



ELKHORN SLOUGH RESTORATION PROJECT

Restoration of endangered California grassland ecosystems



FEBRUARY 1, 2015

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Abstract:

A culmination restoration project at the Elkhorn Slough National Estuary Reserve in Moss Landing, California. The restoration of endangered California Grassland ecosystems and coastal riparian areas, this project was performed over the course of two months where the researcher was introduced to an unfamiliar ecosystem and the associated issues that have caused degradation and loss of historical fidelity. The researcher worked with government and non-profit organization balancing stake holder engagement and a volunteer workforce to complete the replanting of native grass species at two unique sites.

Introduction

The grasslands of California, an altered and endangered ecosystem, are a unique product of the climate and weather patterns of central to northern California. The Mediterranean climate of long dry summers and wet cool winters has given rise to this particular ecosystem type along the coast of California. These grassland ecosystems have been endangered by the rapid development of agriculture brought by European settlers as they moved north into the Monterey Bay and Salinas Valley regions of the state. The native grass species have been replaced by invasive perennial species and this invasion has had a cascade effect through the trophic levels resulting in a changing the makeup the ecosystem as a whole. The Elkhorn Slough, a tidal inlet that mixes fresh water running off the surrounding Santa Cruz Mountains with salt water from the Monterey Bay creating a brackish marsh ecosystem, is located in Moss Landing at the confluence of the Pajaro River and the Monterey Bay.

The Slough is a nationally protected area under the stewardship of the California Department of Fish and Game alongside a not for profit organization called the Elkhorn Slough Foundation. The ESF owns other properties surrounding the Slough and attempts to restore them to pre-agricultural ecosystems in an effort to maintain water quality in the Slough. The properties surrounding the Slough are excellent samples of the unique grassland ecosystems of the central California coast; several kilometers inland from the coast and beneath the Santa Cruz mountain range, these ecosystems have become so altered as to be almost unrecognizable. This restoration project comprised of replanting native grasses into several sites to re-establish native communities and create a cascade effect where by other native species return in abundance.

Ecological Context

Grassland Characteristics

A grassland ecosystem is defined obviously as an ecosystem where the predominate vegetation are grasses (*Poaceae*) with little to no large woody species. However as obvious as it may seem to classify these ecosystems, a strict all-encompassing definition is elusive leading many to assume we know one when we see one or even to define a grassland by the absence, rather than presence, of specific features. Along with the presence of grass species there are other important factors in the classification of a grassland including the presence of deep, fertile, organic-rich soils, frequent natural fire regime, and large herds of grazing mammals. Grasslands are both climatically and geographically determined, as stated the amount of annual precipitation affects the creation of a grassland, however the presence of a rain shadow caused by a mountain range or a river basin drainage can result in a grassland. (Gibson, 2009)

However one defines a grassland it is undeniable that these ecosystems make up a large part of the earth's primary producing ecosystems. According to H. L. Shantz grasslands, including savannah and shrub steppe, is the potential natural vegetation of 33 million km², or 25% of the earth's land surface, occurring in areas that have a period of the year when soil water availability falls below the requirements for forests, yet receive sufficient precipitation during part of the year to sustain grasses (*Gramineae*) [*Poaceae*] as the dominant, or at least, major component of vegetation. (Shantz, 1954) The definition used to reach this estimate may be

outdated, according to The Pilot Analysis of Global Ecosystems (PAGE) Classification estimates that grasslands cover 52 544 000 km² or 40.5% of the total land area. (White, Murray, & Rohweder, 2000)

California Grasslands Structure & Ecology

The grasslands of California are believed to have been dominated by perennial grass species prior to the arrival of Europeans in the late 18th century. Introduced plants date to the Mission Period, and heavy grazing of the native grasses beginning with the Spanish land grants make it difficult to determine what the exact nature of the original vegetation community would have looked like. (Bolen, 1998) A shift in community make up began after European settlement away from perennial towards more annual species Peterson & Soreng recognize “524 grass species in 144 genera; of these, 233 (44.5%) species in 65 genera are introduced and the remaining 291 (55.5%) species in 79 genera are native.” (Soreng & Peterson, 2007) A community of perennial bunchgrasses, principally purple needlegrass (*Stipa pulchra*), and two fescue species; blue (*Festuca caesia*) and California (*Festuca californica*), are representative of the original climate vegetation. This community structure, referred to by some as “California Prairie”, has been largely replaced by annual grasses, many of which came from the Mediterranean region where the climate is similar to central California. Several oat species (*Avena ssp.*), common ryegrasses (*Lolium ssp.*), and soft chess (*Bromus hordeaceus*), all of which are annual, are among the species that are currently dominating these grasslands. Many consider the transformation from perennial to annual vegetation to be a permanent change. (Bolen, 1998)

A unique feature of California grasslands are the vernal pools, areas where during the wet winter season fill with water allowing for a unique community to establish just long enough to reproduce before the drier summer season evaporates the waters. These pools are the breeding grounds for many unique species including the endangered Santa Cruz Long Toed Salamander (*Ambystoma macrodactylum croceum*), a species that has suffered many losses due to the continued drought that plagues California.

Soil Structure and Nutrient Cycle

The soils of grassland ecosystems are recognized for their capacity to sequester carbon due to their high rate of primary productivity, the rate at which nutrients are cycled both above and below ground along with the stability of the by-products produced by soil biological processes during decomposition culminate in highly productive soils. Of the 12 USDA taxonomic soil orders, California’s grasslands occur on five which include: Mollisols, Inceptisols, Entisols, Alfisols, and Vertisols. The other seven soil types do not possess the environmental factors to support grasslands or are not found in significant extents within California. (Jackson, et al., 2007) These soils types have a xeric soil moisture regime which is typical of a Mediterranean climate with warm dry summers and cool wet winters, when evotranspiration is greatest during the dry season when soil profiles are rapidly depleted of moisture to be recharged during the winter. This regime creates condition well suited for grassland and savannah ecosystems. (Jackson, et al., 2007)

Species Composition

Due to the mixing of salt water and fresh water an abundance of fish and bird species exist at the Elkhorn Slough, the area is visited by many birders each year. The Slough is recognized as Globally Important Bird Area and Western Hemisphere Shorebird Reserve. A wide range of aquatic and terrestrial species can be found at the Slough, provided is a list of native plant species found in the California Grassland ecosystem (Appendix A) and for an extensive species list see. (DeVogelaere, Holte, Silberstein, & Jacobi, 1998)

The Project

Stakeholders:

The Elkhorn Slough is situated almost directly in the centre of the Monterey Bay, close to the town of Moss Landing in Monterey County California. The Elkhorn Slough National Estuarine Research Reserve (ESNERR) is one of 28 National Estuarine Research Reserves established nationwide as field laboratories for scientific research and estuarine education. The Reserve is administered by the National Oceanic and Atmospheric Administration and managed by the California Department of Fish and Wildlife. The Elkhorn Slough Foundation is a non-profit organization whose mission is to conserve and restore the Slough and its nearly 4,000 acres in watershed. They have been directly involved in the restoration of key habitats including tidal wetlands, coastal prairie, oak woodlands, freshwater ponds, riparian corridors and maritime chaparral.

The ESF has received a 3 million dollar grant from the California Department of Fish and Game to restore the salt marshes in the riparian areas of the Elkhorn Slough. The government of California wants to use these natural salt marshes in the sequestration of atmospheric carbon, they are “particularly important as “carbon sinks,” (natural systems that can absorb and store carbon) because the carbon they capture is buried indefinitely.” The ever increasing layers of sediment and detritus that build up in the marshes are trapped by the marsh vegetation’s root system and held there. “Compared to other vegetation types, salt marshes store extremely high amounts of carbon per unit area and produce negligible emissions of the potent greenhouse gases methane and nitrous oxide, which have significantly higher global warming potential than carbon dioxide.” (Elkhorn Slough Foundation, 2015)

The Elkhorn Slough however has been degraded by the rapid development of the area, particularly agricultural development, this has contributed to the loss of ecosystem function. “Since 1870, nearly 50% of Elkhorn Slough’s historic tidal marshes have been diked and drained to create pasture and farmland. Once drained, the ground of these former marshes subsided, dropping from one to six feet below historic elevations. Because these areas are now situated too low to support healthy salt marsh, the estuary is no longer serving its full capacity as a carbon sink.” (Elkhorn Slough Foundation, 2015) The aim of this large scale project is to raise the water table by adding sediment into the marshes to increase the acreage of the salt marshes. Within this project there is concern as for the health of the riparian areas of the tidal marshes, water laden with agricultural runoff can lead to a growth of vegetation that will choke out the brackish water tolerant plants.

Riparian Grassland Restoration:

This aspect of the project was aimed at not only restoring the grasslands surrounding the tidal salt marshes but repairing them using native vegetation to restore the ecosystem to its Coastal Prairie state. The ESF has been given lands in trust that they will be stewarded, many of these lands are in the inland watershed areas surrounding the Slough and were typically used for agriculture. Two of these sites were chosen as test sites for a grassland restoration due to their proximity to the Slough as well as access for equipment that was needed for the restoration. The sites Minhoto and Inniguez (Appendix B) were chosen for the initial plantings to be done in the early spring of 2015.

Methods

Site Analysis:

The Inniguez site is to the west of the Elkhorn Slough Reserve headquarters, it lies on higher ground in the Elkhorn watershed beside two active agricultural operations. The site is set back 43.35m back from the top of the slope on a flat area. The site was measured using a Google Earth Pro mapping software and determined to be 191.29m by 38.78m equalling 7418.23m². The site was once used for agriculture but has been left fallow for 3 years, the vegetation on the top of this slope was minimal consisting of short tuft grasses. This area is above the floodplain and due to high drought conditions does not receive much water. A drip irrigation system was used for farming when the site was active and there exists a well a few meters away from the site. It was determined that drip tape irrigation would be used again after the plantings were completed.

The second site, named Minhoto is south of the Elkhorn Slough Reserve headquarters, along the actual an arm of slough itself, this site was much more clearly an agricultural site having only been left fallow for 2 years. The site is a 6424.19m² rectangle set back 12m from a salt marsh, this site has a slope of 32% towards the marsh and has slightly varying soils from the upper slope to the lower. The upper slope soil is thin, light, Moder like in composition, however due to heavy agriculture use it is difficult to classify; while at the lower slope closer to the water's edge the soil turns darker and thicker and more Mul like in composition. The change in soil is very abrupt and easily identifiable with the naked eye, this is likely due to the proximity to salt water and tidal flats, the lower slope of the site may be inundated or receive ground water flow during large precipitation events. Pipe irrigation was used on this site for agriculture and a well is pump located over 800m across the field; this site will have pipe irrigation again to water the plantings.

Species Description:

The initial portion of the project was spent seeding the grass plugs that would eventually be planted at the chosen sites. Five species of grasses native to the Coastal Prairie ecosystems were chosen to be seeded: Blue Wildrye (*Elymus glaucus*), Purple Needlegrass (*Stipa pulchra*), California Oatgrass (*Danthonia californica*), Tufted Hairgrass (*Deschampsia cespitosa*), and Blue Fescue (*Festuca idahoensis*). A brief description of each species along with an image,

identifying factors, and the role the species plays in restoration is provided by the United States Department of Agriculture's Natural Resource Conservation Service.

Blue Wildrye:

Description:



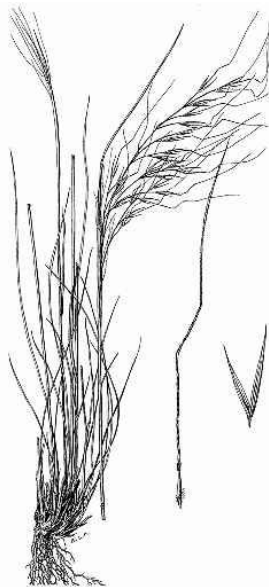
A tufted perennial grass that usually grows in clumps, 0.5 to 1.5m in height. The leaf blades are thin and flat, ranging from 4-12mm wide. Leaf color changes from green to blue green, with a white waxy coating. Found in both wetlands and drier areas and slopes.

Restoration:

Blue wildrye is good for stream bank restoration, meadow and swale seeding. It is also excellent for reseeding burned or disturbed areas in oak woodland or forest. It is very tolerant of fire, burning quickly with little downward transfer of heat. Blue wildrye can also provide excellent wildlife habitat for mammals, birds, and waterfowl. It provides good forage early in the season, but later, may be too coarse and stemmy. (Dryer, O'Beck, & Stannard, 2005)

Purple Needlegrass:

Description:

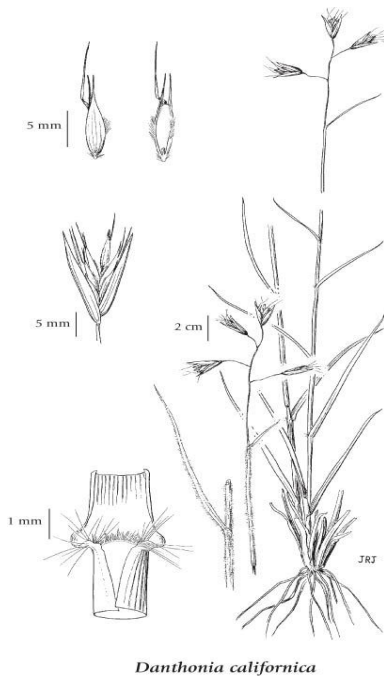


Purple needlegrass is a densely tufted, long-lived, upright perennial bunchgrass with conspicuously long awns. It has numerous basal leaves and a distinct nodding habit at anthesis. Plants are generally 0.6 to 0.9 m producing an open, nodding panicle of 10 to 20 cm. The leaf blades are smooth to finely hairy. (Tilley, Dryer, & Anderson , 2009)

Restoration:

The species is highly valued as an erosion control grass due to its longevity, tolerance to poor soil conditions and its ability to establish a coarse root system on disturbed sites with low soil fertility. It has been successfully used in re- establishing native perennial grasses following weed control on sites previously occupied by introduced annual species. (Tilley, Dryer, & Anderson , 2009)

California Oatgrass:



Danthonia californica

Description

Slow establishing yet long lived, cool season (C3) perennial bunchgrass of intermediate texture. Its stems (culms) grow 30-100 (10-130) cm tall and disarticulate (separate) at the lower nodes (joints). The leaf sheaths are smooth to densely hairy. Leaves are both basal and attached to the stem with the upper blades being 8-25 (10-30) cm long, flat to in-rolled, and spreading to abruptly bent.

Restoration

California oatgrass is an important native constituent of drier upland and moist lowland prairies as well as open woodlands. Therefore, it is commonly recommended for revegetation, wildlife plantings, and restoration of oak savannas, transitional wetlands, and grasslands, especially in the Pacific Coast states where it is most common. Native bunchgrasses like California oatgrass are valuable for enhancing biodiversity. Healthy stands can reduce invasion by exotic species yet exhibit a spatial distribution compatible with forbs.

Combined with other native grasses and forbs, California oatgrass improves habitat diversity for feeding, nesting, and hiding by songbirds, as well as other animals. (Darris & Gonzalves, 2008)

Tufted Hairgrass:



Description:

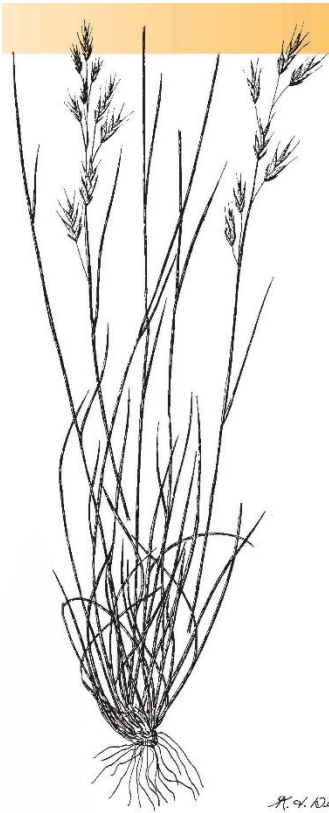
Tufted hairgrass is a highly variable, perennial cool season species that grows 0.5m to 1.5m tall. Stems are erect and the leaves are 0.1cm to 0.4cm wide, flat or rolled, and mostly basal in a dense tuft. The panicle (seed head or inflorescence) is upright to nodding, loosely branched, open, and 10 to 25cm long. There are two flowers per spikelet.

Restoration:

Tufted hairgrass is useful for restoring moist to seasonally wet prairies and stabilizing disturbed sites, streambanks, canals, shorelines, and upper tidal marshes. Other applications include acid and heavy metal mine spoil reclamation, alpine and boreal revegetation work, and bio-filtration swales. As a range or pasture grass, it is both a desirable, productive forage for cattle and sheep particularly at

higher elevations, and a species of lesser or low value in regions where plants are coarse and less palatable. The species is sometimes cut for hay. Utilization by deer, elk, pronghorn, bison, bear, horses, and rabbits is variable. (Darris & Gonzalves, 2009)

Blue Fescue:



Description

Idaho fescue is a native, perennial, cool-season grass. Idaho fescue culms are erect, 0.3 to 1.0 m tall, glabrous and glaucous, sparsely leaved with most leaves basal. The fine narrow leaves usually have a bluish green to green color. The leaf sheaths are flattened, keeled, either glabrous or scabrous; the basal sheaths are short, open and wider than the blade. The sheath collars are indistinct and the auricles are either small or absent. The blades are involute, 5 to 25 cm long.

Restoration

Idaho fescue is fairly drought resistant, stands are persistent and it is adapted to stabilization of disturbed soils. It does not compete well with aggressive introduced grasses. Its drought tolerance, combined with extensive root systems and good seedling vigor, make this species ideal for reclamation in areas receiving 14 to 20 inches annual precipitation. (Ogle, Henson, & Stannard, 2006)

Results

Prior to the plantings a local farmer was brought in to till both sites the two sites using a 16 inch rotary disc tiller towed behind a tractor. After this the trays of grass plugs were brought to each site to be planted using a CT-5 mechanical transplanter towed behind a tractor. 120 trays with 100 cells, roughly 12 000 grass plugs, were used to at the planting site. Due to the difference in gestation periods the species used at each site were not uniform in composition or maturity.

At the Minhoto site 60 trays were used; 25 *Stipa*, 15 *Elymus*, 10 *Deschamsia* and 10 *Danthonia*. The plugs were unloaded into the tray of the transplanter and two planters seated behind the tractor loaded the plugs into every second arm of the wheel on the planter to give a distance of roughly 0.3m between each plug. During the first planting issues arose with the automatic planter, the difference in soil needed to be corrected for in the height of the plow on the planter. Success was had on the lower slope of the site, however the drier finer soils did not hold the plugs, volunteers were needed to follow the planter and replant any plugs that failed to be planted properly.

After several attempts with the transplanter it was determined that before planting on the Inniguez site, some adjustments would need to be made to the planter. A wheel needed to be attached to the back to allow for the planter to adjust itself to the height of the ground keeping a consistent soil depth. A further setback at the Minhoto site happened when water pressure was lost during the setup of the pipe irrigation system, the old irrigation system had a broken valve somewhere along the line. When it was repaired it was discovered that the well from which the water was piped had become too salinated to be used for watering. The fate of the Minhoto site remains unknown.

The Inniguez site was planted with the remaining 60 trays, 20 *Stipa*, 15 *Fescue*, 10 *Danthonia*, 10 *Deschampsia*, and 5 *Elymus*. The planter was repaired with the wheel and the results were much better, the uniformity of the soil at the Inniguez site decreased the number of replants substantially. Once all 60 trays of plugs were planted the drip tape irrigation system was set up and there were no issues with the water quality at the well site.

Monitoring

The Elkhorn Slough Foundation will have constant monitoring of these sites in the course of their work, however I will likely be unable to return to monitor these sites on a regular basis. The failure of the plantings at the Minhoto site was a setback however that site is slated to be part of the much larger marsh restoration project. It is my hope that something will be able to be done once that project is underway to repair the entire riparian area.

These sites will need to be monitored closely for invasive species as the tiller may have disturbed the seed bank of invasive species. If the planted plugs do not gain a foothold there is a high chance that invasive species favouring disturbed sites will return. As these grasses that have been planted are perennial, weeding and herbicides will need to be used to control the invasive species until the grass plugs are able to compete.

Conclusions

This project was a pilot for a larger scale project at the Elkhorn Slough and as a result the conclusions are somewhat limited in scope. However the replanting of native species into an endangered ecosystem can never be said to be a total failure; lessons were learned on this project about the maintenance of equipment and the coordination of volunteer efforts.

This project was the first experience with a large scale restoration team and the stakeholders involved in implementing projects of this scope. The experience with working and coordinating with a government body and a non-profit organization gave me valuable insight into stakeholder engagement practices. While I valued the chance to learn about an ecosystem that is very different from those I have worked in before, gaining ecological perspective and new species knowledge about unique and threatened habitats in Northern California.

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Photos Credits

Needlegrass http://www.desert-tropicals.com/Plants/Poaceae/Nassella_pulchra.html

Wildrye: <http://www.agf.gov.bc.ca/range/RangeID/Plants/ElymGlau.html>

California Oatgrass:

http://wikis.evergreen.edu/pugetprairieplants/index.php/Danthonia_californica

Tufted Hairgrass http://www.desert-tropicals.com/Plants/Poaceae/Deschampsia_caespitosa.html

Blue Fescue: <http://www.agf.gov.bc.ca/range/RangeID/Plants/FestIdah.html>

Appendix A

Definitive coastal prairie plants. Adapted from Stromberg, et al. 2001. Composition, invasibility, and diversity in coastal California grasslands. *Madroño* 48:236–252.

Native Coastal Prairie Grasses and Rushes

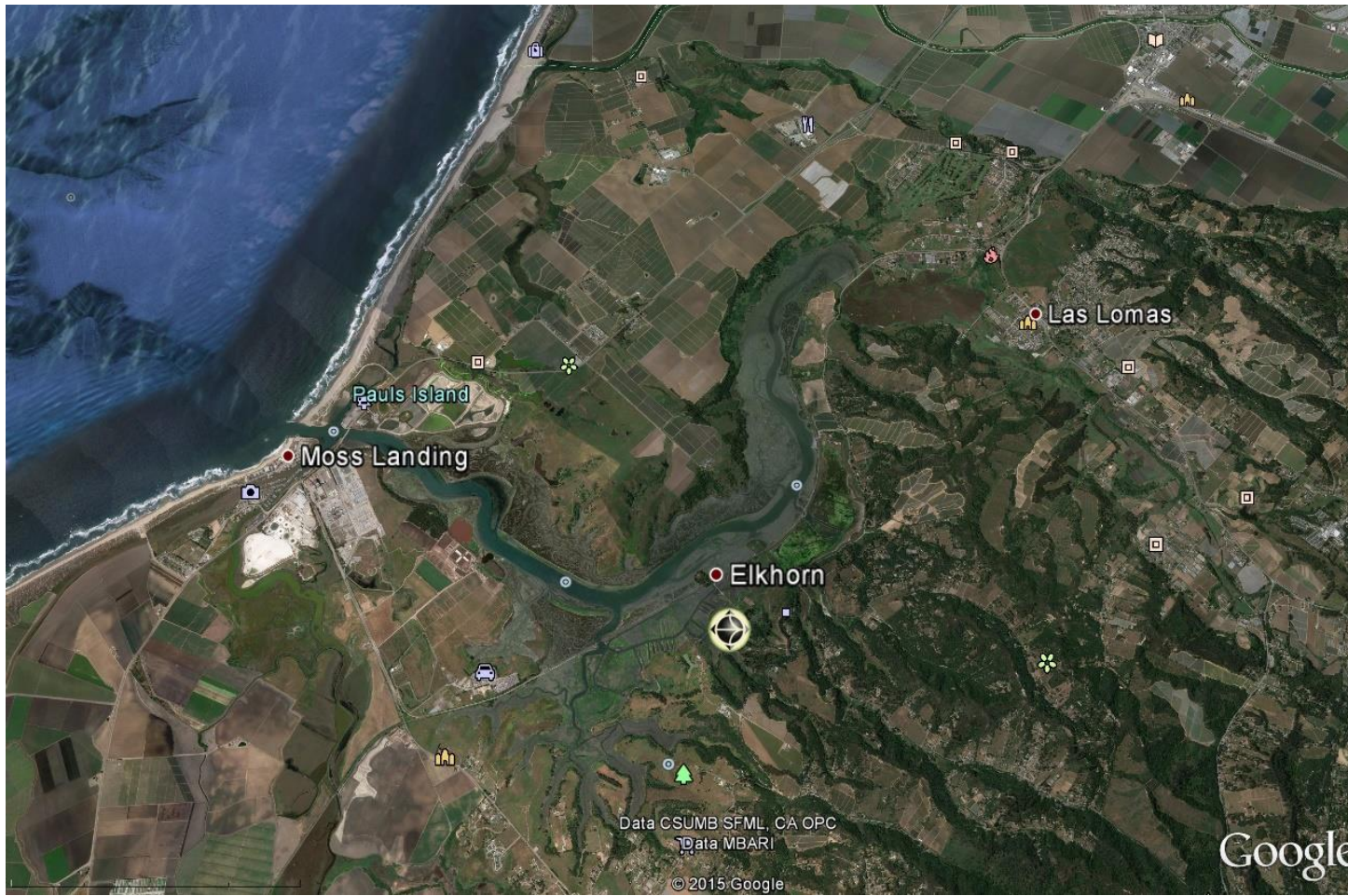
Common Name Species Name

California oat grass <i>Danthonia californica</i>	Foothill needlegrass <i>Nassella lepida</i>
Purple needlegrass <i>Nassella pulchra</i>	Creeping wildrye <i>Leymus triticoides</i>
Brown-headed rush <i>Juncus phaeocephalus</i>	Salt grass <i>Distichlis spicata</i>
Tufted hairgrass <i>Deschampsia cespitosa</i>	California brome <i>Bromus carinatus</i>
Blue wildrye <i>Elymus glaucus</i>	Meadow barley <i>Hordeum brachyantherum</i>
Toad rush <i>Juncus bufonius</i>	Nodding needlegrass <i>Nassella cernua</i>

Native Coastal Prairie Forbs and Shrubs

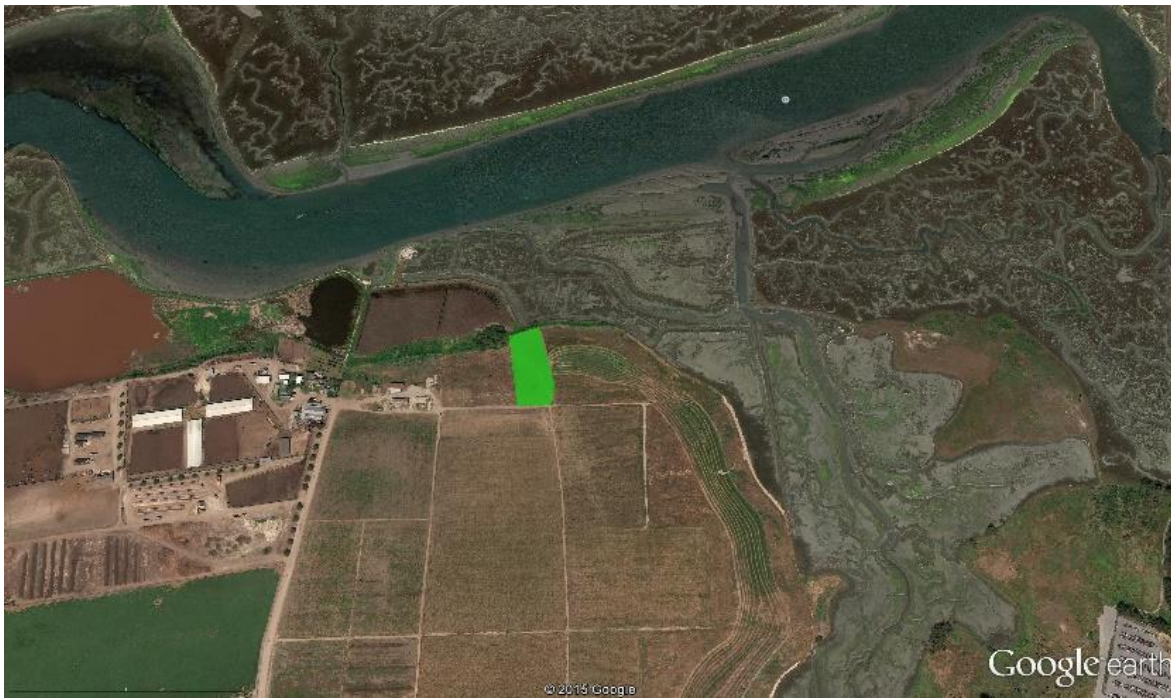
Coyote brush <i>Baccharis pilularis</i>	Blue-eyed grass <i>Sisyrinchium bellum</i>
California plantain <i>Plantago erecta</i>	American carrot <i>Daucus pusillus</i>
Small tarweed <i>Madia exigua</i>	Everlasting <i>Gnaphalium purpureum</i>
Buttercup <i>Ranunculus californicus</i>	Soap plant <i>Chlorogalum pomeridianum</i>
Johnny jump-up <i>Viola pedunculata</i>	Coastal eryngo <i>Eryngium armatum</i>
Checker mallow <i>Sidalcea malviflora californica</i>	California acaena <i>Acaena pinnatifida</i>
Sun cup <i>Camissonia ovata</i>	

Appendix B
Elkhorn Slough



Appendix C

Site Maps



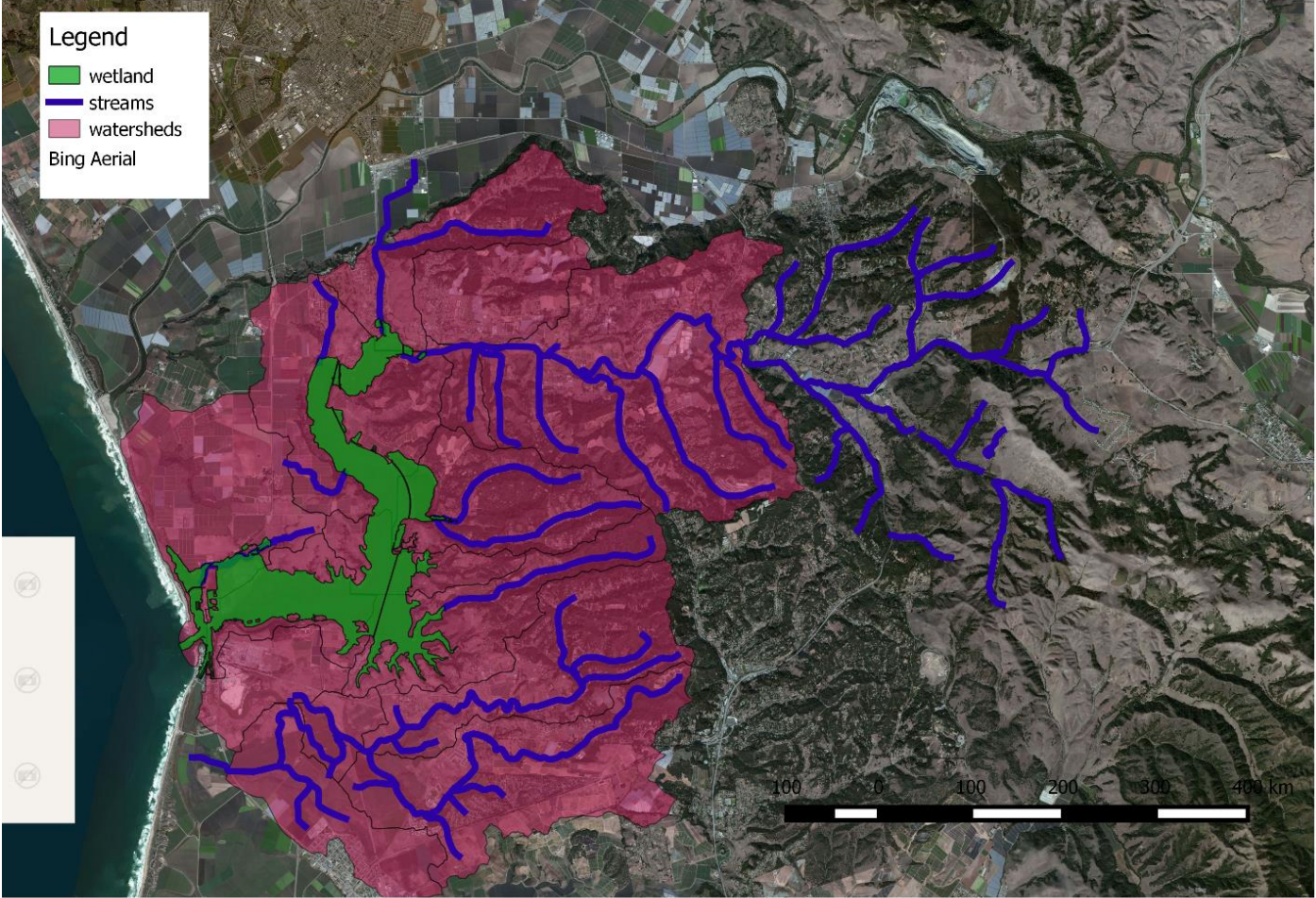
Minhoto Site



Iniguez Site

Appendix D

Elkhorn Slough Watershed Map



Appendix E

Areas protected by the Elkhorn Slough Foundation in 2004

