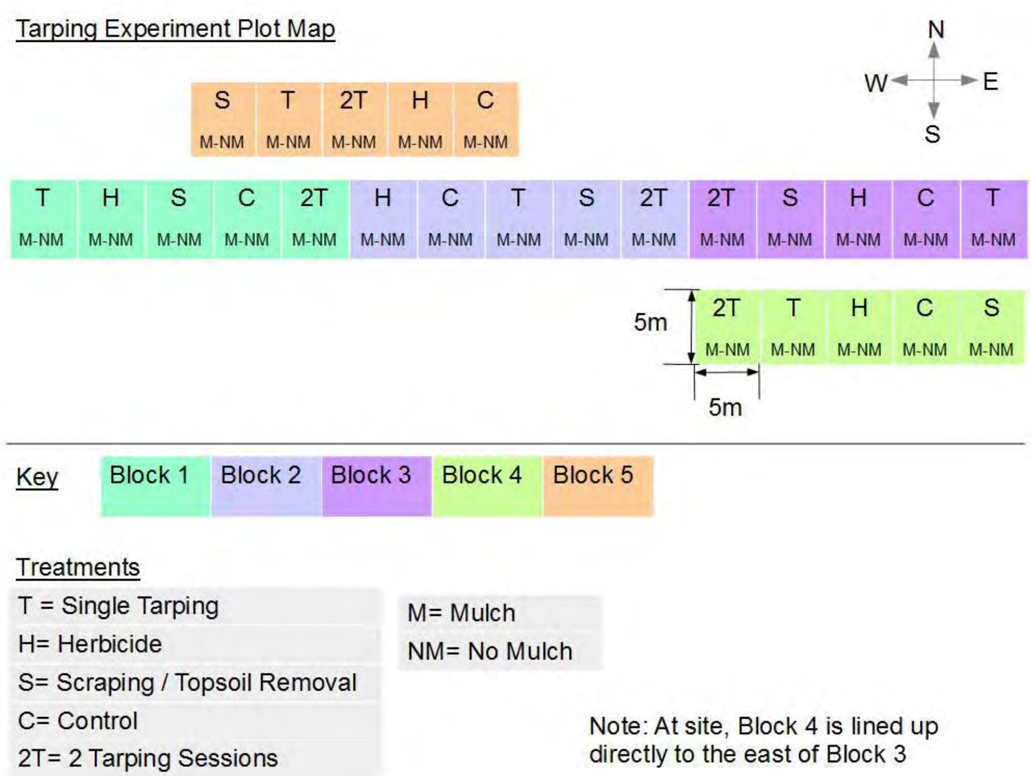
Variance in conditions and data, throughout the years of the study, exemplify the need for long term monitoring and analysis. During the initial setup of the study site, the scraped plots were flooded from rain, which may have negatively affected survival of recently planted plugs. Following that wet year, the area experienced four years of drought. Particularly in California, differences in interannual rainfall often interact with the efficacy of restoration treatments. In this study, the changes in short term versus long term influence of the methods, as well as, differences in climate conditions may be in play.

As I conducted the sixth year of research, my analysis focused on how time and environmental stochasticity influence the treatment's efficacy. My goal was to determine which method provides the greatest suppression of exotic species and the fullest establishment of native grasses. I hypothesized that the topsoil removal plots would continue to increase in effectiveness, because of the dramatic change between 2013 and 2015 data.

In addition, 2016 was the the first year that plots were mowed, since the initial treatment application. Mowing is a management technique used to mimic the disturbance regime of grazing that California grasslands evolved with (Hayes and Holl 2011). The goal of mowing was to reduce *Raphanus sativus, Cirsium vulgare* and *Carduus pycnocephalus,* exotic forbs that had become prevalent in the plots. Their abundance and size was of concern as it could lead to competitive exclusion of desired native grasses. Past studies show mowing has had success with reducing invasives and thatch, thus promoting growth and biodiversity of native species (Niederer et al. 2014, Lepš 2014). However, the effect of mowing is dependent on the plant guild. Additional studies show that mowing will reduce high stature species, yet favor low stature forbs above all other guilds (Hayes and Holl 2011). Therefore, I expected that mowing would decrease large exotic forbs, yet increase competition between native grasses and low stature forbs.

Methods

Younger Lagoon reserve is located on the coast in Santa Cruz, California. Chan (2011) and DeSilva (2011) set up the experiment in fall 2010. The experiment consists of five blocks, each containing five 5 × 5 m plots with a 0.5 m buffer around the edges, all within 40-50 m of the ocean to minimize environmental fluctuations (Angulo 2014). Each block contains the treatments of herbicide, scraping, tarping once, tarping twice, and control, randomly appointed to one of the plots. A 2.5 × 5 meter subplot within each treatment plot was designated to receive mulch.



The following description of the experiment was written by Sara Angulo (2014). [The experiment began with tarping x2 in August 2010, during which the plots were irrigated for 10 minutes per day for a period of 18 days (Chan, 2011). Following irrigation, black plastic tarps were laid over the vegetation for 6.5 weeks (Chan, 2011). The tarps were then removed, and left uncovered for 18 days in October 2010. After this period, tarps were then reapplied at the same time as the tarping x1 treatment in early November 2010. The tarps were left in place for both treatments for a period of eight weeks. Mulch was applied directly after all tarps were removed in January 2011.

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

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

The control plots received no treatment other than mowing, which was administered to all plots. This treatment also received mulch after mowing. Following all treatments and mulch application, all plots were planted with three native grass species, which were grown at the UCSC greenhouse from seeds collected locally at Franklin Point (Russell 2012). *Stipa pulchra* was planted 14 January 2011, *Elymus glaucus* on 21 January, and *Hordeum brachyantherum* on 6 February (Chan 2011).]

Since the initial treatments, plots did not receive additional maintenance until 2016. From January 11-14, 2016 isolated shrubs of *Lupinus arboreus* were removed from the experiment site and *Eriophyllum staechadifolium* were removed from the plot edges. From February 3-4, 2016 all plots were mowed to reduce *Raphanus sativus, Cirsium vulgare* and *Carduus pycnocephalus*. This maintenance was intended to reduce biomass of shrubs and broadleaf exotic species to potentially enhance native cover.

Covers of the three planted native grass species, and competing species and guilds, have been recorded annually. This year, data were collected between April 5 and 19, 2016. [We used a pre-existing map to determine the location of each block, treatment, and presence of mulch.

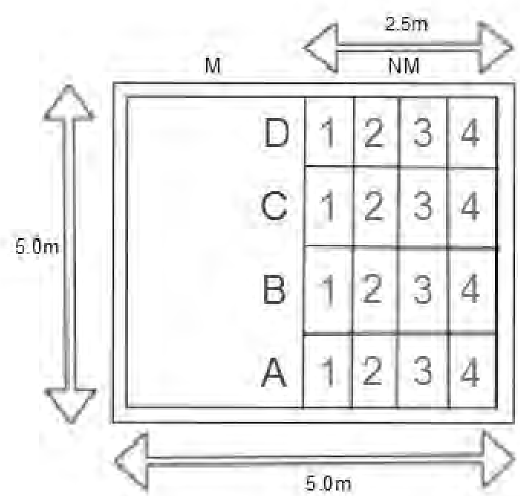


Fig. 1: Measurement locations for transect and mulched (M) and nonmulched (NM) sections within each plot. Quadrants A,B,C,and D were sampled in both mulched and nonmulched sides by randomly generating a sampling position of 1,2,3, or 4.

Facing away from the ocean, a tape measurer was placed along the bottom perimeter of each plot. We measured halfway along the perimeter to 2.5 meters, where, in general, the left side of the plot contained mulch, and the right side contained no mulch. For each mulched and non-mulched section of the plots, we laid a perpendicular transect at 2.5 (Fig.1). Starting 0.5m in from the bottom edge of the plot, we used four 0.25 x 1.0-m quadrats to measure percent cover, starting with quadrat A, followed by B, C, and D. The quadrat position along the transect was randomly assigned 1, 2, 3, or 4 (Fig. 1). This method was used to account for the planting of natives in rows, which could bias our data during quadrat placement.

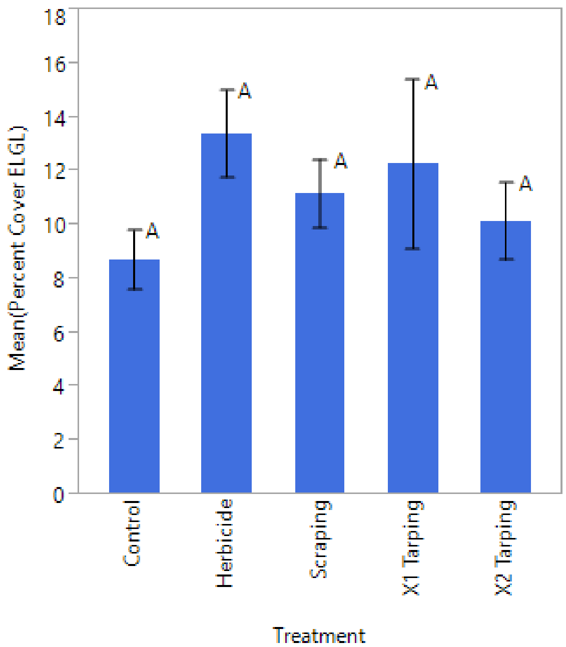
Within each quadrat, we measured percent cover using 5% classes, starting at 0-5%. The estimated percent cover was recorded as the midpoint of each class. For example, a percent cover estimated at 0-5% would be recorded as 2.5% cover. Percent cover values were recorded for three guilds: non-native grasses, non-native forbs, and native grasses. Percent cover was also measured for the three planted native grass species (*S. pulchra, H. brachyantherum, and E. glaucus*), wild radish (*Raphanus sativus*), and thistle (*Cirsium vulgare* and *Carduus pycnocephalus*), as well as for bare ground and mulch. Although previous studies measured survivorship, our study omitted this data because of the difficulty in discerning individual plants at this stage in their growth.]

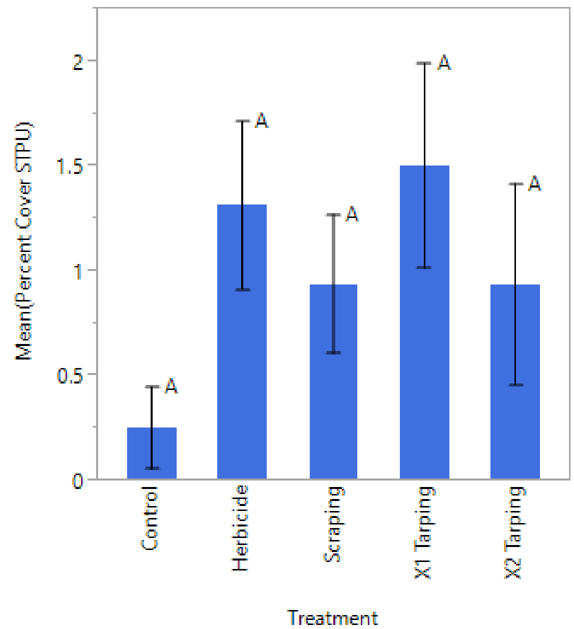
The results of this year's data were analyzed using JMP. The effects of treatment, mulch, and the treatment x mulch interaction on the different plant species and guilds were determined using two-way analyses of variance (ANOVA) with a blocking factor. A preliminary analysis with ANOVA indicated no significant mulch effect, or treatment x mulch interaction, so I focused on primary treatment effects and inter-annual differences in plant composition. Tukey's post-hoc comparison procedure was used to compare the differences between the five restoration treatments. Rainfall data collected from a gauge at the location of the study site was obtained to assist the analysis of interannual results.

Results

Elymus glaucus had similar cover across all treatments. However, *Hordeum brachyantherum* cover was highest (9.6%) in herbicide treatments, followed by scraping, 2x tarping, 1x tarping, and was lowest in control (3.8%). Though the p-value of *H. brachyantherum* indicates a statistically significant difference between treatments ($p = 0.0373$, Table 1), the Tukey post-hoc comparison did not reflect this, but the overall trend favors herbicides (Fig. 2). *Stipa pulchra* showed a similar trend to *H. brachyantherum* but the differences were not significant due to lower overall cover and high within-treatment variance. The only other species that differed across treatments were the thistles *Cirsium vulgare* and *Carduus pycnocephalus* (Fig.3); the x2 tarped plots contained the highest percentage of cover (16.1%), scraped plots (8.4%) and once tarped plots (12.3%) were intermediate, and control and herbicide had the lowest of 6.4 and 6.6% respectively. None of the other species or guilds differed across treatments including bare ground (mean 0.6% across all plots), litter (mean 26.7%), and *Raphanus sativus* (mean 20.7%). The native forbs *Erigeron canadensis, Achillea millefolium,* and *Pseudognaphalium stramineum* naturally established in plots and together had a mean cover of 1.2%. The mulch and the treatment x mulch interactions were not significant for any guild.

Cover of several plant guilds changed substantially from 2014 to 2016. Total exotic forb cover in 2016 was twice that in 2015 and nearly four times the cover in 2014 (Table 2). The dominant exotic forbs included *Medicago polymorpha* and *Geranium dissectum,* in addition to the thistle species and *Raphanus sativus.* Overall native grass cover decreased by 15.8% since 2015 and by 26.9% since 2014 (Table 2), which was mainly due to changes in *Elymus glaucus,* the largest component of native grass cover in the plots. In contrast, *Hordeum brachyantherum* and *Stipa pulchra* have decreased, by 6% and 2.4%, since 2015; 13.6% and 4.6%, since 2014 (Table 2). Exotic grasses, primarily *Festuca myuros, Bromus diandrus,* and *Festuca perennis,* have declined slightly over the three years (8.3%).





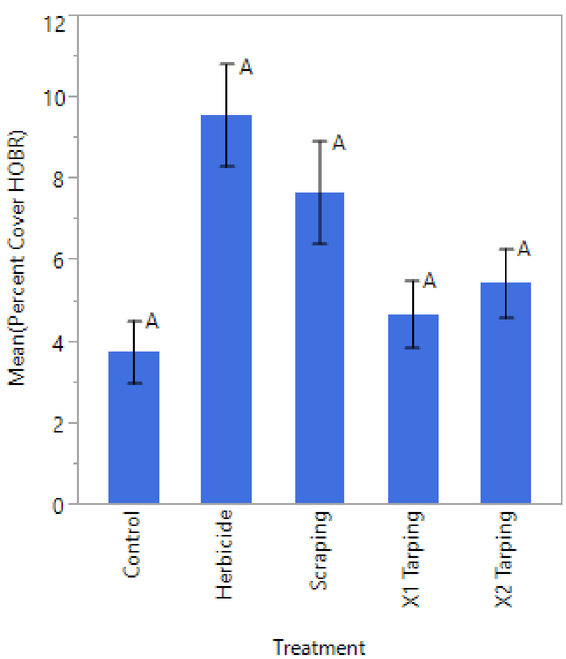


Fig. 2: Mean percent cover of *Elymus glaucus* (*ELGL*), *Stipa pulchra* (*STPU*), and *Hordeum branchyantherum* (*HOBR*) by treatment. Values are means ±1 SE for n = 5 plots. Note different y-axis scales.

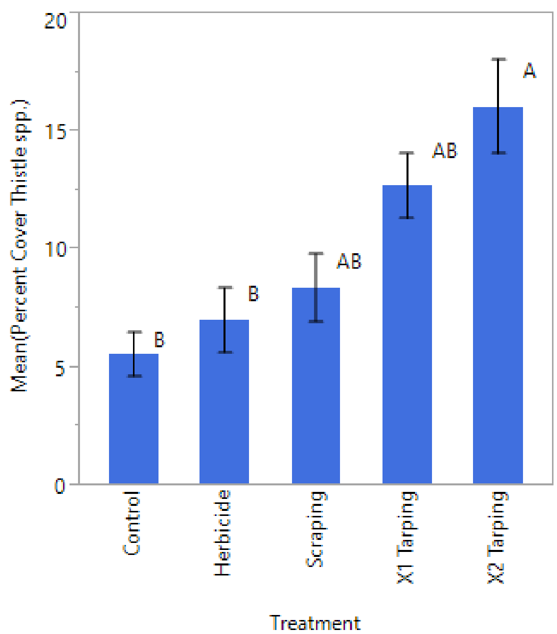


Fig. 3: Mean percent cover of the thistle species, *Cirsium vulgare* and *Carduus pycnocephalus,* by treatment. Values are means ± 1 SE for n = 5 plots.

Table 1: F-ratios and P-values of treatments. P-values less than 0.05 are considered as significant. F-ratios and P-values for the mulch and treatment x mulch interaction terms are not shown as they did not significantly affect any response variable.

Variable (Cover)	Treatment	
	F	P
Individual Species		
Elymus glaucus	0.5	0.7685
Stipa pulchra	0.7	0.6226
Hordeum brachyantherum	2.8	0.0373
Cirsium vulgare and *Carduus pycnocephalus*	3.6	0.0136
Raphanus sativus	0.7	0.6084
Guilds		
Native Grasses	1.8	0.1441
Exotic Grasses	0.2	0.9263
Exotic Forbs	1.2	0.3291

Table 2: Yearly comparison of overall mean percent cover of main plant species and guilds.

Variable	2014		2015		2016	
	Mean Cover	Standard Error	Mean Cover	Standard Error	Mean Cover	Standard Error
Individual Species						
Elymus glaucus	23.1%	1.3	18.6%	1.4	11.1%	0.8
Hordeum brachyantherum	19.8%	1.2	12.2%	1.2	6.2%	0.5
Stipa pulchra	5.6%	0.7	3.4%	0.6	1.0%	0.2
Cirsium vulgare and *Carduus pycnocephalus*	4.1%	0.6	7.3%	1.0	9.9%	1.1
Guilds						
Native Grasses	45.2%	2.5	34.1%	1.8	18.3%	1.0
Exotic Grasses	29.5%	1.4	27.5%	1.8	21.2%	1.0
Exotic Forbs	24.1%	1.5	40.3%	2.1	88.7%	1.9

Table 3: Yearly rainfall totals calculated from October 1st to September 30th each rainfall year. Excluding 2015-2016, for which data was limited to October 1, 2015 through March 31, 2016.

Year	Total Rain (mm)
2013-2014	240.7
2014-2015	437.3
2015-2016	1185.2

Discussion

The treatment effects have diminished with time, which is common in restoration studies (Matthews and Spyreas 2010; Rinella et al. 2012; Seabloom 2011). In 2016, canopy cover of the majority of species and guilds were similar across treatments, with the exception of *Hordeum brachyantherum, Cirsium vulgare* and *Carduus pycnocephalus*. By 2014, the fourth year of study, treatment effects had already started to converge. Likewise, mulching effects diminished by 2013 and were not observed this year, which is not surprising given that there had been much time for decomposition since application. Because herbicide is the only treatment which has consistently resulted in higher native cover than control over time, if controversies subside, I would recommend it as the most effective restoration method.

If controversy over herbicides potential to cause cancer continues to heighten, I would recommend additional research into other methods. Because scraping may have experienced extra obstacles to germination from flooding at the start of the experiment and still began to produce beneficial results in 2015, I believe that under different circumstances it may be an effective management option.

My results suggest that inter-annual differences in rainfall have stronger effects than the restoration treatments. Multiple reasons may explain the drastic increase in exotic forb cover over previous years, while all other guilds are declining. First, the location received substantially more rain in 2016, which was an El Niňo year, than in 2015 and 2014. Rainfall is a major driver of plant composition in semi-arid regions (Holmgren et al. 2006), including California grasslands. Increased rainfall years favor the germination, growth, and seed production of ephemeral and herbaceous species (Holmgren et al. 2006), which could explain the observed increase in exotic annual forbs. These species thrive under heavy pulses of rain and use wet years to maximize growth and seed production (Holmgren et al. 2006). This allows them to create a large enough seed bank to remain dormant in dry years and resume dominance in future wet years (Holmgren et al. 2006). A similar trend was seen in Chile; ephemeral plant cover increased from 11-16% prior to an El Niňo event up to 54-80%, during the El Niňo (Holmgren et al. 2006).

Second, the mowing in February 2016, may have increased exotic annual forb growth. Mowing was included this year to target the exotic broadleaf species of *Raphanus sativus, Cirsium vulgare* and *Carduus pycnocephalus.* However, mowing may have induced unintended consequences. Studies show that mowing is capable of shifting community composition in grasslands to favor low stature annual forbs (Hayes and Holl 2011), including the dominant *Medicago polymorpha* and *Geranium dissectum*. As a result of this study, I would only recommend the management of mowing in systems with a large percentage of high stature exotic forbs. If low stature forbs are substantially present in the community, mowing may have adverse effects on native grass cover.

In addition to changing climatic conditions and maintenance regimes, possible variation in sampling estimates must be considered. Although a similar methodology was used for data collection each year, the process was conducted by different people. As estimating canopy cover utilizes an element of visual discretion for the estimates, some variation may be amplified throughout the years of the study.

Conclusion

My results suggest that initial effects of restoration treatments in California coastal prairie will diminish with time and be overshadowed by influences of rainfall events. Although most treatments effects have converged by the sixth year since application, herbicides influence on community composition remains strongest. Controversy over herbicide use warrants the need for further research on the methods of scraping and mowing. Scraping produced native grass cover comparable to herbicide and lower exotic forb cover in 2015, even after initial obstacles to germination. This leads me to believe that trend would have continued into 2016 under non El Niňo conditions, which likely facilitated the overall dominance of exotic annual forbs, thus decreasing significance between treatments and control. Testing the timing of mowing, as well considering the specific species present in the plant community may be significant for this method's success.

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Jack Rusk

Efficacy of restoration treatments in California's coastal grassland influenced by variability in rainfall

Abstract

When agricultural land in coastal California transitions to grassland, exotic species are quick to dominate the landscape. Using combinations of restoration treatments to ameliorate this invasion and establish native vegetation is a persistent challenge for land managers along the California coast. This study, at Younger Lagoon Reserve near Santa Cruz, CA, investigates the effects of initial mulching and yearly mowing on two different planting designs (entire-area planting or planting "island" patches) of grasses and forbs at a former agricultural site. In this year's sampling, native forbs and grasses were scattered in patches throughout a matrix dominated by exotics across both planting treatments. Previous years' results described an establishment of native cover across treatments and high levels of recruitment outside of plantings in nucleated plots; this year, effects were muted and recruitment scattered. Island plantings show promising levels of recruitment, even in this unfavorable year, illustrating these planting designs may provide a cost-saving alternative to entire-area planting in restoration areas. The reduction of thatch in mowed plots may encourage the persistence and recruitment of native grasses. Effects of the recent El Niño event may explain some of the variation in effects seen this year but this cannot be confirmed without a dataset that captures greater patterns of climatic variation. In light of high interannual variation in results, this study underscores the importance of continuing restoration studies over the the long-term.

Introduction

In many of California's coastal grasslands, the dominance of exotic species has become the norm and dominance of natives the exception. This pattern is by no means recent. Burcham (1956) listed four waves of invasion of European species into California grasslands to which DiTomaso (2007) amends a fifth more recent wave. To make matters worse, conditions at degraded sites may intensify already strong patterns of invasion. Many of the invaded sites along California's coast are former agricultural sites whose degraded soil communities that favor exotic invaders (Middleton 2012). Native species in degraded grasslands are also often heavily seed-limited (Stanley 2011) while exotic annuals can produce large quantities of propagules (Cox and Allen 2007). In the face of a wide range of obstacles to grassland restoration, multiple simultaneous restoration treatments may be necessary (Stanley 2011). This management may be labor-intensive, especially in the first few years of treatments (Stromberg 1996). The dynamism and complexity of the system suggests that there is no singular panacea for reducing exotics and restoring native species to their former abundance.

California coastal grasslands exist under a Mediterranean climate regime of wet winters and dry summers. This yearly pattern is nested with a larger-scale pattern of periodic droughts and wetter El Niño periods. These nested periodicities affect year-to-year community composition in California grasslands (Hobbs and Mooney 1991). Changes in community composition due to climatic events may be hard to detect due to time lags in the between climatic events and their effects (Hobbs et al. 2007). These time lags stack the effects of several events simultaneously, making it difficult to assess their individual impacts (Hobbs et al 2007). While these patterns may be difficult to untangle, understanding them is essential if restoration is to be successful. The effects of climate change in California will vary regionally but are likely to increase the frequency of extreme temperature and precipitation events everywhere (Bell et al 2004).

Competing patterns of habitat segregation and aggregation create heterogeneity across many scales within California grasslands (Seabloom 2005). Processes like establishment, dispersal and competition create spatial structure on scales as small as a single square meter (Seabloom 2005). At a higher level, disturbances such as grazing by ungulates or fire play an important role in maintaining species richness over the landscape as a whole (MacDougall and Turkington 2007). Layering of large-scale patterns of disturbance with small-scale patterns in the vegetative structure create a high level of heterogeneity through space. The variation in disturbance also creates dynamism through time: Climate, together with other factors, can push California's coastal grasslands towards any of multiple distinct stable states (Seabloom 2003). Changes in disturbance regimes have been shown to shift land that was once California grasslands to tree- or shrub-dominated communities (Callaway 1993).

The goal of grassland restoration is to establish favorable initial conditions, combined with cost-effective disturbance/maintenance regimes, to maintain native species cover into the long-term. The treatments must be able to maintain the native cover in the grassland system and prevent the shift to a different stable state wherein exotics dominate. This study at Younger Lagoon studies effects of initial mulching and yearly mowing on native grasses and forbs planted in two different designs. Initially, subplots were planted with native forbs or grass species over their entire area (Full, F) or in a central cluster (Island, I). Half of each of these plots were mulched. This gives four treatments: island-planted and mulched (I-M), island-planted and unmulched (I-NM), full-planted and mulched (F-M) and full-planted and unmulched (F-NM). I-NM plots were removed from the study before sampling in 2014 due to persistently low native cover. For the three remaining treatments, half of the subplots are mowed annually in May.

Planting restoration areas in "islands", dense clusters of seedlings within an unplanted matrix, may establish native cover similar to planting across 100% of a restoration area at a fraction of the cost. This approach has been used in other grassland systems: In Minnesota, Grygiel (2009) showed that plots planted at 25% densities established similar species richness to plots seeded at 50% densities. Planting at lower densities can decrease the cost of restoration in both labor and materials. Nucleated plantings are preferable in forest communities because they mirror natural patterns of habitat heterogeneity (Corbin and Holl 2012). Given the high level of heterogeneity in the grassland, nucleated plantings may be similarly desirable.

Previous grassland experiments have demonstrated the efficacy of mowing treatments, timed with the phenology of the exotic or native species, to restore native cover by releasing them from competitive exclusion by exotics (Wilson and Clark 2001). Less desirably, mowing may also shift a landscape dominated by tall-stature exotic grasses to one dominated by low-stature exotic forbs (Hayes and Holl 2003). The timing of mow treatments with phenology can strongly determine their effects (Wilson and Clark 2001). This phenology, and thus appropriate timing of the mowing treatment, can be strongly influenced by climatic variation such as El Niño events (Cleland 2007).

In previous years at this site, the addition of mulch has favored native species (Arneson 2014). The effects of mulch are most pronounced in initial years (Schreiber 2015). The longevity of the mulch, and its direct effects, is about two years in the coastal climate (Holl 2014).

Hypotheses for this year's sampling are based on results from previous years. At this site, no mulch effects were seen past the second year (Arneson 2014), consistent with the findings of Holl (2014). I hypothesized that this trend would continue in the present year. Mowing, as in past years, was predicted to increase the cover of exotic grasses. In island-planted plots, native cover was anticipated to be highest in the planted area, decreasing at the edge of islands and decreasing further in the "out" plots. Although I anticipated effects of the El Niño event, increased precipitation has been shown to have nonlinear effects or no effects at all (Corbin 2004, Hobbs et al 2007), so the direction and intensity of these effects is difficult to predict.

Methods

Younger Lagoon Reserve

From Schreiber (2015):

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

Experimental design

From Tang (2013):

> In October 2011, prior to the start of the experiment, the entire study area was mowed and sprayed with a glyphosate herbicide to reduce the cover of exotic background vegetation. The area was also fenced to exclude rabbits and humans. We marked plot boundaries and randomly assigned the plot treatments. We added wood mulch (comprised mostly of coast redwood, tanbark oak, bay laurel, and Monterey cypress) to the plots that were assigned a mulch treatment. In January 2012, a few days before planting, we applied a second round of glyphosate herbicide.
>
> The study was set up as a split-plot design with four main treatments crossed with a mowing treatment. We set up 20 10x10-m plots with 1-m buffers between the plots; each plot was randomly assigned one of four main treatments for five replicates of each treatment: 1) fully-planted with mulch (F-M), 2) fully-planted with no mulch (F-NM), 3) island planting with mulch (I-M), and 4) island planting with no mulch (I-NM).
>
> We planted three native perennial grass species—*Stipa pulchra* (formerly *Nassella pulchra*), *Hordeum brachyantherum*, and *Bromus carinatus*.—alongside five forb species—*Achillea millefolium, Clarkia davyi, Grindelia stricta*, *Trifolium willdenovii*, and *Symphyotrichum chilense* (formerly *Aster chilensis*) [Table 1]. We also planted one species of rush, *Juncus patens* [excluded from results in 2016 due to very low establishment]. We collected native plant seeds during June-September 2011 from local sites with characteristics similar to that of YLR. The seeds were processed and then propagated as seedling plugs at the UCSC Greenhouses and at a local native plant nursery (Central Coast Wilds). All seedlings (except *Symphyotrichum chilense*) were approximately three months old at the time of planting in late January 2012 and had individual covers of $\leq$0.25 dm^2.

Symphyotrichum chilense seedlings had delayed germination and were planted in May 2012.

The entire 10x10-m area of each fully-planted plot was planted in 22 rows of 22 plants for a total of 484 plants per plot [Appendix 1]. The plugs were planted at a distance of 45.45 cm from each other and plot boundaries. Each row was planted with a single species, and there were 11 rows of forbs/rushes and 11 rows of grasses. In each plot, there were two rows of *A. millefolium, C. davyi, G. stricta, T. wildenovii, J. patens*; one row of *Symphyotrichum chilense*; four rows of *H. brachyantherum* and *B. carinatus*; and three rows of *Stipa pulchra* planted in an alternating pattern. The forbs/rushes were planted on one side of each plot, and the grasses were planted on the other side. This layout was designed to allow the use of broadleaf and grass-specific herbicides for future control of exotic species.

One third of the 10m x 10m area of each island plot was planted with plugs. The seedlings were planted in four 2.25m x 2.25m islands with 2.5 m between each island and 1.5 m between the islands and plot boundaries [Appendix 1]. Each island had 6 rows of 6 plants, for a total of 144 plants per plot. As in the fully-planted plots, the plugs were planted 45.45 cm apart, and each row had one species. There were two forb/rush islands and two grass islands, with forbs/rushes on one side of the plot and grasses on the other side. Each forb/rush island had one row of each species, and each grass island had two rows of each species planted in an alternating pattern.

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

As stated above, the full planting-no mulch plots were removed from the experiment before the 2014 sampling. No individuals of *Clarkia davyi* and *Trifolium willdenovii* were seen after the second year of the study and thus are also excluded from the current analysis.

Data Collection (adapted from Schreiber 2015)
I collected data April 16 and 17, 2016. Data collection methods were adapted from Arneson (2014) and Schreiber (2015). Plots were split into four 4 x 4 m subplots (with a 1-m buffer at the edge of plot) representing four treatment combinations; mowed grass planting, unmowed grass planting, mowed forb planting and unmowed forb planting. In full planted plots, I randomly placed four 1 x 0.25 m quadrats in each subplot, totaling 16 per plot.

Nucleation planted plots were sampled with two quadrats within the planting area (In), two abutting the edges of the planting (Edge) and two outside the planted area (Out). Some of the Out quadrats were with 0.25 m of the planted area on the short edge to allow all quadrats to run parallel to the plantings and stay inside the bounds of the subplot. In total there were 24 quadrats sampled in each island-planted plot.

Samples were randomized using an imaginary numbered grid delineated by two transects running perpendicular, 1 m from the edge of the subplot, and using a random number generator. This layout was modified for nucleation planted plots by creating zones for each of the three locations within each subplot (Appendix 1). I adjusted locations to always place quadrats parallel to planted rows. In each quadrat, I estimated percent cover of individual native grass and forb species to the nearest 5% interval for estimates greater than 10%; for example, if I estimated cover to be 20-25% then I assigned 22.5%. For percent cover less than 10% percent, I estimated native grass and forb cover by species to the nearest 1%. The same cover categories were used to estimate total exotic grass and forb cover. Due to canopy overlap, percent cover per quadrat can sum to >100%.

Annual precipitation from a weather station at the study site was summed from October of one year to September of the next. Only six months of precipitation are summed for the most recent period.

Statistical Analysis

Data were analyzed with the JMP Pro 12 Statistical Software. Vegetation cover values were analyzed using a two-way ANOVA with treatment (F-M, I-M, or F-NM), mowing, and their interaction as model terms. Percent cover values were arcsine-square root transformed to reduce heteroscedasticity. A post-hoc Tukey's HSD was used to compare treatment combinations. Native cover was analyzed by species and by guild (forb or grass). In the test for correlation between thatch and native grass cover, the data were log(x+1) transformed. P-values of <0.05 are considered significant; marginal p-values of 0.05-0.1 are also included in the discussion and noted as such.

Results

The study site was dominated by exotic grasses and forbs, but there was no effect of treatment on their cover (Table 1); mean exotic grass cover across all treatments was 40.5±14.4% and exotic forb cover was 48.9±16.0%. Native forb cover was generally lower in in F-NM plots than in the other two treatments but was highly variable across all treatments (Figure 1, Table 1). This effect is in part due to the significant treatment effects of *Symphyotrichum chilense* (34% of native forb cover) and marginally significant treatment effect on *Grindelia stricta* (25% of native forb cover). Bare ground was present in only two quadrats and had <5% cover in both.

In island plantings, native forb and grass species had spread outside the planted area (Figure 2, Table 2) by both vegetative growth and new recruitment. While the mean forb cover outside the plantings showed a trend toward lower values, these differences were statistically indistinguishable due to high variance.

Mowing increased exotic grass cover from 33.0±9.0% to 48.0±15.0% (Table 1). Thatch cover (primarily senescent grasses) was lower in mowed (2.1± 0.97) than in unmowed (8.5 ± 0.97) subplots. The mowing and planting treatment had an interactive effect on native grass cover due to the steep difference in native grass cover between mowed and unmowed I-M plots. (Figure 2). Native grass cover was strongly correlated with thatch (figure 3) and showed no significant correlation with exotic grass cover (r^2 = 0.094, p=0.0980). Exotic grass cover was not correlated with the amount of thatch (r^2 = 0.067, p=0.1673).

Precipitation in the rainy season before sampling was more than twice that of the previous year and more than four times the precipitation in either of the two years preceding (Figure 4).

The most abundant exotic grasses at the site were *Avena barbata*, *Bromus diandrus* and *Festuca myuros* (formerly *Vulpia myuros*); the most abundant exotic forbs were *Geranium dissectum*, *Medicago lupulina* and *Plantago* spp. Native grasses and forbs were absent from most quadrats (Figure 5). When natives were present, they were well-established, especially in the cases of colony-forming forbs like *Grindelia stricta, Achillea millifolium*.

Discussion

Nucleated plantings continue to show promise to restore native grass and forb cover into the fifth year of this study. Although recruitment outside of the nucleated planting was less this year than in the previous year (Schreiber 2015), nucleated plantings still achieved total native cover similar to fully-planted plots, especially compared across mowed plots. Some of the spread recorded outside of the planted area was due to vegetative growth from outplanted individuals while other patches appeared to have recruited from seed. Slowness in recruiting outside of planted areas, as well as heterogeneity of establishment, suggest that efforts in restoring native grasses may be seed- and recruitment- limited, a pattern also observed by Seabloom (2003). Given the spatially scattered recruitment, random quadrat sampling includes some patches and excludes others. Despite the exclusion of some patches of established natives in island-planted plots, they achieved similar overall cover to full-planted plots. This bolsters the idea that nucleated plantings are a suitable alternative to full plantings in California's coastal grasslands.

While it may be a strong filter, establishment is not the only driver of vegetative patterns. If native forbs and grasses were solely recruitment-limited, then a larger difference between full and island plantings would be expected. Schreiber (2015) hypothesized that island plantings encourage native plant establishment by allowing established natives to act as nurse plants for new recruits. A mechanism like this would reinforce patchiness by a process wherein established patches have higher recruitment and colonization to new areas is difficult. This intuition is bolstered by the patchy establishment observed across all sites. Native forbs and grasses have, in some quadrats, percent cover much higher that the target native cover of 20% (UCSC 2010). In many others, they were not present at all. In lieu of wider-reaching establishment from seed, vegetative spread of perennial forbs and grasses may circumvent recruitment limitation and reinforce patterns of patchiness. Further study into the mechanisms behind patchiness could help to identify treatments to support nucleated treatments in coastal prairie systems.

Mulching shows promise in increasing establishment of native forbs. Suppressive effect of mulch on exotics were observed in the first two years of the study (Schreiber 2015, Arneson 2014). Holl (2014) described the suppressive effect on mulch were highest in the first year and diminished each year after that. Consistent with those predictions, mulched plots had higher cover of native forbs and grasses two years into the study. While the effects of mulch may have diminished over the years, the positive effect of an initial mulching on native cover persisted five years into this study.

The effect of mowing treatment on thatch ($p<0.0001$) was much stronger than its effect on native grasses ($p=0.0506$). Results from this and other studies (Reynolds and Corbin 2001) indicate that the presence of thatch may have an inhibitory effect on the establishment or growth of native grasses. The strong negative correlation between thatch and native grass in this study may help explain the significant positive effect of mowing on the cover of native grasses. Thatch shows no effect on exotic grasses, suggesting that mowing may increase native grass cover by favoring natives, not by suppressing exotics.

In broader terms, mowing is not strictly favorable: Exotic grass cover was also higher in mowed plots. Mowing at a sufficiently high frequency can also shift the dominant cover from exotic grasses to exotic forbs (Hayes and Holl 2003), not a desirable outcome. Timing of the mowing treatment can determine the strength and direction of its effect (Wilson and Clark 2001). By timing mowing correctly, it may be possible to encourage native grasses. Unpredictable patterns of year-to-year precipitation may change the timing of phenological events, changing the effect of mowing treatments performed at prescribed times. Flexibility in the mowing schedule, coupled with close observation of plant phenology in the grasslands, may be necessary if the treatment is to be successful.

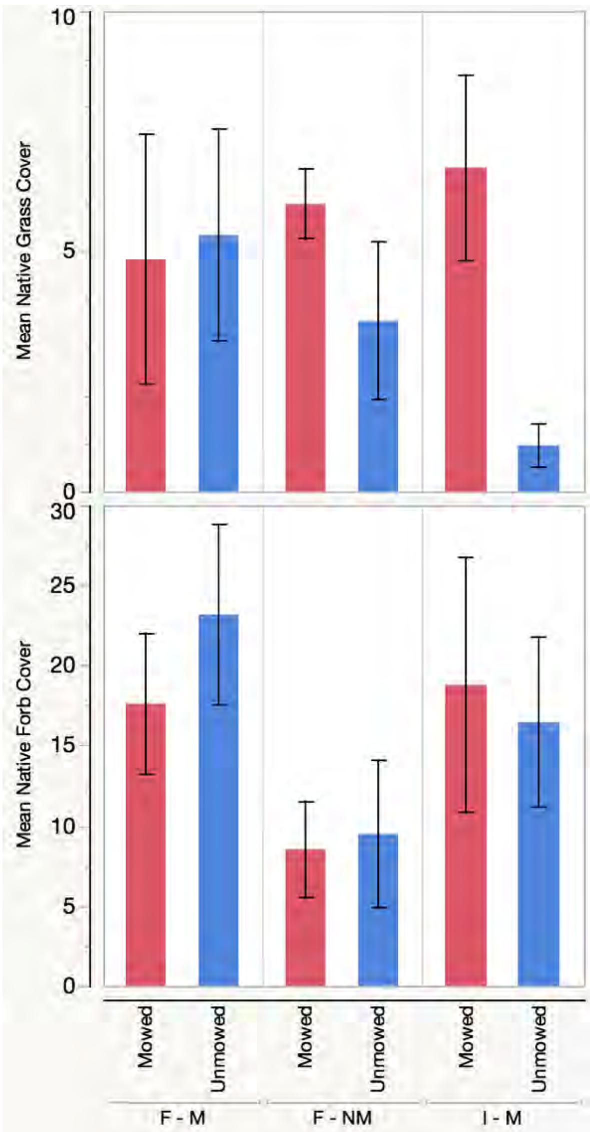
Beyond treatment effects, observations from this year may be strongly influenced by climatic events. The winter of 2015-2016 was marked by a significant El Niño event. Precipitation in the six months before sampling was more than the total precipitation at the site in the three years prior (figure 4). Effects of precipitation are not explicitly included in the study but still provide important context in which to understand this year's results. Increased precipitation can favor invasion of grassland systems, though these invasions can be limited by soil nutrients (Eskelinin and Harrison 2014). Given their prodigious stature and cover, the presence of exotics in the 2016 growing season show no particular signs of nutrient limitation. The flush of exotic annuals in response to increased rainfall may help explain the reduction in mean native cover in this year (21% in island-planted plots) as compared to last year (31% in island-planted plots) (Schreiber 2015). Exotic forbs have shown higher cover in years with higher precipitation (Hayes and Holl 2003), a trend observed at this site when this year's sampling is compared to last year's data (27% in 2015 vs. 48% this year) (Schreiber 2015). Conversely, the decreased precipitation of previous years may have helped native species establish (Hayes and Holl 2003). Native grassland species may fare better in resource-limited periods such as the extended drought of the prior years (Seabloom 2003). Alternatively, the native species may have been unprepared to take advantage of the water resources of the El Niño storms. Native seeds dormant in the seed bank may germinate in years of higher precipitation—but no native seed bank exists at the study site. If a native seed bank develops over time, future high precipitation events may have more favorable effects on natives. The reality of anthropogenic climate change and the attendant increase in dramatic precipitation events necessitates serious consideration of the effect of climatic variation over the long term.

Management Recommendations

The results of this study point towards some recommendations for land managers in California's coastal grasslands:

1) Island-planting represents a viable alternative to full-planting restoration areas in coastal grasslands. The failure of the unmulched island-planted plots illustrate the necessity of using mulch in conjunction with this planting regime.
2) Mowing treatments increase the cover of native and of exotic grasses. The timing of these treatments can be an important determinant of their effects; proper timing may vary with climatic conditions.
3) The site-specific goal of 20% total native cover within 7 years (UCSC 2010) is feasible with nucleated restoration plantings. The efficacy of the plantings may be affected by year-to-year variation in climate.

Additional years of study at this site hone our understanding of restoration treatments, allowing land managers to make better-informed decisions. The importance of long-term studies of restoration techniques is also paramount, especially given the annual variability of California's climate.



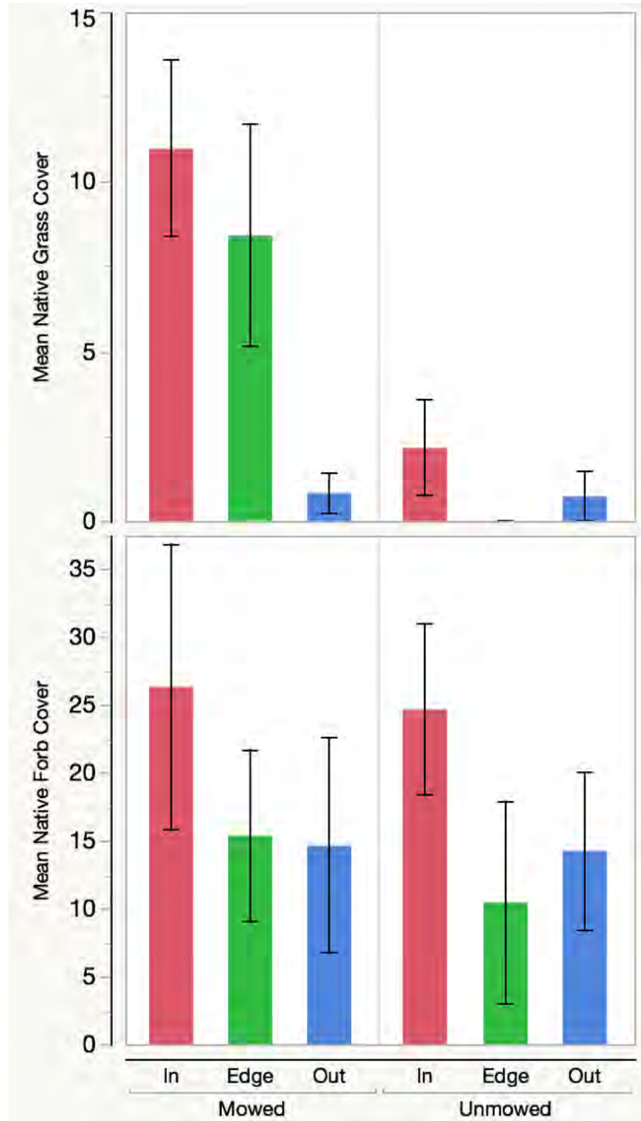


Figure 1. Cover of native forbs and grasses across planting, mulching and mowing treatments. Blue bars are mowed and red bars are unmowed. Treatments are fully planted mulched (F-NM), fully planted unmulched (F-UM) and island-planted mulched (I-M). Bars represent mean values ± 1 SE.

Figure 2. Cover of native forbs and grasses within island-planted plots across plot and between mowing treatments. Samples were within the planted area (In), adjacent and parallel to the planting area (Edge) and nonadjacent or nonparallel to the plantings (Out). Bars represent mean values ± 1 SE.

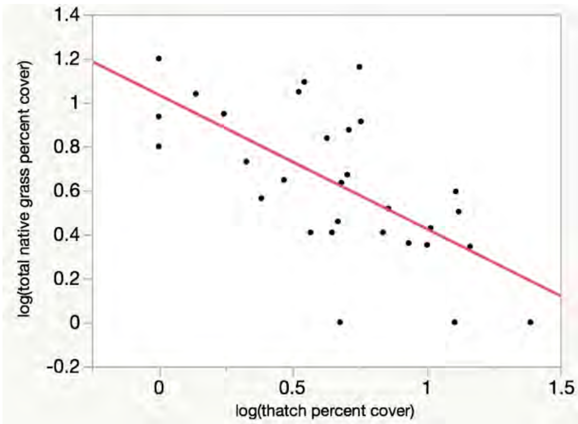


Figure 3. Correlation between total native grass cover and thatch cover ($r^2 = 0.43$, $p < 0.0001$) across all samples.

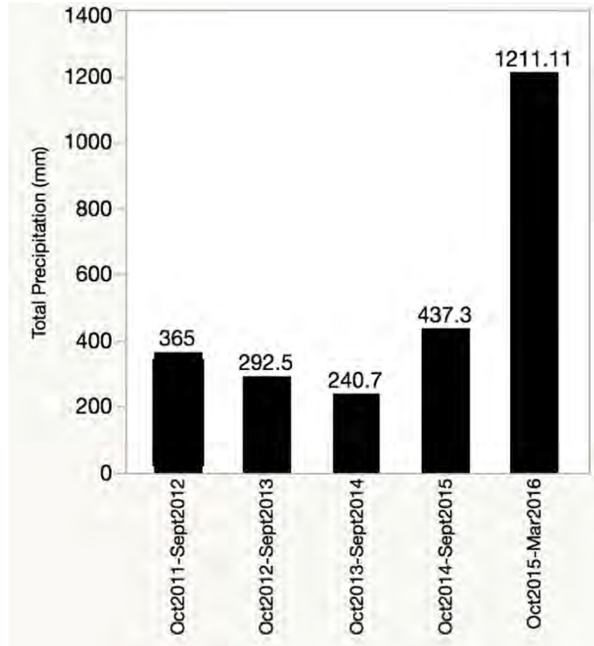


Figure 4. Annual precipitation totals from October 2011 through the 2016 sampling. Note that the most recent period only covers six months.

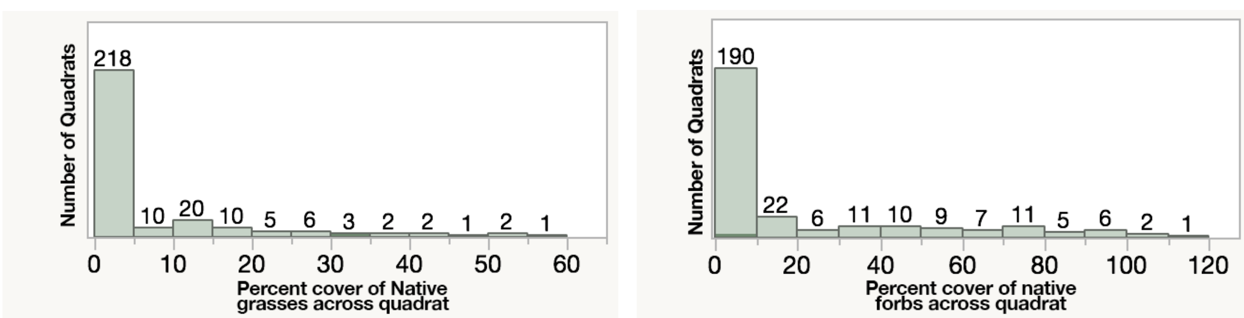


Figure 5. Percent cover of total native forbs and grasses across all quadrats. Values are the number of quadrats with the percent cover on the x-axis. Values are summed across multiple species that may have overlapping canopies, so totals can exceed 100% cover.

	Treatment		Mow		Mow*Treatment	
	F	**P**	**F**	**p**	**F**	**p**
Guilds						
Exotic Grasses	2.2	0.1379	11.2	0.0026	0.3	0.7152
Exotic Forbs	1.4	0.2619	1.2	0.2847	0.1	0.9145
Native Grasses	0.7	0.5105	4.2	0.0506	3.0	0.0688
Native Forbs	3.7	0.0402	1.0	0.3302	1.6	0.2193
Species						
Bromus carinatus	0.2	0.8565	0.8	0.3754	1.2	0.3211
Hordeum brachyantherum	2.8	0.0786	3.5	0.0747	0.7	0.5301
Stipa pulchra	0.6	0.5508	0.3	0.5825	1.0	0.3673
Grindelia stricta	2.9	0.0765	1.0	0.3342	0.9	0.4252
Achillea millefolium	0.1	0.9137	0.2	0.6522	0.5	0.5938
Symphyotrichum chilense	4.0	0.0316	0.0	0.8698	0.2	0.8334
Thatch	1.4	0.2740	22.8	<0.0001	1.0	0.1665

Table 1. ANOVA results for treatment (F-M, F-NM, I-M), mow and treatment by mow interactions.

	Distance from planting (In, edge, out)		Mow		Mow*Distance	
	F	**p**	**F**	**p**	**F**	**p**
Guilds						
Exotic Grasses	4.9	0.0159	21.3	0.0001	0.4	0.6689
Exotic Forbs	0.3	0.7601	2.8	0.1060	0.0	0.9916
Native Grasses	5.5	0.0106	19.3	0.0002	3.5	0.0455
Native Forbs	1.5	0.2419	0.0	0.9383	0.4	0.7084
Species						
Bromus carinatus	1.9	0.1654	5.2	0.0315	2.7	0.0900
Hordeum brachyantherum	6.2	0.0068	6.7	0.0158	0.6	0.5479
Stipa pulchra	0.1	0.9412	2.8	0.1027	0.1	0.9412
Grindelia stricta	11.1	0.0004	0.2	0.6499	0.2	0.7861
Achillea millefolium	0.2	0.7843	0.2	0.6279	3.0	0.0735
Symphyotrichum chilense	0.1	0.8886	0.1	0.7271	0.5	0.6064
Thatch	0.4	0.6468	39.3	<0.0001	1.7	0.1964

Table 2. ANOVA results for island-planted subplots, showing effects of distance from planting area, mowing, and distance by mow interactions.

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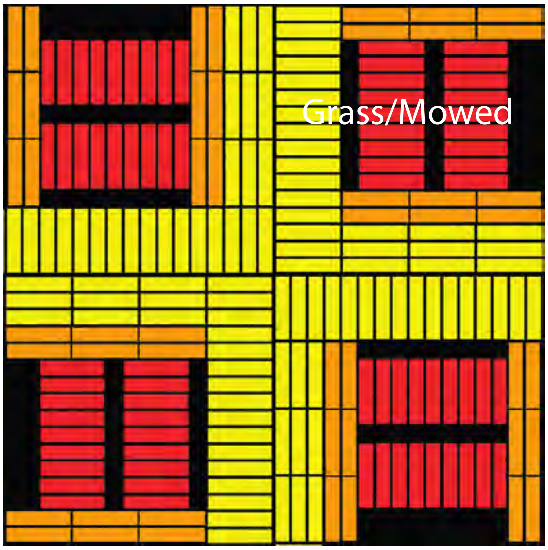
Appendix 1: Sampling Design



3: Grass/Mowed

Sampling design for island-planted plots. Red areas are within the planting area (In), orange areas are adjacent to the planting area (Edge) and yellow areas are nonadjacent to the planting area (Out). Two quadrats per distance per subplot were randomly selected and sampled. North is towards the top of the page.

Sampling design for full-planted plots. Four quadrats per distance per subplot were randomly selected and sampled. North is towards the top of the page.

Daniel E. Williams

June 8th, 2016

The Effects of Drought on Coastal Prairie Grassland Photosynthesis

Abstract

Drought has the potential to affect ecosystems across the globe which will have important implications for these ecosystems. In order to better understand these implications, a coastal grassland prairie dominated by an exotic annual grass (*Avena barbata*) and an exotic forb (*Raphanus sativus*) was examined. Soil moisture content, water potential, stomatal conductance, and carbon dioxide assimilation were measured under drought simulation structures to assess the response of the plant species to 60% reduction in rainfall. Water potential measurements were made for *Bromus diandrus* as well as a grass comparison. *Avena* showed signs of relative drought tolerance compared to *Raphanus*

Introduction:

Drought is a major problem the world now faces, and will continue to face. Warmer temperatures and drier climate is predicted to affect certain parts of the globe more frequently, more intensely, or both (Breshears et al., 2005). These changes in weather and climate patterns will negatively affect ecosystem functionality, diminishing their ability to provide services of ecological and economic benefit (Pederson et al, 2005). On a more local scale, climate change has created a severe drought in California causing massive vegetation die-offs and creating negative implications for agriculture as well as natural ecosystems (Breshears et al., 2005; Jackson et al, 2011).. California's severe drought has caused natural resource problems such as groundwater being overdrawn which causes large amounts of subsidence in the central valley agricultural regions, as well as saltwater intrusion in the coastal zones (MacDonald, 2007).

Understanding the responses ecosystems will have to drought will be increasingly important for land management efforts in the future.

An experiment was set up to better understand the drought response of a local ecosystem. This experiment is part of a larger, worldwide experiment aimed at quantifying the effects of drought on various ecosystems. The site is located near Younger Lagoon, a coastal grassland prairie in Santa Cruz, California (36.951191, -122.066518, Sea level). Coastal prairies are important ecosystems for many species of birds and other animals, some of which are endangered (Noss et al., 1995). Younger Lagoon is also considered a seasonal wetland. Wetlands are areas of extremely high biodiversity and have important ecological functions and economic benefits for humans (Noss et al., 1995). The parameters being measured in this study include soil moisture content, photosynthetic rates of select plants, stomatal conductance, and water potential. These variables can tell us about the relationships between weather, soil water, and plant health (Breda et al, 2006). Drought can reduce the availability of soil water. In that case, the ratio of evaporative demand to available water is then increased and can result in stomatal closure and the limiting of gas exchange with the atmosphere, thus limiting growth (Breda et al, 2006). Therefore it is important to understand how this may affect these ecosystems that will likely suffer from more intense drought. I hypothesize that plants subjected to drought conditions will experience negative impacts on photosynthesis, gas exchange, and stomatal conductance, and thus less net primary productivity (NPP). These negative impacts are likely due to soil moisture content and respective water potential values.

Methods/Materials:

There are 25 plots (5 plots per treatment) on site, each measuring 4 m^2 with a 1 m buffer zone around each. Treatments relevant to this study include drought shelter and control (no drought shelters) plots for background vegetation (invaded grassland). These plots are labeled IC (International Control), and IS (International Shelter) for IDE (International Drought Experiment). The drought shelters simulate drought at a 60% reduction in rainfall. Plots and shelters were set up along an East-West transect.

Photosynthetic gas exchange was compared for distal leaves (representing 1 to 3 cm of stem length) of *Raphanus sativus* (California wild radish) and *Avena barbata* (exotic grass) on treatment plots. Leaves were spread out to minimize overlap, but measurements represent projected area. Water potential measurements occurred at the same time of day, but on the leaves of different plants to minimize potential effects of stem removal on stomatal conductance and photosynthesis.

Carbon dioxide assimilation, and stomatal conductance to water vapor were measured using a LI-6400 open-mode portable photosynthesis system (Li-Cor, Inc., Lincoln, NE, USA). Vapor pressure deficit within the chamber was maintained at pre-measurement ambient levels. The CO_2 concentration within the leaf measurement chamber was maintained at a constant level (400 μmol mol^{-1}) by scrubbing the incoming airstream with soda lime, and the addition of precise amounts of CO_2 from an external cartridge. Photosynthetically Active Radiation (PAR; 400-700 nm) within the chamber was maintained at 1500 μmol m^{-2} s^{-1} using Li-Cor red-blue LEDs in the 2 × 3cm rectangular chamber. Leaf temperatures were recorded with a copper-constantan thermocouple pressed to the abaxial surface of the leaf within the cuvette. Distal, fully mature leaves were inserted into the cuvette at their natural branch orientation, and photosynthetic measurements were recorded when all stability criteria were met and the coefficient of variation for A and g_s combined was below 0.5%.

Soil moisture was quantified as gravimetric water content, expressed as a percentage (100 *((Fresh weight – dry weight)/dry weight)). After collecting soil samples from all 25 plots we measured the sample's wet weight and samples were re-weighed after spending on average 5 days in a drying oven at 40°C until fully dry.

Soil moisture was also monitored with Decagon Devices (Pullman, WA) soil aquameters (Model EC5) and an EM50 data logger. The Decagon soil moisture sensors are connected to the logger with one in an IDE control plot (IC) and the other in an IDE sheltered plot (IS). The Decagon EM50 logger records the soil moisture in the control plot while recording the soil moisture and temperature in the sheltered plot every 30 minutes.

Soil moisture was measured using a TDR soil moisture meter (TDR 100, FieldScout) at Younger Lagoon UC Natural Reserve as well. Four measurements were recorded, in each plot; one on each side corresponding to the cardinal direction. The metal probes of the TDR meter were pushed into the soil until completely submerged and the plastic meter was level with the soil surface. The soil moisture measurement was then determined from the reading displayed on the TDR meter's screen after pressing the "read" button. Measurements were recorded for every plot.

Among the 25 plots, *R. sativus* and *A. barbata*, and *Bromus diandrus* were chosen to measure stem water potential. Measurements were gathered from the IDE control and shelter plots. Leaves from *R. sativus* were cut with approximately 4 cm of stem remaining. *A. barbata* blades were cut about 10 cm in length. The stem or blade was placed into the center hole of a rubber stopper facing upward, to be viewed through the chamber cap. Nitrogen gas was applied until liquid exuded from the cut petiole or blade surface, at this moment stem water potential was recorded in MegaPascals (MPa). Leaves and stems were cut as straight and flush as possible in order to avoid uneven liquid discharge.

Statistical student's t-tests were run on all data. T-tests were run for both species and plot comparisons for photosynthesis and water potential for Raphanus and Avena but not for the other parameters. Both JMP and Microsoft Excel were used to run the statistical tests.

Results:

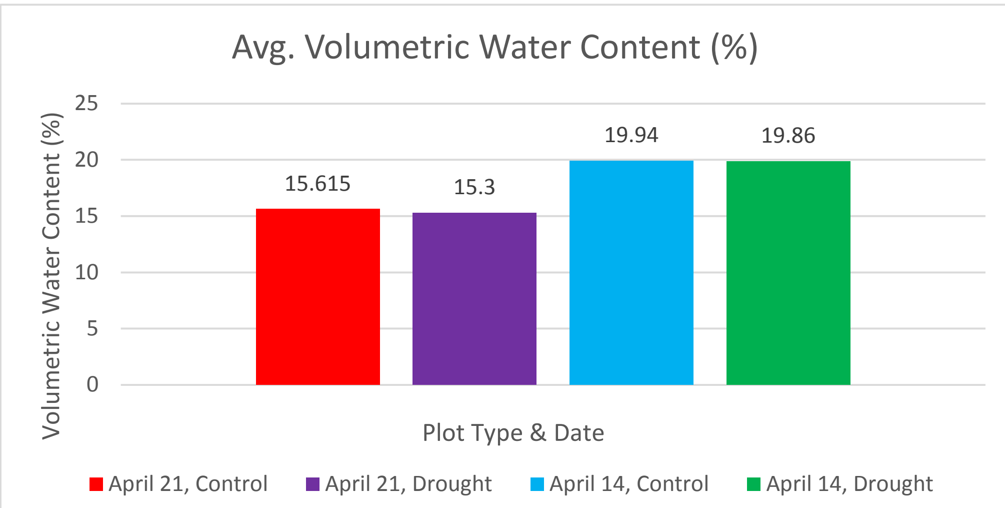


Figure 1: Shows the average volumetric water content (VWC) of the soil matrix

Soil volumetric water content (VWC) was on average slightly higher in the control plots relative to the drought pots (Fig. 2). These data were measured on two dates, April 14th and 21st. The VWC decreased from April 14th to April 21st. T-test analysis of the VWC means show that April 14th and April 21st data are not statistically different (P=0.969) and (P=0.899), have a mean of 19.94 and 15.615, and a standard deviation of 8.2 and 11.03, respectively. However the trend is still the same from

0.08% to 0.315%, although the difference is not significant statistically, it does indicate a drier soil matrix.

Water potential measurements for *A. barbata* and *R. sativus* were on average only marginally different. *Raphanus* showed increased values from sheltered drought to control plots. Values for *Avena* were the same for both control and sheltered plots. Results of the t-test indicate that there is no significant difference between the sheltered and control plots (P=0.723). However, there is a statistical difference between *Raphanus* and *Avena spp.* (P<0.001). The values were lower overall for *Avena* compared to *Raphanus*, at -2.0 MPa (both values for *Avena*), -1.1 MPa, and -1.25 MPa respectively.

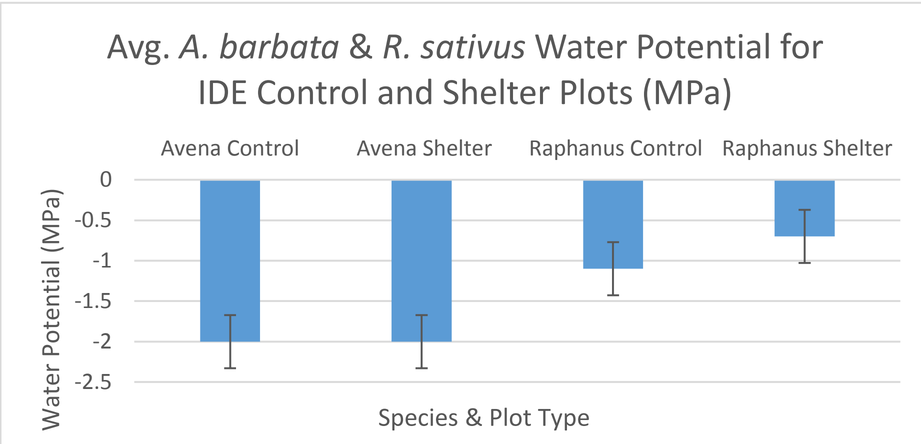


Figure 2: Shows average water potential values for *Avena barbata* and *Raphanus sativus* for drought shelter and control plots

Bromus diandrus and *R. sativus* water potential showed no statistical difference for both species between control and drought plots (P=0.154) and (P=0.364) respectively. Although the values were still higher for drought treatments than control (Fig. 4). Grass species

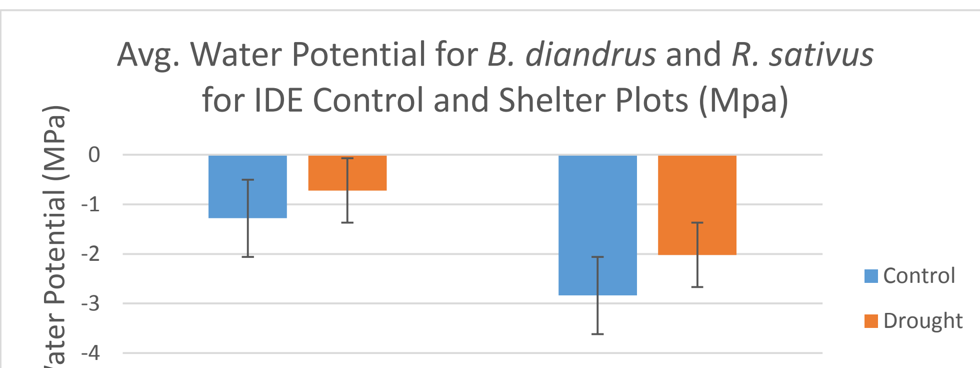


Figure 3: Shows average water potential values for *Bromus diandrus* and *Raphanus sativus* in drought sheltered and control plots

decreased by a difference of -0.82 MPa, and the forb showed a change of -0.56 MPa. A trend of wetter plants in drought sheltered plots were found in these data.

Stomatal conductance values for *Avena* between drought and control plots were highly statistically different ($P<0.01$). Whereas the *Raphanus* values were not statistically different ($P=1.07$) between drought and control plots. Although *Raphanus* values were not different statistically, they showed a larger difference than does *Avena* numerically. Drought treatments show lower stomatal conductance than do control treatments (Fig. 5).

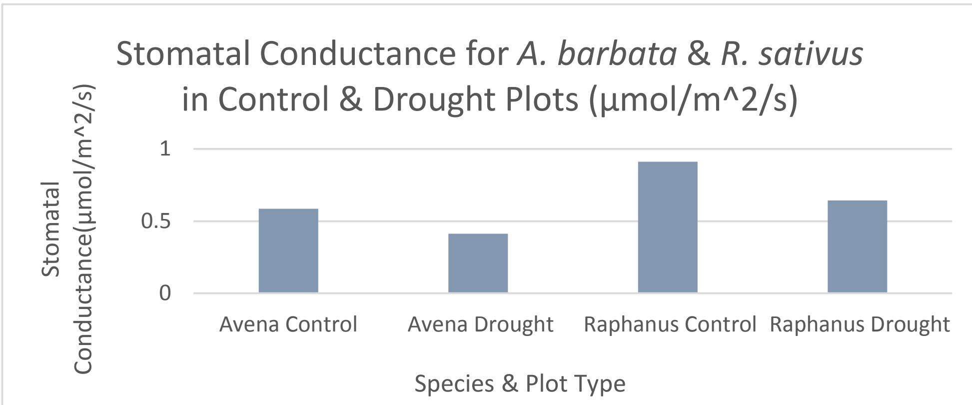


Figure 4: Shows stomatal conductance for *Avena barbata* and *Raphanus sativus* species between plot types.

Photosynthesis results for *Avena* and *Raphanus* were complex. *Avena* had increased average photosynthetic levels under the drought treatment with a mean of 21.52 $\mu mol\ m^{-2}\ s^{-1}$, whereas *Raphanus* had a slight increase from drought to control with a mean of 23.76 $\mu mol\ m^{-2}\ s^{-1}$. *Raphanus* on average decreased by 0.3 76 $\mu mol\ m^{-2}\ s^{-1}$

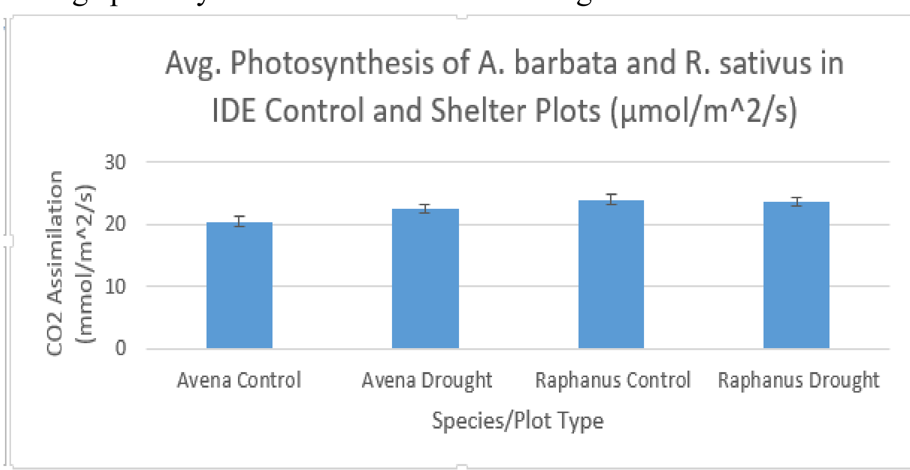


Figure 5: *Shows average photosynthetic rates of both A. barbata & R. sativus in droughted plots and full rainfall control plots.*

whereas *Avena* showed an increase of 2.1 76 μmol m^{-2} s^{-1} (Fig. 1). Standard deviation of the photosynthetic rates were 4.84 and 5.92 for *Avena* and *Raphanus* respectively. The grass species in the sheltered plot had overall higher photosynthetic rates than did control plots with full rain inputs. Conversely, the measured forb species (*R. sativus*) showed decreased levels of photosynthesis relative to full rainfall control plots. In sum, *Avena* exhibited improved growth in drought conditions, whereas the *Raphanus* experienced a slight decrease in growth. However, results of the t-test indicate that *Raphanus* and *Avena* photosynthetic rates are not statistically different (P=0.9331).

Discussion:

Drought impacts all plant functions (Larcher, 2001). While *A. barbata* actually showed signs of increased photosynthesis *R. sativus* did not. Although both species showed a decrease in stomatal conductance. Thus the results do not support the original hypothesis, but do support that drought decreases photosynthetic rates only in the forb species and not the grass species (data not shown for *B. diandrus*). According to the data, this indicates that the grass species is more drought tolerant than the forb species. This also suggests that stomatal conductance is a much more important factor for rates of photosynthesis in *Raphanus*, relative to *Avena.* Due to their wide range and abundance, both of these species while naturalized are non-native weeds by definition (Baker, 1974), which means this could have important implications for land managers and restoration efforts in California in a changing climate. California's climate is modeled to warm by 1.5°C by a conservative scenario by the end of the century (Cayan et al., 2008). If this warming trend continues, *A. barbata* may become more of a problem for land managers in the future.

Stomatal conductance is a known factor that, when restricted, can limit photosynthesis (Flexas & Medrano, 2002). Because stomata influence the gas and water exchange from plants to the atmosphere, restriction of stomatal conductance due to drought can have major effects on carbon assimilation (Flexas & Medrano, 2002). Resistance to, and improved photosynthesis under simulated drought conditions could also be due to differences in specificity of tolerance to drought and subsequent photosynthetic rates (Flexas & Medrano, 2002). For example, different populations of *A. barbata* in California were shown to have a higher water use efficiency than others due to environmentally adapted morphological and physiological traits (Somersalo et al., 1998).

Results of this study do not show any clear patterns of photosynthesis inhibition due to drought in *A. barbata* and *B. diandrus*. However, the data indicate that *R. sativus* is more susceptible than the annual grasses. Although, as total soil water decreased over time, the water potentials of *R. sativus, B. diandrus* and *A. barbata* either showed no change or increased under drought shelters. Drought stress was expected to dry out plants due to decreased soil water and thus less water available to plants. However, measurements were taken only near the soil surface, so soil water content values could be skewed due to the heterogeneity of water in the soil matrix. This heterogeneity may influence the water availability to the plants because of their root distribution and depth; hence root depth is likely an important factor in these results. This probably indicates that the drought shelters worked as intended and that VWC data are correct, but that this amount of exclusion is not enough to affect *A. barbata*, although it is hard to be certain. Under drier annual conditions, effects of drought may be more pronounced and the continuation of this study could help clarify this issue if subsequent years are notably drier.

Stomatal conductance data follows the expected trend of increased closure with increased drought stress. However, photosynthetic data indicate that *Avena* actually showed improved photosynthesis regardless of the decrease in stomatal conductance. This is not consistent with Flexas & Medrano, but may indicate that the ATP synthesis is more important for *A. barbata* than *R. sativus* photosynthesis (2002). Along with ATP synthesis, photophosphorylation, Ribulose-1-5-bisphosphate (RuBP), and rubisco activity can be responsible for the closure of the stomata under water stress (Reddy et al., 2004). Furthermore, rubisco and RuBP synthesis are a main determinate of photosynthetic rates and carbon assimilation, and drought has been shown to reduce activity of rubisco in some plants (Reddy et al, 2004). This implies that stomatal conductance is not the most important factor controlling photosynthetic carbon assimilation for *A. barbata* and *B. diandrus.* In addition, Reddy et al. state that ATP activase is responsible for keeping rubisco activity stable, and that impaired ATP activase activity is due to reduced ATP synthesis which can occur under water stress (2004). The conflicting data for increased photosynthetic rates with higher values for stomatal conductance may be better explained by adaptations preventing destruction of important plant chemicals and enzymes such as ATP reduction via drought stress.

Arbuscular mycorrhizal (AM) fungi have also been shown to increase drought tolerance in some agricultural crops due to increased nutrient and water uptake (Porcel & Lozano, 2004). Although no AM fungi data were taken, this is likely another factor influencing *A. barbata*'s higher relative resistance to water stress. Hawkes et al, have documented *A. barbata* significantly altering the AM fungi community in a California site in Mendocino County (2005). This suggests that *A. barbata* has a significant mycorrhizal association and would likely have an increased tolerance to drought. *Raphanus* then either does not benefit as much from the mycorrhizae or is not able to form the symbiotic association. This has implications in guiding the control of *R. sativus* populations as well as *A. barbata*.

Conclusions:

The response of plants to drought differs between species and severity of drought. An exotic annual grass (*Avena barbata*) was found to be relatively resistant to water stress, as it showed increased levels of carbon assimilation under 60% rainfall reduction treatments. This is not the case in an exotic forb (*Raphanus sativus*). While it did not prove to be resistant, photosynthetic assimilation was not altered significantly. Depending on the level of warming California experiences, *A. barbata* may become a problem. As an invasive exotic, these results will have implications for land management as California's climate continues to warm. With these data, the question now remains, at what drought level *does A. barbata* experience water stress?

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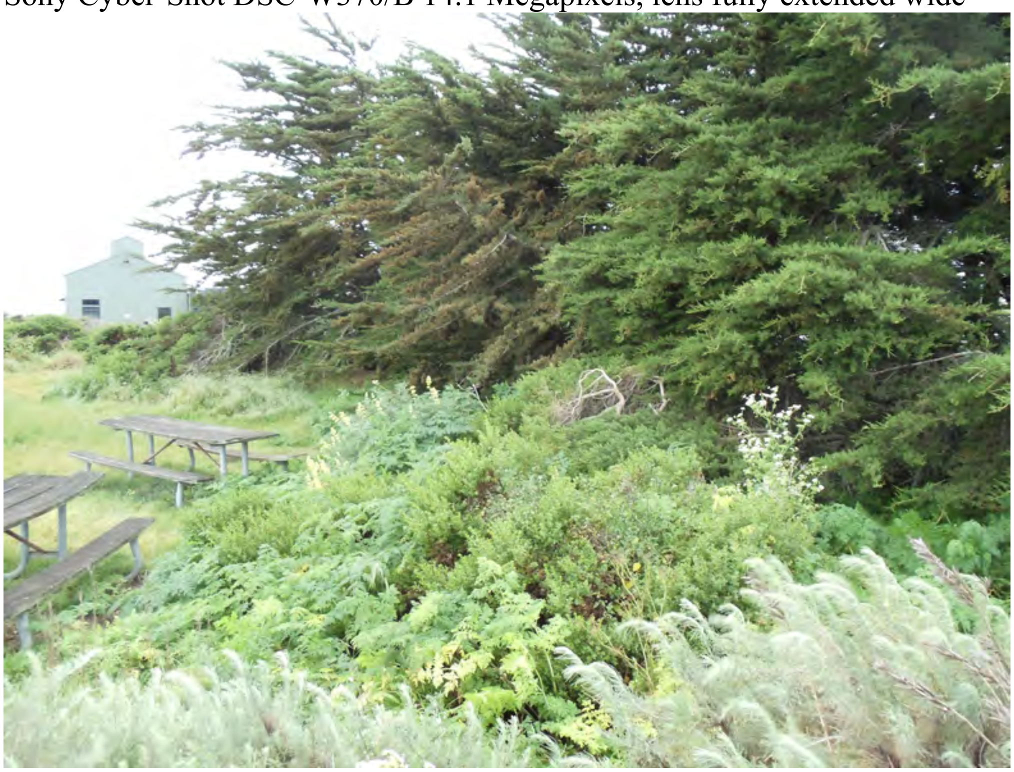

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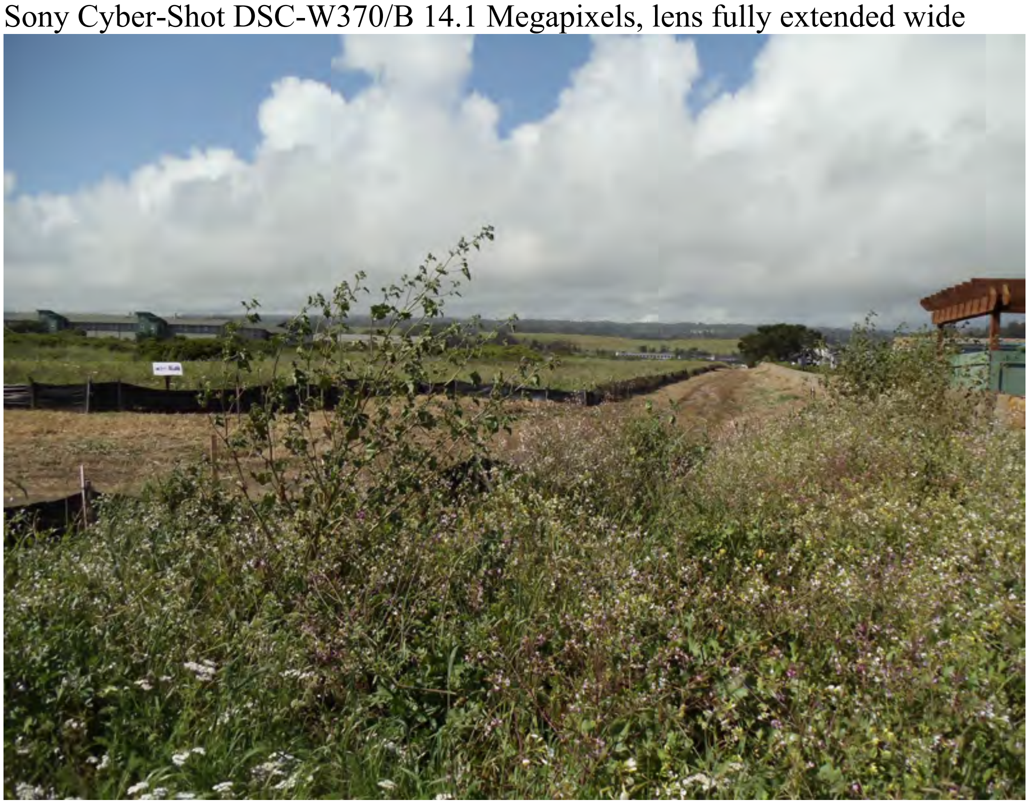

YLR Terrace Photopoint #10. April 22, 2016. Photographer: Delaney Wong. Camera: Sony Cyber-Shot DSC-W370/B 14.1 Megapixels, lens fully extended wide

Notice of Impending Development 8 16-1

A Notice of Impending Development (NOID) provides notice to the public and the California Coastal Commission of UC Santa Cruz' intention to undertake a development project at its Coastal Science Campus (CSC, formerly the Marine Science Campus). In order for a project to be implemented, it must be contemplated by and within the parameters of the Marine Science Campus Coastal Long Range Development Plan (CLRDP). The CLRDP is available at UCSC's McHenry Library, the Santa Cruz Public Library and at: http://lrdp.ucsc.edu/

The California Coastal Commission will review the project that is the subject of this NOID and determine if it is consistent with the CLRDP. The California Coastal Commission will provide advanced public notice of the date of the hearing.

Project Summary for NOID 8 16-1
Coastal Science Campus Parking Lots and CLRDP Amendment #2

The Project is construction of a new parking lot E and reconfiguration and expansion of the existing Seymour Marine Discovery Center ("Seymour Center") parking lot at the CSC. The new parking lot E would provide 91 spaces on an approximately 1-acre site north of the Coastal Biology Building (CBB), currently under construction as part of the Marine Science Campus Projects (MSC Projects). The site is now being used as a contractor staging area in the middle terrace of the CSC. The Seymour Center parking lot, which is located near the southern end of the campus (in the lower terrace), currently provides 82 parking spaces, including 10 dedicated for coastal access visitors and 40 dual-use (coastal access visitors and visitors to the Seymour Center). Under the proposed project, the lot would be reconfigured and expanded by about 16,000 square feet, to add 55 spaces. The Project also includes an amendment to the CLRDP to revise the resource buffer by 100 square feet into the lower terrace development zone.

Supporting Information, which includes more details about this project is available at: http://ppc.ucsc.edu/planning/EnvDoc.html **A hard copy is available for review at UC Santa Cruz Office of Physical Planning and Construction, 1156 High Street, Barn G, Santa Cruz, CA 95064.**

University Approval Date **7/15/16**
see CLRDP 8.1.4 (5)

NOID Posting Date **11/30/16**
see CLRDP 8.2.4

Environmental Compliance (CEQA/NEPA) Date **October 20, 2009**
see CLRDP 8.1.4 (5)

_X_ CEQA Marine Science Campus Projects EIR, Addendum #1
CEQA document

__ NEPA ______________________
NEPA document

UC Santa Cruz Project Manager

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Coastal Commission Contact

Name Ryan Moroney
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Supporting Information

see CLRDP 8.2.5

Table of Contents

1. Project Report

1a. NOID 8 16-1 Project Description

The campus is proposing a project to include construction of a new parking lot E and reconfiguration and expansion of the existing Seymour Marine Discovery Center ("Seymour Center") parking lot. The new parking lot E would provide 91 spaces on an approximately 1-acre site north of the Coastal Biology Building (CBB), currently under construction as part of the Marine Science Campus Projects (MSC Projects). The site is now being used as a contractor staging area in the middle terrace of the Coastal Science Campus (formerly the Marine Science Campus). The Seymour Center parking lot, which is located near the southern end of the campus (in the lower terrace), currently provides 82 parking spaces, including 10 dedicated for coastal access visitors and 40 dual-use (coastal access visitors and visitors to the Seymour Center). Under the proposed project, the lot would be reconfigured and expanded by about 16,000 sf, to add 55 spaces. The modifications to the Seymour Center lot would also improve storm water management and ADA access.

Multiple "spot surveys" conducted during Summer and Fall 2016 (while construction was underway) found between 170 and 175 non-construction vehicles parked in the 184 available parking spaces (equivalent to 92% - 95% utilization). An additional 70-90 non-construction vehicles were parked on primarily near the NOAA facility (Middle Terrace) but also near the existing Ocean Health building and Seymour Center facilities (Lower Terrace). Thus, the current total number of vehicles parked ranged between 240 and 265 — equivalent to 120% to 133% utilization of the existing formal parking capacity.

Construction of Lots C and D, currently under construction as part of the Marine Science Campus Projects (MSC Projects), in early 2017, prior to the CBB opening, will provide an additional 115 parking spaces in the Middle Terrace (including 5 dedicated coastal access visitor spaces), temporarily accommodating the current parking demand. However, Lots C and D were designed to accommodate CBB's estimated parking demand of between 106 and 164 vehicle) upon project completion in September 2017. At that time, total parking demand would range between 346 and 429 vehicles, equivalent to 110% and 137% utilization—both in excess of the 90% threshold identified in CLRDP Implementation Measure 5.4.1

The two proposed projects are intended to accommodate increased campus visitation and peak parking demand associated with occasional conferences, workshops, and special events occurring at NOAA, CBB, existing Ocean Health building, etc. Both projects further support Implementation Measure 5.3.7 by providing additional peak parking capacity on-site.

The proposed construction of Lot E would provide 91 parking spaces for use during peak parking demand periods associated with events occurring at NOAA and CBB. For example, scientific workshop and conferences hosted by NOAA typically occur on weekdays 1-2 times per month and attract 50-80 attendees—most of who are arriving by car. Similar events are understood to occur on an occasional basis at the other facilities located on the Middle and Lower Terraces, and could also be accommodated by Lot E parking. The regular availability of Lot E to accommodate occasional peak parking demands will further Implementation Measure 5.3.7 "to ensure that parking demand associated with CLRDP development does not impact public parking or coastal access on streets adjacent to the MSC, including Delaware Avenue."

Parking lot E

The proposed parking lot E would be located in the Middle Terrace development zone as defined in the CLRDP. Before the site was cleared to create a staging area for construction of the MSC Projects in May 2015, the site was undeveloped. The site was prepared for use as a construction staging/laydown area, by removing brush and laying down 8 inches of drain rock over filter fabric.

As analyzed in the MSC Projects EIR, after construction of the MSC Projects is completed, the gravel and filter fabric would be removed, the ground surface scarified to alleviate compaction resulting from construction use, and the area hydroseeded in a sterilized annual grass cover crop, such as barley, that does not have the capacity to reseed and therefore could not spread into adjacent areas. The project proposes to develop a new parking lot in place of the restoration.

The new parking lot E would cover an area of approximately 32,000 sf and provide 91 parking spaces. The parking lot would be surfaced with TrueGrid permeable pavers over crushed aggregate. Access to the lot from McAllister Way would be off of the driveway north of the new CBB facility. A 30 - 60-inch-high earthen berm would be constructed along the western edge of the lot and a portion of the northern edge to provide visual screening from McAllister Way. A pay station would be installed near the entrance to the lot. A new trench drain would be installed across the driveway to maintain the connectivity of an existing drainage swale along the southern edge of the site. A pedestrian path leading off the southeast corner of the new parking lot E would connect to the paved pathway at the northeast corner of CBB. Another pathway at the southwest corner of the lot would connect to the sidewalk along McAllister Way.

Seymour Center Parking Lot Expansion

The Seymour Center parking lot is located in the Lower Terrace development zone. The lot covers an area of 0.9 acres and provides 82 parking spaces (10 dedicated for coastal visitors and 40 duel use for visitors and coastal access visitors). The existing lot is bounded by McAllister Way on the west, the Seymour Marine Discovery Center building on the south, and a 3-foot-high landscaped berm on the north and east. A recently improved trail providing access to overlooks toward the wetland to the east runs roughly parallel to the berm, 45 to 90 feet from the edge of the existing lot.

The Project would expand the existing Seymour Center parking lot by approximately 16,000 sf and reconfigure it to add 55 additional spaces. The entrance to the parking lot would be moved to the north, to align with the entrance to the Center for Ocean Health parking lot on the other side of McAllister Way. The parking spaces would be surfaced with TrueGrid permeable pavers over crushed aggregate. In the existing drive aisles, most of the existing road section would be retained and the top lift of asphalt would be replaced or an overlay of asphalt added. The existing berm would be reconstructed in the remaining available space between the parking lot and the trail. Grading for the Project would result in a net excess of 1,400 cubic yards of soil. Three ADA-compliant accessible parking spaces would be included in the southeast corner of the lot. A new path would provide barrier-free access from these spaces to Overlook A. New, high-efficiency LED lighting would be provided. The project would not change the number of visitor and public coastal access parking spaces.

CLRDP Amendment #2

As required by the CLRDP for all new development (Implementation Measure 3.3.1), in August 2016, the Campus conducted a reverification of the CCC wetland boundary the portion of Wetland W5 adjacent to the proposed Seymour Marine Discovery Center parking lot expansion area (Huffman-Broadway Group, 2016, attached in Section 5). No variations in wetland soil and hydrology indicators were found along the previously delineated 2011 CCC wetland boundary or in the previously identified adjacent upland areas. However, changes were found in the perimeter of the previously mapped colonies of the obligate wetland plant false willow (Baccharis douglasii). These changes included both areas where false willow extended into previously mapped adjacent upland / non-jurisdictional areas and areas where the colonial expansion of false willow observed in 2011 had reversed.

The wetland verification technical report includes a 2016 CCC wetland boundary and wetland buffer boundary. The proposed development does not extend into the 2016 wetland buffer.

As required by the CLRDP, the University is proposing to amend the CLRDP to reflect the newly identified wetlands and wetland buffers and to revise a wetland buffer area (approximately 100 square feet) into the Lower Terrace Development Zone. The revised wetland buffer boundary does not affect any development subareas.

1b. CLRDP Consistency Determination

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

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

CHAPTER 5 Long Range Land Use Development Plan

5.1 Application of the Long Range Land Use Development Plan

Policy 1.1 Development Consistency

The University finds the project contemplated under NOID 8 16-1 to be consistent with the CLRDP.

IM 1.1.1 Figures of Chapter 5.

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

~~IM 1.1.2 Lease Agreements.~~

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

Policy 1.2 University Commitments

The University commitments identified in the CLRDP have been undertaken.

5.2. Land Use

~~Figure 5.1 Building Program~~

Figure 5.2 Land Use Diagram–Project is consistent: parking lots may be constructed anywhere in the Development Zones

Figure 5.3 Locational Restrictions for Building Program:–*no locational restrictions for parking.*

Policy 2.1 Maintaining a Stable Urban / Rural Boundary

~~IM 2.1.1 Over sizing of Utility Lines Prohibited.~~

~~IM 2.1.2 Utility Prohibition Zone.~~

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

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

Policy 2.3 Designing for the Urban Edge

IM 2.3.1 Cluster Development.: New parking would be adjacent to existing development.

IM 2.3.2 Impervious Coverage: After the project completion, at least 30% of lower and middle terrace is pervious.

~~IM 2.3.3 Windbreak Vegetation~~

IM 2.3.4 Buildout Planning.: Parking consistent with CLRDP

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

Short-term and Caretaker Accommodations

Policy 2.4 Short-term and Caretaker Accommodations

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

~~IM 2.4.2 Caretaker Accommodations.~~

~~IM 2.4.3 Use Conversion.~~

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

Policy 2.5 Ensuring Appropriate Land Uses on the Marine Science Campus

5.3 Natural Resource Protection

Policy 3.1 Protection of the Marine Environment

~~IM 3.1.1 Seawater System.~~

IM 3.1.2 Discharge of Drainage/Storm water: Storm water drainage systems consistent with drainage and grading master plan.

Policy 3.2 Protection and Restoration of Habitat Areas

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

~~IM 3.2.2 Management of Terrace Wetlands.~~

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

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

~~IM 3.2.5 Protect Habitat Areas From Human Intrusion.~~
~~IM 3.2.6 Natural Area Management.~~
IM 3.2.7 Management of Water Quality and Drainage Features:-Storm water drainage systems consistent with drainage and grading master plan.
~~IM 3.2.8 Maintenance and Monitoring of Terrace Habitats.~~
IM 3.2.9 Wetland Buffers:-Wetlands and wetland buffers were redefined in August 2016 and the revised boundaries will be incorporated into the CLRDP. Projects are outside the buffers.
~~IM 3.2.10 Natural Areas Habitat Management.~~
IM 3.2.11 CRLF Protection: CRLF surveys included in project.
IM 3.2.12 USFWS Consultation Required: USFWS consultation by ACOE for project permit.
~~IM 3.2.13 Rodenticides.~~
~~IM 3.2.14 Non-Invasive Native Plant Species Required.~~
Policy 3.3 Use and Protection of Coastal Waters and Wetlands
IM 3.3.1 Pre-development Evaluation of Wetland Conditions. A reverification of the CCC wetland boundary at the portion of Wetland W5 adjacent to the proposed Seymour Marine Discovery Center parking lot expansion area was performed in August 2016.
IM 3.3.2 Update CLRDP With Respect to Wetlands:-Proposed CLRDP Amendment #2 would update the CLRDP with respect to the wetland and wetland buffer boundaries identified through the August 2016 verification.
Policy 3.4 Protection of Environmentally Sensitive Areas (ESHAs)
~~IM 3.4.1 Additional Measures to Protect Habitat Areas.~~
IM 3.4.2 Noise Intrusion into Terrace ESHA:-Parking lot sites are not within 100 feet of ESHA.
IM 3.4.3 Noise Intrusion into YLR (original YLR):-Additional parking would not create additional noise at original YLR.
~~IM 3.4.4 Pre-development Evaluation of ESHA Conditions.~~
~~IM 3.4.5 Update CLRDP With Respect to ESHA.~~
Younger Lagoon Reserve
Policy 3.5 Special Protection for the Original Younger Lagoon Reserve
~~IM 3.5.1 Protection and Enhancement of YLR Habitats.~~
~~IM 3.5.2 Protection of Special Status Species in YLR.~~
~~IM 3.5.3 Protection of YLR Resources.~~
IM 3.5.4 Development of Monitoring and Maintenance Program: New storm water drainage systems will be included in the monitoring and maintenance program.
~~IM 3.5.5 Siting of Windbreak Vegetation.~~
IM 3.5.6 YLR Manager Consultation.
The Administrative Director of the UCSC Natural Reserves and the Manager of the Younger Lagoon Natural Reserve have reviewed the scope of the Project (NOID 8 16-1) and concur the Project would not result in impacts to the Reserve.

________________________________ __________
Gage Dayton, Administrative Director, UCSC Natural Reserves Date

IM 3.5.7 Movement Not Visible From YLR (Original YLR). (known post-CLRDP approval as YLNR): Activity within the new Parking Lot E and the expanded Seymour Center parking lot would not be visible from the original YLR, due to existing berms, vegetation, and buildings.
~~IM 3.5.8 Protective Measures for YLR (Original YLR) in Middle Terrace.~~
Policy 3.6 Public Access to and within YLR (Original YLR)
~~IM 3.6.1 Provision of Controlled Access within YLR (Original YLR).~~
~~IM 3.6.2 Visual Access to YLR (Original YLR).~~
~~IM 3.6.3 Public Beach Access within YLR (Original YLR).~~
Coastal Bluffs and Blufftops
Policy 3.7 Protection of Coastal Bluff and Bluff top Areas
~~IM 3.7.1 Bluff Setbacks.~~
~~IM 3.7.2 Coastal Bluff and Bluff top Area Protection and Enhancement Measures.~~
~~IM 3.7.3 Protecting Existing Development from Coastal Erosion.~~
Agricultural Resources
Policy 3.8 Protection of Adjacent Agricultural Resources
~~IM 3.8.1 Cooperation.~~
~~IM 3.8.2 Agreement to Indemnify and Hold Harmless.~~
Cultural Resources
Policy 3.9 Conservation of Cultural Resources
IM 3.9.1 Construction Monitoring: Included in the construction contract documents.
Hazardous Materials Management
Policy 3.10 Hazardous Materials Management
~~IM 3.10.1 Hazardous Materials Management.~~

~~IM 3.10.2 Protective Measures for Laydown Yard.~~

Air Quality and Energy Consumption

Policy 3.11 Energy Efficiency in New Construction

IM 3.11.1 Energy Efficiency in New Construction: Parking lot lighting will be provided only as needed for safety and will consist of high-efficiency LED luminaires.

~~IM 3.11.2 Energy Efficiency in Use.~~

Policy 3.12 Air Quality and Energy Conservation through Land Use and Transportation Controls

~~IM 3.12.1 Air Quality and Energy Conservation through On-Campus Short-Term Accommodations.~~

~~IM 3.12.2 Air Quality and Energy Conservation through Controlling Travel Mode Split.~~

~~IM 3.12.3 Air Quality and Energy Conservation through Parking Control.~~

~~IM 3.12.4 Air Quality and Energy Conservation through Alternative Transportation.~~

~~IM 3.12.5 Air Quality and Energy Conservation through Transportation Demand Management.~~

Natural Resource Protection Analysis

Policy 3.13 Natural Resource Protection Analysis Required

Consistency of the proposed additional parking lot construction with the natural resource protection provisions of the CLRDP is analyzed in Addendum #1, under *Biological Resources* and *Hydrology and Water Quality*.

Policy 3.14 Permanent Protection

~~IM 3.14.1 Natural Areas Protection.~~

5.4. Scenic and Visual Qualities

~~Figure 5.4 Development Subareas~~

Policy 4.1 Protection of Scenic Views

IM 4.1.1 Location of Development: Consistent with CLRDP

Policy 4.2 Protection of Scenic Quality

IM 4.2.1 Design Standards and Illustrative Campus Build out Site Plan: Consistent with CLRDP.

IM 4.2.2 Alteration of Natural Landforms: Consistent with CLRDP and sited on level land.

~~IM 4.2.3 Building and Other Structure Heights.~~

~~IM 4.2.4 Laboratory Buildings.~~

~~IM 4.2.5 Maximum Building Gross Square Footage.~~

~~IM 4.2.6 Maximum Additional Gross Square Footage in Lower Terrace.~~

~~IM 4.2.7 Construction Materials.~~

~~IM 4.2.8 Building Setbacks.~~

~~IM 4.2.9 Building Length Limitations.~~

IM 4.2.10 Placement of Utility Lines Underground: All proposed utility lines would be underground.

~~IM 4.2.11 Windbreak Vegetation.~~

~~IM 4.2.12 Development in Northernmost Portion of Middle Terrace.~~

~~IM 4.2.13 Development Along Edge of Lower Terrace.~~

~~IM 4.2.14 Building Development West of McAllister Way in Lower Terrace.~~

~~IM 4.2.15 Building Development West of McAllister Way in Middle Terrace.~~

~~IM 4.2.16 Building Development Outside of Subareas Prohibited.~~

Policy 4.3 Visual Intrusion and Lighting

IM 4.3.1 Visual Intrusion into YLR (Original YLR): Existing berms and buildings would screen the new parking lot activity and lighting so that they would not be visible from within the original YLR.

IM 4.3.2 Visual Intrusion into YLR (TerraceLands): The proposed parking lot development would include shielded lighting, non-reflective surfaces, and screening with vegetation and earthen berms.

IM 4.3.3 All Lighting: Lighting would be provided only as necessary for safety and navigation.

~~IM 4.3.4 Building Lighting.~~

~~IM 4.3.5 Street and Trail Lighting.~~

IM 4.3.6 Parking Lot and Maintenance Yard Lighting: Lighting in the new parking lot E and the renovated Seymour Center lot would be full cut-off lighting and would pole mounted.

~~IM 4.3.7 Sign Lighting.~~

~~IM 4.3.8 Lighting Plan Required.~~

5.5. Circulation and Parking

~~Figure 5.5 Circulation and Parking Diagram~~

Auto Circulation

Policy 5.1 Vehicular Access

~~IM 5.1.1 New Circulation System.~~

~~IM 5.1.2 Improve Shaffer Road / Delaware Avenue Intersection~~

~~IM 5.1.3 Shaffer Road Improvements.~~

~~IM 5.1.4 Access for Wildlife Across Shaffer Road (Upper Wildlife Corridor).~~

~~IM 5.1.5 Access for Wildlife Across Shaffer Road (Lower Wildlife Corridor).~~

~~IM 5.1.6 Use of Former Access Road.~~

~~IM 5.1.7 Emergency Access.~~

Travel Mode Split

Policy 5.2 Travel Mode Split

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

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

Parking
Policy 5.3 Parking for Campus Use and Public Coastal Access
~~IM 5.3.1 All Campus Users Off-Hour Parking.~~
IM 5.3.2 Public Coastal Access Parking: Project would not affect existing public coastal access parking.
~~IM 5.3.3 Campus Entrance Public Coastal Access Parking.~~
~~IM 5.3.4 Middle Terrace Public Coastal Access Parking.~~
~~IM 5.3.5 Lower Terrace Dual Use Parking (Public Coastal Access Parking and Discovery Center Parking).~~
~~IM 5.3.6 Lower Terrace Public Coastal Access Parking.~~
~~IM 5.3.7 Parking Demand Satisfied On-Campus.~~
~~IM 5.3.8 Free and/or Low Cost Public Coastal Access Parking.~~
Parking Supply
Policy 5.4 Parking Supply
IM 5.4.1 Development of New Parking: Project is consistent with the CLRDP.
~~IM 5.4.2 Lease Agreements~~
IM 5.4.3 Distribution and Intensity of Parking: Project is consistent with the CLRDP.
Parking Management
Policy 5.5 Parking Management
~~IM 5.5.1 Permits Required.~~
~~IM 5.5.2 Public Coastal Access Parking.~~
~~IM 5.5.3 Carpools and Vanpools.~~
~~IM 5.5.4 Parking Management Strategy for Special and/or Temporary Events.~~
~~IM 5.5.5 Entrance Kiosk.~~
~~IM 5.5.6 Parking Limitation Seaward of Whale Skeleton.~~
~~IM 5.5.7 Parking Enforcement.~~
Pedestrian and Bicycle Facilities
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~~IM 5.6.1 Sheltered and Secured Bike Parking.~~
~~IM 5.6.2 Bike Parking Outside Buildings.~~
~~IM 5.6.3 Personal Lockers and Showers.~~
~~IM 5.6.4 Coordinated Marketing with City of Santa Cruz.~~
~~IM 5.6.5 Crosswalk Design.~~
~~IM 5.6.6 Siting Buildings for Ease of Access.~~
Transit
Policy 5.7 Promotion of Transit Use
~~IM 5.7.1 Extension of Santa Cruz Municipal Transit District Transit Services.~~
~~IM 5.7.2 Expansion of Shuttle Services.~~
IM 5.7.3 Physical Infrastructure for Transit: Project would provide space for buses to turn around.
Transportation Demand Management (TDM) Coordination
Policy 5.8 TDM Coordination
~~IM 5.8.1 Carpool and Vanpool Services.~~
~~IM 5.8.2 TDM Coordination.~~
~~IM 5.8.3 Transportation Information.~~
Traffic Impacts on City Streets
Policy 5.9 Impacts Offset
Circulation and Parking Plan
Policy 5.10 Circulation and Parking Plan Required
5.6. Public Access and Recreation
~~Figure 5.6 Coastal Access and Recreation Diagram~~
Policy 6.1 Public Access to the Marine Science Campus
~~IM 6.1.1 Free Public Access for Visitors.~~
IM 6.1.2 Public Access Parking: Project would not affect existing public coastal access parking.
~~IM 6.1.3 Public Access Trails.~~
~~IM 6.1.4 Public Access Overlooks.~~
~~IM 6.1.5 Docent-Led Tours and Education Programs for the Public.~~
~~IM 6.1.6 Educational Programs for Pre-College Students.~~
~~IM 6.1.7 Interpretive Information.~~
Policy 6.2 Management of Public Areas
~~IM 6.2.1 Public Use Hours for the Marine Science Campus.~~
~~IM 6.2.2 Public Trail Continuity.~~
~~IM 6.2.3 Access to Resource Protection Areas.~~
~~IM 6.2.4 Access to Resource Protection Buffer Areas.~~
~~IM 6.2.5 Access to Coastal Bluffs.~~
~~IM 6.2.6 Access to Laboratories and Research Areas.~~
~~IM 6.2.7 Caretaker Residence and Lab Security.~~
~~IM 6.2.8 Bicycles on the Marine Science Campus.~~
~~IM 6.2.9 Domestic Pets.~~

~~IM 6.2.10 Public Access Signage.~~
~~IM 6.2.11 Off-Campus Trail Connectivity.~~
~~IM 6.2.12 Maintenance of Existing Public Access.~~
~~IM 6.2.13 Public Access to Younger Lagoon Beach.~~
Policy 6.3 Public Access and Recreation Plan Required

5.7. Hydrology and Water Quality
~~Figure 5.7 Utilities Diagram~~
Policy 7.1 Productivity and Quality of Coastal Waters
IM 7.1.1 Management of Storm water and Other Runoff: Storm water drainage systems consistent with drainage and grading master plan and the requirements of the CLRDP.
~~IM 7.1.2 Water Quality Standards.~~
~~IM 7.1.3 Pre- and Post-Development Flows.~~
~~IM 7.1.4 Pre-Development Drainage Patterns Defined.~~
~~IM 7.1.5 Pre-Development Drainage Peak Flow Rates Defined.~~
IM 7.1.6 Groundwater Recharge: The new parking lot E and the addition to the Seymour Center lot would be surfaced with a pervious pavement system.
~~IM 7.1.7 Seawater System (Seawater Containment)~~
~~IM 7.1.8 Irrigation and Use of Chemicals for Landscaping.~~
~~IM 7.1.9 Wastewater.~~
~~IM 7.1.10 Elements of the Storm water Treatment Train.~~
~~IM 7.1.11 Runoff Containment for Laydown Yard and Food Service Washdown Areas.~~
~~IM 7.1.12 Location of Treatment Train Components.~~
~~IM 7.1.13 Permeable Hardscape.~~
~~IM 7.1.14 Ocean Discharge.~~
~~IM 7.1.15 Drainage System Interpretive Signs.~~
~~IM 7.1.16 Design of Vegetated Storm water Basins.~~
~~IM 7.1.17 Designation of Treatment Train.~~
Policy 7.2 Long-Term Maintenance and Monitoring
~~IM 7.2.1 Drainage System Monitoring and Maintenance.~~
~~IM 7.2.2 Storm water System Natural Features Maintenance.~~
~~IM 7.2.3 Drainage System Sampling.~~
~~IM 7.2.4 Long-Term Maintenance of Storm water System.~~
Policy 7.3 Drainage Discharge Points
~~IM 7.3.1 Discharge to the Original Younger Lagoon Reserve.~~
~~IM 7.3.2 Discharge Siting and Design.~~
Policy 7.4 Drainage Plan Required

5.8 Utilities
Policy 8.1 Provision of Public Works Facilities
~~IM 8.1.1 Sizing of Utilities.~~
~~IM 8.1.2 Seawater System.~~
Policy 8.2 Protection of Biological Productivity and Quality of Coastal Waters When Providing Public Works Facilities
~~IM 8.2.1 Installation of New Utility Lines and Related Facilities.~~
~~IM 8.2.2 Seawater System.~~
~~IM 8.2.3 Evaluation of Western Utility Corridor.~~
Policy 8.3 Water Conservation Required
Policy 8.4 Impacts to City Water and Sewer Systems Offset
Policy 8.5 Utility Plan Required

CHAPTER 6 Design Guidelines
~~6.1 Building Design~~
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6.6 Lighting Design: Consistent with CLRDP Parking Area Lighting.
~~6.7 Signage Design~~
~~6.8 Fence / Barrier Design~~

CHAPTER 7 Illustrative Campus Buildout Site Plan and Preliminary Designs
This project will not construct any new buildings, roads or pathways and is consistent with the CLRDP

CHAPTER 8 Development Procedures

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

CHAPTER 9 Capital Improvement Program

The proposed project is consistent with the Chapter 9 requirements.

APPENDIX A Resource Management Plan

The proposed project is consistent with the Resource Management Plan

APPENDIX B Drainage Concept Plan

The proposed project would create no impervious surface and thus would not affect storm water runoff.

1c. Environmental Compliance Documentation

See Section 3

1d. Technical Reports

See Section 5

1e. Consultation Documentation with other Agencies

Not required for this NOID.

1f. Implementing Mechanisms

See Section3 – Environmental Compliance Documentation. There are no other implementing mechanisms for the proposed project.

1g. Correspondence Received

Correspondence that has been received on the proposed project is in the final environmental document.

1h. Project Manager

Tanya Guerrera, Physical Planning and Construction, 831.459.2170

2. University Approval Documentation

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

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PHYSICAL PLANNING AND CONSTRUCTION · SANTA CRUZ, CALIFORNIA 95064

JULY 14, 2016

VICE CHANCELLOR LATHAM
Business and Administrative Services

Re: Design Approval
Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E

Dear Sarah:

Regents Delegation of Authority DA 2575 concerning approval of project design delegates to Chancellors "the authority to approve the design for projects with a total individual project cost not exceeding $10,000,000." The Chancellor re-delegated authority to the Vice Chancellor of Business and Administrative Services in February 2014 (copy enclosed). The Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E falls into this category.

Attached for your consideration and approval are the following documents:

Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E

1. Item for Action for Vice Chancellor Approval
2. Design graphics of the Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E
3. Addendum #1 to the Marine Science Campus Projects Environmental Impact Report
4. Responses to comments received on Addendum #1.
5. CEQA Findings for the Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E

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

Sincerely,

John

John Barnes, AIA
Campus Architect
Physical Planning & Construction

attachments

July 14, 2016

ACTION ITEM FOR VICE-CHANCELLOR, BUSINESS AND ADMINISTRATIVE SERVICES, APPROVAL

APPROVAL OF DESIGN FOR SEYMOUR MARINE DISCOVERY CENTER PARKING LOT EXPANSION AND NEW PARKING LOT E COASTAL SCIENCE CAMPUS

CAMPUS	Santa Cruz Coastal Science Campus
PROJECT	Seymour Marine Discovery Center Parking Lot Expansion and New Parking Lot E
PROJECT NUMBER	976550
PROPOSED ACTIONS	1. Determine that the environmental consequences of the proposed Seymour Marine Discovery Center parking lot expansion and the development of new parking lot E are adequately analyzed in the Marine Science Campus Projects Environmental Impact Report (MSC Projects EIR) as modified by Addendum #1 thereto. 2. Adopt the CEQA Findings. 3. Approval of Design.
Previous Actions:	Design of the Marine Science Campus Projects, consisting of the Coastal Biology Building Project, the MSC Parking Phase 1 Project (now known as the Coastal Science Campus [CSC] Parking Phase 1 Project), the Environmental Health and Safety Project, and the Specific Resource Plan Phase 1B, was approved by the Regents in January 2012.
Background	The approved MSC Parking Phase 1 Project includes the construction of approximately 115 automobile parking spaces in two surface parking lots adjoining McAllister Way. The MSC Parking Phase 1 Project also includes removal of approximately 48 informal spaces along McAllister Way. This parking lot construction was planned to coincide with construction of the Coastal Biology Building (CBB) project (2015-2017) and the work was bid concurrently. A Spring 2015 utilization survey of the existing parking which serves the Seymour Marine Discovery Center and the Long Marine Lab in the Lower Terrace Development Zone, estimated that the average utilization of the 185 spaces was approximately 93 percent. With the elimination of the 48 informal spaces in Spring 2016, the number of spaces has been reduced to 137, and demand exceeds supply. The MSC Projects EIR estimated that development of the CBB Building and greenhouses in the Middle Terrace Development Zone would generate demand for up to164 parking spaces. Therefore, the EIR projected that when the CBB Project is occupied in 2017, some campus affiliates will not be able to park on the Campus. The excess demand would be met by existing street parking on Delaware Avenue and Shaffer Road or at other UC-owned facilities, as allowed under the CLRDP.

PROJECT SUMMARY	
PROJECT SUMMARY	The proposed development includes the reconfiguration and expansion of the existing Seymour Marine Discovery Center parking lot and the development of a new parking lot E. The Seymour Marine Discovery Center parking lot, which is located near the southern end of the campus, currently provides 82 parking spaces. Under the proposed change order, the lot would be reconfigured and expanded by about 16,000 sf, to add 55 spaces. The entrance to the parking lot would be moved to the north, to align with the southern entrance to the Center for Ocean Health parking lot on the other side of McAllister Way. The parking spaces would be surfaced with a TrueGrid permeable paving system installed over crushed aggregate. In the existing drive aisles, most of the existing road section would be retained and the asphalt replaced. The existing berm would be reconstructed in the remaining available space between the parking lot and the trail. Three ADA-compliant accessible parking spaces would be included in the southeast corner of the lot. A new path would provide barrier-free access from these spaces to an existing wetland overlook east of the site. New, high-efficiency LED lighting would be provided. A pay station would be installed in an island at the southern end of the lot. The new parking lot E would cover an area of approximately 32,000 sf and provide 91 spaces north of the CBB, on a site which is currently being used as a construction staging area. The parking lot would be surfaced with a TrueGrid permeable paving system installed over crushed aggregate. Access to the lot from McAllister Way would be off of the driveway north of the new CBB facility. A 30-inch-high earthen berm would be constructed along the western edge of the lot and a portion of the northern edge to provide visual screening from McAllister Way. A pay station would be installed near the entrance to the lot. A new pedestrian path leading off the southeast corner of the new parking lot E would connect to a paved pathway at the northeast corner of CBB. Another pathway at the southwest corner of the lot would connect to the sidewalk along McAllister Way.
Square Footage/ Efficiency Factor	Not applicable
TOTAL CAPITAL PROJECT COST	A. The CSC Parking Phase 1 Project: $1,611,000, will cover the cost of the Seymour Marine Discovery Center parking lot expansion B. Parking Lot E: $300,000
Building Cost/OGSF Project Cost/OGSF	Not applicable
FUNDING SOURCE	CSC Parking Phase 1, including Seymour Center parking lot: $300,000 parking reserves, $1,311,000 externally financed Parking Lot E: Funding source has not been identified

CEQA COMPLIANCE	
In accordance with University procedures and the requirements of the California Environmental Quality Act (CEQA), the environmental effects of the project were analyzed as summarized below.	
Environmental Document	Addendum #1 to Marine Science Campus Projects (MSC Projects) EIR, certified by the UC Regents in January 2012
Tiered from LRDP EIR or Other Previously Certified EIR	Tiered from CLRDP EIR, certified by the UC Regents in September 2004.
Public Review Dates	June 13, 2016 – July 13, 2016
Project-Specific Impacts Reduced to Less than Significant Level with New Project Mitigation	Addendum #1 did not identify any new potentially significant impacts which were not previously analyzed in the MSC Projects EIR.
Project Impacts Adequately Addressed in Previously Certified EIR	Addendum #1 determined that all Project impacts were adequately addressed in the MSC Projects EIR.
New Significant and Unavoidable Impacts	None.
Alternatives Analyzed	Not part of Addendum, see below.
Public Comment letters	One comment letter from a member of the public. No comments from agencies or organizations.
Environmental Topic Area Issues Raised in Comments and How They were Resolved	Comment letter requested that a new EIR be prepared because significant new effects to the environment, caused by greenhouse gases, have been discovered since the EIR was approved in January 2012. This comment letter and a response are provided in Attachment 3. No changes were made to the environmental analysis in Addendum #1.
Mitigation Monitoring program	MSC Projects EIR, Chapter 9.
Final Environmental Document	See Attachments 2 and 3.
Findings	See Attachment 4.
Project level Statement of Overriding Considerations	None required.

RECOMMENDATION

The Associate Vice Chancellor, Physical Planning & Construction recommends to the Vice Chancellor, BAS, the following actions:

1. Determine that the environmental consequences of the proposed Seymour Marine Discovery Center parking lot expansion and the development of new parking lot E are adequately analyzed in the Marine Science Campus Projects Environmental Impact Report (MSC Projects EIR) as modified by Addendum #1 thereto.

2. Adopt the CEQA Findings (Attachment 4)

3. Approve the Design (Attachment 1)

APPROVED

Sarah C. Latham 7/15/2016

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

cc:
Project File 4932
AVC Barnes

ATTACHMENTS:

Attachment 1:	Design Graphics
Attachment 2:	Addendum#1 to MSC Projects EIR
Attachment 3:	Response to comment on Addendum #1
Attachment 4:	CEQA Findings
Attachment 5:	MSC Projects EIR

3. Environmental Compliance Documentation

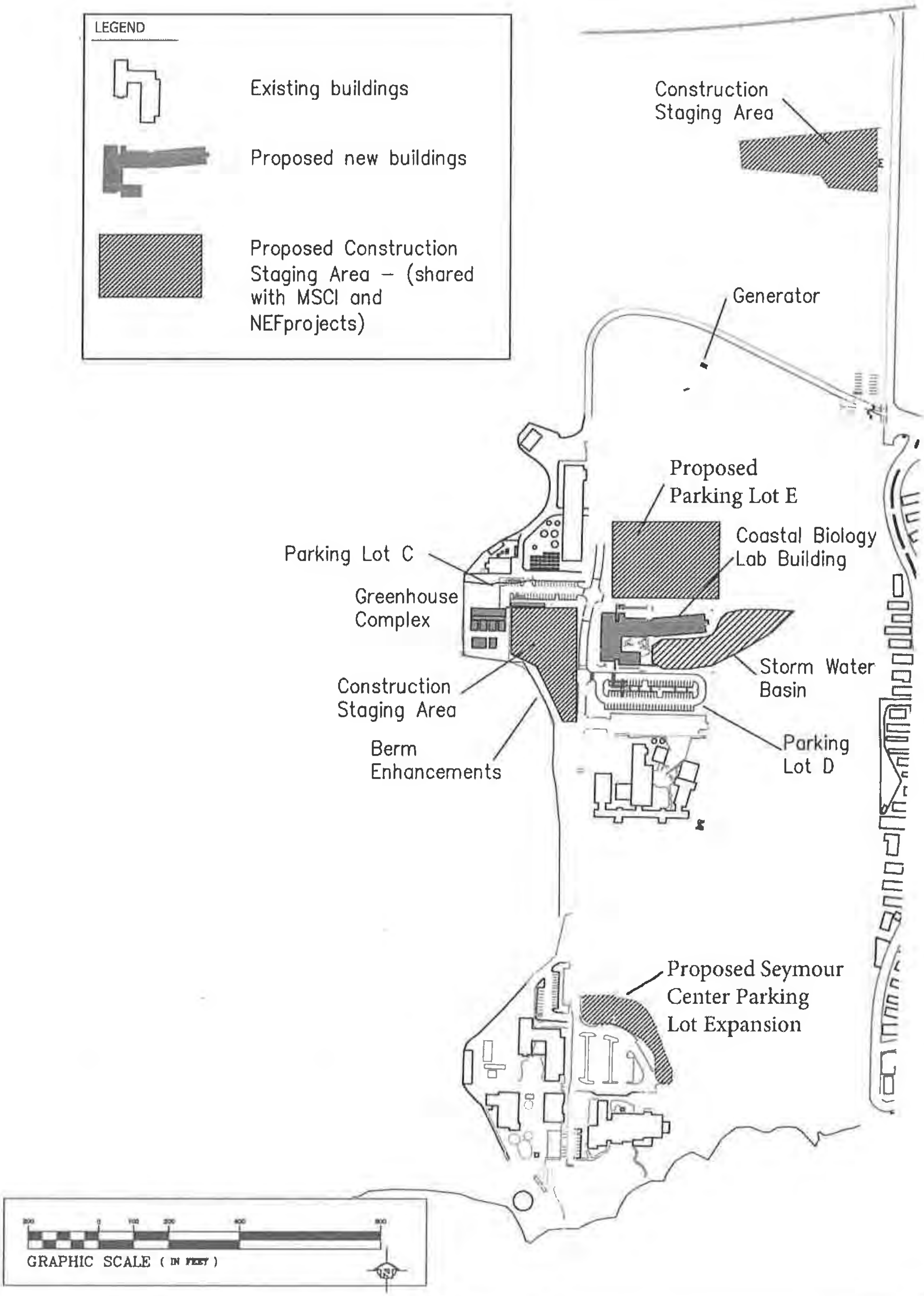
See attached: Marine Science Campus Projects Addendum #1

(http://mediafiles.ucsc.edu/ppc/envdoc/AddendumCSCparkinglots-Final_complete.pdf)

4. Plans, Specifications, etc.

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

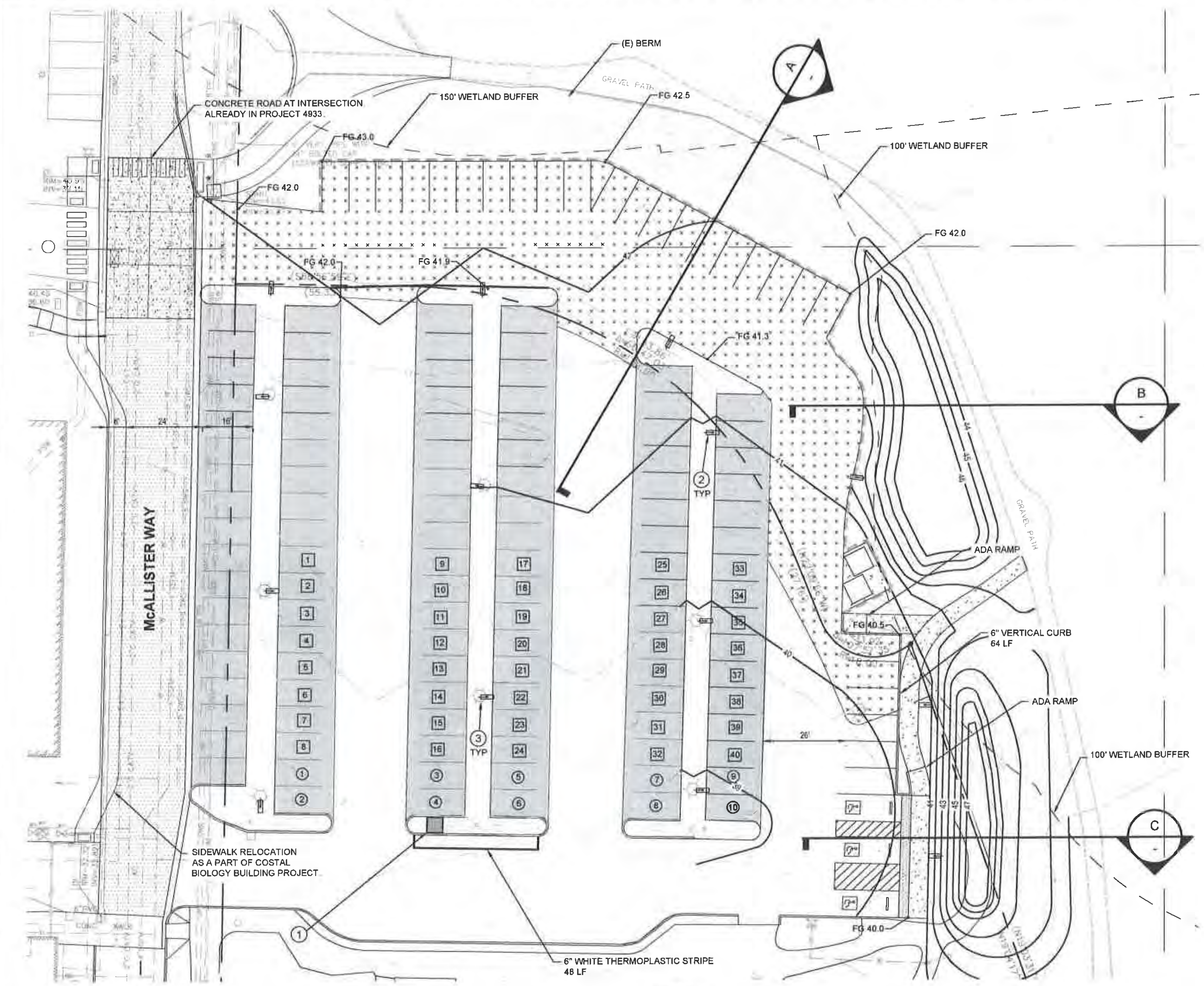
See attached:



UC Santa Cruz, Marine Science Campus Coastal Biology Building and Infrastructure Improvements Addendum #1 to MSC Projects EIR May 2016	Proposed CBB Project Elements Revised to show proposed additional parking lot construction.	Figure 2

Seymour Center Parking Lot

University of California, Santa Cruz



PLAN

SCALE: 1"=20'

LEGEND

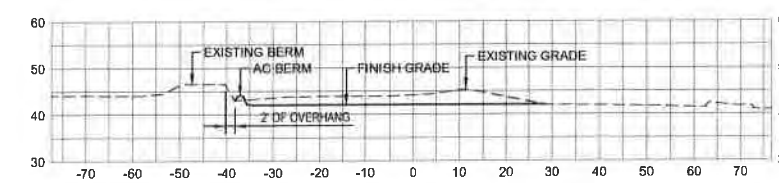
	0.25' HMA PAVEMENT OVER 0.67 CL II AB
	0.25' HMA PAVEMENT OVERLAY
	1.8" TRUEGRID, 6" CRUSHED AGGREGATE
	4" CONCRETE OVER 2" SAND
	TRUNCATED DOME DETECTABLE WARNING SURFACE
	(N) PARKING LOT LIGHT
	(E) PARKING LOT LIGHT
	6" AC DIKE
①	COASTAL VISITOR STALLS (RED SUPERSPOTS)
1	COSTAL VISITOR/CAMPUS VISITOR STALLS (YELLOW SUPERSPOTS)

SHEET NOTES

1. INSTALL PAYSTATION (LUKE II BY DIGITAL PAYMENT TECHNOLOGIES
2. NEW FIXTURE, POLE AND BASE
3. NEW FIXTURE ON (E) POLE

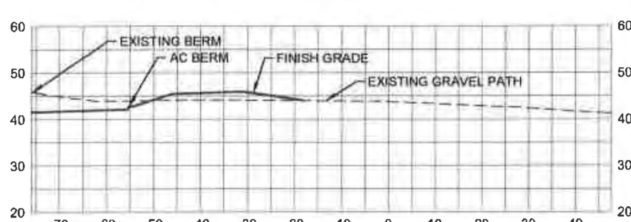
GRADING QUANTITIES

CUT	FILL	NET (EXCESS)
1900 CY	350 CY	1550 CY



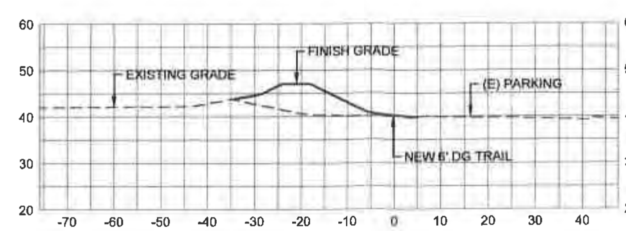
SECTION A

SCALE: 1"=20'



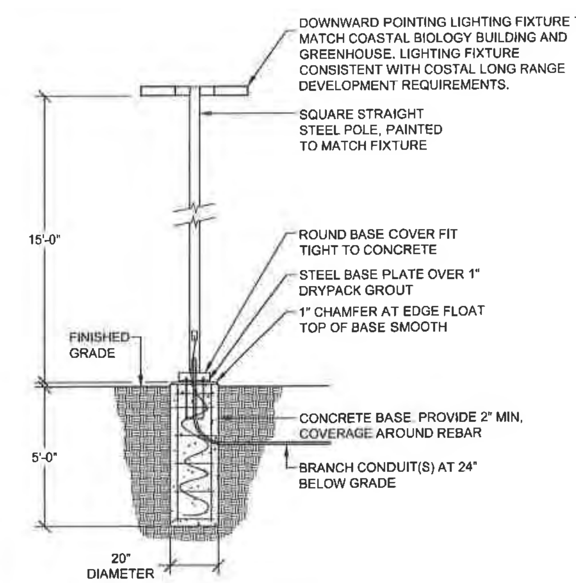
SECTION B

SCALE: 1"=20'



SECTION C

SCALE: 1"=20'



3 LIGHT POLE ELEVATION

NOT TO SCALE

SUPER SPOTS

NTS

Consultant

GHD Inc

Stamp

Printing / Date

No.	Revisions	Date

Scale

Drawn by CB

EHDD Job Number 11109127

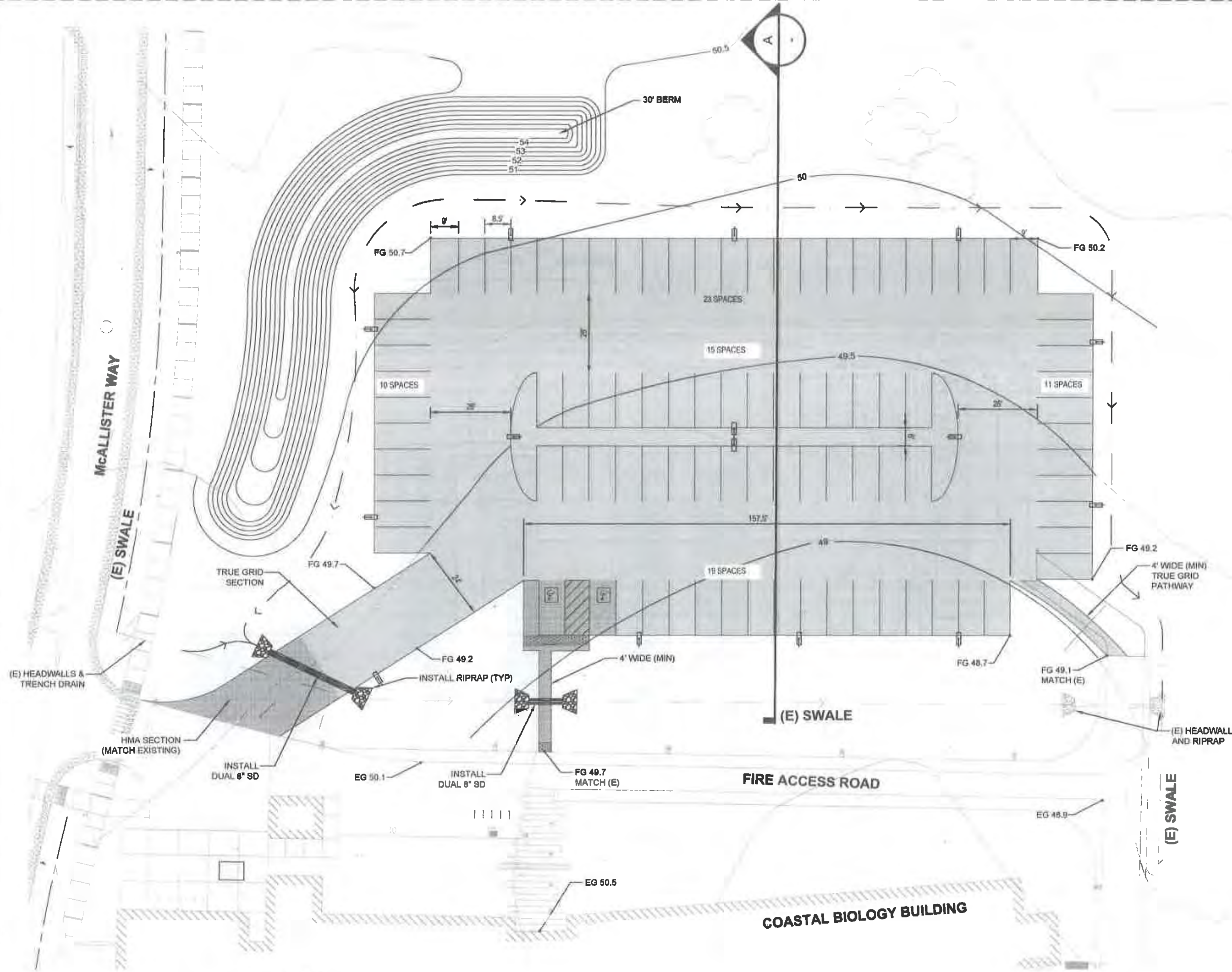
Sheet Title

CIVIL IMPROVEMENTS

INCREMENT #1

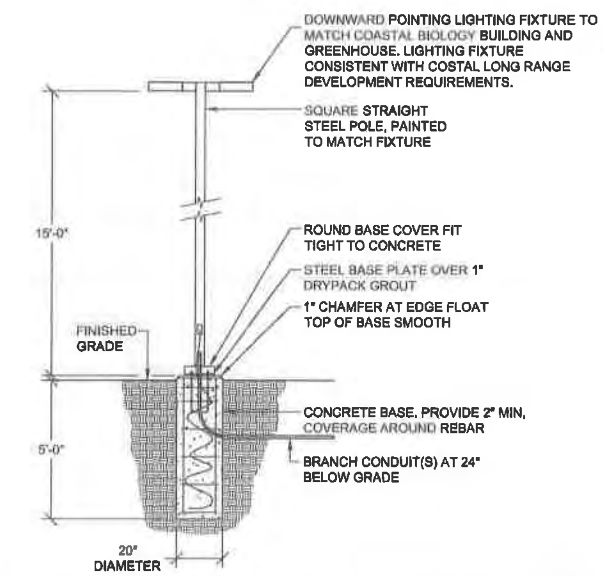
Sheet Number

1



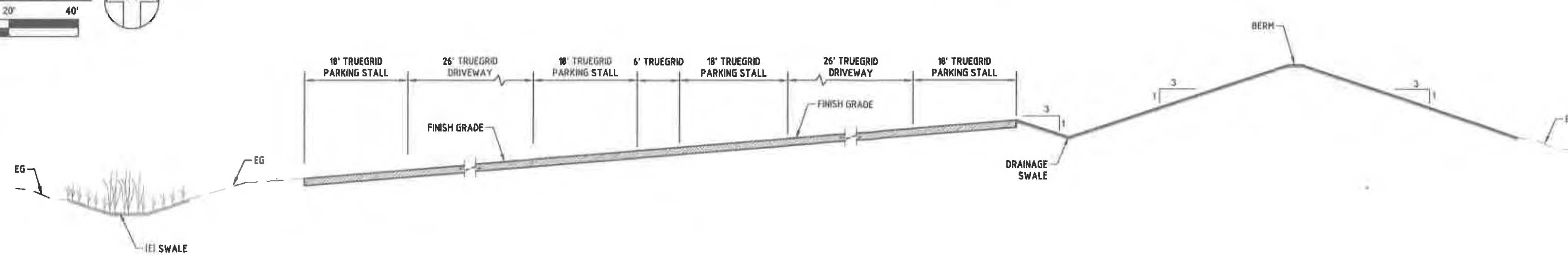
PLAN

SCALE: 1"=20' 0 20' 40'



1 **LIGHT POLE ELEVATION**

NOT TO SCALE



A **PARKING LOT E SECTION**

SCALE: NONE

LEGEND

(shaded)	1.8" TRUEGRID, 6" CRUSHED AGGREGATE
(dotted)	TRUNCATED DOME DETECTABLE WARNING SURFACE
(symbol)	(N) PARKING LOT LIGHT (1)
(shaded)	4" HMA OVER 8" CL II AB

PARKING LOT E

University of California, Santa Cruz

Consultant

GHD

GHD Inc

Stamp

Printing / Date

5.03.2015

No.	Revisions	Date

Scale

Drawn by

BM

EHDD Job Number

11109127

Sheet Title

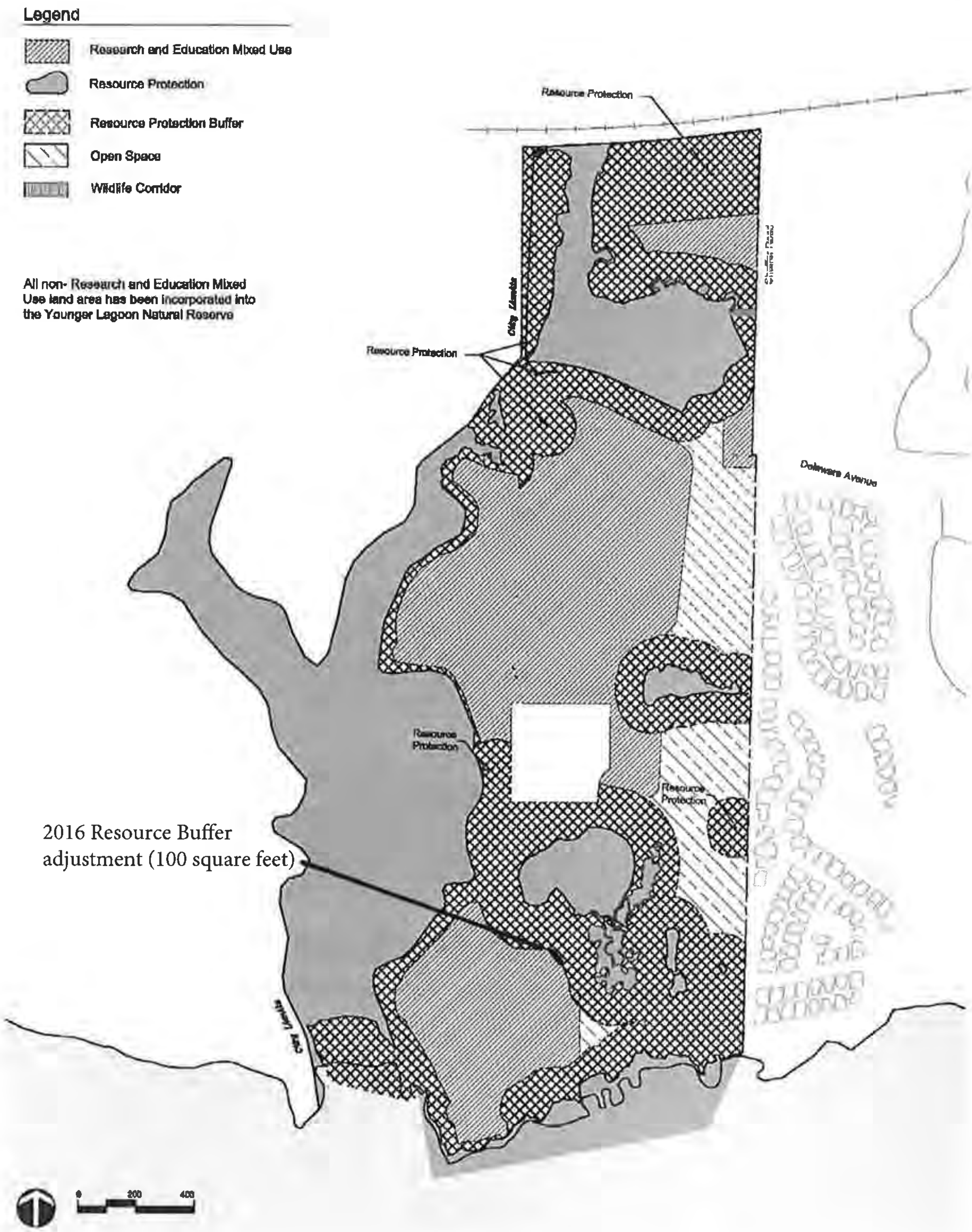
CIVIL IMPROVEMENTS

INCREMENT #1

Sheet Number

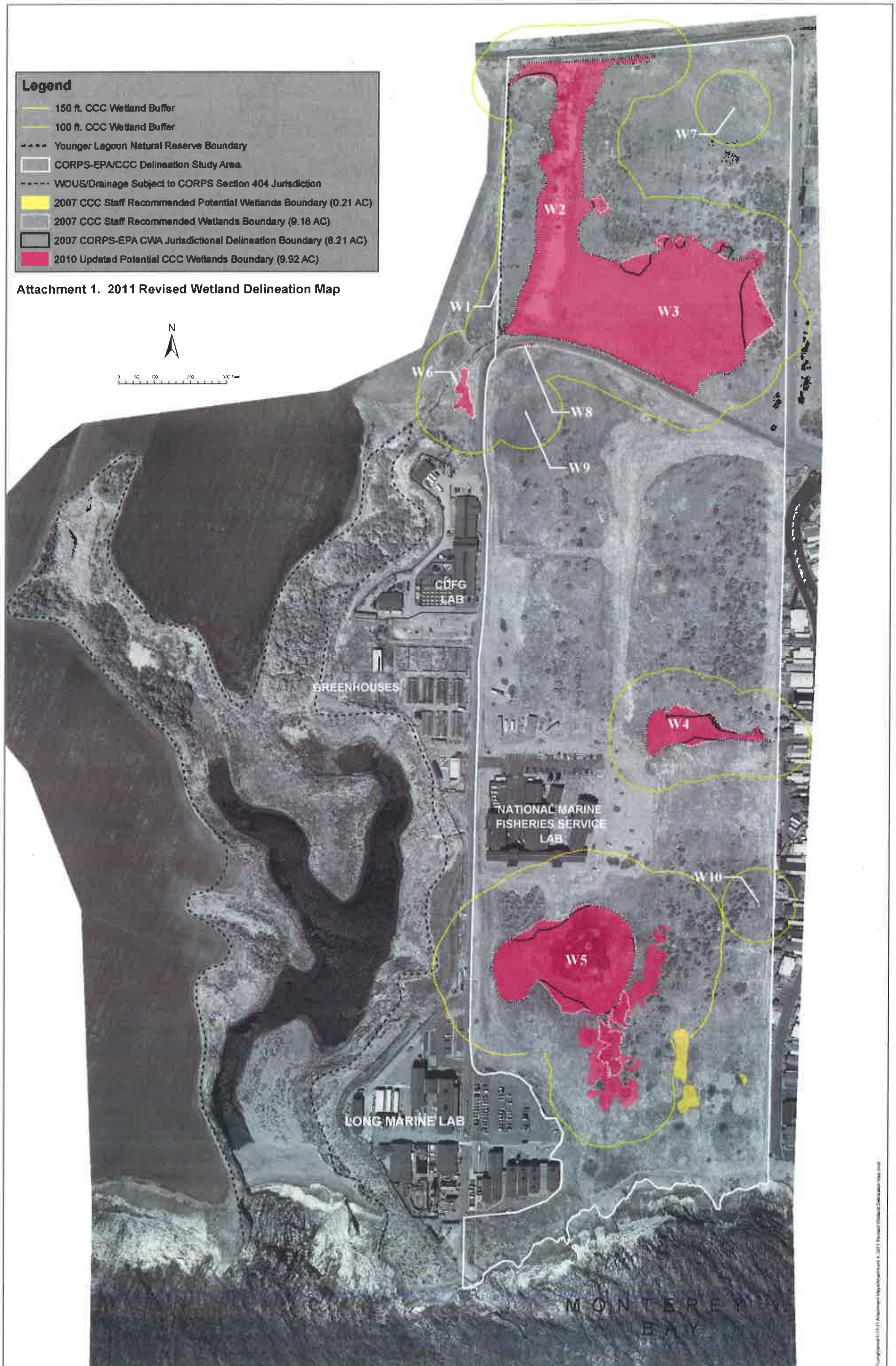
1

Fig. 5.2 Land Use Diagram (2016 verification)



5. Technical Reports

See attached:



Attachment 1. 2011 Revised Wetland Delineation Map

Attachment 2. 2016 Sample Locations

ATTACHMENT 4

WETS Precipitation Data

WETS Station Santa Cruz, CA7916
Santa Cruz, California

UC Santa Cruz, Santa Cruz County, California
Precipitation Data Summary, October 1, 2015 – September 30, 2016
and Comparison with Normal Precipitation Range, WETS Station Santa Cruz, CA7916

Month	Total precipitation (inches)	Average precipitation 1971 – 2000 (inches)	Normal precipitation range* (inches)	Within normal precipitation range for month?
October 2015	0.08	1.44	0.45 – 1.75	Below normal range
November 2015	4.42	4.08	1.30 – 4.87	Within normal range
December 2015	6.43	4.22	1.88 – 5.15	Above normal range
January 2016	11.80	6.49	2.66 – 7.89	Above normal range
February 2016	1.03	6.15	2.63 – 7.49	Below normal range
March 2016	7.65	4.78	2.13 – 5.83	Above normal range
April 2016	0.89	1.97	0.78 – 2.39	Within normal range
May 2016	0.25	0.70	0.06 – 0.74	Within normal range
June 2016	0.00	0.18	0.00 – 0.22	Within normal range
July 2016	0.01	0.14	0.00 – 0.00	Above normal range
August 2016	0.04	0.11	0.00 – 0.03	Above normal range
September 2016	0.03	0.41	0.00 – 0.44	Within normal range

* 30 percent chance precipitation will be less than the lower value or greater than the higher value.

Historical Precipitation Data, 1971 – 2000
WETS Station Santa Cruz, CA7916
Santa Cruz, California

WETS Station : SANTA CRUZ, CA7916 Creation Date: 10/03/2016
Latitude: 3659 Longitude: 12159 Elevation: 00130
State FIPS/County(FIPS): 06087 County Name: Santa Cruz
Start yr. - 1971 End yr. - 2000

Month	Temperature (Degrees F.) avg daily max	avg daily min	avg	Precipitation (Inches) avg	30% chance will have less than	more than	avg # of days w/.1 or more	avg total snow fall
January	61.0	40.2	50.6	6.49	2.66	7.89	8	0.0
February	62.9	42.3	52.6	6.15	2.63	7.49	8	0.0
March	64.6	43.3	54.0	4.78	2.13	5.83	8	0.0
April	68.8	44.4	56.6	1.97	0.78	2.39	4	0.0
May	71.0	47.2	59.1	0.70	0.06	0.74	2	0.0
June	74.0	50.4	62.2	0.18	0.00	0.22	1	0.0
July	74.8	52.6	63.7	0.14	0.00	0.00	0	0.0
August	75.5	53.0	64.3	0.11	0.00	0.03	0	0.0
September	75.6	52.1	63.9	0.41	0.00	0.44	1	0.0
October	72.5	48.3	60.4	1.44	0.45	1.75	2	0.0
November	65.3	43.4	54.4	4.08	1.30	4.87	6	0.0
December	60.8	39.6	50.2	4.22	1.88	5.15	6	0.0
Annual	-----	-----	-----	------	23.78	35.54	--	----
Average	68.9	46.4	57.7	------	------	------	--	----
Average	-----	-----	-----	30.67	------	------	45	0.0

GROWING SEASON DATES

Probability	Temperature 24 F or higher	28 F or higher	32 F or higher
	Beginning and Ending Dates Growing Season Length		
50 percent *			
70 percent *			

* Percent chance of the growing season occurring between the Beginning and Ending dates.

total 1893-2016 prcp

Station : CA7916, SANTA CRUZ
------- Unit = inches

yr	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	annl
93	5.30	4.25	M9.95	1.65	0.36	0.00	0.00		0.25	0.75	4.40	3.50	30.41
94	7.02	M8.60	M2.09	0.66	2.36	0.72	M0.01	M0.00	2.77	M3.39	M0.40	M13.44	41.46
95	9.11	M4.07	M3.08	2.02	1.15				0.18	0.49	1.89	2.15	24.14
96	8.52	0.25	3.69	3.07	1.66	0.00	0.05	0.73	0.35	1.88	6.79	4.87	31.86
97	3.72	4.96	4.86	0.22	0.24	M0.10		M0.00	0.17	1.49	M0.55		16.31
98	2.17	2.67	1.39	0.52	1.35	0.06		0.00	2.21	0.40	0.86	2.24	13.87
99	7.27	0.45	9.31	1.21	0.95	0.14	0.00	0.05	0.00	7.05	3.70	4.42	34.55
0	5.49	0.99	3.58	2.21	0.94	0.00	0.00	0.00	M0.06	2.11	7.87	2.48	25.73
1	4.30	5.91	0.94	2.01	0.52	0.00	0.00	0.00	0.64	0.88	3.28	1.80	20.28
2	2.31	14.74	3.23	1.83	0.64	0.00	0.00	0.00	0.00	2.10	2.74	2.23	29.82
3	6.25	2.07	11.06	0.25	0.00	0.00		0.00	0.00		8.59		28.22
4	1.85	M5.55	8.35	3.14	0.02	0.00	0.00	M0.50	4.70	3.63	2.37	2.11	32.22
5	6.95	4.65	5.15		3.47	M0.15	0.02	0.00	0.00	0.00	M2.50	2.09	24.98
6	4.93	7.70	8.69	1.50	M3.85	0.98	0.00		0.30	0.00	2.30	M8.03	38.28
7	8.22	4.10	10.85	0.10	0.35	1.10	0.00	M0.00	0.40	3.00	0.00	5.50	33.62
8	6.55	4.85	2.35	M0.40	0.42	0.00		0.00	0.25	1.41	2.04	3.95	22.22
9	19.90	9.35	M4.60	0.03	0.00	0.10	0.00	0.00	1.47	1.80	1.77	11.39	50.41
10	M6.50		6.50	0.50	0.00	0.05	0.00	0.00	0.04	1.21	0.70	1.80	17.30
11	16.03	5.63	5.71	1.63	0.50	0.25	0.00			0.85	1.10	M3.41	35.11
12	M5.06	0.61	4.65	2.17	1.86	0.45	0.00	0.00	0.73	0.77	1.82	1.13	19.25
13	5.57	0.37	2.05	0.58	0.82	0.25	0.35	M0.04	0.00	0.00	5.78	9.23	25.04
14	M9.79	M5.74	1.03	M2.27	0.25	0.65	0.10	0.02	0.05	1.57	2.62	8.51	32.60
15	10.05	M9.90	2.17	M1.63	5.55		M0.10		0.02	0.02	0.55	4.45	34.44
16	M15.49	5.77	2.85	M0.07	0.25	0.00	M0.25	0.00	0.65	0.70	M1.35	6.75	34.13
17	2.72	M4.60	1.20	0.75	0.20				M0.10		1.25	1.55	12.37
18	1.25	4.33	M3.11	0.44	M0.00			0.05	6.60	0.46	4.20	2.40	22.84
19	1.70	9.12	3.07	0.04	0.07			M0.00	0.60	M0.25	M1.10	M6.18	22.13
20	2.90	2.00	5.57	1.95		0.30		M0.10	M0.10	2.88	M4.92	7.47	28.19
21	5.82	3.30	1.65	0.80	1.35					0.50	1.60	10.10	25.12
22	3.95	M6.15	4.15	M0.78	M0.70	M0.00		0.00		M2.92	3.25	8.70	30.60
23	4.45	M1.45		6.60		0.60			0.65	M0.25	0.50	2.35	16.85
24	3.15	M1.10	2.55	0.30	0.00				0.00	2.45	M2.95	M3.85	16.35
25	M2.65	7.80	M2.75	2.55	5.00		0.00		0.50	0.50	2.20	2.10	26.05
26	6.35	M8.25	0.25	5.60	0.30	0.00	0.00	0.00	0.00	1.20	6.25	1.30	29.50
27	4.75	10.45	2.75	2.10	0.00	0.35	0.00	0.00	0.10	M2.50	3.20	5.30	31.50
28	M1.85	3.30	5.30	0.30	0.25		0.00	0.00	0.00	0.00	3.80	M5.75	20.55
29	1.05	1.90	1.65	1.95	0.00	1.75	0.00	0.00	0.35	0.00	0.00	3.20	11.85
30	6.32	5.85	4.70	0.75	0.30				0.75	0.25	2.50	M0.30	21.72
31	M3.22	1.60	1.80	0.45	1.10	M0.50	0.00	0.00	0.00	0.85	2.20	11.90	23.62
32	4.15	5.22	0.93	0.71	M1.31	0.03	0.05	0.02	0.01	0.02	1.13	3.75	17.33
33	9.98	1.51	3.35	0.30	1.47	0.06	0.02	0.03	0.08	1.43	0.00	7.48	25.71
34	0.61	6.54	0.02	0.40	0.32	1.32	0.00	0.02	0.25	1.33	3.90	5.95	20.66
35	M6.29	0.79	4.60	6.40	0.05	0.00	0.00	0.69	0.06	2.74	0.66	4.68	26.96
36	6.30	11.98	1.55	1.69	1.72	0.84	0.53	0.00	0.00	1.10	0.06	7.20	32.97
37	7.39	7.49	9.49	0.92	0.08	M0.31	0.00	0.00	0.01	M0.93	2.82	M8.91	38.35
38	7.35	M11.91	8.10	2.02	0.23	0.02	0.00	M0.00	0.12	3.02	1.36	1.36	35.49
39	4.71	M3.08	3.93	0.25	1.21	0.00	0.00	0.00	1.32	1.07	0.68	1.61	17.86
40	M19.81	10.85	8.21	0.71	M1.15	M0.02	0.12	0.00	M0.24	2.09	M1.06	12.83	57.09
41	13.61	14.41	M7.61	M7.66	1.77	0.22	0.00	M0.00	0.03	M0.86	2.22	M14.86	63.25
42	6.96	7.18	3.04	4.34	2.50	0.00	0.00	0.00	0.07	1.62	7.97	7.00	40.68
43	8.80	M4.25	7.87	2.01	0.00	0.00	0.00	0.00	0.00	1.58	0.81	3.33	28.65
44	7.90	8.13	1.41	2.17	1.55	0.51	0.00	0.00	0.00	2.59	8.58	3.62	36.46
45	2.22	8.58	5.95	0.44	1.13	0.08	0.00	0.00	0.00	2.15	3.43	13.48	37.46
46	1.73	3.96	3.64	0.00	1.72	M0.00	0.04	0.00	0.11	0.38	6.47	2.89	20.94
47	0.94	3.20	4.01	0.22	0.55	0.40	0.00	0.00	0.00	5.22	1.37	2.61	18.52
48	1.38	2.77	M4.80	5.07	1.39	0.05	0.00	0.04	0.00	0.74	0.70	10.49	27.43

49	4.23	M3.83	8.19	0.02	0.36	0.00	0.03	0.07	0.08	0.05	2.11	4.91	23.88
50	11.72	7.11	2.48	1.87	0.76	0.03	0.01	0.00	0.35	1.97	11.39	9.35	47.04
51	5.31	4.20	3.60	1.46	1.00	0.03	0.00	0.04	0.00	1.49	2.11	15.79	35.03
52	13.60	3.24	5.87	1.38	0.33	0.77	0.00	0.00	0.00	0.00	2.86	7.82	35.87
53	3.53	0.00	4.10	4.97	0.69	0.22	0.00	0.22	0.00	0.33	3.73	0.73	18.52
54	4.60	3.79	6.65	2.56	0.64	0.47	0.00	0.34	0.00	0.10	M5.61	4.82	29.58
55	6.58	1.88	0.48	3.58	0.83	0.00	0.00	0.00	0.00	M0.05	3.74	21.07	38.21
56	9.34	1.46	0.26	1.89	1.49	0.00	0.07	0.02	0.28	1.83	0.02	0.96	17.62
57	5.90	4.90	2.03	1.96	4.03	0.16	0.06	0.05	0.29	5.34	0.97	5.48	31.17
58	7.70	13.86	M7.51	M4.47	0.43	0.18	0.00	0.00	0.32	0.06	0.37	M0.75	35.65
59	10.40	7.13	1.01	0.56	0.00	0.00	0.00	0.09	M2.71	M0.00	0.00	0.78	22.68
60	8.98	7.03	2.44	1.67	0.39	0.02	0.02	0.02	M0.08	0.31	4.35	1.76	27.07
61	3.92	1.27	3.97	M0.04	M0.70	M0.15	M0.00	M0.11	0.16	M0.05	M3.66	2.08	16.11
62	3.68	11.96	4.70	0.80	0.02	0.04	0.00	0.05	0.31	2.95	0.99	3.70	29.20
63	7.15	4.91	5.81	7.41	0.55	0.03	0.02	0.06	0.16	1.85	6.72	0.33	35.00
64	5.33	0.20	3.26	0.16	0.44	0.37	0.00	0.17	0.20	1.67	3.81	13.06	28.67
65	3.78	1.71	2.98	3.43	0.02	0.07	0.00	0.11	0.00	0.12	6.93	4.54	23.69
66	2.17	4.72	0.39	0.79	0.10	0.15	0.32	0.10	0.15	0.05	6.17	6.87	21.98
67	8.74	0.74	7.26	8.26	0.40	1.51	0.00	0.00	0.00	0.13	2.14	3.10	32.28
68	3.82	4.93	5.64	0.97	0.18	0.00	0.00	0.55	0.00	1.50	4.31	7.27	29.17
69	14.80	12.01	1.99	2.87	0.08	0.04	0.00	0.00	0.07	1.77	1.34	6.75	41.72
70	13.03	3.11	3.39	0.23	0.03	0.53	0.00	0.00	0.00	1.24	9.55	8.18	39.29
71	2.44	1.02	2.45	1.74	0.24	0.00	0.00	0.06	0.32	0.48	3.74	7.48	19.97
72	1.79	1.81	0.32	1.92	0.03	0.14	0.04	0.00	1.33	3.41	10.54	3.38	24.71
73	7.84	12.99	5.01	0.05	0.04	0.00	0.00	0.00	0.41	2.71	9.56	6.27	44.88
74	5.99	2.00	7.35	4.86	0.02	0.31	2.89	0.00	0.00	1.94	1.07	3.91	30.34
75	1.28	5.72	6.65	2.63	0.00	0.10	0.14	0.85	0.00	3.65	0.49	0.30	21.81
76	0.32	3.89	1.93	2.11	0.00	0.20	0.01	1.25	1.22	0.46	3.80	2.63	17.82
77	1.75	1.55	2.24	0.21	0.74	0.07	0.01	0.00	1.35	0.26	1.72	6.09	15.99
78	11.40	6.13	5.98	5.30	0.01	0.08	0.00	0.00	0.62	0.00	4.48	1.08	35.08
79	10.06	7.55	3.83	1.29	0.66	0.00	0.20	0.00	0.00	3.45	2.52	6.79	36.35
80	9.97	8.69	2.02	2.21	0.61	0.17	0.71	0.00	0.00	0.04	0.17	2.57	27.16
81	7.05	2.62	8.51	0.26	0.35	0.00	0.00	0.00	0.17	1.26	7.05	4.36	31.63
82	M13.38	6.63	7.84	M6.05	0.05	0.27	0.00	0.06	1.19	2.50	6.47	2.99	47.43
83	9.16	9.74	15.16	5.08	0.60	0.00	0.00	0.23	2.00	1.07	8.58	8.14	59.76
84	0.33	2.40	1.94	1.18	0.11	0.15	0.00	0.00	0.11	3.59	11.06	2.39	23.26
85	1.71	3.28	6.60	0.42	0.20	0.14	0.13	0.02	0.14	0.92	5.68	3.91	23.15
86	6.93	12.20	8.24	0.77	M0.60	0.00	0.00	0.00	1.74	0.05	0.05	1.68	32.26
87	M3.47	5.28	4.48	0.84	0.00	0.00	0.00	0.00	0.00	0.94	3.05	7.16	25.22
88	4.44	0.74	0.05	1.74	0.59	0.02	0.00	0.00	0.00	0.30	4.46	7.72	20.06
89	1.36	1.52	7.00	0.72	0.10	0.02	0.00	0.07	0.87	2.19	1.12	0.05	15.02
90	2.64	3.33	M2.65	0.43	4.11	0.03	0.00	0.00	0.21	0.67	0.47	1.65	16.19
91	0.81	4.92	10.60	0.80	0.06	0.26	0.02	0.04	0.06	2.26	1.51	4.25	25.59
92	3.19	11.10	4.35	0.28	0.00	0.55	0.00	0.02	0.00	1.18	0.23	7.10	28.00
93	13.85	8.02	3.44	1.37	0.94	0.56	0.00	0.00	0.00	0.61	2.73	4.00	35.52
94	2.59	8.18	0.74	1.82	1.98	0.00	0.00	0.00	0.06	0.36	4.88	3.24	23.85
95	17.56	0.47	8.49	5.13	1.34	1.54	0.00	0.00	0.00	0.00	0.19	6.54	41.26
96	8.40	9.20	3.15	1.58	2.43	0.00	0.00	0.00	0.00	2.44	7.33	13.74	48.27
97	10.12	0.29	1.26	0.70	0.07	0.19	0.00	0.45	0.01	0.47	9.59	3.67	26.82
98	15.58	18.63	4.68	3.11	3.87	0.14	0.00	0.00	0.08	0.88	5.30	1.74	54.01
99	7.44	10.66	4.08	2.97	0.04	0.34	0.00	0.02	0.18	0.29	3.41	0.77	30.20
0	11.86	14.06	2.41	1.60	1.27	0.19	0.00	0.22	0.31	4.84	1.28	1.04	39.08
1	5.92	7.00	3.29	1.76	0.00	0.10	0.00	0.02	0.20	0.70	6.28	11.07	36.34
2	3.73	2.28	3.52	0.35	0.81	0.00	0.01	0.04	0.00	0.00	4.27	15.21	30.22
3	1.85	1.86	1.47	3.50	0.90	0.07	0.00	0.01	0.00	0.31	3.38	9.93	23.28
4	3.27	5.64	1.34	0.43	0.09	0.01	0.06	0.00	0.02	5.80	2.20	10.28	29.14
5	5.98	6.26	7.65	3.03	1.34	1.05	0.01	0.02	0.01	0.12	1.86	12.62	39.95
6	6.37	2.76	10.99	7.00	0.78	0.00	0.00	0.00	0.00	0.14	3.26	4.73	36.03
7	0.80	5.86	0.33	1.53	0.55	0.00	0.00	0.01	0.38	1.40	0.54	3.83	15.23
8	12.16	6.10	0.51	0.48	0.00	0.00	0.01	0.00	0.01	0.80	1.94	3.00	25.01
9	1.84	10.30	2.07	0.42	1.67	0.00	0.00	0.02	0.36	4.08	0.19	4.06	25.01

10	8.19	5.78	3.17	4.49	0.74	0.00	0.02	0.03	0.01	3.16	4.05	9.40	39.04
11	M2.17	M5.75	M10.87	M0.66	M1.53	M2.35	M0.01	M0.06	M0.05	M2.63	M2.54	M0.13	28.75
12	M3.68	0.94	7.38	M3.10	0.06	0.19	0.03	0.00	0.02	0.53	5.56	7.95	29.44
13	0.90	0.31	1.45	0.93	0.02	0.16	0.03	0.00	0.19	0.07	0.72	0.29	5.07
14	0.05	7.19	3.76	1.21	0.04	0.02	0.13	0.00	0.92	0.84	3.83	11.49	29.48
15	0.00	2.85	0.51	1.98	0.10	0.01	0.03	0.03	0.03	0.08	4.42	6.43	16.47
16	11.80	1.03	7.65	0.89	0.25	0.00	0.01	0.04	0.03	M0.00			21.70

Monthly Precipitation Data
Water Year October 2015 – September 2016
WETS Station Santa Cruz, CA7916
Santa Cruz, California

SANTA CRUZ (047916)
Observed Daily Data
Month: Oct 2015

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	76	59	67.5	18	28	0.03		
2	74	53	63.5	14	24	0.00		
3	70	55	62.5	13	23	0.00		
4	74	51	62.5	13	23	0.00		
5	73	52	62.5	13	23	0.00		
6	76	56	66.0	16	26	0.00		
7	85	52	68.5	19	29	0.00		
8	91	55	73.0	23	33	0.00		
9	89	54	71.5	22	32	0.00		
10	80	54	67.0	17	27	0.00		
11	79	55	67.0	17	27	0.00		
12	90	51	70.5	21	31	0.00		
13	87	56	71.5	22	32	0.00		
14	81	60	70.5	21	31	0.00		
15	80	64	72.0	22	32	0.03		
16	78	61	69.5	20	30	0.00		
17	74	62	68.0	18	28	0.00		
18	75	55	65.0	15	25	0.00		
19	73	56	64.5	15	25	0.00		
20	73	52	62.5	13	23	0.00		
21	75	50	62.5	13	23	0.00		
22	72	50	61.0	11	21	0.00		
23	74	50	62.0	12	22	0.00		
24	80	49	64.5	15	25	0.00		
25	79	55	67.0	17	27	0.00		
26	80	50	65.0	15	25	0.00		
27	70	53	61.5	12	22	0.00		
28	76	58	67.0	17	27	0.02		
29	79	51	65.0	15	25	0.00		
30	75	52	63.5	14	24	0.00		
31	76	51	63.5	14	24	0.00		
Smry	77.9	54.3	66.1	507	817	0.08		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Nov 2015

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	75	50	62.5	13	23	0.00		
2	64	53	58.5	9	19	1.05		
3	69	45	57.0	7	17	0.00		
4	72	43	57.5	8	18	0.00		
5	68	43	55.5	6	16	0.00		
6	69	41	55.0	5	15	0.00		
7	67	43	55.0	5	15	0.00		
8	65	45	55.0	5	15	0.20		
9	60	48	54.0	4	14	1.53		
10	62	41	51.5	2	12	0.01		
11	66	36	51.0	1	11	0.00		
12	67	38	52.5	3	13	0.00		
13	72	38	55.0	5	15	0.00		
14	69	40	54.5	5	15	0.00		
15	60	47	53.5	4	14	0.75		
16	62	40	51.0	1	11	0.00		
17	63	43	53.0	3	13	0.00		
18	66	44	55.0	5	15	0.00		
19	68	44	56.0	6	16	0.00		
20	75	47	61.0	11	21	0.00		
21	77	46	61.5	12	22	0.00		
22	76	46	61.0	11	21	0.00		
23	58	46	52.0	2	12	0.00		
24	58	44	51.0	1	11	0.78		
25	56	38	47.0	0	7	0.10		
26	58	34	46.0	0	6	0.00		
27	59	32	45.5	0	6	0.00		
28	61	31	46.0	0	6	0.00		
29	63	30	46.5	0	7	0.00		
30	57	32	44.5	0	5	0.00		
Smry	65.4	41.6	53.5	134	411	4.42		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Dec 2015

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	68	37	52.5	3	13	0.00		
2	66	39	52.5	3	13	0.00		
3	59	41	50.0	0	10	0.41		
4	61	42	51.5	2	12	0.09		
5	60	39	49.5	0	10	0.00		
6	64	42	53.0	3	13	0.00		
7	65	48	56.5	7	17	0.00		
8	64	46	55.0	5	15	0.00		
9	64	46	55.0	5	15	0.00		
10	63	53	58.0	8	18	0.46		
11	62	45	53.5	4	14	0.26		
12	62	39	50.5	1	11	0.00		
13	55	42	48.5	0	9	1.01		
14	56	35	45.5	0	6	0.00		
15	57	37	47.0	0	7	0.00		
16	60	31	45.5	0	6	0.00		
17	62	33	47.5	0	8	0.00		
18	60	36	48.0	0	8	0.00		
19	59	43	51.0	1	11	0.41		
20	54	35	44.5	0	5	0.48		
21	58	48	53.0	3	13	2.10		
22	62	54	58.0	8	18	1.03		
23	59	41	50.0	0	10	0.00		
24	55	37	46.0	0	6	0.11		
25	57	34	45.5	0	6	0.00		
26	56	37	46.5	0	7	0.00		
27	55	27	41.0	0	1	0.00		
28	53	38	45.5	0	6	0.07		
29	56	31	43.5	0	4	0.00		
30	57	30	43.5	0	4	0.00		
31	59	39	49.0	0	9	0.00		
Smry	59.6	39.5	49.6	53	305	6.43		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Jan 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	54	35	44.5	0	5	0.00		
2	59	41	50.0	0	10	0.00		
3	61	46	53.5	4	14	0.00		
4	59	50	54.5	5	15	0.46		
5	55	47	51.0	1	11	2.36		
6	54	47	50.5	1	11	1.07		
7	55	44	49.5	0	10	0.51		
8	54	38	46.0	0	6	0.00		
9	53	47	50.0	0	10	0.04		
10	59	46	52.5	3	13	0.00		
11	64	48	56.0	6	16	0.00		
12	65	43	54.0	4	14	0.00		
13	65	52	58.5	9	19	0.31		
14	57	40	48.5	0	9	0.22		
15	66	48	57.0	7	17	0.46		
16	58	52	55.0	5	15	0.42		
17	57	55	56.0	6	16	0.25		
18	65	50	57.5	8	18	1.24		
19	63	52	57.5	8	18	1.74		
20	65	50	57.5	8	18	0.00		
21	63	47	55.0	5	15	0.00		
22	59	54	56.5	7	17	1.79		
23	59	50	54.5	5	15	0.17		
24	63	40	51.5	2	12	0.00		
25	66	40	53.0	3	13	0.00		
26	68	41	54.5	5	15	0.00		
27	66	45	55.5	6	16	0.00		
28	61	39	50.0	0	10	0.00		
29	61	54	57.5	8	18	0.12		
30	59	50	54.5	5	15	0.33		
31	57	44	50.5	1	11	0.31		
Smry	60.3	46.3	53.3	122	422	11.80		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Feb 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	60	39	49.5	0	10	0.00		
2	59	38	48.5	0	9	0.19		
3	58	37	47.5	0	8	0.00		
4	67	40	53.5	4	14	0.00		
5	73	38	55.5	6	16	0.00		
6	73	40	56.5	7	17	0.00		
7	76	43	59.5	10	20	0.00		
8	85	46	65.5	16	26	0.00		
9	73	44	58.5	9	19	0.00		
10	79	45	62.0	12	22	0.00		
11	72	45	58.5	9	19	0.00		
12	70	46	58.0	8	18	0.00		
13	72	45	58.5	9	19	0.00		
14	79	45	62.0	12	22	0.00		
15	79	49	64.0	14	24	0.00		
16	84	47	65.5	16	26	0.00		
17	63	56	59.5	10	20	0.37		
18	63	49	56.0	6	16	0.47		
19	62	43	52.5	3	13	0.00		
20	69	46	57.5	8	18	0.00		
21	71	42	56.5	7	17	0.00		
22	70	42	56.0	6	16	0.00		
23	78	41	59.5	10	20	0.00		
24	76	41	58.5	9	19	0.00		
25	79	44	61.5	12	22	0.00		
26	70	46	58.0	8	18	0.00		
27	74	52	63.0	13	23	0.00		
28	68	45	56.5	7	17	0.00		
29	80	44	62.0	12	22	0.00		
Smry	71.8	44.1	57.9	243	530	1.03		

SANTA CRUZ (047916)
Observed Daily Data
Month: Mar 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	75	47	61.0	11	21	0.00		
2	68	45	56.5	7	17	0.00		
3	70	54	62.0	12	22	0.04		
4	62	58	60.0	10	20	0.69		
5	60	57	58.5	9	19	2.19		
6	64	47	55.5	6	16	1.07		
7	61	45	53.0	3	13	0.95		
8	62	41	51.5	2	12	0.02		
9	63	51	57.0	7	17	0.13		
10	68	51	59.5	10	20	0.00		
11	60	50	55.0	5	15	0.66		
12	56	43	49.5	0	10	0.17		
13	59	55	57.0	7	17	1.26		
14	64	49	56.5	7	17	0.17		
15	72	41	56.5	7	17	0.00		
16	74	42	58.0	8	18	0.00		
17	72	48	60.0	10	20	0.00		
18	70	53	61.5	12	22	0.00		
19	70	52	61.0	11	21	0.00		
20	68	49	58.5	9	19	0.08		
21	63	47	55.0	5	15	0.12		
22	66	42	54.0	4	14	0.10		
23	68	41	54.5	5	15	0.00		
24	75	42	58.5	9	19	0.00		
25	72	47	59.5	10	20	0.00		
26	73	43	58.0	8	18	0.00		
27	74	48	61.0	11	21	0.00		
28	65	45	55.0	5	15	0.00		
29	64	37	50.5	1	11	0.00		
30	68	37	52.5	3	13	0.00		
31	69	46	57.5	8	18	0.00		
Smry	66.9	46.9	56.9	222	532	7.65		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Apr 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	69	46	57.5	8	18	0.00		
2	74	44	59.0	9	19	0.00		
3	66	52	59.0	9	19	0.00		
4	76	45	60.5	11	21	0.00		
5	84	44	64.0	14	24	0.00		
6	91	48	69.5	20	30	0.00		
7	68	56	62.0	12	22	0.00		
8	66	56	61.0	11	21	0.07		
9	68	57	62.5	13	23	0.16		
10	59	56	57.5	8	18	0.21		
11	68	51	59.5	10	20	0.00		
12	68	53	60.5	11	21	0.00		
13	73	45	59.0	9	19	0.00		
14	68	46	57.0	7	17	0.12		
15	75	45	60.0	10	20	0.00		
16	85	46	65.5	16	26	0.00		
17	83	43	63.0	13	23	0.00		
18	86	45	65.5	16	26	0.00		
19	80	48	64.0	14	24	0.00		
20	74	42	58.0	8	18	0.00		
21	72	57	64.5	15	25	0.00		
22	64	56	60.0	10	20	0.28		
23	72	44	58.0	8	18	0.00		
24	70	51	60.5	11	21	0.00		
25	72	45	58.5	9	19	0.00		
26	70	41	55.5	6	16	0.00		
27	65	44	54.5	5	15	0.05		
28	74	44	59.0	9	19	0.00		
29	72	48	60.0	10	20	0.00		
30	80	44	62.0	12	22	0.00		
Smry	73.1	48.1	60.6	324	624	0.89		

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SANTA CRUZ (047916)
Observed Daily Data
Month: May 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	76	46	61.0	11	21	0.00		
2	70	55	62.5	13	23	0.00		
3	71	54	62.5	13	23	0.00		
4	66	55	60.5	11	21	0.00		
5	65	56	60.5	11	21	0.03		
6	65	55	60.0	10	20	0.21		
7	63	55	59.0	9	19	0.00		
8	69	50	59.5	10	20	0.00		
9	67	55	61.0	11	21	0.00		
10	66	53	59.5	10	20	0.00		
11	67	54	60.5	11	21	0.01		
12	68	55	61.5	12	22	0.00		
13	68	55	61.5	12	22	0.00		
14	77	47	62.0	12	22	0.00		
15	77	50	63.5	14	24	0.00		
16	74	50	62.0	12	22	0.00		
17	76	53	64.5	15	25	0.00		
18	70	50	60.0	10	20	0.00		
19	76	54	65.0	15	25	0.00		
20	66	49	57.5	8	18	0.00		
21	65	47	56.0	6	16	0.00		
22	68	43	55.5	6	16	0.00		
23	71	45	58.0	8	18	0.00		
24	68	51	59.5	10	20	0.00		
25	68	50	59.0	9	19	0.00		
26	68	50	59.0	9	19	0.00		
27	72	54	63.0	13	23	0.00		
28	70	48	59.0	9	19	0.00		
29	67	55	61.0	11	21	0.00		
30	68	54	61.0	11	21	0.00		
31	73	53	63.0	13	23	0.00		
Smry	69.5	51.6	60.6	335	645	0.25		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Jun 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	65	55	60.0	10	20	0.00		
2	72	55	63.5	14	24	0.00		
3	85	47	66.0	16	26	0.00		
4	70	55	62.5	13	23	0.00		
5	69	56	62.5	13	23	0.00		
6	68	56	62.0	12	22	0.00		
7	74	59	66.5	17	27	0.00		
8	77	59	68.0	18	28	0.00		
9	75	52	63.5	14	24	0.00		
10	78	51	64.5	15	25	0.00		
11	72	46	59.0	9	19	0.00		
12	74	53	63.5	14	24	0.00		
13	74	56	65.0	15	25	0.00		
14	76	50	63.0	13	23	0.00		
15	68	46	57.0	7	17	0.00		
16	75	46	60.5	11	21	0.00		
17	75	53	64.0	14	24	0.00		
18	82	54	68.0	18	28	0.00		
19	92	52	72.0	22	32	0.00		
20	84	50	67.0	17	27	0.00		
21	84	51	67.5	18	28	0.00		
22	82	51	66.5	17	27	0.00		
23	85	49	67.0	17	27	0.00		
24	79	51	65.0	15	25	0.00		
25	79	50	64.5	15	25	0.00		
26	79	48	63.5	14	24	0.00		
27	78	50	64.0	14	24	0.00		
28	75	51	63.0	13	23	0.00		
29	71	52	61.5	12	22	0.00		
30	67	54	60.5	11	21	0.00		
Smry	76.1	51.9	64.0	428	728	0.00		

Product generated by ACIS - NOAA Regional Climate Centers.

SANTA CRUZ (047916)
Observed Daily Data
Month: Jul 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	66	52	59.0	9	19	0.00		
2	66	55	60.5	11	21	0.00		
3	66	55	60.5	11	21	0.00		
4	65	54	59.5	10	20	0.00		
5	67	56	61.5	12	22	0.01		
6	75	56	65.5	16	26	0.00		
7	75	57	66.0	16	26	0.00		
8	76	57	66.5	17	27	0.00		
9	86	52	69.0	19	29	0.00		
10	80	50	65.0	15	25	0.00		
11	79	48	63.5	14	24	0.00		
12	75	55	65.0	15	25	0.00		
13	76	49	62.5	13	23	0.00		
14	71	50	60.5	11	21	0.00		
15	70	54	62.0	12	22	0.00		
16	68	56	62.0	12	22	0.00		
17	69	57	63.0	13	23	0.00		
18	79	52	65.5	16	26	0.00		
19	79	49	64.0	14	24	0.00		
20	80	48	64.0	14	24	0.00		
21	81	48	64.5	15	25	0.00		
22	76	48	62.0	12	22	0.00		
23	81	48	64.5	15	25	0.00		
24	76	51	63.5	14	24	0.00		
25	70	54	62.0	12	22	0.00		
26	74	53	63.5	14	24	0.00		
27	75	52	63.5	14	24	0.00		
28	76	55	65.5	16	26	0.00		
29	76	56	66.0	16	26	0.00		
30	74	55	64.5	15	25	0.00		
31	71	56	63.5	14	24	0.00		
Smry	74.1	52.8	63.5	427	737	0.01		

SANTA CRUZ (047916)
Observed Daily Data
Month: Aug 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	76	60	68.0	18	28	0.00		
2	68	57	62.5	13	23	0.00		
3	68	55	61.5	12	22	0.00		
4	73	56	64.5	15	25	0.01		
5	69	57	63.0	13	23	0.01		
6	71	53	62.0	12	22	0.00		
7	75	51	63.0	13	23	0.00		
8	72	51	61.5	12	22	0.00		
9	68	54	61.0	11	21	0.00		
10	71	55	63.0	13	23	0.00		
11	69	57	63.0	13	23	0.00		
12	71	57	64.0	14	24	0.00		
13	77	54	65.5	16	26	0.00		
14	74	55	64.5	15	25	0.00		
15	69	56	62.5	13	23	0.00		
16	74	54	64.0	14	24	0.00		
17	71	57	64.0	14	24	0.00		
18	68	57	62.5	13	23	0.00		
19	71	58	64.5	15	25	0.00		
20	78	57	67.5	18	28	0.00		
21	75	58	66.5	17	27	0.00		
22	74	54	64.0	14	24	0.00		
23	71	59	65.0	15	25	0.00		
24	74	58	66.0	16	26	0.00		
25	69	57	63.0	13	23	0.00		
26	68	59	63.5	14	24	0.02		
27	72	60	66.0	16	26	0.00		
28	77	55	66.0	16	26	0.00		
29	79	51	65.0	15	25	0.00		
30	81	53	67.0	17	27	0.00		
31	84	52	68.0	18	28	0.00		
Smry	72.8	55.7	64.3	448	758	0.04		

SANTA CRUZ (047916)
Observed Daily Data
Month: Sep 2016

Day	Max Temp	Min Temp	Avg Temp	GDD B50	GDD B40	Total Prcpn	New Snow	Snow Depth
1	76	57	66.5	17	27	0.00		
2	72	51	61.5	12	22	0.00		
3	75	53	64.0	14	24	0.00		
4	71	47	59.0	9	19	0.00		
5	74	55	64.5	15	25	0.00		
6	82	47	64.5	15	25	0.00		
7	81	49	65.0	15	25	0.00		
8	72	59	65.5	16	26	0.00		
9	70	49	59.5	10	20	0.00		
10	69	55	62.0	12	22	0.00		
11	68	57	62.5	13	23	0.00		
12	67	57	62.0	12	22	0.00		
13	69	57	63.0	13	23	0.03		
14	75	49	62.0	12	22	0.00		
15	77	48	62.5	13	23	0.00		
16	74	52	63.0	13	23	0.00		
17	81	51	66.0	16	26	0.00		
18	91	49	70.0	20	30	0.00		
19	84	57	70.5	21	31	0.00		
20	76	57	66.5	17	27	0.00		
21	79	57	68.0	18	28	0.00		
22	76	51	63.5	14	24	0.00		
23	81	47	64.0	14	24	0.00		
24	85	53	69.0	19	29	0.00		
25	95	56	75.5	26	36	0.00		
26	97	58	77.5	28	38	0.00		
27	88	58	73.0	23	33	0.00		
28	73	55	64.0	14	24	0.00		
29	71	55	63.0	13	23	0.00		
30	72	53	62.5	13	23	0.00		
Smry	77.4	53.3	65.3	467	767	0.03		

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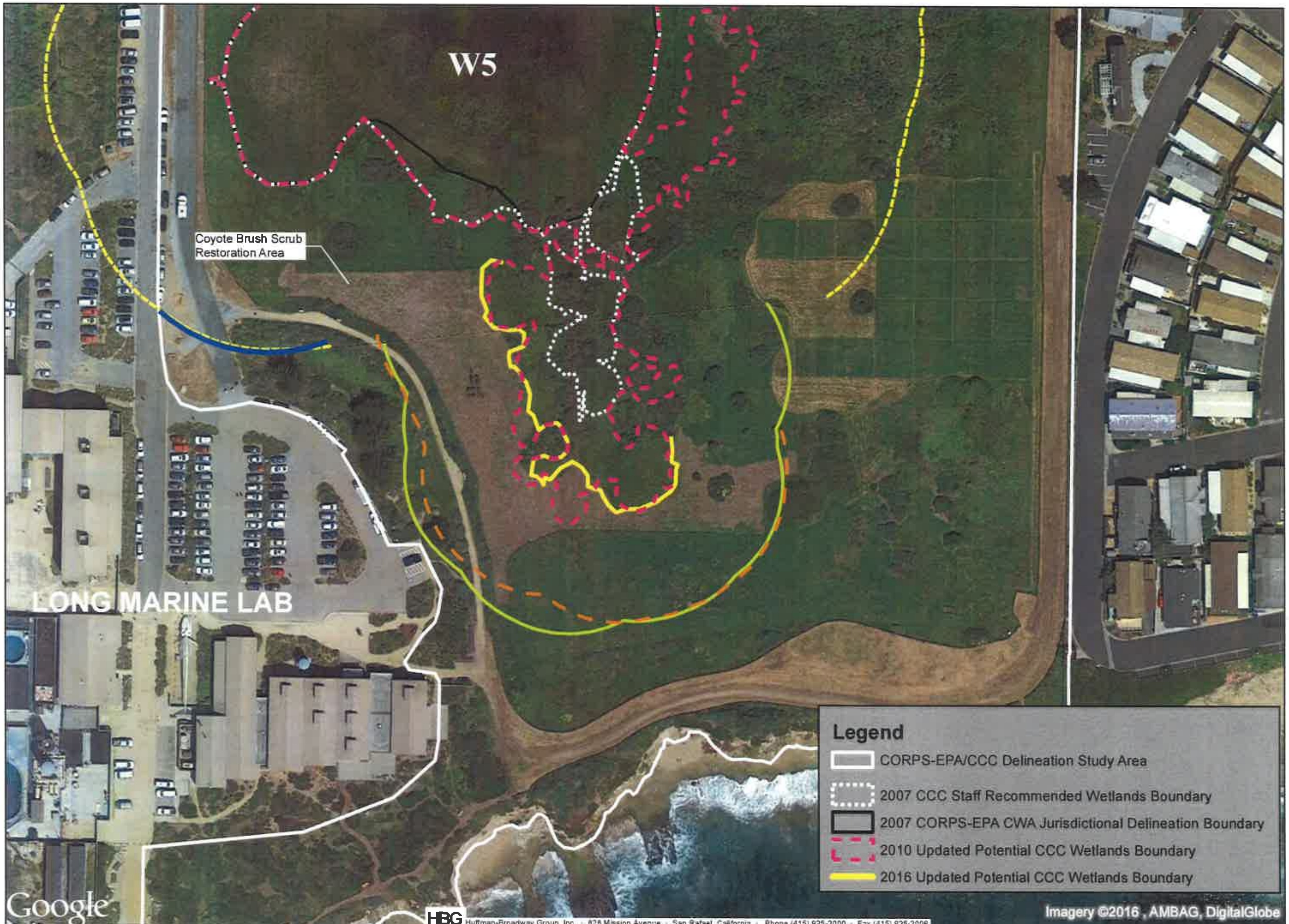

Attachment 5. Comparison of 2016 and 2010 California Coastal Act Wetland Boundaries