

2015 ENH 160 PROJECT: SOLANO COUNTY RCD URBAN GREENING PROJECT CENTENNIAL PARK (VACAVILLE, CA)



**Report by Students of University of California, Davis
Restoration Ecology Class (ENH160 & 160L)**

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Notes

This document is a product from UC Davis' Restoration Ecology class (ENH 160 & 160L) in the spring of 2015, and is a result of the hard work of the students. Each topic was written by an individual student, as noted at the start of each report. Some of these reports have been modified in an effort to synthesize and streamline this report. Due to logistical issues (inability to import parts) some figures are missing. Synthesis sections derive from class discussion and lab data collected.

Acknowledgements

We thank Katherine Holmes from Solano County RCD for guidance on key topics that they needed addressed, lecturing to the class and lab, giving tours and background information on the site, and allowing us access to the study site.

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INTRODUCTION TO THE REPORT

The integration of science and management is a highly desirable goal for both the management and scientific communities. There are many obstacles to this goal, but some particularly important challenges include:

1. The need to train students who are familiar with both science and management, and who can balance the tendency of science to be focused and rigorous, with the need for management to consider many factors, many of which are difficult to control or isolate.
2. The difficulty in collecting and synthesizing an overwhelming amount of scientific literature that is scattered across many sources.
3. The challenge in both science and management to consider:
 - a. a wide diversity of interacting goals and constraints, and the potential for trade-offs and win-win scenarios
 - b. Changes in patterns and controls over biotic and abiotic factors over space and time

This report is a result of the collaboration between Solano County's Resource Conservation District, and the Restoration Ecology Class (ENH 160) at University of California, Davis. Solano RCD graciously agreed to serve as a test case for this project, and set the stage for it by:

- providing a list of key questions, topics, challenges, organisms, and ecosystem services of concern
- providing background information on the sites
- providing access to lab students for monitoring and observational activities
- lecturing in class about the challenges of implementing restoration projects, and providing background information on the Vacaville Greening Project.

The overall goal of class project was to develop a restoration handbook for Solano County RCD's Urban Greening Program. Each student was in charge of a different restoration goal (a key organism, ecosystem-type, or ecosystem service), and was instructed to do a thorough literature search to determine:

- the status of that organism, ecosystem, or ecosystem service
- the key ecological and socio-economic controls over that goal
- successes and failures of previous management/restoration attempts
- key gaps in knowledge
- possible funding sources for management and restoration of their goal

Using this information, each student was instructed to design a management/restoration plan for their goal in California's Central Valley. Our hope is that these individual reports provide a handy literature review on key individual restoration and management goals.

These individual projects were just the start of the instructional, and project-wide goal. The lab section of the class was focused on applying this background knowledge to a specific Solano RCD project site, Centennial Park in Vacaville, CA. The lab surveyed the site for ecological potential, and presented that information to the class. This involved a thorough on-site assessment of current site characteristics at Centennial Park, including topography, soil type and characteristics, vegetation zones, key natives and invasive

species of vegetation and wildlife, and ecosystem services such as erosion control, fire prevention, and pollination.

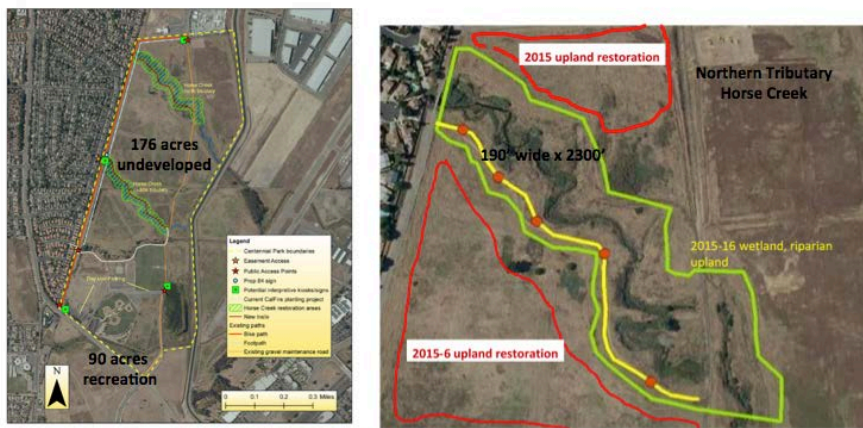
Our ultimate goal was to develop some overall management options for Centennial Park based on all of these goals—coming up with alternative management scenarios that carefully stressed the multiple goals they could achieve, and the tradeoffs in other goals. To do this, after the individual phase of the project was completed, each student presented a summary of their individual projects. We then spent a few class sessions integrating all of the individual projects to come up with management scenarios that could attain these multiple goals, given the site conditions determined by the lab. These goals often varied across sites and in some cases, resulted in direct and indirect tradeoffs. To address this, for each goal, we considered how the goal varied across the site in: which species it targeted, the steps needed for site preparation, management and monitoring, and specific thresholds for management action.

Results of these discussions can be found in the “Project synthesis” section. A full description of the students’ assignment can be found in Appendix I.

While this report is far from perfect or complete, it should be a handy guide for both science and management- providing literature reviews on many important topics in California grassland, wetland, and riparian zones, and pointing to some key holes in our scientific understanding that will aid with the implementation of restoration and management programs. The management recommendations are very preliminary due to time limitations, but the literature reviews and lists of trade-offs should provide important information for those managing California grasslands and riparian areas. We are very proud of all of the hard work, open minds and synthetic thinking that the students invested in this project.

SOLANO COUNTY RCD URBAN GREENING PROJECT- CENTENNIAL PARK SITE

Summary: Centennial Park site is a 265-acre open space nested within intensive urban and suburban development. Water is delivered to the site through two tributaries that run belowground through the suburban housing development before resurfacing at the western edge of the park. Due to the timing of planned restoration activities and the limited timescale of our class project, the following management recommendations focus on the upland, riparian, and wetland habitat adjacent to the North tributary, which runs 195 ft wide by 2300 ft long from the northwest corner of the park.



Owned and maintained by City of Vacaville since 1992

Solano County RCD



CENTENNIAL PARK SITE HISTORY

History of Vacaville:

1850's-1800's Dry Grain Farming



Abc.net.au

1880- Fruit orchards (were the fruit industry originated)



Hawkeburyheritage.blogspot.com

1892- Massive Urban development



Vacaville Heritage Counsel

1930 Great Depression collapse of fruit industry in Vacaville



Vintageadbrowser.com

Ebay.com

History of Centennial Park:

Solano County RCD

- Dry grain farming
- Riparian areas deforested
- Annual disking of firebreaks
- 1992 Became City Park
- 1990's South tributary tree planting
- 1990's Baseball fields constructed
- 1998 Construction of soccer complex
- 2000 complex opens
- 2012-13 bike trail tree planting

- 40 acre park includes:
- 1 Pony League/Babe Ruth field
- 3 Little League fields,
- 4 soccer fields
- 1 large and 1 small artificial turf soccer fields
- 1 Wiffle-ball field
- Outdoor roller hockey court
- 4 tennis courts
- Hiking trail
- on-site parking for approximately 300 cars
- restroom and concession complex

Horse Creek

Soccer Complex

Home to VYSL and VUSC

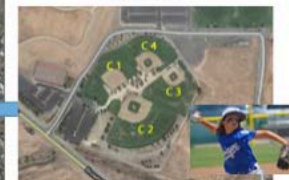


Horse Creek provides a family safe environment. Please follow Rules

<http://www.vysl.org/page/show/173167-horse-creek-soccer-complex-centennial-park>



Engagecanmore.ca



<http://www.steam.com/VacavilleCentral/LittleLeague/locations/>

Vacavilleinsider.com

RCD's OVERARCHING PROJECT GOALS

Goals for restoring Centennial Park include the creation of a **recreational riparian trail system (2.5 mile loop)** and restoring target areas to native communities through **invasive species removal** and **planting native species**. Additional goals include restoring several **key ecosystem services**:

- Wildlife habitat
- Wildfire control
- Mitigate Air and water quality
- Urban heat mitigation
- Flood control
- Water storage and provision

Planting Native Species

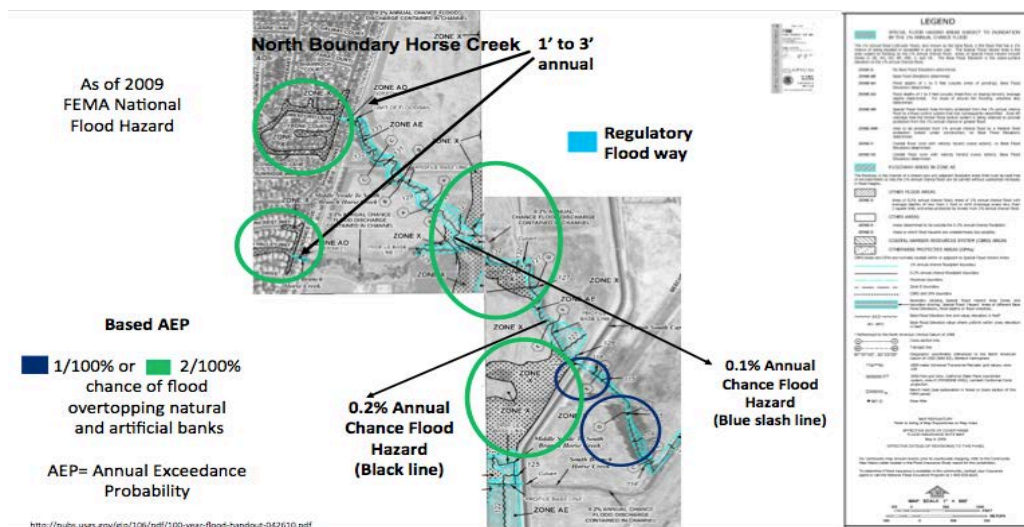
Restoration efforts will be focused on several restoration target areas, including Two tributaries of Horse Creek (16 acres), which will be planted with herbaceous plugs, (sedges, rushes, grasses, etc.) in the channel and riparian trees and shrubs outside the channel, and a large Upland area (12.5 acres), which will be seeded with grasses and wildflowers.

Overall, through restoration planting, the project aims to establish:

- 1,250 trees/shrubs (with access to driplines)
- 15,000 forb/sedge/rhizomatous grass plugs
- 313 lbs native seed (across 12.5 acres)

Flood Control:

The Centennial Park site is currently being managed for flood control, a critical component of this project due to its close proximity to adjacent residential and commercial areas.



SPECIFIC HABITAT GOALS:

Goals for restoring Centennial Park can be divided into four main zones:

Upland zone:

- Decrease invasive species
- Enhance native cover
- Provide wildlife habitat
- Minimize wildfires

Wetland zone:

- Minimal manipulations
- Decrease invasive species
- Enhance native cover
- Provide beaver habitat while minimizing disruption of woody species

Riparian zone:

–Within creek bed

- No additional woody plants allowed (maximizes creek volume for flood control)
- Prevent erosion
- Invasive species control
- Enhance native cover – sedge, grass, forb plantings

– Within areas that have enough ground water access to be riparian,

- Improve riparian habitat- trees, shrubs, vines, understory

Transition zones:

- Determine potential goals and challenges (e.g. invasive species)
 - “Oxbow areas”
 - Seasonal wetlands and creek areas

PROJECT SYNTHESIS

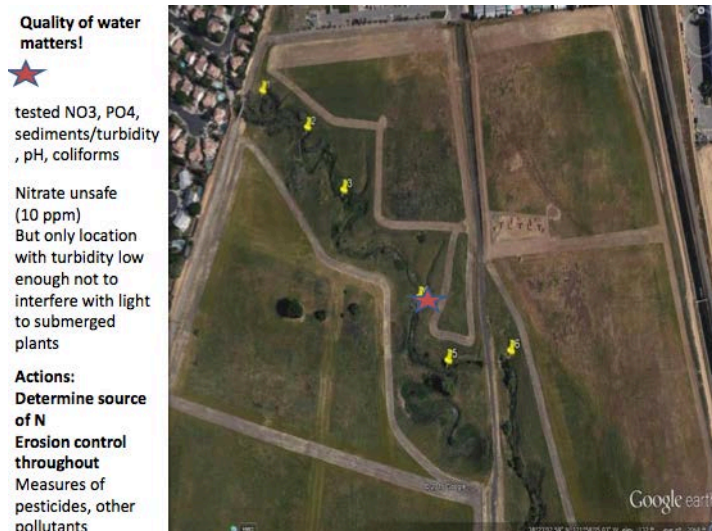
Through site monitoring, we determined several environmental conditions that are key to shaping potential restoration activities across the site.

Water availability and topography: Water serves as both a direct resource and as habitat at the site, determining which species of wildlife and vegetation are suitable in which areas. Water is limited by depth of standing water and the depth to water table, as well as the seasonality of water availability in the tributary. While we cannot control the inputs of water quality and quantity entering the site.

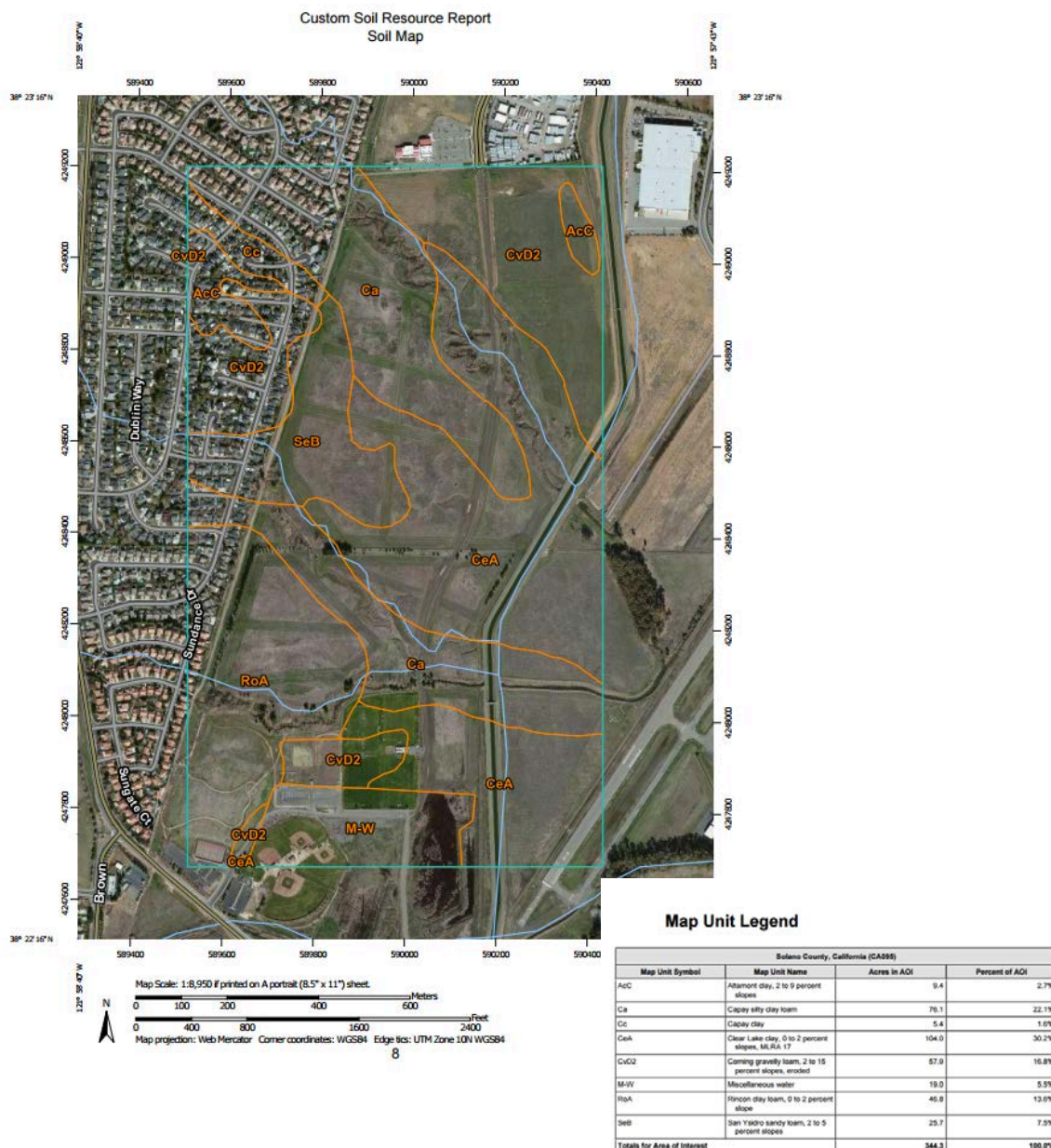
Water flow and depth during the dry season: The water depth and flow can be manipulated during the dry season to encourage ponding. This can be achieved through adding woody debris and encouraging habitat for the formation of beaver dams.

Water Quality: Water quality determines the suitability of habitat for wildlife and plant species, and is limited by inputs from the residential zone through which it flows on the western boundary of the park. Water quality was tested at six sites along the Northern tributary for NO₃, PO₄, sediments/turbidity, pH, and coliforms. All but one site were found to meet EPA drinking water quality standards for all measurements, however, one site was found to exceed the drinking water quality safety standards for nitrate. This site was found to have a nitrate level of 10 ppm and is marked with a star on the map below and should be carefully tested and monitored before planning restoration activities in this area. If possible, the source of this nitrate pollution should be investigated and identified. While it is unlikely that we can significantly alter water quality at the site, if this source of nitrate is a small local source, it is possible that it could be alleviated. Turbidity was found to be high at all six locations, and may be too murky for the establishment of submerged vegetation such as cattails. Interestingly, the only site with low enough turbidity to support the establishment of cattails was the same site which exceeded the nitrate standards, stressing the importance of alleviating nitrate pollution in this area.

To reduce turbidity throughout the site, management actions should focus on reducing erosion along the stream bank.



Soil conditions: Soil also serves as both a direct resource and as habitat to the site, determining which species of wildlife and vegetation are suitable in which areas. There are four types of soil at the site, Corning Gravelly loam, Clear Lake, Capay and San Ysidro, each of which best support a different suite of vegetation types. The San Ysidro and Clear Lake soil types will present the largest limitation at the site, because they do not support the establishment of any deep-rooted species. The underlying soil type is too difficult to alter at the site. However, one advantage of this is that the unique soil types provide heterogeneity in habitat, including rare vernal pool habitat.



Soils

Soil Types	Corning	Capay	San Ysidro
Soil Texture	Clay Loam	Silty Clay Loam	Sandy Clay Loam
Water Holding Capacity	1.64 g/cm ³	1.95 g/cm ³	1.70 g/cm ³
pH	5.5-8	6.5-8	6-8
Salinity	N/A	Low	Low

ENH 160 (2015)
USDA 2015



Invasions: Invasive species control needs to be controlled both above and belowground, since there is a significant exotic seedbank present at the site. We can reduce the invasive seedbank through a combination of mechanical and chemical weed control techniques, with careful consideration for areas with rare or sensitive species.

**Vegetation- largely non-native, low diversity
Centennial Park Invasive Species**

Type of Invasive	Plant ID	% Cover	Zone
Annual Grass	Avena fatua	> 75%	Upper Land
Annual Grass	Bromus diandrus	> 25%	Upper Land
Annual Grass	Phalaris canariensis	< 25%	Upper Land
Annual Grass	Lolium multiflorum	< 25%	Upper Land
Perennial	Pepperweed	> 25%	Riparian
Perennial	Blackberry	< 50%	Riparian-Wetland
Annual	Teasel	< 25%	Riparian
Perennial	Cattail	< 50%	Wetland
Annual	Vicia americana	> 75%	Upper Land, Riparian
Tree	Sapium sebiferum	< 50%	Riparian-Wetland
Tree	Ficus	2%	Upper Land
Annual	Leontodon	< 25%	Fire Break Zones
Annual	Elymus caput-medusae		Upland

Flood Control Policy: The Solano County RCD must keep in mind that this site is being managed for flood control; and cannot plant woody vegetation in the creek channel that would reduce the capacity of this channel to enhance flood control.

Size/connectivity: This site is limited by its relatively small size and lack of connectivity to other open space areas. The creek runs underground to the west of the site, reducing the possibility of connectivity through the creek channel.



Heterogeneity: The potential for this site to provide wildlife habitat to a diverse array of species is limited by the current landscape heterogeneity at the site, including heterogeneity in topography, soil type, and vegetation.

Wetland Management Summary:

Distribution of water on the site:

Despite the small relative area of wet habitat, wet habitat in Centennial Park is characterized by high heterogeneity, including riparian channel, year-round wetland, and seasonal wetland.



There are 10.5 acres of seasonal wetlands at the Centennial Park site. These seasonal wetlands are usually dried up completely by mid-Spring, but this is likely to vary depending on annual precipitation. In drier years, these wetlands could be dry much earlier in the season. In wetter years, it is possible that these seasonal wetlands could remain inundated for the entire year. This is important when considering the habitat needs of species that may rely on this seasonality to complete their life cycle, such as sensitive amphibian species.



The small aquatic regions (creek, seasonal wetlands, year-round wetlands) are likely to serve as the “hot spots” for many species at Centennial Park. Many of the target species were found to require wet habitat, and the high use of these small areas may lead to increased biotic competition and predation among the species that utilize these sites. This may lead to tradeoffs in management practices across multiple species, since two desired species may compete with one another or may be more exposed to high densities of predators within this spatially-limited wet habitat.

Year-round water sources (wetland, creek)

Natives

- Western Pond turtle
- Tricolored blackbird
- Beaver
- Quail
- Pheasant
- Waterfowl (15-20cm depth winter and spring)
- Require year-round moist area (adjacent to year-round water)
- Ornate shrew

Invasives

- Red-eared slider
- Bullfrog (year-round or just long inundation?)

Ecosystem services (year-long and seasonal)

- Flood control, water supply
- C storage

Seasonal wetlands/oxbows/creek portions

Required by:

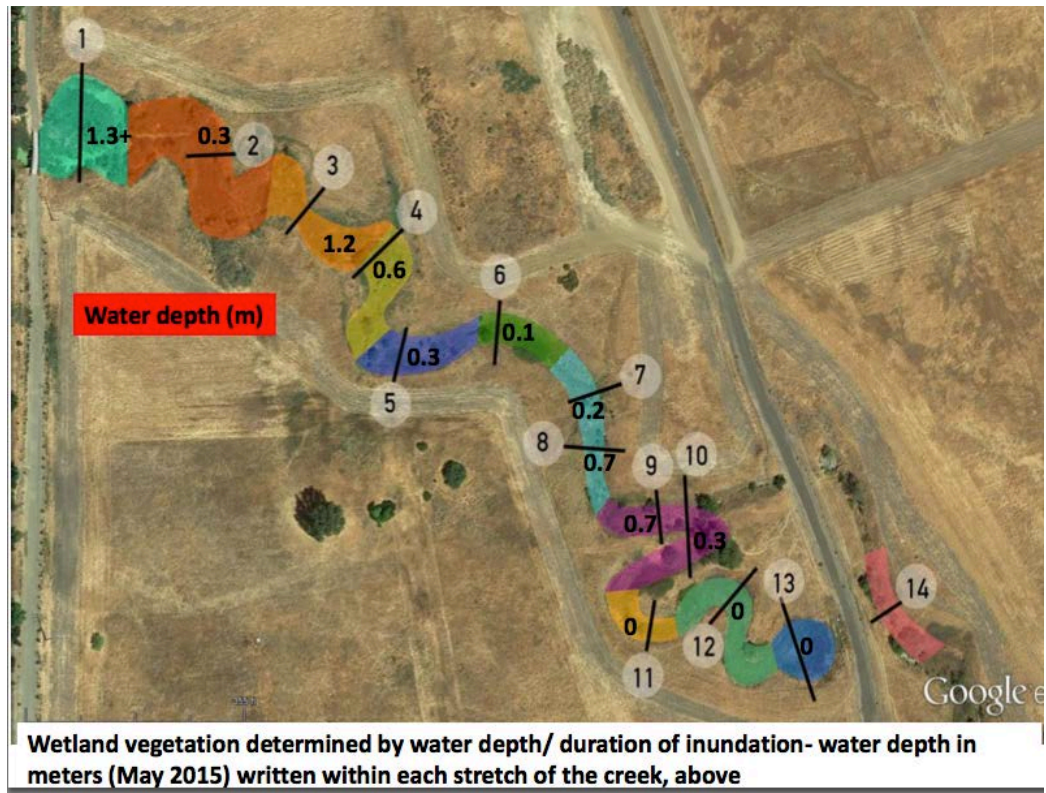
- Western spadefoot toad (30-35 days of inundation)
- Waterfowl (15-20 cm depth in winter and spring)
- Migratory song birds

Inhospitable to:

- Bullfrogs (if inundation period is short enough)

Habitat suitability for wetland vegetation is

determined by water depth and duration of flooding. The map below shows the results of water depth monitoring undertaken in May 2015.



The table below indicates the species most suitable to areas with specific water depths, providing guidelines for which wetland species would be most suitable for the different zones highlighted in the map, above. . While it is not possible to manipulate the amount of water flow into the site, manipulation of water depth (through encouraging ponding with coarse woody debris) would allow for more control over which species can establish and survive within the wetland zones (see table below).

Wetland plant zones - depth of water/ duration of flooding

Water depth	Inundation	Potential species	Zones (based on this drought year)
> 3m, or water too cloudy to support submerged vegetation	All year	Floating plants (e.g. Duckweed (Lemna))	1?
Saturated soil to 3m depth (does best at over 1.5m water depth)	All year	Reeds (Phragmites)- not native	Edges of 1, 2-10
>15 cm depth (replace bulrushes as water is deeper)	All year	Cattails (Typha)	1-5, 8, 9
.75-25 cm	All year	Bulrushes, (Schoenoplectus) Tules (Scirpus) Perennial pepperweed	6,7
Shallow/ edges	Can be in moist soil all year, tolerates occasional floods	Sedges (Carex) Rush (Juncus) Spike rush (Eleocharis) Perennial pepperweed	Edges of all 6-7 11-13?
Seasonal wetlands	1-5 months	Yarrow, western columbine, coffeeberry, yerba buena, brodiaea, tritelia, Lillies, poppy, phacelia, lotus purshianus, lupinus succulentus, lupinus densiflorus microcarpus, milkweed, blueyed grass, aster chilensis, solidago californica (goldenrod) , stachys ajugoides (hedge nettle), heliotropium curassavicum, lathrus vestitus (wild pea), licorice, sedges, rushes, grindelia, mugwort, elymus triticoides (creeping wild rye) Perennial pepperweed	11-13 "arms" of creek? Non-creek areas off map

Eradicate bullfrog and red-eared slider:

Wildlife surveys found evidence of several exotic wildlife species in the wetlands, including the bullfrog and Red-eared slider, which can have devastating effects on native reptile and amphibian species.

While complete eradication may be too large of a challenge because of the nearby canal that may be hosting these species, reducing the population of these exotics will help encourage native populations.

Riparian Management Summary:

The riparian zone at Centennial Park is has high variation in slope and depth to groundwater, as well as variation in soil type. Current restoration challenges include high invasive exotic cover and high erosion, leading to turbidity in the river channel. Additionally, the Solano County RCD is managing this site for flood control, which restricts the planting of woody species in the stream channel.

Riparian management should therefore focus on:

Removing high invasive cover: According to the vegetation surveys that were conducted within this same time frame, the majority of the plant species within 6-15 meters of the creek are exotic. Only two native and one naturalized species out of over 24 identified species were identified in these surveys. (see table below).

Common Name	Scientific name	Native V. Exotic
Purple Grass	Poaceae	N/A
Fox Tail Barley	Hordeum spp	Exotic
Rip Gut Brome	Bromus diandrus	Exotic
Italian thistle	Carduus pycnocephalus ssp. pycnocephalus	Exotic
Bristly Ox tongue	Picris echioides	Exotic
Italian Rye Grass	Lolium multiflorum	Exotic
soft brome	Bromus hordeaceus	Exotic
Poison Hemlock	Conium maculatum	Exotic
Purple Vetch	Vicia americana	Naturalized
Brassica(Mustard)	Brassica Spp.	Exotic
Bed Straw	Galium aparine	Exotic
Avena	Avena Fatua	Exotic
Geranium	Geranium Dissectum	Native
Prickly lettuce(oxtail)	Lactuca serriola	Exotic
Pepperweed	Lepidium latifolium	Exotic
Standard grass	Poaceae	N/A
Field Bind weed	Convolvulus arvensis	Exotic
Black Berry	Rubus armeniacus	Exotic
Cattail	Typha domingensis	Native
Medusa Head	Elymus caput-medusae	Exotic
Morning Glory	Calestegia spp.	Exotic
Barbed Goat grass	Aegilops triuncialis	Exotic
Ragweed	Ambrosia artemisiifolia	Exotic
Arroyo Willow	Salix lasiolepis	Native

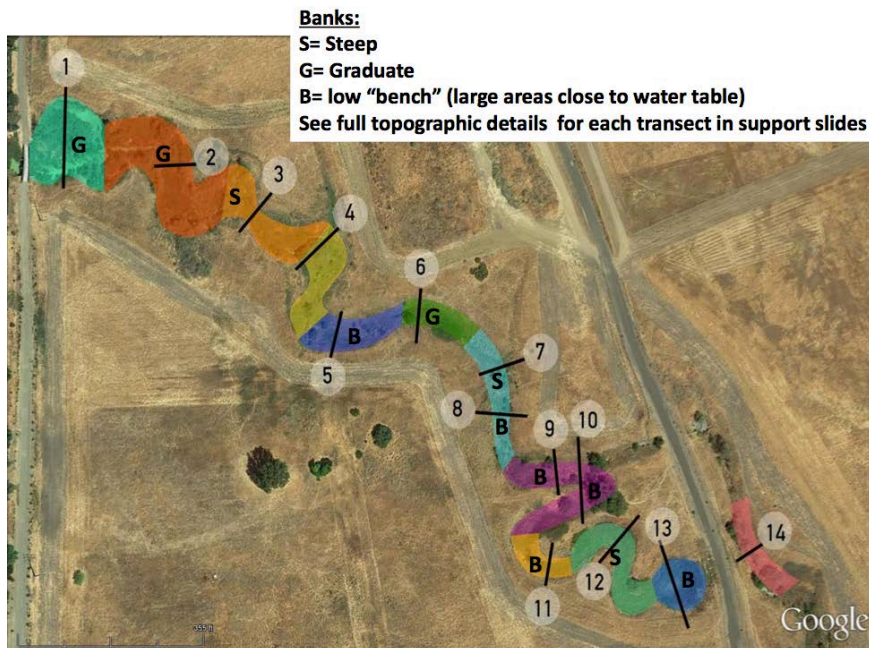
Current
vegetation
within 6-15 m of
creek: mostly
exotic

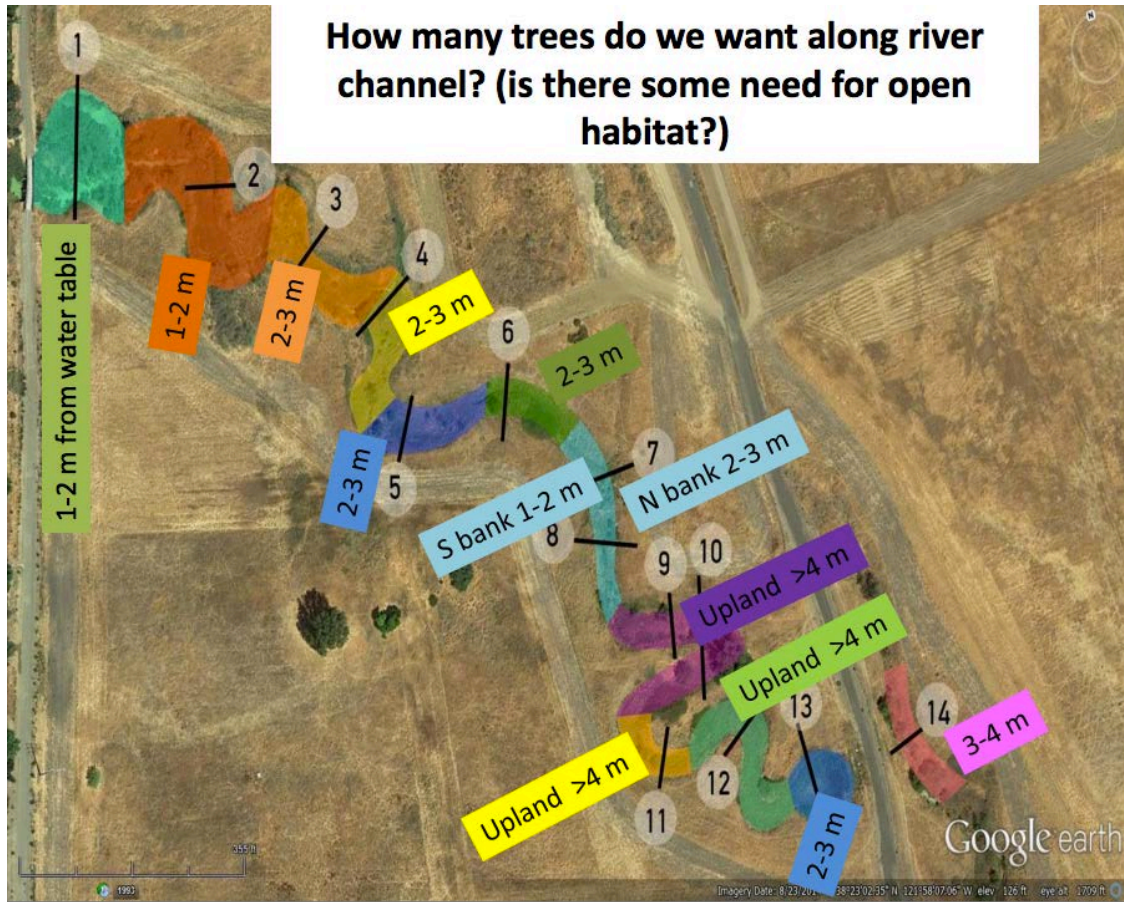
Exotic species removal can be approached through a combination of herbicides (to target fennel and teasel) and mowing in the spring through the fall (though not near teasel areas, where mowing encourages growth). A major tradeoff of this management strategy includes potential damage to wildlife sensitive to herbicides (especially amphibians, bees, and tricolored blackbirds). Potential solutions to this include the use of selective herbicides with less impact on the wildlife. However, it may be necessary to sacrifice short-term wildlife habitat and health for long-term habitat improvement. For low

mobility species, can herbicide small sections of the riparian area at a time, to preserve key habitat.

Replace with native cover- See table below for a list of riparian herbaceous plants by zone. Due to high variability in the water table based on annual precipitation, it is advised to plant species that are both drought and flood tolerant in the riparian zones. Once these natives have been planted, it is important to avoid herbicide for 2-3 years, and to mow 1-3 times per season in the mid-winter to mid-summer.

Prioritize erosion control (high turbidity in water): The riparian zone is characterized by a variety of low “bench” areas with low depth to groundwater and frequent flooding as well as steep slopes as well as relatively steep, steady slopes to upland. In the low bench areas, there is an opportunity to plant wetland and low riparian species (see table below).





Depth to Water Table (meters)

Riparian herbaceous plant zones - moisture/ duration of flooding

Depth to water	Inundation duration	Potential species
Saturated soil	Frequent	See wetlands
Seasonally saturated/ seasonally dry	occasional	Many Carex (e.g. Subfusca) W. Columbine Spike rush (Eleocharis) Scirpus Clematis ligusticifolia Perennial pepperweed
Wet but well drained	occasional	Mugwort Meadow barley Perennial pepperweed
Best on moist, but drought tolerant	Infrequent	Blue wildrye Creeping wild rye Milkweed Meadow barley Slender wheatgrass Perennial pepperweed Teasel Fennel
Mid- riparian (drier, drought tolerant) for long periods	Infrequent	Blue wildrye Eriophyllum (sunflower) Deergrass Deschampsia cespitosa Calamagrostis nutkaensis Calochortus albus Festuca californica Lonicera involucrata, milkweed, centromadia sp, (tarweed), lupinus sp, trifolium wormskieldii, licorice, Perennial pepperweed Teasel Fenne
Upper riparian- occasionally moist, long drought	Extremely infrequent	soap plant, poppy, brodia, milkweed, , centromadia sp, (tarweed) licorice, lupinus sp, trifolium wormskieldii,, purple needlegrass, elymus, leymus

Management for grasses vs. pollinator plants, similar need for fire control:

Herbaceous cover in the riparian zone will benefit from frequent disturbance, including mowing, grazing, or burning, which will benefit wildlife indirectly by enhancing habitat. However, this disturbance can also directly threaten wildlife, especially ground nesting bees and birds. Other species can tolerate disturbance as long as it has been timed correctly to avoid sensitive periods in the life cycle. The table below gives examples of temporal management strategies for enhancing riparian vegetation while protecting certain wildlife species.

Species and Management Strategies

	<i>Mowing</i>	<i>Grazing</i>	<i>Burning</i>	<i>Flooding</i>	<i>Vehicle traffic</i>	<i>Herbicide/ pesticide use</i>
<i>Tri-colored blackbird</i>	<i>Jul-Feb</i>	<i>Jul-Feb</i>	<i>Jul-Feb</i>	<i>Jul-Feb</i>	<i>Jul-Feb</i>	<i>Aug-Jan</i>
<i>W. Spadefoot Toad</i>	<i>no</i>	<i>no</i>	<i>June-Dec</i>	<i>Jan-May</i>	<i>no</i>	<i>little/none</i>
<i>W. Pond Turtle</i>	<i>Yes outside of spring</i>	<i>Yes outside of spring</i>	<i>no</i>	<i>yes</i>	<i>no</i>	<i>no</i>
<i>Waterfowl</i>	<i>n/a</i>	<i>no</i>	<i>no</i>	<i>depends</i>	<i>n/a, but probably no</i>	<i>no</i>
<i>Migratory Songbirds</i>	<i>Sept-Feb</i>	<i>Sept-Feb</i>	<i>Sept-Feb</i>	<i>Sept-Feb</i>	<i>n/a</i>	<i>Sept-Feb</i>

Removal of feral cats: Feral cats pose a major threat to wildlife at Centennial Park, especially amphibians, reptiles, and migratory birds. The nearby residential areas may pose a challenge to feral cat removal, due to the fact that these areas may harbor and encourage feral cats.

Woody Species Management Summary:

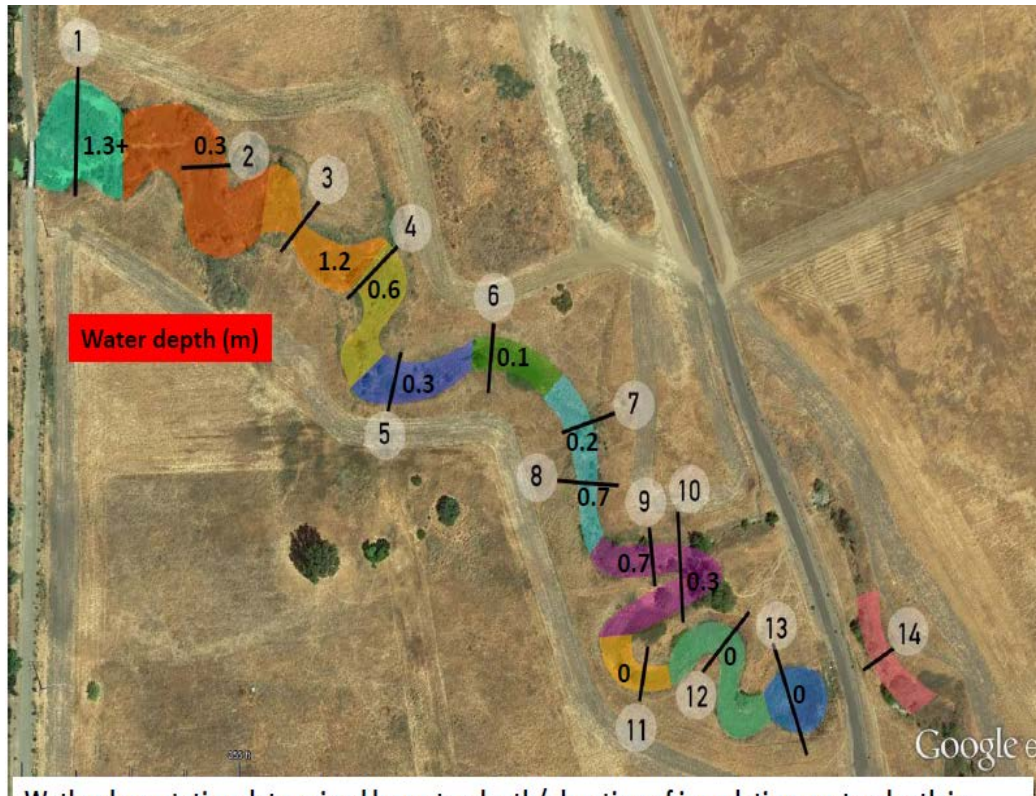
Woody species are currently distributed in the stream channel, along the streambank, and in the upland areas. See map below for current distribution on woody vegetation:



Potential areas that can Support Woody Species

Woody species are a critical for providing many of the Solano County RCD target goals, including habitat for native species and several ecosystem services. However, the RCD is limited in where it can plant these species due to the fact that the site is being managed for flood control. Therefore, **no woody species can be planted in the creek channel.** However, **woody species can be planted the upland areas outside of the creek channel.** However, the distribution of woody species are limited by two factors: **water availability and soil type:**

-The **upland areas at the edge of the creek channel** (streambank) show **high potential for woody species.** Topographical surveys showed that most areas just outside of the creek channel are close enough to the water table to support riparian trees, which are located mostly in the 2-3 m and 3-4 m zones. This potential for riparian species is particularly high in the northwest corner of the property.



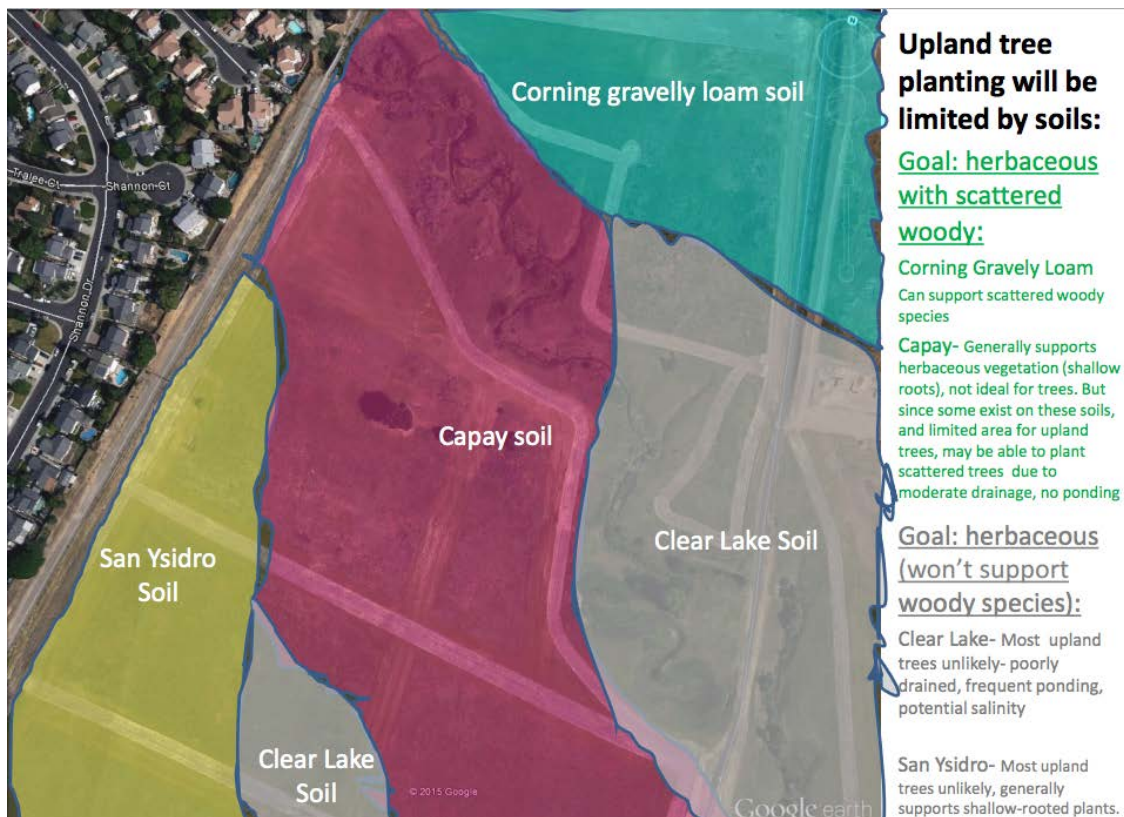
Wetland vegetation determined by water depth/ duration of inundation- water depth in meters (May 2015) written within each stretch of the creek, above

Woody plant zones - depth from water table

>4m	3-4 m	2-3 m	1-2 m	<1 m
- Boxelder, - Bay, - sycamore, - oaks (valley, canyon live,), - Ceanothus , buckeye, - rose, - coyote bush , holly leaf cherry, - silver bush lupine, - toyon, - redbud, - poison oak - Coffee berry, - snowberry, - monkey flower - fuschia - Chinese tallow	- Valley oak - Goodings willow - Buttonbrush - Elderberry - Mugwort - redbud, - fuschia - maple - Chinese tallow	- Valley oak - Goodings willow - Arroyo willow - Cottonwood - Ash - White alder - Walnut - Sycamore - Cottonwood - Narrowleaf willow - Mulefat - Buttonbrush - CA rose - Blackberry - Edleberry - Mugwort - redbud, - Fuschia - Maple - Grape - Chinese tallow - Fig	- Cottonwood - Goodings willow - Buttonbrush - Boxelder - White alder - Ash - Red willow - Arroyo willow - Narrowleaf willow - Mulefat - CA rose - Blackberry - Mugwort - redbud, - Dogwood - Spicebush? - Grape - Chinese tallow	- Goodings willow - Narrowleaf willow - Red willow - Aroyo willow - White alder - Ash - Cottonwood - Valley oak - Interior oak - Buttonbush - CA rose - Blackberry - Mugwort - Dogwood - Grape - Chinese tallow

Red= invasive

In the **upland areas located away from the creek channel**, where ground water is deeper and less accessible, **woody species are limited by soil type**. Woody species are limited but supported in Corning Gravelly Loam, and Capay soils, both which are characterized by moderate drainage and no ponding. These soils make up about one quarter of the area. The other two soil types, Clear Lake and San Ysidro, can only support shallow-rooted species and therefore are unable to support woody species. See map below.



Goals for woody species:

After considering the environmental limitations to planting woody species at the site, it is important to consider, within these limitations, the optimal distribution and density of these woody species for addressing the Solano County RCD restoration goals.

High cover of woody species is necessary for the following ecosystem services:

- Carbon storage
- Air pollution
- Heat island mitigation

However, planting the maximum density of trees will risk the depletion of groundwater, which could dry out the creek.

High cover of woody species would also provide habitat for several species that require trees, including:

- Beaver: uses riparian trees
- Swainson's hawk: Need single, large isolated trees for nesting more off in the upland
- Coyote: uses riparian area
- Cavity nesting birds: need shrub cover, middle, canopy species, varied density
- California Quail: heterogeneous habitat

However, , for most of these species, the goals of creating wildlife habitat would be better achieved by planting a **heterogeneous mix of trees and open habitat**. This is important because many species require open habitat, including shade intolerant wetland and riparian species, as well as reptiles that require open basking sites. The following is a list of types of species that require open habitat and would **not benefit from planting the maximum cover** of woody species and would be better served by a **heterogeneous mix of woody species and open space**:

- Reptiles and amphibians (Western Pond Turtle, Spadefoot toad): need basking space
- Bees: need ground nesting habitat, are also affected by Buckeye trees, which are toxic to honeybees (only toxic to non-natives, not natives)
- Small rodents
- Many grasses and wildflowers that are not shade resistant
- Many aquatic plants and wetlands are shade intolerant (see table below)

Herbaceous wetland/riparian species and shade tolerance

- Shade tolerant
 - Blackberry
 - Snowberry
 - Toyon
 - Poison oak
 - Coyotebush
 - Purple needlegrass
 - Elymus glaucus
 - Monkey flower
- Light shade to full sun
 - CA meadow barley
 - Elymus triticoides (plant where there's high erosion risk)
- Full sun
 - Snowberry
 - Milkweed
 - Goldenrod

Therefore, it is recommended that woody species be planted below maximum possible density. One possible solution to this tradeoff is to consider where woody species may help achieve other goals, such as creating natural barriers that would limit people going off trail and into sensitive habitat. Planting shrub thickets will discourage the public from leaving the trail, and can be placed strategically near sensitive wetland areas.

Upland Management Summary:

Management strategies in the upland areas focus on establishing native vegetation and creating habitat for wildlife. Both of these goals are constrained by upland soil type, which confine most of the plantings to herbaceous vegetation, with scattered areas for woody plants.

These goals include:

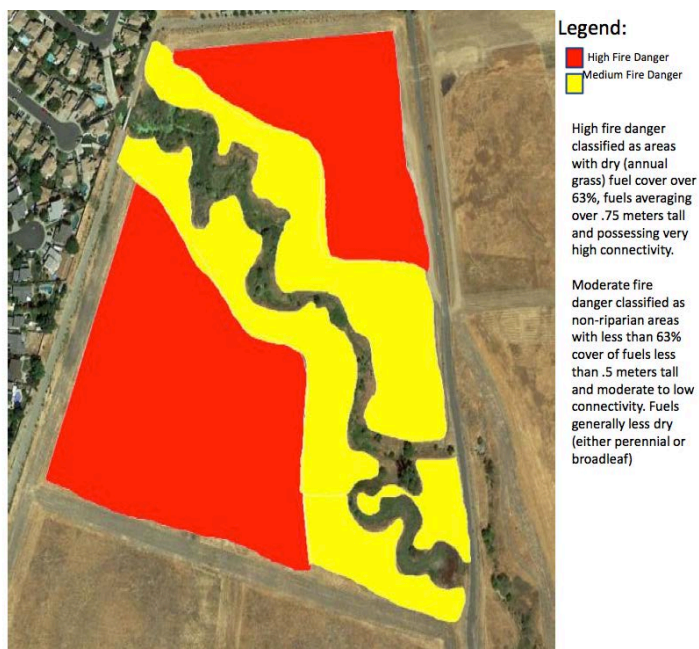
Vegetation

- Keep fire danger low
- Decrease invasives- *Medusahead, Avena , Lolium & other annual grasses, Vicia*
- Enhance native grasses
- Enhance native forbs, particularly pollinator plants

Decreasing invasives using herbicides presents the same tradeoffs and challenges as described in the riparian vegetation management summary. Potential solutions to this include the use of selective herbicides with less impact on the wildlife. However, it may be necessary to sacrifice short-term wildlife habitat and health for long-term habitat improvement. For low mobility species, herbicide can be used on small sections of the riparian area at a time, to preserve key habitat. Other invasive control strategies such as mowing, grazing, and fire, are natural features of grassland ecosystems, and will be discussed in more detail below. Below is a map of potential upland native plantings stratified by type of upland (wet/dry zone), soil type, and proximity to residential areas.



Planting perennial bunchgrasses and woody species will help reduce fire hazard in the uplands. Fire hazard areas are outlined below:



Planting hedgerows around the bike path will encourage the public to stay on the bike path and provide habitat for pollinators and other wildlife.

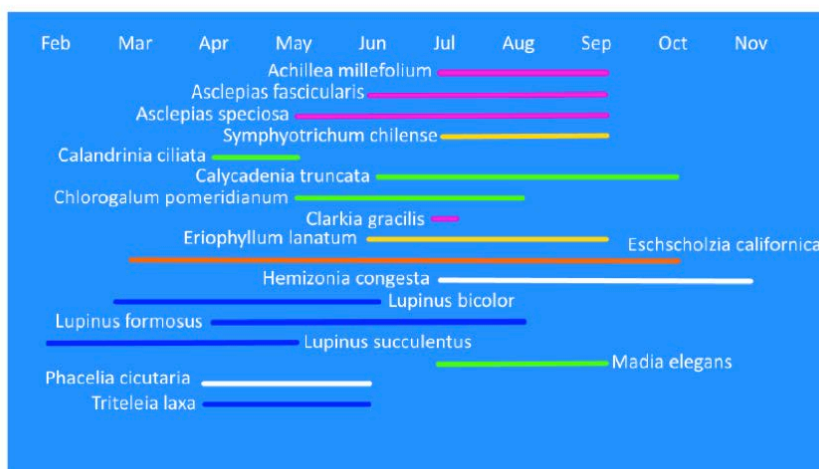
Species for Hedgerows Along Bike Path

N a m e	Texture Type	Drainage of Soil	Water Storage of Soil	Early Season	Early to Mid-Season	Mid-Season	Mid to Late Season	Late Season
C a p a y	Silty Clay Loam	Well Drained	Moderate	<i>Ceanothus Frosty Blue</i>	<i>Heteromeles arbutifolia</i>	<i>Eriogonum fasciculatum</i>	<i>Grindelia camporum</i>	<i>Baccharis pilularis</i>
			<u>WUE</u>	<u>low</u>	<u>low</u>	<u>low</u>	<u>low</u>	
C l e a r L a k e	Clay	Poor Drainage	High	<i>Salix laevigata</i>	<i>Baccharis salicifolia</i>	<i>Rosa californica</i>	<i>Agastache urticifolia</i>	n/a
			<u>WUE</u>	<u>high</u>	<u>medium</u>	<u>medium</u>	<u>medium</u>	

Wildlife: It is important to create heterogeneous habitat with access to water, woody cover, and perch sites in order to accommodate the largest suite of species possible. Grasslands will also be important for hunting and nesting. Grass height can also be important to certain species, for example, voles require grass of height 3" or higher and many predators require grass of a height of 2- 3".

For pollinators, it will be important to plant a mix of pollinator plants with continuous blooming to encourage pollination throughout the year.

Mix of pollinator plants to encourage blooming throughout the year





The image above shows the potential distribution of tree, shrub, grass, and forb species after restoration at the Centennial park site.

Maintaining the upland herbaceous community will require **repeated disturbances** (e.g. grazing, tilling, burning, mowing). This is critical to combat the

build up of invasive thatch, which can decrease plant productivity, wildflower blooms, and fire control. Grasslands are evolved for this type of disturbance, but there are tradeoffs in the timing and the management of certain species.

Mowing can be detrimental to ground nesting birds and bees, especially in April-August. Burning can also affect nesting birds. Wet-season grazing, can compact soils and negatively affect ground-nesting bees. Furthermore, often areas that are targeted for controlled disturbance can be serving as important foraging, pollination, or shelter habitat, and this often changes with the season. For example, pollination surveys at the site found that the exotic milk vetch was heavily used by pollinators as a food source.

Tradeoffs on timing of mowing and tilling include:

Spring mowing

- Pros: To manage weed populations, often need to mow April/May
- Cons: To protect ground nesting birds, should not mow in April-August
- To protect pollinators, no mowing during flower blooms (March-June/July, possibly later)

Fall/winter mowing

Pros: good to enhance forbs, good for wildlife

Tilling

- Pro: Good way to begin restoration, to decrease invasives
- Con: disruptive to: AM, ground nesting bees, voles

Below is a summary of different recommendations and advantages to different disturbance regimes for upland areas. See lab reports for more detailed management recommendations.

Grazing	Mowing	Fire	Tilling
Graze only a 1/3 of area	Mow once a year Try to mow Mar - Sept Minimum height 12- 16 in	Burn only a 1/3 of an area	Have an area of permanent no - tilling
Short amount of time and long period for area to recuperate	This protect above ground nests and overwintering queens	Fire can destroy pollinators that next above ground	This allows bees to have an area to nest.

Conclusion: This summary section provides a brief overview of several environmental conditions that were determined to be key to shaping potential restoration activities

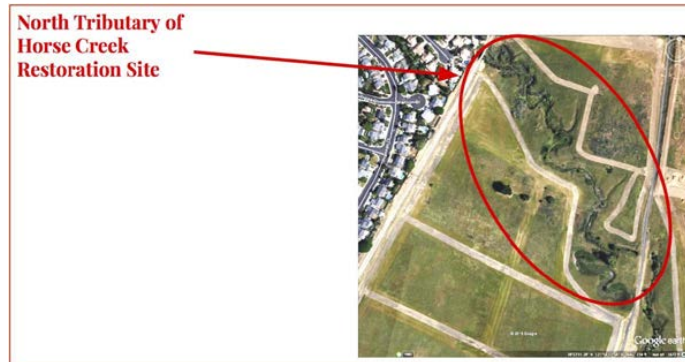
across the Centennial park site, and management strategies that could potentially address multiple restoration goals. More information on field data collected at Centennial Park can be found in the Lab Summaries section, and requirements for individual and species-specific goals can be found in the Individual Reports section.

TOPIC-SPECIFIC LAB SUMMARIES

This goal of the laboratory section was to collect all of the “on-the ground” information to create the knowledge base about the Centennial Park Site. Through weekly site visits and group projects, the students assessed the site potential across a heterogeneous landscape. They delineated how to “stratify” the landscape, based on site conditions and site potential to support different species/habitats (e.g. wetland, creek, seasonal creek, riparian transition zone, upland, other). The following group lab reports outline various site characteristics using the current conditions and species composition found at the Centennial Park site in Spring 2015. Based on the results of these monitoring projects, these lab reports determine habitat sustainability for various restoration activities.

LAB SUMMARY: TOPOGRAPHY

Prepared by: Clancy McConnell, Hailey Pexton, Bethany Celio, and Leticia Macias



INTRODUCTION

Questions that guided our analysis include the following:

- Which locations along the Horse Creek Northern Tributary are representative of changes in slope and structural zones?
- What kinds of habitat can different sections of the tributary facilitate?
- Where are vegetative thresholds for slope angle?
- What are vertical and horizontal distances to water in different zones along the tributary?
- Is there observable incision taking place in the tributary?

Based on the above questions, our goals for monitoring included sampling topography using transect profiling to define slopes, benches, and channel structure change along the tributary. In all, we measured 14 transects along the Horse Creek northern tributary to assess landscape variation along the channel, accounting for slope, distance, and defining characteristics. We then used these measurements to calculate width and depth averages in different sections of the waterway, which can be used by other specialists to determine vegetation design at the site. In particular, they can use our data in reference to depth-to-water, slope angle, and channel width.

METHODS

We assessed background information, including aerial photographs, to determine useful locations for (and amounts of) transects. In particular, we noted total length, channel shape, streamflow, and contours of the tributary. Based on location, we then stratified the site into 3 representative transect units for monitoring days, including a north-western, middle, and south-eastern area of the tributary.

We used a transect tape to measure the length of each transect/bench, a meter stick to measure water and main channel depth, and a clinometer to measure slope angle. In the north-western segment, we measured four individual transect lines from south to north (Transects 1, 2, 3, and 4). Using the same methods, we analyzed the middle segment area with four individual transects (Transects 5, 6, 7, and 8), and, on the last monitoring day, measured the south-eastern area of the tributary with 6 individual transects (Transect 9, 10, 11, 12, 13, and

14). Overall, our topographical measurements are representative of each section of channel structure, and our data analysis shows structural changes along the tributary.

DATA SUMMARY

Image 1. location of transects (#10 is a double transect and #14 is in the adjacent drainage)

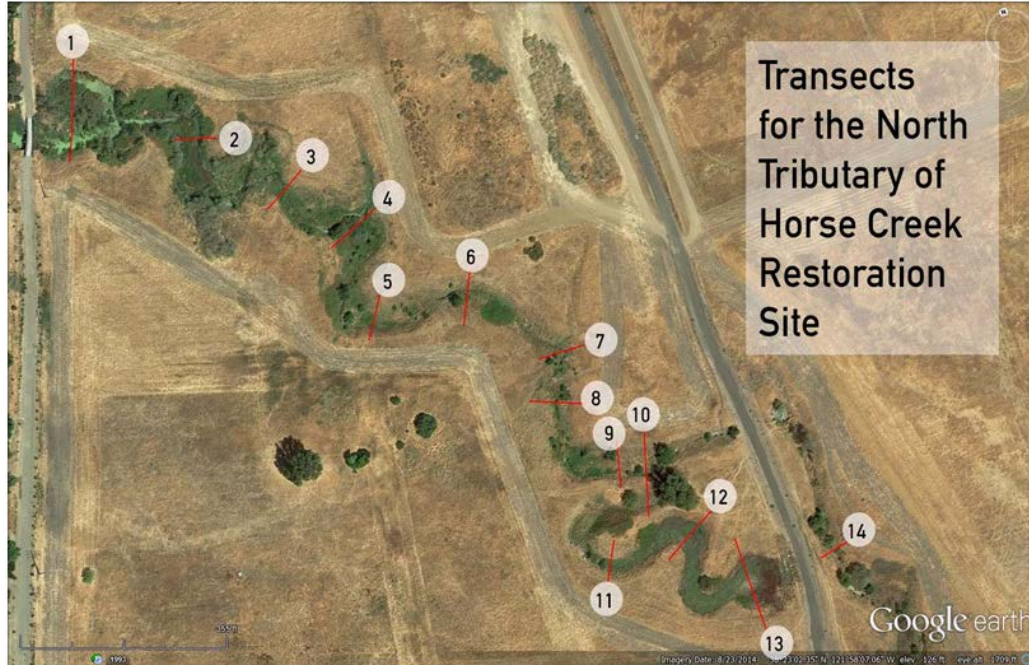


Table 1. Transect Data

RESULTS

Notable Findings:

- Estimated range of slope angle: **15-30°**
- Average width of bottom/main channel: **6.87 m**
- Total length of north tributary: **647.49 m**
- There was wide variation in channel depth and width, however:
 - Average total depth: **3.61 m**
 - Average total width: **31.44 m**

Image 2. Transect locations and estimated areas of the channel to which they apply (shaded)

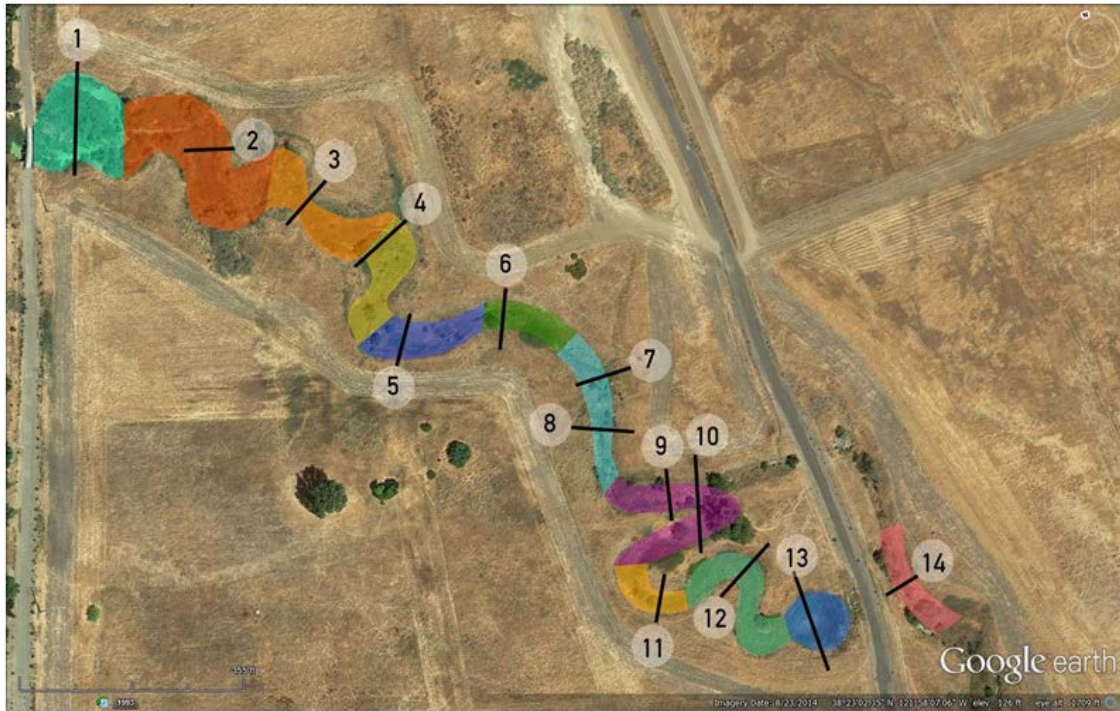
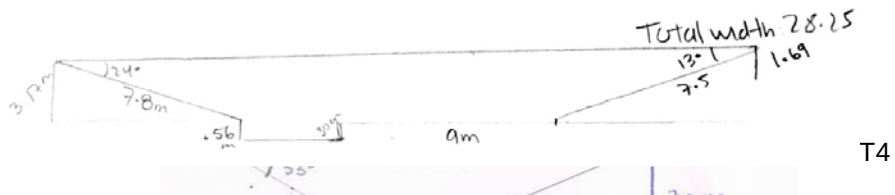
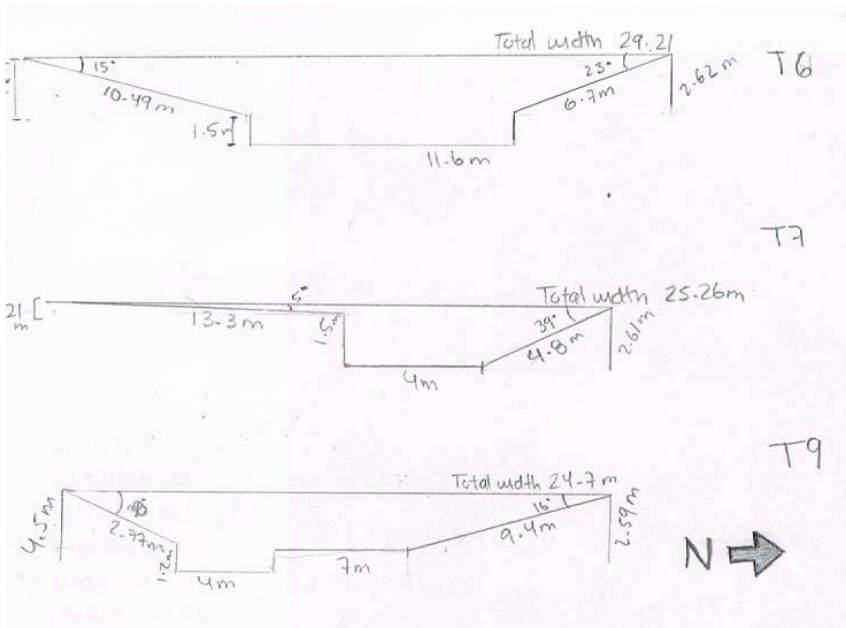
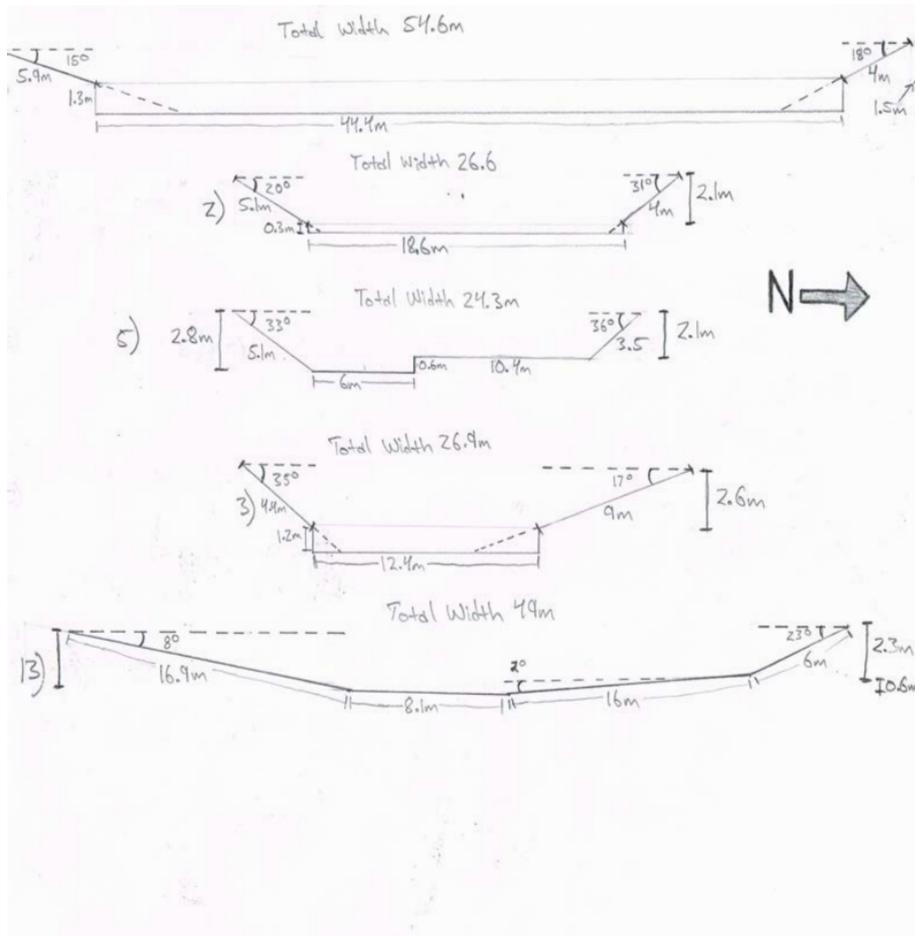
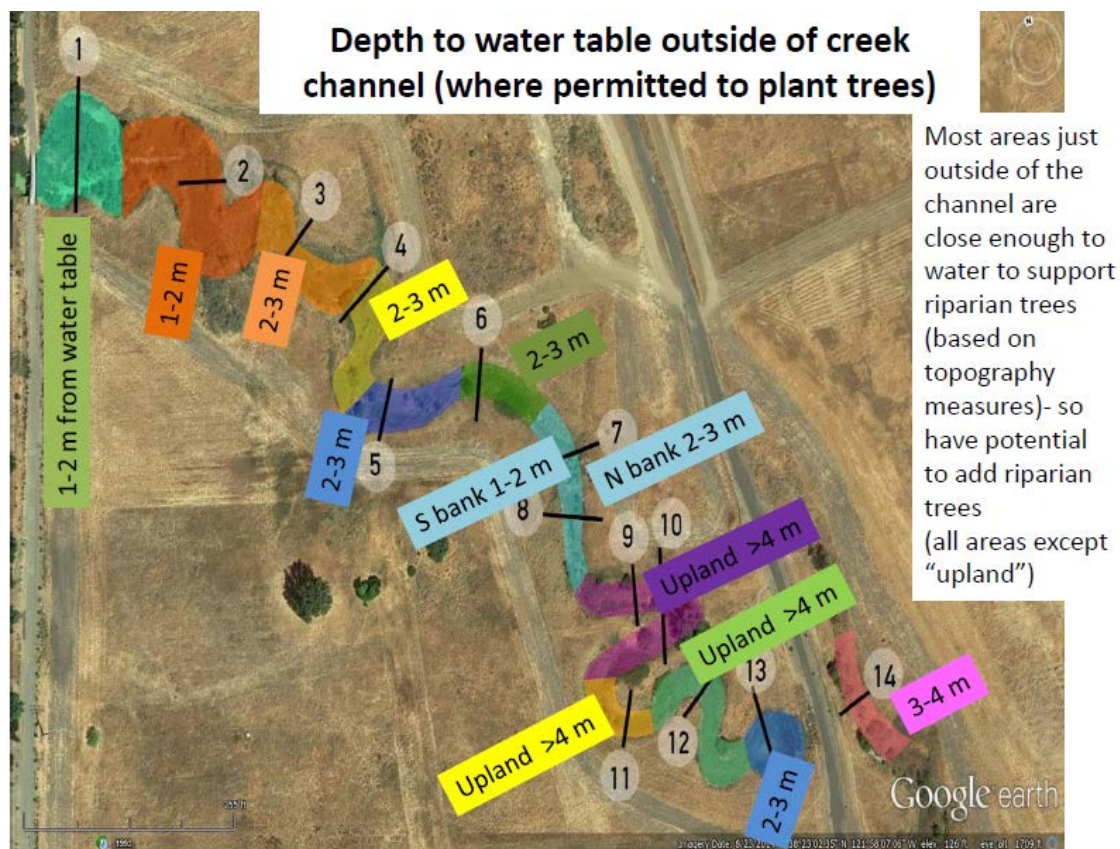
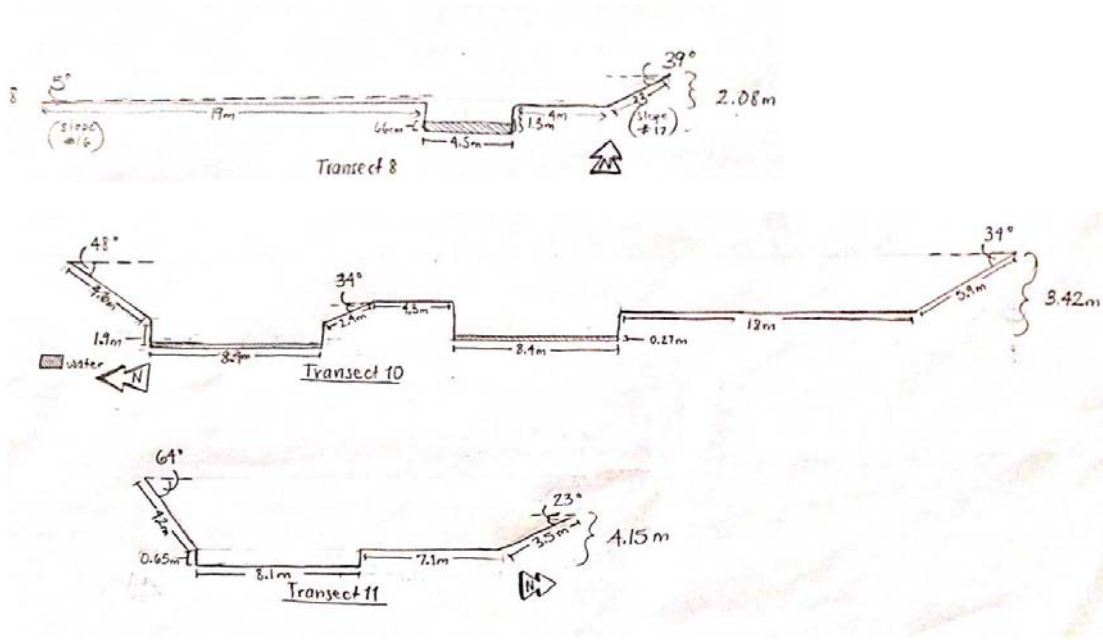
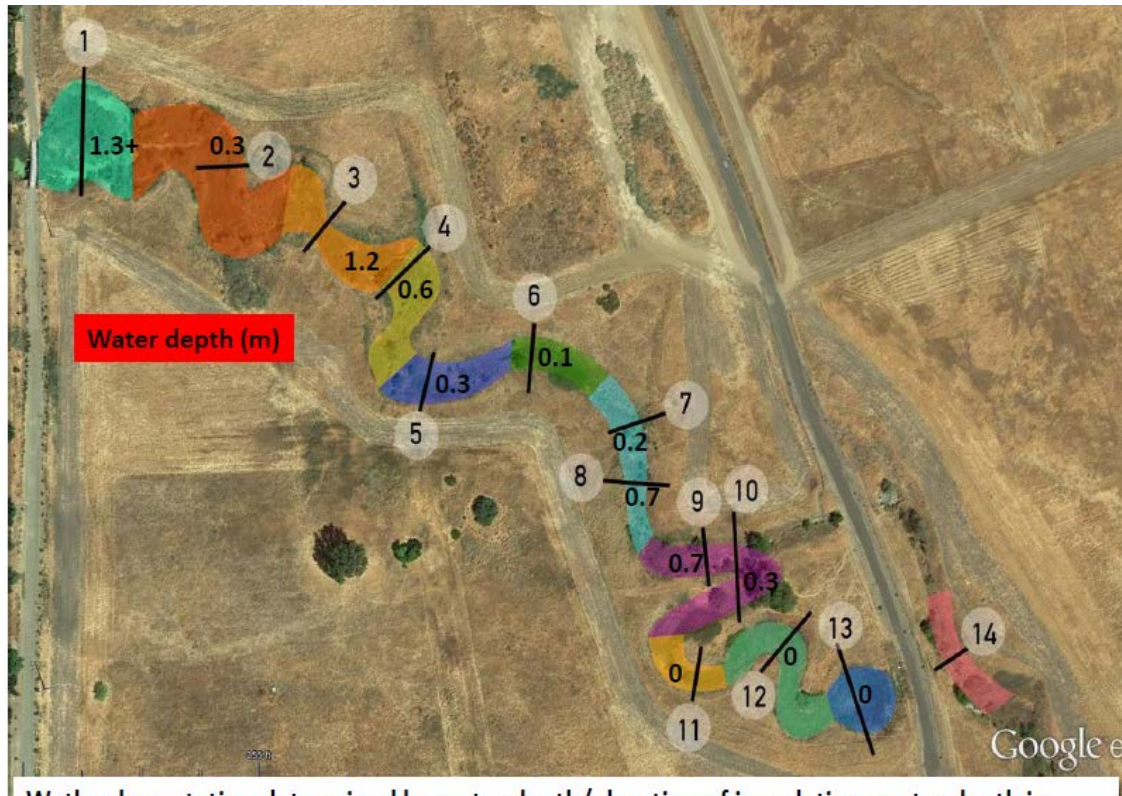


Image 4. Cluster of transect sketches (not in order). Sketches are accurate, but size or scale relative to one another has been warped by scanning and Microsoft Word. In the actual paper sketches, 5mm=1m and the north/northeast side is the right side, unless otherwise noted.







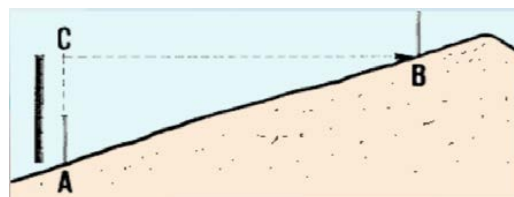


Wetland vegetation determined by water depth/ duration of inundation- water depth in meters (May 2015) written within each stretch of the creek, above
CHALLENGES AND OPPORTUNITIES

Transect data and metadata can be enhanced by the accompaniment of GPS waypoints taken at each of the transects and/or slopes, and can also be used to estimate changes in elevation. This data can then allow for better accuracy regarding the true location of the transects and information that can be projected in ArcGIS. An ArcGIS map that includes this data would be useful for future reference and planning regarding tasks such as the mapping of installed vegetation or other changes in regards to these transects. Other technological enhancements of data acquisition will be important for accuracy and precision.

The use of handheld clinometers, with which slope angles were recorded, often subjective to the user. An alternate method that can control for clinometer misreadings is the actual calculation of slope done by measuring the hypotenuse and height of an include, as depicted in Image 5. Here, one would measure the lengths of both AC and AB, and find the slope: $S\% = 100AC/AB$.

Image 5. Calculating slope (from: ftp.fao.org)



are

It should be noted that the distance measurements taken with measuring tape held by two individuals can easily lead to incorrect readings based on the height at which the individual holds the tape. This is because using a telescoping rod was incompatible with the terrain.

The method with which the transects were drawn involved rough estimations by sight based on the characteristics of the surrounding substrate. GPS points, once again, can allow for the

relatively more accurate depiction of these transects on a map using GoogleEarth, ArcGIS, or other projecting software.

Surveys were restricted by land barriers such as water depths greater than 1.3 meters, a steep rock wall, and harsh vegetation such as blackberry bushes. These limitations are reflected in the locations of the transects and their irregular spacing. It would be beneficial to have transects taken with greater frequency, equal spacing, and in locations that were specifically too difficult to reach.

Lastly, the water level data reported in this analysis is a poor reflection of water level that is to be expected at the site. For one, 2015 has been a drought year and is therefore not an accurate depiction of water conditions under more normal circumstances. It would be informative and useful to have water level data taken at three month intervals to capture seasonality. This should be done over multiple years to control for dry and wet years and interpolate accordingly.

SUMMARY AND RECOMMENDATIONS

Summary/Implications

There was a wide variety of slopes along the entirety of Horse Creek. Transects vary dramatically, but the average width of the channels is 31.44 meters, while the southeastern wetland is 49 meters across. This impacts the velocity of water flow and also the volume of water contained within the creek. In addition, there is variation within the channel troughs, but the average depth is about 1.3 meters; this will impact water flow when the rains come again. The slopes of the banks vary dramatically across the site; the slopes range from non-existent (flat upland, flat benches in the channelized area), to extremes such as 50% and even 90%. Though on average, the slopes range from 15-30 degrees. This has important implications for vegetation plans and water inundation times. This also affects the depth to water from the top of the bank, of which the average was 3.6 m.

Recommendations

In order to maximize seasonal wetland habitat, one recommendation is to add additional bench areas along the edges of the channel. Also, there are significantly steep slopes present at the site that may cause erosion and be difficult to vegetate; thus, it would be beneficial to reduce steep slopes that will cause an erosion hazard and be difficult to stabilize with vegetation.

New or unresolved questions

- What are some ways to alter topography to mitigate the possible effects of erosion?
- What are some more effective ways to accurately capture the landscape aspects along the tributary as a whole?

LAB SUMMARY: SOILS

Genevieve Puccinelli, Sequoia Williams, Brandon Putz, Kit Krupp

The measurements done during our soil survey were conducted to determine how accurate the NCRS and Solano County soil surveys represent the current conditions of Centennial Park's soils. The data collected also served to differentiate various soil types and establish the location of soil boundaries throughout the site. We used the NRCS delineated

soil map available for our site as basis for our sampling location (Figure 1). A CvD2 (Corning gravelly loam) sample was taken in the North West quadrant of the site at 38° 23' 09.5" N 121° 58' 12.8" W. Four samples of Ca (Capay silty clay loam) were taken at 38° 23' 3.97" N 121° 58' 15.2" W, 38° 23' 03.0N 121° 58' 13.8" W, 38°23'01.6"N 121°58'14.9"W and 38°22'59.8"N 121°58'14.0"W. Three samples of SeB (San Ysidro sandy loam) were taken at 38°23'00.3"N 121°58'17.1"W, 38°22'57.9"N 121°58'16.1"W, and 38°22'57.2"N 121°58'18.1"W. The soil characteristics measured at the site include soil texture, bulk density, soil depth and compaction, soil infiltration, soil fertility, and soil pH. Soil texture was determined at 0-15 cm and 15-30 cm deep and the ribbon method was used to determine texture of each soil core. Bulk density was measured by removing a known volume of soil, and weighing the weight of the subsample at field moisture, then using an oven to dry out the soil and again measure the sample's dry weight. Soil depth and compaction was measured using a penetrometer where we measured the amount of pressure needed to reach particular depths of soil. Soil infiltration was measured using an infiltrometer, and we measured how much water was absorbed by the various soil sites during a set period of time. We collected data on soil fertility by using field kit tests to measure the level of nitrogen, phosphorus and potassium in the soil. PH was measured by dissolving pH tablets into a mixture of soil and water, and comparing the developed color to a pH chart.

Since our group decided to focus on the upland area, we had a large area to cover, which proved to be more than we expected. We also had some problems finding our sites from week to week due to difficulties with our GPS unit. Therefore, some of our site locations were rough. However, we still believe the data collected is valid to overall trends of the site.

Figure 1. Sampling Locations



Our data was analyzed by converting and comparing to data found in already existing soil surveys. From our data, we found very comparable results to the NRCS and Solano County soil surveys. For soil texture, the ribbon method proved to be quite accurate for determining the soil texture when compared to the existing soil survey data. The bulk density data showed that the Corning soil (where it was tested), was much less dense than shown in the existing soil survey data. Also, the San Ysidro's bulk density was not accurately represented, as the sample was taken from the first 15cm of soil. The sandy composition of this layer gave the soil a much lower bulk density than expected. Data collected for compaction showed no concerning areas for compaction, save for the San Ysidro soil, which showed a possible area of compaction. This is due to the amount of clay just below the surface, which is susceptible to hard panning. Infiltration data showed that water quickly infiltrated the San Ysidro soil. For NPK and pH measurements, the measurements were very rough. However, the data showed comparable results to previously known data from the soil surveys, despite the low accuracy of the field test kits.

For all of our data, the numbers are rough estimations, rather than data that can be used for statistical analysis and significance. Our purpose in doing these tests was to see if previous soil survey data still holds true. As such, the data collected from the site compares well to previously known measurements in the soil series tested.

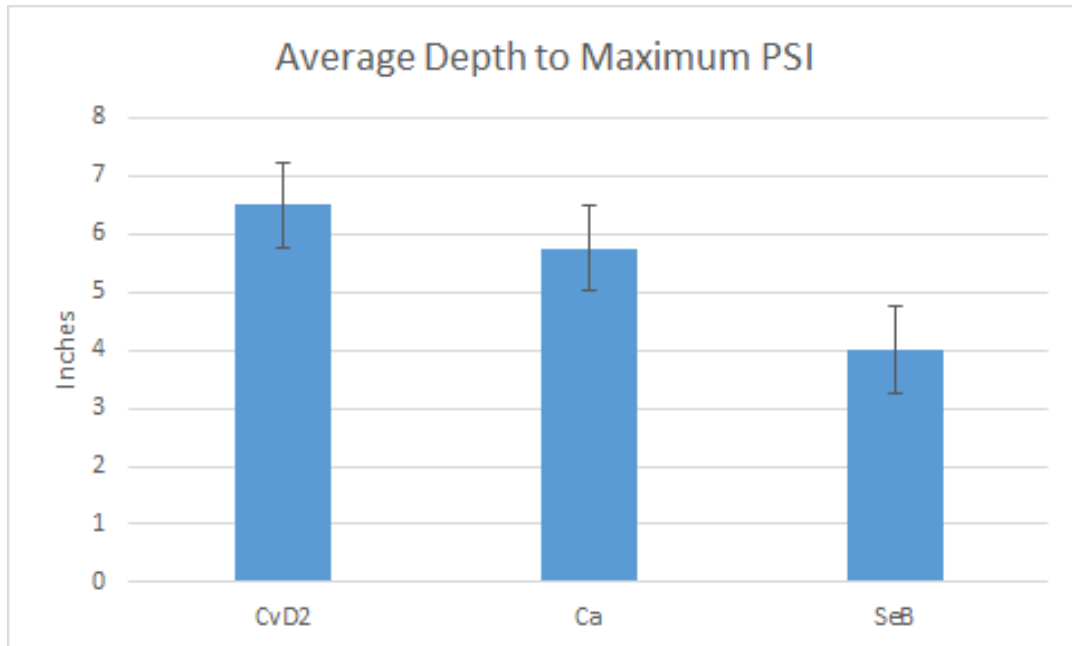
Table 1. Field Texture analysis compared to NRCS soil survey data

	Corning	Capay silty clay loam	San Ysidro
Field 0-15	clay loam	silty clay loam	sandy clay loam
Field 15-30	clay loam	silty clay	clay loam
NRCS	gravelly loam	silty clay loam	sandy loam-sandy clay loam

Table 2. Field bulk density compared to Solano County soil survey

	Corning	Capay silty clay loam	San Ysidro
Field test	0.79 g/cm ³	1.71 g/cm ³	1.28 g/cm ³
Solano Co	1.64 g/cm ³	1.95 g/cm ³	1.70 g/cm ³

Figure 2. Field Compaction Data



Maximum PSI: CvD2-205 Ca- 212.5 SeB-219.2

Table 3. Field Mineral Nutrient Data compared with Solano County soil survey

	Corning	Capay silty clay loam	San Ysidro
Field test N	12.61 Meq/L	12.61 Meq/L	12.61 Meq/L
Solano Co N	12.7 Meq/L	10.3 Meq/L	6.4 Meq/L
Field test P	2.84 Meq/L	11.38 Meq/L	2.84 Meq/L
Solano Co P	--	--	--
Field test K	0.05 Meq/L	0.14 Meq/L	0.10 Meq/L
Solano Co K	0.4 Meq/L	0.1 Meq/L	0.3 Meq/L

Table 4. Infiltration Field Data

	Corning	Capay silty clay loam	San Ysidro
Field test	2.3 ml/s	1.77 ml/s	3.07 ml/s

Table 5. Field pH compared to NRCS Soil Survey

	Corning	Capay silty clay loam	San Ysidro
Field test	6	7	6
NRCS	5.5	6.5	6.5

On most of the 2015-2016 restoration site, soil will not be a limiting factor in plant establishment. Mineral nutrient loads and pH are all adequate for most plants in all soil types. The San Ysidro soil may not be appropriate for plants that require 30cm or more of sandy loam soil, or greater than 30 inches to the water table. The textural change from sandy clay loam to clay loam is attendant with an increase in compaction that may prevent roots from penetrating the clay layer. Also, the clay loam may create a perched water table in wet conditions. Shrubs planted on San Ysidro soil on-site had poor establishment and survival. Therefore, we recommend planting shallow-rooted plants that prefer sandy clay loam on San Ysidro soils. We were unable to test whether San Ysidro soils would have perched water tables under heavy irrigation or rain regimes, so additional testing is needed to determine whether plants also must be able to survive inundation. Overall, our findings reflected those of the NRCS and Solano County surveys, implying that the data in those surveys is still accurate with regards to current site conditions.

The accuracy and applicability of extant soil surveys is key considering that we did not get a clear delineation of where soil types and characteristics change across the site. This is partially due to the fact that soil characteristics often change across gradients instead of distinctly. However, we believe if we had chosen more sites and performed fewer measurements on each site, we would have had a more clear overlay of the chosen measurements. For example, the bulk density measurement and the penetrometer measurement were similar so we could have just performed the bulk density measurement. However, with our limited time we believe we have collected a comprehensive and useful set of soil data for the Centennial Park 2015-2016 restoration plan.



Upland tree planting will be limited by soils:

Goal: herbaceous with scattered woody:

Corning Gravelly Loam

Can support scattered woody species

Capay- Generally supports herbaceous vegetation (shallow roots), not ideal for trees. But since some exist on these soils, and limited area for upland trees, may be able to plant scattered trees due to moderate drainage, no ponding

Goal: herbaceous (won't support woody species):

Clear Lake- Most upland trees unlikely- poorly drained, frequent ponding, potential salinity

San Ysidro- Most upland trees unlikely, generally supports shallow-rooted plants. moderately well drained, no ponding- low water storage

LAB SUMMARY: VEGETATION

Our project site was located at Centennial Park, Vacaville. It is currently undergoing restoration by the Resource Conservation District.

Key Guiding Questions:

- What vegetation occupies the area now (i.e. natives vs. exotics)?
- Where and which species of natives are successful/will be successful?
- Where do non-natives/invasives need to be removed?

Methods & Materials:

- Our sampling began at what we identified as the "mouth" of the stream/wetland pool interface. 30 transects were taken in total along the creek. (See image 1)
- We initially used 6x2 meter transects and we sampled every 50 meters along the bank in order to collect a variety of species along the shores.
- We then modified our method and created a 15 meter transect line and took 1x1 meter zipper quadrats at 0, 5, 10, and 15 meter intervals on the transect line.
- Our measurements inside the transects included:
 - percent bare ground
 - percent dead cover
 - when area turned to upland
 - percent coverage of all other present species
- Transects are denoted by number, letter (A /B sides of the river), and interval.
- The distance across the river was measured, as this may be variable.

Challenges

- Environmental Conditions: Unusual environmental conditions (i.e. California drought) might have caused our group to miss certain key species in the area that may not be germinating due to improper environmental conditions. Changing environmental conditions in the area could be favoring certain species in the area that are not present under normal condition (i.e. drought, higher winter temperatures). Our collected data may not represent the site vegetation under normal conditions.

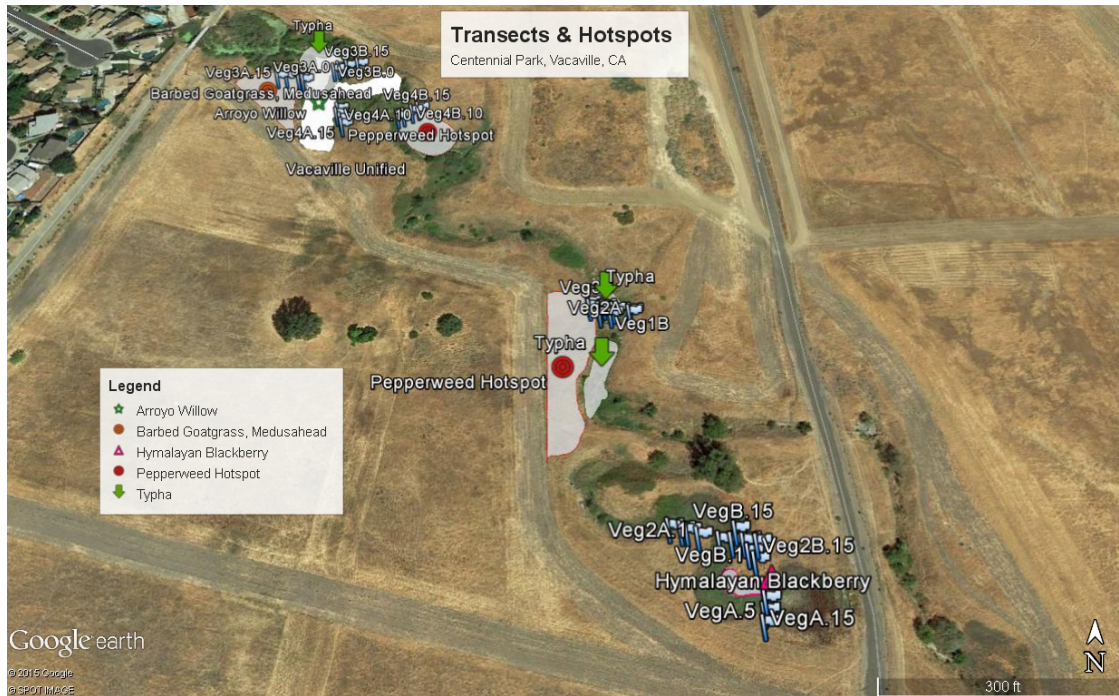


Image 1. Vegetation group transects and corresponding vegetation hotspots. Blue flags denote transect locations.

Species were collected, identified, and placed into Figure 1. Below, these species were then classified as native or exotic in regards to California flora. Only 2 species out of 29 were found to native to California, Purple Vetch was considered naturalized, and all others were considered invasive species

Common Name	Scientific name	Native V. Exotic
Purple Grass	Poaceae	N/A
Fox Tail Barley	Hordeum spp	Exotic
Rip Gut Brome	Bromus diandrus	Exotic
Italian thistle	Carduus pycnocephalus ssp. pycnocephalus	Exotic
Bristly Ox tongue	Picris echioides	Exotic
Italian Rye Grass	Lolium multiflorum	Exotic
soft brome	Bromus hordeaceus	Exotic
Poison Hemlock	Conium maculatum	Exotic
Purple Vetch	Vicia americana	Naturalized
Brassica(Mustard)	Brassica Spp.	Exotic
Bed Straw	Galium aparine	Exotic
Avena	Avena Fatua	Exotic
Geranium	Geranium Dissectum	Native
Prickly lettuce(oxtail)	Lactuca serriola	Exotic
Pepperweed	Lepidium latifolium	Exotic
Standard grass	Poaceae	N/A
Field Bind weed	Convolvulus arvensis	Exotic
Black Berry	Rubus armeniacus	Exotic
Cattail	Typha domingensis	Native
Medusa Head	Elymus caput-medusae	Exotic
Morning Glory	Calestegia spp.	Exotic
Barbed Goat grass	Aegilops triuncialis	Exotic
Ragweed	Ambrosia artemisiifolia	Exotic
Arroyo Willow	Salix lasiolepis	Exotic

Figure 1.

From the data above we then calculated species richness as seen in Figure 2. This measures

how many species were found in each transect (transect locations can be seen on image 1). Transect 1 had the highest diversity with a total of 9 species, while transects 2A5, 3A10, 3A15, 4A15, 4B0, 4B5, and 4B15 had only 1 species present.

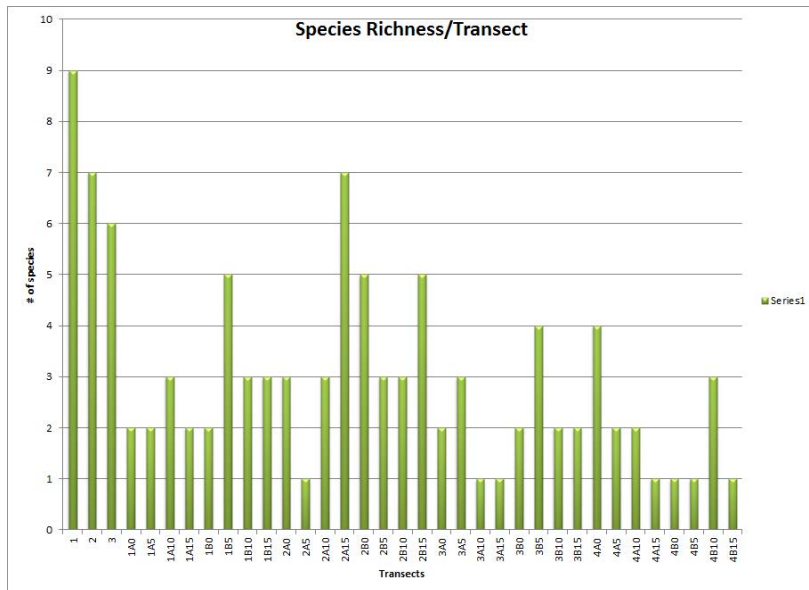


Figure 2.

Figure 3. is a species accumulation graph. This graph shows how many new species were found in each transect. Diversity was low at the site with only 28 species found in total and no more than 3 new species appearing after the initial finding of 9 species.

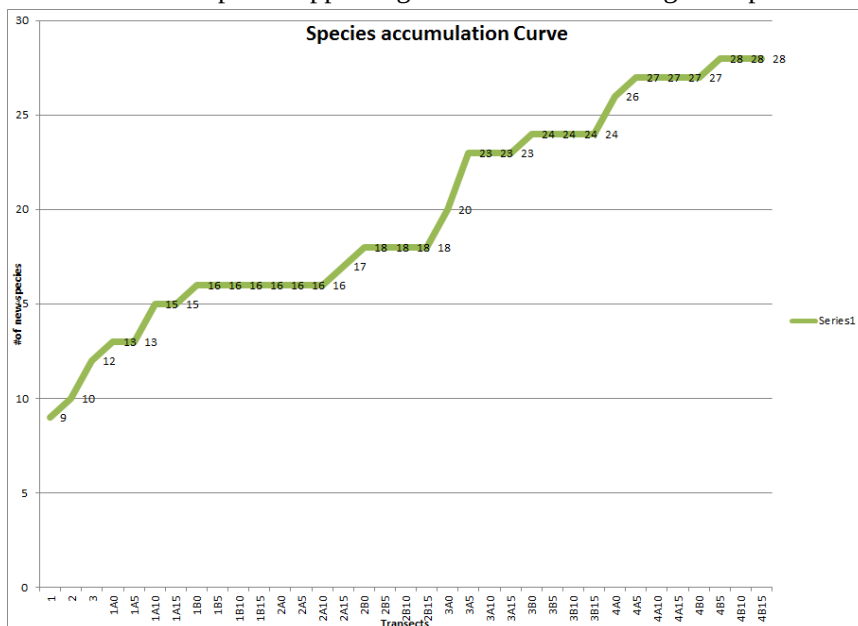


Figure 3.

Results

The results from Figure 1 show that the majority of species found at centennial park are weedy invasive species. This severely limits the amount of diversity that could be found in the area as these species are highly competitive and known to dominate once established. The species richness data shows where species are most prevalent in the transects sampled. This allows a clear picture to be drawn of where certain types of invasives are and where management actions are most necessary or where certain species are the most dominant. Figure 3 supports this by showing where diversity began to be limited in transects. From the trend line it is safe to assume that the maximum amount of species 6-15m from the creek is not much higher than 29, however more sampling is needed to say this with any certainty. Overall our data showed the area has a low diversity of species and is highly dominated by invasive weedy species.

LAB SUMMARY: ECOSYSTEM SERVICES

Water Quality

Water Quality Protocol

As modeled by the EPA Water: Monitoring and Assessment protocol found at <http://water.epa.gov/type/rsi/monitoring/vms50.cfm>

Different components of water quality can be found by taking water samples, then using the samples to determine the various conditions of the water. This includes temperature, pH, nitrogen, phosphorus, and turbidity.

1. The first part to water sampling is preparing the bottles that will be used to sample.
 - a. Determine at which points along the stream or in the waterbed that the samples will be taken.
 - b. Take GPS waypoints at each of the respective locations to ensure precision when recording data.
 - c. Decide the number of samples to be taken in the field (it ended up being 6 sample sites of 5 samples each, plus one chloroform sample).
2. The second task is to collect the samples.
 - b. To begin the collection process, you should be facing upstream. Dip the bottle into the water still facing upstream. Do not collect any sediment.
 - c. The water sample should be collected between the top and bottom surfaces of the stream.
 - d. Turn the bottle underwater in the direction of the current, and lift the bottle up. There should be at least an inch of air between the cap and the water sample.
 - e. Record the bottle number and location on a datasheet.
 - f. Repeat.

Sampling Challenges

We were limited both by time and materials. There were only a limited number of nitrogen and phosphorus samples possible in the kit. This made it so we had to limit the sample locations to 6. Also, the short time frame limited any further exploration on the state of the water quality.

Images and Data Table



Sample Number	Nitrate (ppm)	Phosphate (ppm)	pH	Temperature (Celsius)	Turbidity (JTU)
1	4	2	8.5	26	20
2	4	<1	7.5	24	30
3	5	2	7	24	40
4	10	2	8	22	5
5	5	2	6	24	10
6	5	0	8.5	25	10

Coliform test – negative

Data Analysis

The preliminary water quality tests revealed that the overall water quality of the stream had the following concerns:

1. The pH of the water near the housing and infrastructure is slightly basic. This could be due to the polluted runoff of the houses/infrastructure. If plants are extremely sensitive to basic conditions, then it might be best not to introduce them near the housing area.
2. At the sample point 4, there were unusually high nitrate levels (10 ppm). This could be further tested or monitored, as the EPA deems nitrate levels at 10 ppm unsafe.
3. Turbidity, at all points other than #4 was high enough to decrease light availability to submerged plants.

Further Questions

Can the high nitrate levels at sample point 4 be explained through Centennial Park's history as an agriculture field? Why are the levels high at this particular spot, and not others along the stream?

What is most likely the cause of the basic pH at the forefront of the stream? Can this be changed by further regulating the runoff?

Weed Control

Modeled by the San Francisco Estuary & Watershed Science. Wildlife Response to Riparian Restoration on the Sacramento River. Found at:

<http://escholarship.org/uc/item/4z17h9qm#page-1>

1. Identify the various types of plant species (both native and invasive) within each zone.
 - i. Stratified sample within each zone (upland, riparian, and wetland) then random sample.
2. Evaluate which species is causing the most substantial impact to the environment.
3. Waypoint hotspots of invasive species.

Tools Needed:

1. GPS to collect waypoints
2. California Weed ID Manual

3. Noxious Weed Control Manual
4. Herbicide guide

It is crucial to identify invasive species versus native species, be familiar with their life cycle as well as their growth habitat. Consider the various ways of dispersal, and the location where weeds are most likely to occur.

Goals: Identify the various types of plant species present within each zone of the site, wetlands, riparian areas and upper areas. Map the area covered by invasive plants and determine the best way to eradicate them.

- It is very important to clean all equipment properly before visiting or sampling a new site, this in order to prevent further dispersal of invasives. The best way of controlling weeds is by preventing dispersal.

Methods:

I . Identify invasive species and be familiar with their habitat and growing conditions to select the best approach to decrease their soil seed bank.

- a. Take pictures and/ or collect samples for identification.
- b. Make a notation of which plants thrive better and in which areas.
- c. Based on similar growth conditions assess which species of invasives can be grouped for control.
- d. Evaluate which species are causing the most substantial impact to the environment, particularly within each sub-ecosystem.

Data Collected

Centennial Park Invasive Species			
Type of Invasive	Plant ID	% Cover	Zone
Annual Grass	Avena fatua	> 75%	Upper Land
Annual Grass	Bromus diandrus	> 25%	Upper Land
Annual Grass	Phalaris canariensis	< 25%	Upper Land
Annual Grass	Lolium multiflorum	< 25%	Upper Land
Perennial	Pepperweed	> 25%	Riparian
Perennial	Blackberry	< 50%	Riparian-Wetland
Annual	Teasel	< 25%	Riparian
Perennial	Cattail	< 50%	Wetland
Annual	Vicia americana	> 75%	Upper Land, Riparian
Tree	Sapium sebiferum	< 50%	Riparian-Wetland
Tree	Ficus	2%	Upper Land
Annual	Leontodon	< 25%	Fire Break Zones



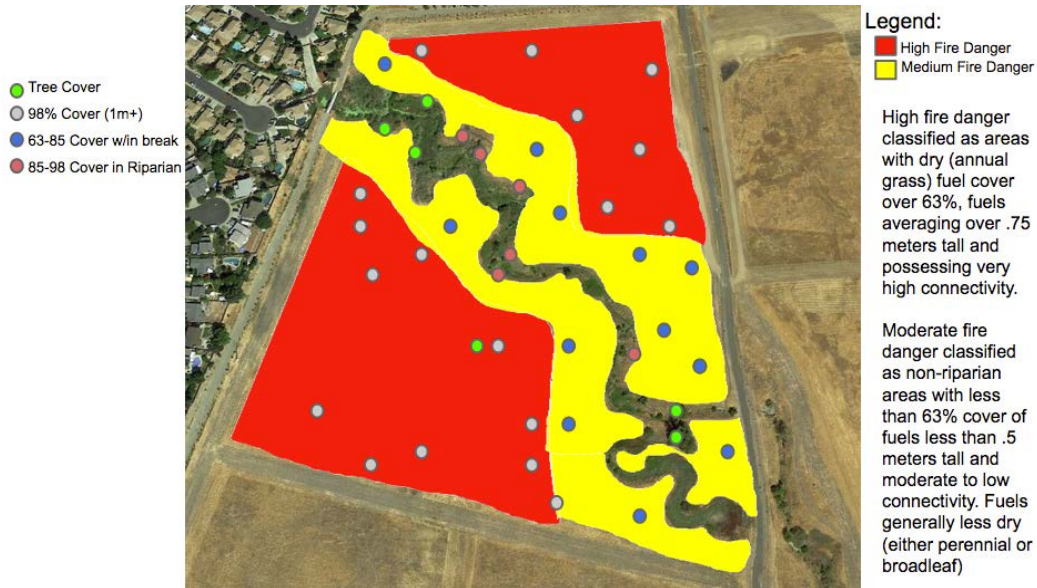
Stratified sample within each zone, then random sample to identify hotspot zones of invaders.

Fire/Fuel Assessment Protocol:

In order to assess what ecosystem services with regards to fire control might be offered by future restoration work, existing fuels as well as fuel continuity were characterized across the site. In order to characterize existing fuels on site, vegetation cover was first determined by categorizing areas chosen to represent a broad sample of the site into the following classes:

Cover (Actual)	Cover (Recorded)	Height
0-5%	2.5%	1.25-1.50m
6-20%	13%	1.01-1.25m
21-50%	35.5%	0.76-1.00 m
51-75%	63%	0.51-0.75 m
76-95%	85%	0.26-0.50 m
96-100%	98%	0.25-0.00 m

After this was done, we determined existing threat level by characterizing fuel types by geographic area and assessing vertical and horizontal fuel continuity using observations and aerial images. We then classify fuels in riparian and upland areas as patchy or continuous and summarized findings and Map areas based on fuel load/threat, taking note of areas of greatest risk for damage to property and infrastructure. Due to the inevitable stochasticity in classifying vegetation, certain areas might be improperly classified given small variations in vegetation (i.e. small patch annual grass that could burn within channel). The changes in vegetation with each visit also led to some inconstancy with height classifications.



After analyzing the data, it is clear that a large portion of the site had very high fire danger. Had disking and herbicide control not already been implemented, almost the entire site outside the banks of the riparian area would likely have been subject to high fire danger. Fire danger within the area controlled was generally far lower, both due to decreased cover (and thus less continuity) as well as much shorter fuel. Moving forward with restoration work, it will be critical to further diversify vegetation on the site and increase perennial plant and tree cover. The bike path as proposed also poses the potential to provide a good firebreak. Further research should be done to determine what fuel load would like in areas that had been undergone control this year as well as on the entire site in drought conditions. Answers to these questions could enable the restoration effort to better negate against potential for undesired fire.

Pollination Services

Protocol/Methods

Adapted from California Pollinator Project: Citizen Scientist Pollinator Monitoring Guide

http://www.xerces.org/wp-content/uploads/2010/06/CA_CSM_guide.pdf

To run transects along areas where bees are likely to determine the absent/present of morphospecies present

1. Determine areas of high value to pollinators by looking at areas of high flowering vegetation (Purple vetch [*Vicia americana*] was flowering at the time).
2. I chose 2 spots to run a 100 ft transect that were dominated by purple vetch. I monitored 1 site for 30 min and the other site for 15 min.

Time was 3:00 - 4:30 pm, slightly windy.

Sampling Challenges

We were limited by resources and people available to complete tasks for more data collection. More data on nesting in the park would be valuable but would not have been an efficient use of time having 1 or 2 people walk around looking at the ground for nests or in trees. Having a map of areas of nesting would have been valuable data.

Data

Transect	1	2
Bumble Bee	X	
Honey Bee	X	X
Carpenter Bee		X

Data Analysis

The data showed that three morphological species of bee were present: bumble bee, honey bees, and carpenter bees. Looking at our fire maps, purple vetch at the time of visitation, was the source of foraging for pollination.

Further Questions

How have the invasive species like purple vetch influenced the forage habits of pollinators over native species?

Do the native perennial species have a higher fitness within a grassland/park area at full growth versus an annual invasive species?

Group - Further Questions

How will each particular service change overtime? Will there be improvements in each of the services post-restoration?

Is there a linkage between any particular service(eg a relationship between water quality and pollinators)? Do improvements of one service have a synergistic effect on the others?

Water Quantity

Fluvial processes and morphology assessment methods from Jim Quinn, Information Center for the Environment or retrieved from:

http://cwam.ucdavis.edu/Volume_2/TOC.htm

Brief description of methods used, where sampled, number of samples

For water quantity our group started with several important questions. These questions included the type of channel observed; the volume of water the channel holds at bank full, including the flow and percolation regime at the site; and whether sedimentation is of concern.

In order to answer these questions the group used both qualitative and quantitative methods: We observed the channel at several sampling locations over the span of four lab days in order to gather data. We chose seven sampling locations including sites of heterogeneous morphology and observable flow velocities. We sampled specifically for sedimentation and water flow at these sites. Sites overlapped with water quality measures in many cases. We were careful to observe changes to flow velocity and storage in response to precipitation events. At each sampling location we took a sediment sample from the bottom of the channel and we used both float and dye methods to measure surface flow velocity. After our lab days were over we used topographic data to estimate storage capacity of the site at bankfull. We also baked the sediment samples in an oven to dry them and sifted the samples through a sediment sieve of 2 mm in width. Sand and pebbles left in the sieve were measured using a caliper.

Any challenges/revisions needed while you were sampling

There were a few challenges that we experienced during the sampling process. From pictures the site looks more accessible than it actually is. This made choosing sampling sites a matter of finding safe places to reach the channel floor. We were able to choose a variety of locations that differed in morphology and flow velocity. Sites included both pools and connecting channels. But the level of difficulty was greater than we had imagined. Our group also found it difficult to address the many different aspects of ecosystem services and sometimes struggled to stay focused on specific data collection needs. In terms of specific measures, we started with flow velocity. Timing flow velocity was difficult because of the structure of the flow regime at the site. In the absence of precipitation events there is virtually no flow. This meant

that we could measure flow velocity on only one of the lab days, but this also gave us a great amount of qualitative data about the functional hydrology of the site.

Brief summary of data analysis

For water quantity and supply we first calculated the flow velocity for the one site for which we had data. We found that even in the days following a rainstorm, flow velocity is relatively low. We then used data from the topography group to calculate an estimated water holding capacity for the site and found that the present channel has a relatively small holding capacity. Finally, we analyzed, dried and sieved sediment samples to find a predominance of fine sediment with some sand and gravel. We also considered qualitative data about channel morphology, noticing that the channel consists of small pools with connecting channels.

Results:

Figures, tables, maps summarizing your data



Numbered sampling sites.

site #	type	time
#1	channel	17.01 sec. for 1.3 m; 0.076 m/sec
#2	pool	0, no movement
#3	pool	0, no movement
#4	outflow from the road cut	low the week after the precip event; none two weeks later
#5	channel	0, no movement
#6	channel	0, no movement
#7	channel	0, no movement

Flow velocity.

Sediment sample	size	type	description
#1	2mm-20mm	gravel/sand	multicolored gravel and sand
#2	2mm-8mm	sediment	medium homogeneous light brown sediment
#3	<2mm	fine sediment	tan
#4	<2mm	fine sediment	medium, black/brown color
#5	<2mm	fine sediment	same as #4; includes other org material
#6	2 mm	sand/fine sediment	mixture of sand and black/brown sediment
#7	2mm	sediment	medium homogeneous light brown sediment

Sediment samples.

Transect #	Channel Depth	Channel Width	Area of the triangle
#7	150	300	22500
#8	130	450	29250
#9	120	400	24000
#10	190	840	79800
#11	65	810	26325
#12	130	1680	109200
#14	75	330	12375
Average, cm			43350
Average, m			433.5
Full channel, m>2	Channel length, m	647.49	280686.9
Full channel, acre ft.			227.6

Estimated channel volume.

Reach Scale Channel Classification	
Cascade (>0.03)	Steep reaches with boulders and cobbles that are not organized in recognizable patterns...sediment supply is limited to inputs from adjacent hill slope mass movement
Plane-bed ($0.01-0.03$)	Cobble and gravel that exhibits a relatively featureless topographic profile and represent a transition between supply-limited and transport-limited morphology
Riffle-pool ($0.01-0.001$)	Undulating gravel bed profile; commonly spaced 5-7 channel widths apart
Dune-ripple (<0.001)	Low-gradient sand bed streams where the sand bed form evolves depending on flow depth and velocity. Sand can be transported a relatively low flow stages

Brief summary of key points/findings

The flow velocity data was affected by precipitation events and gives an accurate picture of the flow regime. The site's flow regime is driven by precipitation events that fill the channel with runoff from urban areas in the sub-catchment. This runoff fills both the channel and oxbows left from channel meander over time. The one flow velocity level that the group did achieve occurred the lab day after a rainstorm. This resulted in an estimated velocity of 0.076 meters/sec. The topography of the site is characterized by an initial wetland area of over a meter in depth followed by an incised channel connecting small pools. The final road cut inhibits flow through the channel. This natural and built morphology increases percolation within the site. Using topography data from another group we estimated the capacity of the channel to be at least 227.6 acre-feet. This estimate did not include oxbows and other areas that could fill without overflowing the Centennial Park grounds. By way of comparison, we looked at other ponding basins in the Central Valley. These range from 200-20,000 acre-feet of holding capacity. We estimate that the site provides a small to medium amount of water storage in comparison to these sites. In terms of sedimentation, the group found mostly fine sediment with one site (#1) that included

sand and gravel. These findings led us to categorize the channel as a riffle pool using the rough reach scale classification displayed above which was developed for streams in the Pacific Northwest. Through qualitative and empirical observation we decided that the site fit the “undulating gravel bed” description best. We did not have enough data to calculate the ratio of transport capacity but hypothesized that a lower ratio fit the site best considering the relatively slow flow velocity that occurs only during and after precipitation events.

Brief summary/conclusions

In summary, the group concluded that the site provides interesting and varied strengths as a flood control basin and for regulation of runoff from surrounding urban areas. In terms of storage, the site provides a small to medium amount of storage but these estimates may be lower than the real amount because of extensive areas that may fill under flood conditions without overflowing. The flow regime is affected by the morphology of the site, in particular the road cut at the end of the channel. While flow is inhibited, this reality also seems to enhance percolation at the site. There is some evidence of sedimentation but it is unclear if this is erosion from previous agricultural use or from other environmental conditions at the site.

Include any new questions/ unresolved questions

Further research might explore more deeply the presence of sedimentation. A reach scale channel classification might also be developed for urban streams and waterways. Finally, calculations of soil water holding capacity at the site might provide additional information about the site’s storage capacity.

LAB SUMMARY: WILDLIFE

Nicolle Herr, Mia Bianchi, Lauren Broder, Joong Hoon Sim, Lauren Mount, Marcus Rodriguez

Methods

We initially surveyed the area on April 13th, 2015 for three sites to place our 60 meter transects to monitor for wildlife. We decided to pick sites that contained a diverse range of habitats in order to obtain data that best represented the site as a whole. The transects ran through wetland, riparian, and upland habitats. In addition monitoring for species that we found directly on and around the transect, we also recorded the many opportunistic sightings we saw, such as turkey vultures flying nearby. We monitored one 60 meter transect per day over the course of three days: April 13th, 20th, and 27th. We stopped to every 20 meters along the transect to monitor for 10 minutes. We used several tools during monitoring to help identify the species we saw, these tools included field guides and binoculars to help identify species we saw at and around the site, as well as flags to mark each 20 meter delineation along the transect. Among our team of six we divided into three groups that monitored for each class of animals. One group monitored for mammals, another for birds, and the last group monitored for reptiles and amphibians, also known as herps.

To identify the species we observed, each group used species identification books as well as online resources. Each group recorded species they observed, suitable habitat for their class of animals, and indicators of presence on site. In addition to live observations, the birds group also surveyed along the transects for nests, eggs, and any remains that might have been left behind by a predator. They also used bird calls to help distinguish between species they could not identify visually. However, identifying these species based on their calls alone proved to be difficult. The mammals group approached their monitoring in a slightly different way. Due to the lack of live observations on site, they relied primarily on habitat and species indicators rather than actual sightings. They recorded the presence of dens, burrows, scat, and remains as well as the occasional auditory cue. The final group monitored the sites for both reptiles and amphibians, commonly referred to as herps. Similar to the mammals group, the herps group relied on suitable habitat and species indicators rather than actual sightings, although sightings were still recorded if there were any. This group monitored for burrows, eggs, scat, and suitable habitat for amphibians or reptiles.

Challenges

It was particularly difficult to observe species and indicators on site due to high vegetation cover, timing of observations, and human disturbance. Much of the upland and some of the riparian areas were densely vegetated, hiding indicators such as tracks and scat. This occasionally limited our mobility, further hindering our monitoring

efforts. Monitoring was also limited to mid to late afternoon between 2-4:30 pm. Many wildlife species of interest are nocturnal or crepuscular in nature, and were likely missed during this limited observation window. This problem was compounded by the multitudes of people wandering about in the monitoring area, potentially scaring off whatever wildlife may have been present. The combination of these three factors implies that the site was likely undersampled, with more wildlife is present than suggested by our results. If possible, future monitoring should take place at different times of the day for more opportunistic sightings and incorporate trapping for more accurate monitoring.

Results:

Birds

In situ monitoring for birds was done as described in the methods section, monitoring for species and species indicators. Both regime and opportunistic monitoring was done. Redwing Blackbirds were the most common species sighted. Other common species included swallows and hummingbirds. A variety of resident and migratory waterfowl, prairieland, and woodland species were sighted. Some interesting species we saw included Green Herons, Killdeer, American Bittern, and Northern Mockingbirds.

Due to surveying during mid afternoon, it is likely birds living at the reserve were dispersed to feeding sites. Bird surveying was completed as described in the initial monitoring plan. A revision that may yield an increase in the accuracy of the data may be to monitor in the morning before birds disperse for feeding or in the evening following their return to the colony or nest. Data collected during monitoring can be seen in Figures A, B, C, and D below for April 13th, 20th, 27th, and May 4th, respectively.

Figure A

April 13th	Species	Observation Type	# of Individuals
Spontaneous	Brown-Headed Cowbird	Flight	1
Spontaneous	Brewer's Blackbirds	Flight/Perch	3
Spontaneous	Redwing Blackbirds	Flight/Perch	3
Spontaneous	N. Roughwing Swallows	Flight	20-30
Spontaneous	Turkey Vulture	Flight	1
Spontaneous	Northern Mockingbird	Flight/Perch	1
Spontaneous	Golden Eagle	Flight	1

Figure B

Date and Time:	April 20th, 2015; 2:30-4:30				
Surveyer:	Nicolle and Lauren M.				
Survey Area:	Transect 1				
Transect Location	Species	Species or Indicator Description	Observation Type	# of Individuals	Other Data
Spontaneous	Oak Titmouse	Head tuft, soft blue-gray coloring, 5 inch	Sighting: Perched	1	Dr. Eviner, Riparian
0 meters: 10 min	Redwing Blackbird	Red lesser covert, orange median covert	Sight/Auditory	2	Riparian
0 meters	Turkey Vulture	large brown predator with white remiges below	Sighting: In flight	2	warehouse, hills
0 meters	O.T.U., Swallow	Brown above, white below, 4 inch body	Sighting: In flight	1	Riparian
0 meters	O.T.U.	Large brown above and white below songbird, 10 inch	Sighting: In flight	1	Riparian
20 meters: 10 min	Blackbird/Redwing	Blackbirds, and Redwinged with orange	Sight/Auditory	5	Riparian/Transition
20 meters	O.T.U., Hummingbird	Hummingbird body size, shape, and flight pattern	Sighting: In flight	1	Riparian
20 meters	O.T.U., Swallow	songbird from landing site of O.T.U. from above	Auditory	1	Riparian: in tree
40 meters: 10 min	Rock Pigeons	Sooty and tawny mixed plumage birds	Sighting: In flight	6	warehouse
40 meters	House Finch	Orange-Red headed variation, brown body	Sighting: Perched	2	Riparian: in tree
40 meters	Killdeer	Black and white striped head, tan body	Nesting: ground	1	Transition/Upland
60 meters: 10 min	Redwing Blackbird	Red lesser covert, orange median covert	Sighting: Perched	2	Riparian/Upland
60 meters	O.T.U., Pigeon/Dove	Band-tailed/Mourning (resp.): Gray above, rose below	Sighting: Perched	3	Upland: tree
Spontaneous	Mallard	Green headed large duck	Sighting: In water	1	In pool
Spontaneous	Blackbird Flock	Blackbirds, Redwings, and Brwnheaded Cowbirds	Sighting: Multi	20	20+, Riparian/Upland
Spontaneous	O.T.U.	Brown, white edge remiges, 10-12 inch body, long & thin	Sighting: In flight	2	Upland

Figure C

Date and Time:	April 27th, 2015				
Surveyer:	Nicolle & Lauren M.				
Survey Area:	Vacaville				
Transect Location	Species	Species or Indicator Description	Observation Type	# of Individuals	Other Data
0 meters	Redwing Blackbirds	Males: red lesser covert, Orange Median.	Sighting: Flight & Perch	approx 10	Nesting: Tule reed, pairs
0 meters	O.T.U.: Swallow	Barn swallow coloring on bottom	Sighting: Flight		1
0 meters	O.T.U.	5-6 inch, white below, black tipped primaries & secondaries	Sighting: Flight	approx 10	Flocked. swallow sized/shaped
20 meters	Barn Swallow	Black above and orange below	Sighting: Flight		3
20 meters	O.T.U.	crow-like' call from throat	Auditory		1
20 meters	Redwings & Blackbirds	in addition to the marshland redwings; males & females	Sighting: Flight & Perch	approx 10	Flying within/around grasses
40 meters	Mallard	Green headed large duck	Sighting: Flight		1
40 meters	Rock Pigeons	Sooty and tawny mixed plumage birds	Sighting: Flight		4
40 meters	O.T.U.: Sparrow	brown patterned coloring, 6 inch body	Sighting: Perched		1
40 meters	O.T.U.: Swallow	Tree or Violet Green Swallow: green above, white below	Sighting: Flight		5
40 meters	O.T.U.: Finch		Sighting: Flight		1
60 meters	American Bittern	Red body, yellow feet	Sighting: Flight		1
Opportunistic	Barn Swallow	Black above and orange below	Sighting: Flight		3
Opportunistic	Mockingbird	Gray, long tail	Sighting: Flight & Perch		1
Opportunistic	O.T.U. (thrasher?)	Long tail, 8-9 inches	Sighting: Perched		1
Opportunistic	Turkey Vulture	Large brown scavenger with white remiges below	Sighting: Flight		1
Opportunistic	Green Heron	Green crown, red nape	Sighting: Perched		1
Opportunistic	Mourning Dove	Gray above, buffy pink below	Sighting		1
Opportunistic	O.T.U.	Brown above, white below, dark tips on primaries	Sighting		1
Opportunistic	O.T.U.: Flycatcher	tufted head, 8 inch body, dark brown	Sighting: Flight & Perch		1
					sparrow-like' but larger

Figure D

Date and Time:	May 4th, 2015			
Surveyer:	Nicolle and Lauren M.			
Survey Area:	Vacaville site - Upland			
Transect Location	Species	Species or Indicator Description	Observation Type	# of Individuals
0	Redwing Blackbird	Red lesser covert, orange median covert	Sighting	1
0	O.T.U. Hummingbird	Small and fast hummingbird	Sighting	1
0	O.T.U. Swallow	Brown/green above, white below, 4 inch body	Sighting	1
0	O.T.U.	10-12 inch body, yellow bird	Sighting	1
0	Turkey Vulture	large brown predator with white remiges below	Sighting	1
0	O.T.U.	Very fast moving	Sighting	1
20	O.T.U. Waterfowl	Brown, maybe a killdeer	Sighting	1
20	Turkey Vulture	large brown predator with white remiges below	Sighting	3
20	Mockingbird	Grey with bold white colorings on wings	Sighting/Auditory	2
20	O.T.U. Swallow	Brown/green above, white below, 4 inch body	Sighting	2
40	Redwing Blackbird	Red lesser covert, orange median covert	Sighting/Auditory	1
40	O.T.U. Hummingbird	Small and fast hummingbird	Sighting	1
40	O.T.U. Sparrow	Smaller than a swallow, markings on head	Sighting	1
40	Turkey Vulture	large brown predator with white remiges below	Sighting	1
40	O.T.U. Finch	Small finch	Sighting	1
60	O.T.U. Swallow	Brown/green above, white below, 4 inch body	Sighting	3
Opportunistic	O.T.U. Shorebird/Night	Brown above, yellow below, 10 in., thin, long tail w/split	Sighting	1
Opportunistic	Merlin	Hawklike, approx 12 inches	Sighting	1

The charts show the species we could identify and those we couldn't. Overall there was a wide diversity of species including small, medium, and large birds. There were also many indicators that suggested birds were nesting in the wetland, riparian, and upland habitats. These findings are summarized below in Figure E. Finally, broken eggshells were found indicating predation of nearby nests.

Figure E

Habitat Indicators	Wetland/Creek	Riparian	Transitional	Upland	Vernal Pool
emergent marsh	yes	no	no	no	yes
Blackberry	no	yes	no	no	no
Annual grasses	no	yes	yes	yes	no
Herbs	no	yes	yes	yes	no
Vines	no	yes	yes	no	yes
Groundburrows	no	yes	yes	yes	no
Insects	yes	yes	yes	yes	yes
Bird droppings	yes	no	yes	yes	no
Egg shells	no	no	yes	no	no
Trees	no	yes	yes	yes	yes

Mammals

Monitoring was conducted for mammals by searching for opportunistic sightings as well as species indicators including scat, tracks, potential habitat, and bones. The only live mammal we observed in the field was a single jackrabbit located off of the transect site in a grassy upland area during our second day of monitoring on April 27th. There was a large indication that coyotes and common grey foxes are present within the site based on the amount of scat samples we had identified on all three of the monitoring days. We found scat samples identified as coyote and common grey fox scat throughout the transects and within habitat types including marshland, upland grasses, and riparian areas. We also found three femur bones likely from a common grey fox located under a large upland fig tree on the park premises (see Figure G).

Potential habitat area included small underground holes located in the grasslands areas that could serve as a habitat for small rodents such as voles. The ground contained a thick cover in 1-2 meter grasses in the upland grassy areas, which could provide excellent protection and cover for small mammals.

Although we only saw one live mammal, this was likely due to our monitoring being conducted during the midafternoon where most of the mammals that live in the park would be hiding in the shade. Also, the way that we monitored potentially could have caused mammals to leave the area due to too much noise and disturbance. It is important to note that there is uncertainty about whether the indicators that were found were indicative of current site species makeup. Scat samples of coyote and common grey foxes appeared to be old because as they were bleached white. It is difficult to tell whether this scat is bleached white from being an old sample or whether it has been aged quickly via sun bleaching.

Data from the three monitoring days on April 20th, April 27th, and May 3rd are displayed below as Figures F,G, and H:

Figure F

Date/Time	April 20th, 2015	
Surveyors	Mia Bianchi and Joong Hoon Sim	
Survey Area	Vacaville	
Wildlife Indicator	Appearance	Transect location
Common grey fox scat	Dried up and light brown in hue; contained 15+ red spots, approximately 8 cm in length.	1 st transect (0 meter mark)
potential beaver habitat	Hundreds of branches and twigs piled adjacent to stream. One felled tree approx. 5 meters in length coinciding with branches.	1 st transect (0 meter mark)
potential rodent/reptile holes	5 scattered 3 inch in diameter holes.	2 nd transect (20 meter mark)
cottontail scat	21 small, round pellets white and brown in hue.	2 nd transect (20 meter mark)
potential habitat for foxes, rodents and coyotes	Dry, open ground with 5 in in diameter turned up soil aggregates.	Between transect 2 and 3 (30 meter mark)
potential rodent/ reptile hole	1 hole 3 inches in diameter	2 nd transect (20 meters)
black tailed jackrabbit scat	4-6 small, round pellets that were light brown and grainy in appearance.	3 rd transect (40 meters)
tall grasses (potential habitat for coyotes, foxes, and rodents)	~ .5 meter tall, green grasses.	3 rd transect (60 meters)

Figure G

Date/Time	April 27th, 2015	
Surveyors	Mia Bianchi and Joong Hoon Sim	
Survey Area	Vacaville	
Indicator	Appearance	Transect
Thick cover of green weeds and tule reeds (for small rodents to use as cover)	Bundles of 4-5 feet tall tule reeds. Thick grass ~ 2-3 feet in somewhat murky water	1 (0 meters)
Scat (common grey fox)	9 scat dried specimens, each mostly containing dried red seed parts.	1 (0 meters)
Holes in soil for voles/ reptiles	1 deep, 4 inch diameter hole	2 (20 meters)
Open ground with patches of weeds	Ground with low ground cover (~20 percent)	2 (20 meters)
Scat (coyote)	3 scat specimens (2.5 inches in diameter each) Dry and white grey. Tapered at the ends	2 (20 meters)
tall weeds with scattered woody stalks as cover for animals	2 meter tall weeds and scatter clumps of woody stalks (2 meters tall)	4 (60 meters)

Figure H

Date/Time	May 3rd, 2015	
Surveyors	Mia Bianchi and Joong Hoon Sim	
Survey Area	Vacaville	
Indicator	Appearance	Transect
Tall trees with shade cover good for small rodent habitats	5 trees each with two pronged trunks	1 (0 meters)
Tall grasses for cover	Grasses and weeds that are 2-3 meters	1 (o meters)
Leaf and bark litter (vole habitat)	Thin layer of bark shavings and green leaf litter	1 (0 meters)
Scat (either kit fox or snake)	¾ inch and curved. White and grey in hue.	1 (0 meters)
Tall grasses with thick vegetation. Potential hiding spot for small mammals	Thick, green vegetation covered in small purple flowers.	2 (20 meters)
Scat (muskrat)	1 inch, small and brown	3 (40 meters)
3 bones (could be hind and front legs of common grey fox)	Bones bleached white and each approximately 5 inches in length.	4 (60 meters)

Reptiles and Amphibians

During our monitoring periods we observed two western fence lizards and a single bullfrog tadpole. It is highly likely that these observations are not indicative of a lack of reptiles and amphibians on site, but rather a consequence of circumstance. Due to human disturbance, most individuals were probably hiding, camouflaged, or just not in the sampled area. In addition, monitoring during the middle of the day is not optimal for reptiles and amphibians during late spring to early summer, as they bask less often during these times. Additional monitoring will be required to determine the total species diversity of the area, and if there are any reptile and amphibian hotspots, considering we did not see a significant number of individuals during our surveys.

Despite our lack of live observations, there is a significant amount of suitable habitat for reptiles and amphibians on the site. We observed plenty of suitable habitat such as rotting logs, muddy soil, still water, basking areas, burrowing terrain and ground

cover that are great for the survival of both reptiles and amphibians. Moreover, there were an abundance of reliable food sources between the various insects, minnows, and vegetation available for both reptiles and amphibians.

Reptiles and Amphibians Chart 1: Observations 4/13/15

Location Along Transect	Suitable Habitat Indicators
0 meters	ground cover (leaf litter, twigs, rotting branches)
0 meters	still water
0 meters	moist soil
0 meters	dry soil nearby
0 meters	dry grasses (ground cover)
0 meters	large tree gives shade (cool weather)
0 meters	mostly sunny, where tree isn't providing shade
0 meters	places for basking (clearings, big branches)
walk from 0 to 20 meters	sunny grassland habitat
walk from 0 to 20 meters	grasses and plants (2/3 ft tall)
walk from 0 to 20 meters	shade under plants/grasses
walk from 0 to 20 meters	dry ground cover
walk from 0 to 20 meters	open spaces for basking
20 meters	basking space (clearings between herbaceous areas)
20 meters	dry land
20 meters	suitable dirt for burrows
20 meters	insects (prey)
walk from 20 to 40 meters	dead/dry grasses
walk from 20 to 40 meters	green plants, low to the ground
walk from 20 to 40 meters	thick grass
40 meters	low plants
40 meters	dead plants (places to hide from predators)
40 meters	lots of sun exposure, not much shade
40 meters	edge of meadow
40 meters	insects (prey)
40 meters	some clear space (basking)
walk from 40 to 60 meters	small meadow grasses
walk from 40 to 60 meters	insects (prey)
60 meters	foot-tall grasses
60 meters	lots of ground cover from grass
60 meters	many insects (prey)
Random sightings	soft soil for burrowing
Random sightings	lots of area for basking
Random sightings	still water
Random sightings	meadow
Random sightings	large wetland area near bridge

Reptiles and Amphibians Chart 2: Observations 4/20/15

Location	Suitable Habitat Indicators
0 meters	still, deep water body (pond/marsh, great for eggs of amphibians)
0 meters	moist ground cover (reeds, grasses)
0 meters	muddy areas
0 meters	small fish and bugs (prey)
0 meters	dry ground cover adjacent to water
0 meters	larger fish (possible predator)
walk from 0 to 20 meters	low to the ground plants
walk from 0 to 20 meters	dry/dead grasses
20 meters	dry/dead grasses
20 meters	ground cover from grasses
20 meters	water nearby (downhill)
20 meters	flowers, low to the ground plants (green weeds)
20 meters	rotting tree in water
20 meters	insects (prey)
20 meters	some loose soil for burrowing/hiding from predators
walk from 20 to 40 meters	dead/dry grasses
walk from 20 to 40 meters	open area for basking (flat, dry plants and dirt)
40 meters	dirt with small rocks
40 meters	small amount of ground cover by green weeds
40 meters	dead grass
walk from 40 to 60 meters	dry dirt for basking
walk from 40 to 60 meters	green weeds, grasses
walk from 40 to 60 meters	grasses with some flowers
60 meters	waist-high meadow grasses give shade
60 meters	5-6 ft tall woody plants
60 meters	some dirt is dry and some moist
Random sightings	heard plop into water (possible turtle or frog)

Reptiles and Amphibians Chart 3: Observations 4/27/15

Location	Suitable Habitat Indicators
0 meters	waist-high grasses
0 meters	shaded and sunny areas
0 meters	tall tree
0 meters	small open area under tree
0 meters	insects (prey)
walk from 0 to 20 meters	grasses
walk from 0 to 20 meters	insects (prey)
20 meters	waist-high grasses
20 meters	insects (prey)
20 meters	tall, dry/dead plants
20 meters	flowering plants (knee-high)
walk from 20 to 40 meters	tree with small yellow berries
walk from 20 to 40 meters	knee-high grasses
walk from 20 to 40 meters	some clearing under tree
walk from 20 to 40 meters	insects (prey)
walk from 20 to 40 meters	shaded and sunny areas
walk from 20 to 40 meters	tall, dead weeds
40 meters	tall, dead weeds (5 ft), standing and fallen
40 meters	tall grasses
40 meters	some flowering plants
40 meters	shade from the grasses
40 meters	basking places where tall weeds have fallen
walk from 40 to 60 meters	flowering shrub (6 ft at talles point, possibly rose bush)
walk from 40 to 60 meters	tall grasses
walk from 40 to 60 meters	reed-like plants
60 meters	fig tree (large)
60 meters	native marsh grasses
60 meters	shade, lots of sun around tree
60 meters	thistles
60 meters	tall grasses
60 meters	bones (animal possibly eaten by snake)

Conclusions

There were high levels of bird diversity, abundance, and richness found on site during the allocated observation windows; however, mammals, reptiles, and amphibians were observed at a far lesser frequency. This may not be indicative of a lack of these classes of animals, but rather a consequence of high ground coverage, unfavorable timing of observations, and human disturbance of normal behaviors. The site itself contains a good deal of diverse and suitable habitat such as still water, vegetation, burrowing sites, ground coverage, various forms of prey, etc. However, there is much room for improvement of site conditions. The vast majority of wildlife and bird diversity is centered around the riparian section of of the plot. There is not a significant amount of long-term established foliage such as shrubs and trees in the upland areas, leaving most of the site covered in grasses and tilled soil. We concluded that the restoration plan should focus on protecting and preserving the riparian area, especially the biodiversity hotspot near the bridge, as well as enhancing the habitat quality of the upland regions by establishing more flowers, shrubs, and trees.

Unresolved Questions

-Were there any species that we missed because they weren't present at the site during our monitoring time?

Since we monitored the site only in the afternoons during the same time frame, we may have not been able to locate some species due to their nocturnal, cryptic, or crepuscular nature. It is important that future monitoring occurs at different times of the day (early morning and late night) in order to document any species we may have missed.

INDIVIDUAL PROJECTS

Year-long wetland herbaceous vegetation (sedges, rushes, grasses, etc.)

Vanessa Guzman

Part 1: Project Background and Justification

I. Background and Justification

Wetlands are an important ecosystem that is often overlooked by the general public as compared to places such as different types of forests, however it is a key environment for diversity. It is estimated that only 280-400 thousand acres remain of California wetlands, which is substantially less than historical amounts of wetlands (Framer et al. 1989). Wetlands serve many different ecological services, including the removal of toxins and pollution from water that accumulates, very strong flood control, and are very important habitat for many different species of both fauna and vegetation species (Crites et al. 2014). Herbaceous (non-woody) species are important to wetlands and the diversity present there. They serve as indicators to the health of the wetland; different species are more sensitive to changes than others, as well as the different factors that determine the system's health such as the amount of salt content, nitrogen, phosphorus, heavy metals, etc. (Adamus 1990)

Restoration of these herbaceous species such as sedges and grasses could help in the overall restoration scheme of the wetland. It would also be important to drive out the key competing invasive species that thrive better on non-restored wetland in order to try to revert back to a better wetland environment (Adamus 1990). Grasses and grass-like plants are able to be managed with grazing and mowing as needed, and are a good resource for coexisting with farm communities. They are very diverse and can also help stabilize soils as well as provide nutrients when mowed or when they die. They are also part of other types of ecosystems, so they can border between them without a negative effect when the right types of grass species are present.

Sedges are usually used to help restore wetlands, and would be key in California wetlands since many species are drought tolerant that can be used. Rushes are also very important in wetland diversity; they are very similar to sedges and grow in wet habitats. Both serve as food for a variety of species including birds and mammals both small and large. (Crites et al. 2014) These sorts of species would all be important in erosion control; their presence would reduce the amount of soil being run off into nearby streams and rivers around the wetland habitats, and would greatly benefit the riparian ecosystem by being a buffer with the help of yearlong herbaceous plants. (Reznicek 2013)

II. Literature Review/Fact Sheet

A. Climate Change and Human Interventions:

- a. Wetlands tend to border other habitats such as riparian ecosystems.
- b. Wetland herbaceous species may not be drought tolerate due to the need for moisture; water allocations and lack of water availability will inhibit the flooding of current available wetland areas in the central valley. (Reznicek 2013)
- c. Many herbaceous plants require shady areas that would otherwise be provided by neighboring tall grasses. There may be issues with overgrazing removing these key grasses. Woody species also provide necessary shade for sedges, rushes, etc. (Reznicek 2013)

- d. Presence of dams for water allocation and human flood control has greatly reduced the presence of wetlands, which reduced habitat for herbaceous species that need moisture as well as allows for invasion of exotic species.
- e. Conversion to agriculture of many different crop varieties has reduced the amount of wetland habitat available for native herbaceous species. (Fraye et al. 1989)
- f. Conflict with need for water has prevented the use of available water resources to restore wetland water tables. (US D.O.I.)

B. Ecological Importance

- a. Herbaceous plants are an indicator for several different aspects of the wetland, including the soil quality, nutrient availability, water availability, and toxicity. (Adamus 1990)
- b. Support migratory birds such as waterfowl as a source of food and cover during their season in California wetlands.
- c. Herbaceous species are a source of habitat for many species, including those protected under federal law and many endangered species.
- d. Prevent the spread of excess water and pollutants to neighboring habitats, such as riparian ecosystems. (US D.O.I.)

C. Ecosystem Services:

- a. Wetlands help retain floodwaters and prevent overflows from too much water coming in at once, and slowly release the water. Herbaceous plants (such as the deep rooted common cattail) enhance this by providing an anchor in the soil to prevent erosion, much like the banks along a riparian ecosystem. (US D.O.I.)
- b. The herbaceous plants in wetlands are important to maintain a dual wastewater treatment and wetland habitat. Plants such as bulrushes (common cattails) have the ability to filter out harmful pollutants in water, but also serve as a foraging ground for wildlife. (Crites et al. 2014)

D. Ideal Conditions for Herbaceous Species:

- a. Soil- Herbaceous species can grow in a wide variety of soil types, which is why they are well adapted to wetland soils. Wetland soils are typically low in nutrients. (Crites et al. 2014)
- b. Climate- Loss of water due to drought has decreased the availability of wetland habitat. Good conditions would mean the return of a regular wet season however California's water needs have been the biggest effector to the loss of wetlands. (Fraye et al. 1989)

E. Invasive Species Issues:

- a. Invasive species take over and use resources that herbaceous plants need. With the changing climate and water conditions, it gives exotic species the ability to overcome natives.
- b. Water tables have been affected by invasive species that use all available water, decreasing the amount of herbaceous species that can survive due to needs for moisture that wetlands provide.
- c. Invaders can also shade out or use much more of the nutrients available in the soils before native species can, and overall outcompete them. (California Invasive Plant Council)

F. Uses of Herbaceous Species:

- a. Sedges such as *Carex spp.* were used as a source of material to build things such as baskets, mats, screens, and many other products. They could still be a valuable resource for use in today's products.
- b. Sedges can also be used as garden decorations. They are native to California, so they would not be detrimental if they were accidentally spread, and would not become invasive as a result.
- c. Common cattail and other bulrushes can be used as a filter for toxins and reduce water pollution. (Reznicek 2013)
- d. Deer grass is a pleasant looking plant that can be used in a variety of California habitats and in gardens. It can be both used for central valley riparian and wetland systems as support for many species and the soil for erosion control. (USDA NRCS Plant Material Program 2002)

III. Key Herbaceous Species List

A. Native Herbaceous Plants:

- Mugwort: *Artemisia douglasiana*
- Deergrass: *Muhlenbergia rigens*
- Common Cattail: *Typha latifolia*
- Meadow Barley: *Hordeum brachyantherum*
- Creeping Wild Rye: *Leymus triticoides*
- Sedges- White Sedge: *Carex albida*, Water Sedge: *Carex aquatilis*
Note: There are several species of native Sedges (*Carex spp.*) of California
- Rushes- Common Toad Rush: *Juncus bufonius*, Grassleaf Rush: *Juncus marginatus*
Note: There are also several species of native Rushes (*Juncus spp.*) in California.
- Bulrushes: California Bulrush *Schoenoplectus californicus*, Yosemite Bulrush *Trichophorum clementis*, Slender Bulrush *Schoenoplectus heterochaetus*

B. Invasive Plants of Concern

There are many different invasive plants, however the ones of high concern will be listed, pertaining to herbaceous species (that would otherwise compete with the native herbaceous flora).

- Barb Goatgrass: *Aegilops triuncialis*
-Dangerous to livestock and is a grass that is slowly overcoming any available habitat
- Giant Reed: *Arundo donax*
-Outcompetes both riparian and wetland species for water.
- Mustard Plants, such as Black Mustard (*Brassica nigra*), Common Mustard (*Brassica rapa*), and Saharan Mustard (*Brassica tournefortii*).
- Alligator Reed: *Alternanthera philoxeroides*
- Dense Flowered Cordgrass: *Spartina densiflora*
- Perennial Pepperweed: *Lepidium latifolium*
- Waterthyme: *Hydrilla verticillata*
- Common Water Hyacinth: *Eichhornia crassipes*

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Part 2: Project Goals and Management Plan

Goals:

The restoration of California's central valley wetlands require the use and restoration of current herbaceous species as well as reducing current invasive offenders. There are several different types of sedges, rushes, and other herbaceous species that must be taken into account due to their different needs and preferences (listed below in a table of key species). There are many challenges that will need to be addressed, such as the possibility of needing to alter management plans long term due to climate change and changes in the availability of resources such as water and land. Work with local communities and farming are important in order to promote the goal of restoring remaining wetland and coexistence between wetlands and human developments.

Goal	Description of Goal
Restore current established native populations.	Determine species that have the highest need for restoration and lay out a plan for each of their needs in order to maintain the community and pinpoint those specific species of greater importance.
Reduce and/or remove invading	Determine which invasive species interfere/compete

species that inhibit growth of native species	with current native populations (such as the non-native Giant Reed and Mustard plant species) and determine strategies to eliminate them while maintaining the native populations.
Create a plan to bring water sources to restore wetlands in response to drought conditions.	Work with local water governments to allocate some amount of water to areas that require more moisture to maintain wetland species due to drought stresses. This would also need information on what species needs the most water and their tolerance to drought conditions.
Plant species important to native fauna and ecosystem services	Determine specific species that are beneficial to other fauna of interest (e.g. endangered mammals, migratory birds, etc.) as well as services such as toxin filtration, indicators, and erosion control.
Plant along areas needing erosion control bordering nearby riparian systems.	Find the areas with a need for erosion control and plant species accordingly (e.g. herbaceous species with root systems to stabilize soil from runoff) in order to improve runoff from wetlands and riparian systems. (Riparian ecosystem would benefit from the nearby flood table and stable soil in the wetland.)

Key Native Herbaceous Species, California Central Valley

Common Name: <i>Scientific name</i>	Picture	Preferred Habitat Qualities	Seasons (Blooming , Seeding, Etc.)	Uses (E.g. wildlife use, erosion use, etc.)
California Mugwort: <i>Artemisia douglasiana</i>		Prefers disturbed habitat, occurs in wetlands and other types of habitat. Prefers sun and partial shade. Grows in well-drained soil; fine, medium, or coarse.	Perennial, Blooms May-October	Can stabilize loose soil by the spread of its rhizomes, Beneficial to native bees, Use as nesting material for birds and mammals
Deergrass: <i>Muhlenbergia rigens</i>		Occurs mainly in wetlands in a wide variety of areas.	Perennial, Blooms May-June	Use as a stabilizer for soil, nesting material for native bees such as solitary bees or bumblebees,
Common Cattail/Bulrush : <i>Typha latifolia</i>		Fine, medium, or coarse soils. Non-saline marsh. Almost always occurs naturally in wetlands, preferably freshwater	Perennial, Blooms May-June	Absorbs pollutants from the soils and water, and stores in their stems Several of the stages serve as a food source for wildlife (such as the stems and roots for geese). Also good for shelter/nesting.

		marsh. Aquatic.		
Meadow Barley: <i>Hordeum brachyantheru m</i>		Fine, medium, and coarse soils. It can tolerate many types of soils and is somewhat drought tolerant, but prefers moist soils and full sun.	Perennial, Blooms June-July	Able to be used as a very quick cover for erosion control and a low value food source for grazing and browsing wildlife/livestoc k. Also provides cover for wildlife, and could be an early successor in restoring a site.
Creeping Wild Rye: <i>Leymus triticoides</i>		Grows on dry, moist soil and sandy loam- poorly drained soil. Prefers moderate shade.	Perennial, Blooms May-June	Good foraging for wildlife such as migratory birds, as well as good nesting material. Also a great soil stabilizer
White Sedge: <i>Carex albida</i>		Freshwater marshes, riparian wetlands	Perennial, Blooms May-July	Extremely rare, endemic to California.

Water Sedge: <i>Carex aquatilis</i>		Prefers wet conditions with the water table near the soil surface. Very hardy with temperature and submersion. It highly prefers open areas with little shade.	Perennial, Blooms June-August	Source of food and cover for many types of wildlife. Also a very good for erosion control.
California Bulrush <i>Schoenoplectus californicus</i>		Found only in wet sites and does not tolerate large amounts of salinity. Tends to grow in colonies.	Perennial, Blooms May-June	Reduces shoreline erosion by reducing impacts from waves in open water, and many different wildlife can make use as a source of food and cover.

I. Restoration Plan:

A. Determine Wetland Site

Deciding which type of wetland site to restore in the central valley is important due to the different types of wetlands and their varying vegetation as a result. Once the wetland type is determined, then choices on plants can be made and adjusted according to the conditions on the site. Once the site is selected, then determination of what plants to use will depend on different factors such as; erosion and amount of need for control, pollutants currently present in the environment, and water availability. (Kentula 2002)

The California Central Valley mainly has freshwater marsh communities, so focus should be given to herbaceous species that are best for the current state of California's left over marshes. It must also be taken into account the proximity of the wetland being restored to urban and suburban areas. Since wetlands can be a buffer for floodwaters, too close a proximity may cause several issues. (Kentula 2002)

B. Determine Seeding Mix

An existing emergent wetland would be best for restoration rather than completely recreating a wetland. Depending on the use of the wetland, it can be enhanced to perform a certain ecosystem service such as wastewater treatment or floodwater control. In areas with high amounts of pollutants, a mix of herbaceous species and soils that are able to filter and degrade pollutants is best. In areas that require floodwater control, herbaceous species that can anchor soil as well as provide organic matter can create wetland soils that are able to hold excess waters. (Duffy and Kahara 2011, Kentula 2002)

C. Removal of Exotic Species and Monitoring

Exotics present in any system inhibit the growth of native species, so their removal is key in allowing native species to establish and dominate the area. There are different ways to manage invasive species such as mowing, prescribed fire, herbicide, etc. (Eubanks 2004)

In order to remove current invasive species different methods will be used for specific ones of concern.

Brassica rapa- Before the plants have a chance to mature and seed, manual removal of these plants is best. Removal of *B. rapa* would be labor intensive in high numbers, however other techniques such as prescribed burns are not recommended. (Young-Mathews 2012).

Arundo donax- Removal of *A. donax* is difficult however it can be reduced in number initially then managed over time if it reemerges. To remove initially, tall reeds can be cut after flowering, allowed to regrow partially, and then apply herbicide (glyphosate) to the fresh stalk. Less herbicide is used, and it would be directly on the cut stalk of *A. donax*. Management of persisting *A. donax* can be done manually by removing as much of the rhizome as possible with tools such as a hoe. (McWilliams 2004)

Alternanthera philoxeroides- When dealing with smaller patches of *A. philoxeroides*, physical removal by hand is the best method to reduce the possibility of spreading and reduce damage to nearby native species. In aquatic areas, physical removal is easier and more successful than using herbicide. With large terrestrial patches, herbicide application is the best method to remove *A. philoxeroides*. (Clements 2014)

Lepidium latifolium- *L. latifolium* is highly invasive and difficult to eradicate, so methods may depend on how established it is, and how much native vegetation is around the area. It can be controlled with herbicide use, however it is also key to prevent its growth by establishing native species to override and not allow *L. latifolium*. (Zouhar 2004)

Hydrilla verticillata- Control of this noxious plant depends on the size of the invasion. Small invasions can be manually removed as long as the entirety of the plant is removed. Larger invasions can be removed with the use of herbicide. Any invasions should be quarantined to to the competitive nature of this plant. (Cal-IPC 2015)

Eichhornia crassipes- In smaller amounts, this plant can be controlled by removing by hand. Removal of the entire plant would be necessary so no regrowth can occur. In higher amounts, herbicides can be used to clear *E. crassipes*. (AERF 2005)

After exotic species have been successfully or at least reduced to a very small number, replanting the area is important to prevent any exotic species from reestablishing.

Once there has been establishment from native species, monitoring must be done for invasive species (especially highly competitive species) monthly (and in some cases, weekly due to the quick ability of some invaders to re-propagate) in order to be able to take action on any reemerging plants before it becomes too large of an infestation. Small breakouts of exotics can be handled physically without the use of herbicides, and prevention includes filling current niches with natives and not allowing invasive species to take over resources. (Eubanks 2004)

D. Planting Regime and Monitoring

Early successional species would be types that grow quickly and can reproduce quickly in order to gain a foothold on the environment, then die and provide biomass to the soil. (Eubanks 2004, Roundy 2005) Herbaceous species that are good for this task are *Muhlenbergia rigens*, *Hordeum brachyantherum*, and *Carex aquatilis*. Of these species, all three can be established in the fall.

Muhlenbergia rigens- Since there needs to be a variety of plants instead of one dominant variety, planting from container is the best and more successful method of establishing *M. rigens*. Planting from containers must be spaced out at least 24 inches between each plant.

Depending on the size of the area, more or less of the plants may be set down. Other species can be mixed in with *M. rigens* to prevent invasive plants from trying to propagate. (Anderson 2002)

Hordeum brachyantherum- This species establishes well and there is no dormancy period, so planting in the fall alongside *M. rigens* can be done in moderate amounts. Moderate amounts allow *H. brachyantherum* to be able to fill niche spaces as well as prevent invasive species from growing in areas. It is quick to grow, so it is best for paving the way for other native species to come in natural succession. 1-2 seeds per foot planted with seed equipment would provide a moderate cover. (Darris, 2004)

Carex aquatilis- A mixture of seeding and transplanting would be best to establish *C. aquatilis*. Seeds can be easily collected by hand from the stems and dried. Transplanting *C. aquatilis* in between other seeding areas can help establish native populations by immediately being available to start adding stability to soil and providing food sources for wildlife that may otherwise destroy the restoration site. (Tilley et al. 2011)

After establishing early successors, monitor their progress over the next 6 months in order to determine which plants germinate, which plants establish, what locations they do better or poor in, and what plants do not grow. Also monitor for invasive species and take note of where they invade and the conditions on why they may be able to invade. Other species of native herbaceous plants may be selected, as long as they are able to grow fairly quickly and/or able to tolerate poorer conditions. (Roundy 2005)

Larger and “later” successor plants that require an established area can then be planted in areas that have successfully been able to support the selected flora. Examples of these species includes *Artemisia douglasiana*, *Typha latifolia*, *Leymus triticoides*, and *Schoenoplectus californicus*.

Typha latifolia- Planting a mix from seeds and rootstock would give this plant a better chance at establishing more successfully. Seeds can be planted in moist soils, while root stock can be planted in areas with moving water and elevated water. Seeds can be planted in the fall alongside the other plant species. (Farrell 2000)

Leymus triticoides- Rhizomes can be planted to best establish the species. Seeds are hard to establish because of their low vigor, however if a native plant system is already in place, competition with weeds may improve the success of seeding. Rhizomes should be planted in 2 or 3 foot areas in order to avoid crowding with other species, and allows the plant to be able to spread across the landscape. (Young-Mathews and Winslow 2005)

Schoenoplectus californicus- Rhizomes that have been divided and planted in pots can be planted to ensure the best survival. Plugs can also be planted. Water is required in order to plant plugs or rhizomes, a minimum of one inch and optimal at 12, up to 24 inches of water. Depending on the size of the plant, spacing should accommodate larger plants and surrounding species such as *T. latifolia*. (Peterson 2003)

Once these varieties and similar plants can be established, long term monitoring can occur. Checking for regrowth in a target percent of native plants can help determine if planting is successful. 50% of plant regrowth and succession is a strong indicator of native plant establishment. (Eubanks 2004) The most involved management is control of possible invaders to prevent them from quickly reversing restored areas. Monitoring which plants survive vs. which do not survive is important to determine which to replant and attempt to restore. The areas that grow better or worse should be taken note of in terms of which plants grow where, how fast they mature compared to different areas, and which fauna interact with the plants. (Eubanks 2004)

The best plan for wetland monitoring is to initially plan to allow the wetland to go unmonitored due to the lack of support in wetland restoration and management. Continued monitoring can be expensive, so great care should be taken to choose the species best fit to the specific area that can be maintained with little resources. (Kentula 2002)

E. Potential Issues and Resolutions

Issues that may arise with wetland restoration is determining if their restoration is even possible in some cases due to their historical replacement with agricultural lands. Lost wetlands may not be able to be recovered because of habitat fragmentation as well as human developments such as damming, levee systems, and nearby farming and urban areas. (Frayer et al. 1989) There may also be issues in getting support from sponsors. Due to the spatial scale of wetland restoration of upwards of 50+ years, support may be hard to gain due to the costs involved in monitoring an ecosystem site for such a long period of time. Resolutions such as converting the wetland to an ecosystem service or a benefit to multiple other areas of interest could improve interest in wetland restoration. (Kentula 2002) Risks would include possibly interfering with current plans for water allocation in the state because of drought, as well as treading on nearby farms and urban communities. Restoration of wetland may bring in wildlife that is unsuitable for coexistence near human communities and interfere with agricultural systems.

F. Research that Would Improve the Plan

Having more research done on the different herbaceous plant species that make up the California central valley wetlands could improve understanding of what methods to use in order to subdue invasive plants. Research showing both long and short term benefits of wetlands could improve public moral regarding wetlands.

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Seasonal Wetlands – Vernal Pools Ecology and Restoration Plan

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Part 1: Project Background and Justification

A. Background and Justification

Wetlands have always been an important ecosystem in California's Central Valley. They provide habitat for migrating and resident waterfowl and many species of fish as well as provide bank stabilization and flood protection (Fraye et al., 1989). What started as four million acres of wetlands in 1850 has begun to decline significantly in the California Central Valley. From 1939 to the mid-1980s, freshwater wetlands decreased from 561.5 thousand acres to 318.9 thousand acres, averaging about 5.2 thousand acres lost per year (Fraye et al., 1989). The majority of these losses came from agriculture, especially converting wetlands into rice fields (Fraye et al., 1989). Degradation of seasonal wetlands began in 1850 when farmers diked floodplains for agricultural practices. Then, in the early 1910s, the Sacramento Flood Control Project caused a considerable increase in the conversion of wetlands (Fraye et al., 1989). With increased agriculture and a growing population, the need for water increased. This resulted in groundwater pumping and further degradation of wetlands. Throughout the 1950s, a number of dams and flood control methods were constructed, interfering with the Central Valley's natural water flow, causing damage to what little wetlands remained (Fraye et al., 1989). More recently, however, there have been measures to protect California's wetlands including the California Environmental Quality Act. Planning laws as well as many private foundations (like The Nature Conservancy and Ducks Unlimited Inc.) continue to fight for the preservation of California Central Valley wetlands (Fraye et al., 1989).

In the California Central Valley, vernal pools are a common occurrence. Vernal pools are defined as seasonal wetlands that fill and dry each year (Solomeshch et al., 2007). Much like yearlong wetlands, seasonal wetlands provide habitat for breeding and reproduction of many species like the longhorn and conservancy fairy shrimp, delta green ground beetle, western spadefoot toad, and Pacific tiger salamander. In addition, vernal pools and seasonal wetlands provide habitat for migrating winter waterfowl (Solomeshch et al., 2007). Vernal pools are important because they consist of many endemic species. However, habitat loss from conversion to agricultural lands and housing developments are threatening vernal pools' endemism, causing a need for increased conservation and restoration (Solomeshch et al., 2007). Below, I will discuss the three main characteristics that make up the ecology of vernal pools: soil, hydrology, and vegetation.

B. Literature Review

- Soil (Solomeshch et al., 2007)
 - o Northern Hardpan Vernal Pools (NHVP)
 - Durixeralfs and Palixeralfs
 - Iron-silica-cemented duripan
 - Reddish color
 - Depleted nutrient status
 - o Northern Claypan Vernal Pools (NCVP)
 - Vertisols, Durixeralfs, and Natrixeralfs
 - Developed in parent material stemming from marine sediments
 - Saline and/or alkaline
 - Tend to erode to clay

- o Soil Processes
 - Ferrolysis
 - Cyclic oxidation and reduction of Fe and Mn
 - Results in low pH and mineral erosion in upper soil layers
 - By products – soluble bases, silica, calcium carbonate, iron oxides
 - o Over time, move downward in clay profile
 - Accumulation of organic matter
 - Clay formation and translocation
 - Formation of impermeable layer
 - Claypan, cemented hardpan, or rock
- Hydrology (Solomeshch et al., 2007)
 - o Wet phase
 - 2 to 4 months (beginning around November)
 - Soils are saturated for an additional 1 to 3 months (through April and May)
 - Water levels alter with precipitation
 - Disturbances to wet phase
 - Dry winter – pools recede
 - Wet spring – pools refill (affects growing season)
 - o Dry phase
 - 5 to 8 months (beginning around May and June)
 - Plants are dormant
 - o Water sources
 - Precipitation
 - Groundwater recharge
 - Connectivity between pools – lateral flow and subsurface flow
 - o Water losses
 - Evapotranspiration
 - Groundwater seepage
 - Lateral flow
 - o Water chemistry
 - Fluctuates throughout day
 - Morning – neutral pH, cool water temperature, high CO₂, low O₂
 - Afternoon – increase in pH (by 2 to 3), increase in water temperature, low CO₂, high O₂ (from increased photosynthesis throughout the day)
- Vegetation (Solomeshch et al., 2007)
 - o Factors influencing vegetation presence
 - Inundation – eliminates presence of upland species
 - Dry phase – eliminates presence of aquatic and wetland species
 - Therefore, most plant species are ephemeral (seasonal)
 - o Life cycle follows that of vernal pool cycle – grow during wet period; complete life cycle during dry period
 - Timing and amount of precipitation each year – unpredictable
 - Eliminates plants that are unable to be dormant for several months

- Therefore, vernal pool plants have seed dormancy mechanisms to sustain soil seed banks
- Low in nutrients – eliminates many annual species
- o Dominate genera – have speciated within vernal pool habitat
 - *Downingia*
 - *Lasthenia*
 - *Navarretia*
 - *Plagiobothrys*
 - *Pogogyne*
 - *Psilocarphus*
- o General life cycle – determined by timing and length of inundation
 - Germinate in winter (before pools fill)
 - Grow slowly during winter and spring inundation
 - Grow rapidly once pools dry up, but soil still moist
 - Reproduce in summer
 - Seeds go dormant
- o Vegetation zonation - determined by depth and length of inundation
 - Edges of vernal pools dry earlier – species flower here first
 - Species form concentric zones
 - Edges white from *Limnanthes*
 - Central zone white, yellow, blue, or green from *Plagiobothrys*, *Lasthenia*, or *Downingia*

C. Vegetation ID Guide for Vernal Pools (California Department of Fish and Game)

Vegetation Community	Species Present	Picture
Vernal Pools	Goldfields (<i>Lasthenia</i> spp.)	
	Popcorn flower (<i>Plagiobothrys</i> spp.)	
	<i>Navarretia</i>	
	Woolly-marbles (<i>Psilocarphus</i> spp.)	
	<i>Downingia</i>	

	<i>Limnanthes fremontii</i>		
	Italian ryegrass (nonnative)		
	Colusa grass (<i>Neostapfia colusana</i>)		
	Crampton's tuctoria (<i>Tuctoria mucronata</i>)		

Part 2: Project Goals and Management Plan

A. Goals

Overall, the main goal of the vernal pool restoration project is to restore the total health of the vernal pool ecosystem. This would be done by using natural vernal pools in the same area as a reference for vernal pool health (De Weese, 1998). Specific goals are as follows:

- Reestablish hydrology – timing, length, and depth of inundation is important in reinstating certain species to vernal pool communities, as well as restoring the overall community health and function.
- Eliminate invasive species and reestablish natives– invasive species outcompete natives for important resources, especially a limited resource like water. In addition, they overtake and shrink vernal pool sizes; without control or

eradication, the vernal pool, along with its native species, would eventually disappear.

- Reduce water contamination – decrease the amount of contaminants that enter the vernal pool via agricultural runoff and storm water pollution.
- Minimize habitat loss and degradation due to agricultural land conversion and urbanization.

B. Restoration Plan

Before any restoration plan begins, it's important to survey the designated site first. About a year before the projected implementation of the plan, research and evaluate the site. Gathering information on environmental interactions, ecology, and habitat of the site will help develop a restoration plan that is specific to that area. Each site is different, so having background information will significantly aid in the success of the project. In addition, pick a reference site (as mentioned under the Goals section) for comparison to the restoration project. To reiterate, the reference site should be a natural vernal pool in the same area as the selected restoration site. The reference site will give a good idea of what the restored ecosystem should be like, in terms of ecology and ecosystem function.

As with most ecosystems, the main threat to vernal pools is habitat loss and degradation (U.S. Fish and Wildlife Service). To combat this, it is important to minimize access to vernal pools – the least amount of human interaction the better. Some options to achieve this would be through land acquisition, purchase of conservation easements, designation of land as a reserve, or conservation agreements (U.S. Fish and Wildlife Service). Adding a level of protection to the area would minimize the possibility of human interaction, land conversion, and urbanization.

After minimizing the possibility of habitat destruction, the next step would be to eliminate the threat of invasive species. Invasive species also contribute to loss of habitat of vernal pool areas. They outcompete the native species and alter the ecosystem, completely overwhelming the area (U.S. Fish and Wildlife Service). According to studies, one way to manage invasive species in vernal pool habitat is through managed livestock grazing (Barry, 1998 and Marty, 2005). Usually, livestock is thought to be a threat to ecosystems and biodiversity, however it has been proven that managed grazing of an area actually reduces the presence of invasive species, both in cover and richness (Marty, 2005). Based on this, continuous managed grazing throughout the site – maybe through agreements with local private landowners – would be the best effective management strategy to control invasive species and maintain native species of the vernal pools. To put this into perspective, another method that is typically used in eradicating invasive species is prescribed burning. In the case of vernal pools, however, it was discovered that invasive species had greater species richness at pool sites that were burned versus pool sites that were not burned (Gerhardt and Collinge, 2003). Therefore, if given the choice between managed grazing and prescribed burning, managed grazing would have higher success of controlling invasive species. In addition to grazing, maintaining the hydrology and overall health of the ecosystem will considerably reduce the presence of invasive species (Gerhardt and Collinge, 2003). Maintaining the environment to the preferences of native species will allow the natives to thrive and make it difficult for invasive species to establish (U.S. Fish and Wildlife Service).

Once invasive species are controlled, reestablishing the hydrology of the vernal pool would be the next step, as the pools are dependent on seasonal water patterns. The main source of water for vernal pools is precipitation (Solomeshch et al., 2007), however,

the recent shift to drought conditions in California has some cause for concern. With the onset of drought, there has been less and less precipitation each year. This is important when considering restoring the hydrology to the site. One method would be to wait for precipitation to reestablish the hydrology of the vernal pool, however, weather patterns are unpredictable. Rain could arrive in a month, or rain could arrive in five years. If there is no time constraint on the restoration project, then waiting for a year, maybe two, for precipitation might not be the worst method. If, however, the restoration plan needs to be completed faster, there is the option of constructing vernal pools (De Weese, 1998). To do this, an area within the site would be excavated to similar size and depth of the reference site. Typically, the site would be dug to a depth of about four to six inches (De Weese, 1998), though remember to use the reference site to determine an appropriate depth for the specific area. After manually creating a vernal pool, haul water to the site (most likely by a water truck) and flood the vernal pool. Because of construction, the soil is going to be more compact than typical vernal pool soil. Therefore, it is important to keep the vernal pool inundated for a longer period of time than a natural vernal pool, especially in the first year or two after construction (De Weese, 1998). Constructing a vernal pool would be a speedier way to restore the hydrology of the system, however it is also going to be more expensive and labor-intensive. In addition, it is suggested that construction of vernal pools does not occur in areas where natural vernal pools develop, as it might affect the hydrology of the existing pools (U.S. Fish and Wildlife Service).

After the inundation period (roughly a year), the topsoil and organic material excavated from the site (referred to as inoculum) would be reintegrated into the area, allowing for the seeding and reestablishment of native plants (De Weese, 1998). At first, maintenance of existing native species currently present at the site should be conducted. Only as a last resort should seed collection and propagation be implemented. In addition, reintroductions and introductions should only be conducted at sites that are guaranteed long-term preservation (U.S. Fish and Wildlife Service). Here, we are trying to maintain the natural area as much as possible, only intervening when absolutely necessary.

Finally, it's important to control the amount of contaminants that enter the vernal pool system. Contaminants such as herbicides, fertilizers, and pesticides are discharged from local urban and agricultural areas, causing harmful impacts to many plant and animal species. In particular, herbicides will affect the growth rate of many vernal pool plant species (U.S. Fish and Wildlife Service). Because of this, it is suggested to limit, if not completely abandon, the use of herbicides in the restoration area. In addition, it's imperative to control point sources of pollution, for example, applying end of the pipe treatments to agricultural runoff and stormwater drainage.

C. Monitoring Plan

Following the implementation of the restoration plan, heavy monitoring – at least once a month – of hydrology, invasive species, native species, and water quality should occur in the first two years. After two years, if the site has regained ecosystem function and health (i.e. restored hydrology, establishment of native species, restored ecosystem services), then monitoring can be reduced to once every three to six months. Because vernal pools are subject to variable change (mostly due to weather patterns), site maintenance and monitoring should be continuous.

To monitor hydrology, staff gauges should be installed in the pools (De Weese, 1998). The staff gauges will help document the water depth and inundation patterns of the vernal pool. This information should be compared to the reference site to maintain appropriate depth levels that support the flora and fauna of the vernal pool system. If the depth levels are less than appropriate levels, then water should be hauled in to

restore the depth to the correct level. This will help in maintaining native species as well as reducing establishment of invasive species.

In addition to water depth and inundation, contaminants should be measured each month. Water samples should be taken and analyzed. If water pollutants are far greater than what is normal (again, compare to the reference site), actions need to be taken to reduce the amount of the contaminant. Likewise, point sources of pollution need to be closely monitored. If particular devices were installed to decrease the amount of pollutants entering the water supply, those need to be checked at least once a month, if not once every one to two weeks. These devices need to be maintained to ensure they are working properly.

As mentioned in Part B, grazing of the area should be closely monitored and managed. Livestock grazing will be a significant help in the control of invasive species, but too many grazers or grazing for too long could have negative impacts on the ecosystem. Although there is much research about the benefits of livestock grazing, there aren't many findings on suggested rates of grazing. This would be something to research further when using grazing as a management and monitoring tool for restoration.

Lastly, it's important to conduct community outreach and education. If the community is educated about water pollution and translocation of invasive species, then they will be able to help reduce threats to the restoration area. Although it is important to reduce the amount of human involvement at the site, it is also just as important for community members to engage themselves in nature. Their interactions with the environment will affect the way they contribute to the restoration plan. Therefore, it is important to involve and educate the community to guarantee the long-term preservation of the vernal pool restoration site.

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Riparian herbaceous species (grasses, forbs, sedges)- along gradient between wetland/creek and upland (focus on vegetation zones)

Haley Schrader

Part 1: Project Background and Justification

A. Background & Justification:

Riparian zones act as a stabilizing boundary between land and water ecosystems. These zones are a major factor that influence water quality by preventing sediments, pollutants, and pesticides from reaching the stream (BAE NCSU department and WQG, 2009). Keeping sediment out of the stream is important for preventing degradation of the stream bed over time and preventing nutrient runoff. Roots from vegetation growing in this zone also stabilize the stream bank and help prevent erosion by holding the soil intact during floods and preventing undercutting (Hawes & Smith, 2005). Riparian zones serve as a buffer between upper regions and the water bodies, slowing down the procession of nutrients and allowing them to decompose (Gregory et al., 1991). Additionally, they slow flood waters by providing a rougher surface for water to travel through, protecting down-stream property (BAE NCSU department and WQG, 2009).

Riparian buffers also serve as a source of energy for the surrounding ecosystem, and provide habitat for wildlife (BAE NCSU department and WQG, 2009). Riparian zones directly benefit wildlife by providing cover, breeding grounds, food, and insulation. (Vaghti & Greco, 2007). Riparian zones also provide many ecosystem services to humans, including flood management and recreation (Vaghti & Greco, 2007).

Prior to large scale settling, indigenous cultures practiced careful management of riparian zones. Burning, weeding, and other minimally invasive techniques were used to ensure maximum utility (Vaghti & Greco, 2007). Current management practices fail to utilize the knowledge of these indigenous cultures, and as a result the riparian zones today differ greatly from those seen in the past. It is estimated that about 98.5% of natural riparian ecosystems in the Sacramento Valley have now been lost (Warner & Hendrix, 1984). However, the importance of riparian ecosystems is becoming more widespread, and many efforts are in place to restore these zones (Vaghti & Greco, 2007).

B. Literature Review

Great Valley Basin environmental characteristics:

1. Soils are comprised mainly of Entisols and Alfisols. Lower and flatter regions tend to be Entisol dominant, while slightly higher regions are dominated by Alfisols (Vaghti & Greco, 2007).
2. Average annual precipitation varies from South to North between 13 and 76cm/yr. (Vaghti & Greco, 2007).

3. Maximum summer temperatures can reach up to 39 degrees Celsius, and winter minimum temperatures can be as low as 2 degrees Celsius (Vaghti & Greco, 2007).
4. Freshwater marsh: Contains many hydrophilic plants, tend to be separate from the primary location of water flow (Vaghti & Greco, 2007).

Key disturbances and the role of riparian zones:

1. Fire:

Riparian zones tend to be biologically diverse, and combined with the unpredictable nature of fires the impact on soil nutrients is quite variable (Pettit and Naiman, 2007). Since humans have intervened, many riparian areas are now fragmented. Introducing natural fire regimes back into these areas has been shown to decrease species diversity, because the spatial scale is so much smaller and not as well-equipped to adapt (Stromberg, 2001). Additionally, there are very few studies that focus on how a reestablished natural fire regime would change riparian zones on the west coast, so using fire in these zones would not be recommended (Dwire & Kauffman, 2003).

2. Flooding:

Restoring natural hydraulic conditions is desirable but unrealistic. Due to anthropogenic changes to the hydrologic system like dams and extractions, the water flow is redirected and fragmented to the point where it is no longer recognizable over what it once was. Reestablishing flood regimes would be desirable for herbaceous riparian species, however it is unrealistic to attempt to introduce floods into a now populated area. Considerations must also be made to determine what temporal scale to use when determining historical norms. Choosing a time before urbanization occurred would result in unrealistic goals for restoration. It is advised to compare the current site to a point in time after the surrounding area had already been urbanized, as this provides a baseline for what is realistically attainable under current conditions (Dwire & Kauffman, 2003). After the temporal scale has been chosen, studying past flood regimes will give an accurate idea of the flood frequency needed in the area, with expected peaks in the spring and winter months (Griggs, 2009).

3. Pesticides, Pollutants, and Agriculture:

Riparian zones play an important role in capturing pesticide runoff before it reaches the waterbody. They protect aquatic species and the downstream ecosystems as well as the surrounding populations, as pesticides that reach the groundwater supply can have detrimental effects (Tilman et al., 2001). Similar to pesticides, riparian areas can capture large amounts of animal waste and pollutant runoff before they reach the waterbody. Primarily through the process of denitrification, riparian zones capture and remove the Nitrogen from animal waste before it can be dumped into the water (Tilman et al., 2001). Pollutants, pesticides, and animal waste bond to soil particles and end up with the sediment

deposits in streams. Plants along the riparian buffer zone have the capacity to stop 50-100% of this sediment (Hawes & Smith, 2005). 80-85% of the Phosphorus contained in this sediment can also be trapped before it reaches the stream, as well as storing and transforming Nitrogen and pollutants into less harmful forms (Hawes & Smith, 2005).

Suggested Species List:

Note: Sources listed after tables and images.

Low Zone:

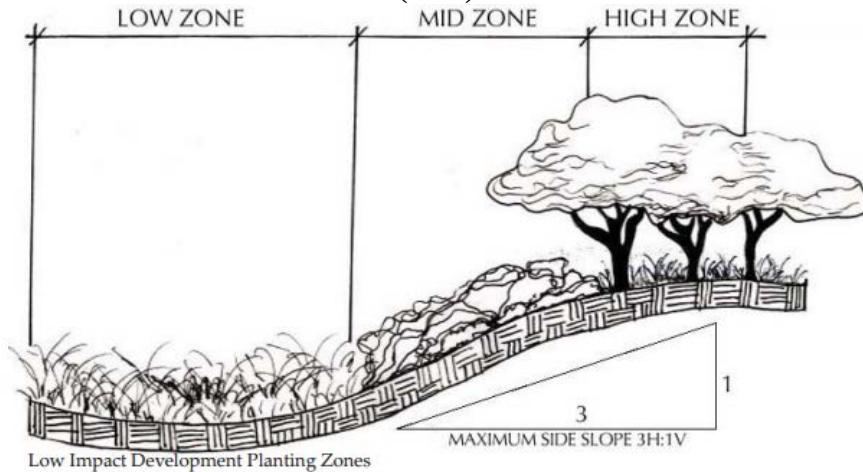
Common Name	Scientific Name	Characteristics
Western Columbine	Aquilegia formosa	Can survive in wetland and non-wetland habitat. Blooms March-May. Hummingbirds and many insects benefit from it. Tolerates medium and coarse textured soils. Tolerates flooding, consistent saturation, and prolonged dry periods. Good filter strip.
California Meadow Sedge	Carex Pansa	Acts as good filter, flood and wind tolerant. Requires drainage.
Slough Sedge	Carex obnupta	Blooms in April and May. Tolerates wind, prolonged saturation, and occasional flooding. Occurs under natural wetland conditions.
Globe sedge	Carex globosa	Good filter strip. Tolerates saturation flooding and wind.
Berkeley Sedge	Carex tumulicola	Tolerates mowing, wind, frequent saturation, flooding, and dry periods.
Common Spikerush	Eleocharis macrostachya	Blooms May-June. Tolerates medium and coarse textured soils. Good for a filter strip. Tolerates wind, saturation, and flooding.
Red Fescue	Festuca rubra	Occurs in wetland and non-wetland habitats. Blooms April-May. Coarse and medium textured soils preferred. Tolerates mowing and wind. Flood and frequent saturation ok. Requires irrigation.
California Gray Rush	Juncus patens	Tolerates fine medium and coarse non-saline soil types. Good filter strip. Tolerates high saturation, occasional flooding, and wind.
Fiber Optic Grass	Scirpus cernuus	Good filter strip. Tolerates dry periods, flooding, saturation, and wind.
Virgin's Bower	Clematis ligusticifolia	Blooms June-August. Minor toxicity. Bees and butterflies benefit from it. Tolerates prolonged dry periods and occasional flooding.

Mid Zones:

Common Name	Scientific Name	Characteristics
California Wild Grape	Vitis californica	Blooms May-June. Provides nesting material for native bees. Host to moths, specifically White-lined sphinx.

		Pests include flies, bacteria, and leafhoppers. Tolerates all soil textures. Tolerates frequent saturation, occasional flooding, periodic dry periods, and wind. Needs partial sun. Don't plant at lowest point.
Tufted Hairgrass	<i>Deschampsia cespitosa</i>	Blooms in July. Provides nesting material for native bees. Host plant for butterflies, particularly the Umber Skipper. Good with medium and coarse soils. Tolerates flooding and long dry periods. Requires good drainage and irrigation.
Pacific Reedgrass	<i>Calamagrostis nutkaensis</i>	Blooms from March-June. Beneficial to many insects. Tolerates flooding and long dry periods.
White Globe Lily	<i>Calochortus albus</i>	Blooms April-May in medium or coarse soils. Tolerates flooding and long dry periods.
California Fescue	<i>Festuca californica</i>	Blooms February-April. Beneficial to many insects. Can tolerate some flooding, long dry periods, and wind. Do not plant in low zone.
Creeping Wild Rye	<i>Leymus triticoides</i>	Blooms June-July. Host plant to butterflies, particularly the Woodland Skipper. Tolerates most soil textures. Tolerates some flooding, extended dry periods, and wind. Very fast spreading.
Twinberry Honeysuckle	<i>Lonicera involucrata</i>	Blooms June-August. Provides nectar to bees and hummingbirds. Tolerates periodic flooding.

Image of low, mid, and high zones copied directly from Joni L. Janecki & Associates, Inc. (2008):



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Part 2: Project Goals and Management Plan

Goals:

Goal	Spatial scale	Temporal scale	Description
Create a good habitat for wildlife	Large	Long	Large plant variety will give cover to a wide range of insects, birds, and mammals. Will also provide feeding sites, attracting more species to the area.
Increase sediment removal and filtration	Large	Long	A riparian wetland zone with dense vegetation will be best for trapping pollutants from urban runoff. This will increase the quality of the stream and ground water.
Wide riparian zone	Large	Short	The optimal width of a riparian zone is between 25 and 200 feet- depending on the level of flooding that occurs. (More flooding/higher flood zone= wider riparian zone).
Establish native plants	Large	Medium	Use drip irrigation to prevent invasives from

			establishing. Native roots should be well established within 2-3 years.
Optimize drainage	Large	Long	For vegetation, important to consider flood tolerance, water requirements, pollutant filtration capacity, and root and leaf structure.
Reduce erosion	Small	Long	Establishing native roots in the soil and ensuring minimal soil exposure to reduce wind erosion.

Sources:

Joni L. Janecki & Associates, Inc. (2008). Prepared by Salinas Permit Center Community and Economic Development Department, Engineering Services Section. Stormwater Development Standards 2008 Revision, Appendix G.

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Restoration Plan:

Preparing the site- Prior to native species planting, extensive weed removal is critical. To ensure maximum weed removal, begin by removing all visible weeds at the site. Following initial weed removal, water the site until saturated. This will spur the growth of emerging weeds and new seeds that may have been dispersed while removing the parent weeds. Remove new weeds immediately to ensure they don't have time to reproduce. Repeat this process until all weeds are removed (County of Ventura, Planning Division, 2006). Tilling can be used to stir up the soil and any remaining seeds. The earlier this process is started, the better-sometimes up to several years prior. However under normal time constraints, weed removal should be expected to take several months. After removing all weeds from the area, do not fertilize the soil. If native species are to be planted, then they are already accustomed to local soil conditions. Fertilizing the soil could also encourage invasive establishment (County of Ventura, Planning Division, 2006).

Low Zone- The low zone is the area of greatest potential for inundation. The ideal plants for this area are extremely water tolerant with significant roots (refer to the species list above for plants that tolerate both periodic flooding and frequent saturation). The goal in this

zone is to maximize pollutant filtration, minimize the speed of run-off water, and prevent erosion. Good vegetative cover will be beneficial for increasing evapotranspiration, and reducing the impact of rain on the soil – thus reducing erosion. Dense root structures will also be imperative to reducing erosion and withstanding floods. Groundcovers and grasses are recommended for this area because they can cover exposed soil rapidly (Joni L. Janecki & Associates, Inc., 2008).

Mid Zone- Depending on how the site drains and the soil type, some mix of ground cover and grasses with some shrubs will be used here. The goal of the mid zone is to reduce runoff from storms. Because this zone is sloped, strong root structure is essential to preventing erosion. Plants in this area should be used to experiencing periods of drought as well as periods of flooding (Joni L. Janecki & Associates, Inc., 2008). See the species list above for plants that are both drought and flood tolerant.

Seeds/Cuttings- There are two basic scenarios for considering when to use seeds and when not to. Consistent high levels of moisture in the soil are a main determining factor of plant survival. In the case of a drought, use cuttings instead of seeds. Cuttings will allow plant establishment at the site much quicker. The ideal timeframe for collecting cuttings is between December and February (County of Ventura, Planning Division, 2006). In the case of normal site conditions, use seeds. If the seeds establish well, they will have a much greater chance of survival. Seeds should be used whenever possible, particularly when planting grasses and annual plants. Native grasses are fast growing, and can protect the slower growing plants while they establish (County of Ventura, Planning Division, 2006).

Planting- Plants should be planted with enough distance to reach full maturity between them and their neighboring plant. Mark native plants with stakes or flags to prevent accidentally removing them while weeding (Joni L. Janecki & Associates, Inc., 2008). If there were native plants in the zone already, do not disturb them. Pay special attention to avoiding compaction of the soil around them. For the low zone in particular, planting will be most successful when the soil is wet. However, the soil is the most saturated during the winter rainy season. Avoid planting during this time as the seeds and cuttings will be washed away. Instead, it is best to plant immediately after the rainy season ends. This is to allow for minimal irrigation and maximum root growth before the summer months come (County of Ventura, Planning Division, 2006). The bare soil in between establishing plants needs to be covered to prevent invasives and erosion. Recommended cover includes annual native grass seed, landscape fabric, biodegradable erosion control mats, or mulch. Good choices for mulch include redwood bark, crushed stone, Nitrogen-fortified bark, chipped gravel, or a blend of half compost and half aged top soil (Joni L. Janecki & Associates, Inc., 2008).

Potential Problems, Risks, and Uncertainties- This paper was based off of research done under normal site conditions. Because California is currently experiencing a drought, the nature of the riparian wetland is much different than normal. It will be challenging to account for planting vegetation that can last through the drought and establish, but also be prepared for flooding events in the future. Because normal time constraints don't allow for years of weeding in advance, some weeds are sure to be left behind following the initial planting of native plants. If careful attention isn't given to weeding consistently while the new plants grow, they could be outcompeted by the weeds that have already adapted to the area.

Monitoring Plan:

1. Pre-Restoration-

Existing site conditions- Before anything is planted keep a careful record of what plants are already present at the site. This will be a good indicator of what native species can persist under current site conditions, and which invasive species to watch out for. The more the current site conditions are studied, the more the restored site can resemble the native community. This makes large time investments on the front end necessary, however could also

dramatically lower the cost of restoration (County of Ventura, Planning Division, 2006). To determine the likelihood that native plants can be restored important factors to include are soil moisture, hydrological patterns, and reproductive capabilities (County of Ventura, Planning Division, 2006). Particular characteristics to test for in the soil include texture, composition, infiltration rate, and cation exchange capacity. This will determine the site's baseline normal soil conditions, and are a determining factor for what vegetation to plant at the site (Joni L. Janecki & Associates, Inc., 2008).

General Plant Considerations- After analyzing the current site conditions, decisions about what to plant at the site can be made. Native species are already adapted to local site conditions, so native plants should be considered first. In general they also tend to require less water to establish, making planting natives more cost effective and better at deterring weeds and invasives. For the soil left exposed during the growth process of natives, turf grasses should be avoided. Turf grasses demand high maintenance, including frequent watering and fertilizing. Because the low zone of the riparian area has the greatest potential for contact with the stream, non-native plants should be particularly avoided here. They have the greatest chance of being spread by water in this zone (Joni L. Janecki & Associates, Inc., 2008).

2. Post-Restoration-

Replanting and Weed Control- If the site conditions remain generally optimal, replanting may not be needed. Assess whether or not invasive plant removal is necessary after 1-2 rainy seasons. Be sure a budget for weed control is in place. Watering plants will take place for 2-3 years. Once the new roots are established, irrigation is no longer necessary. It is recommended to use the cheapest irrigation possible, as this zone is prone to flooding and could remove the irrigation. Weeding frequency and intensity should remain constant for the first few growing seasons, after which point the natives will crowd them out and intense weeding won't be as necessary (County of Ventura, Planning Division, 2006).

Recreation- Recreation in this riparian zone should be avoided. If stream access is necessary, create several access points along the stream. These points will need to be much more intensely monitored than the blocked off areas (DNREC, 2000).

Woody Debris- Woody debris should not be removed from the site. It serves a tool for slowing down runoff, which will allow the vegetation to increase its filtration capabilities (DNREC, 2000).

Informal Monitoring- Informal monitoring should be conducted frequently. This monitoring involves visiting the site and determining if there are any immediate threats that need to be addressed. Any noticeable problems should be more closely evaluated and a plan for action should be made. Problems like this would include missing or altered irrigation, garbage on site, large patches of dead vegetation, or major erosion (Hall, Spooner, & Frederick).

Formal Monitoring- Formal monitoring will take place less frequently than informal monitoring, but will be more extensive. Formal monitoring will involve specific data collection strategies, such as studying specific plots for vegetation success and soil moisture (Hall, Spooner, & Frederick).

Questions to Improve the Plan- Which kinds of ground cover or mulch work best to cover the exposed soil while the new plants establish? Which were best at preventing invasive plants from taking over? Did bringing in different plants increase the amount of wildlife that was able to live in the area, or did it push some out? How well did the riparian zone filter pollutants from urban runoff? Which species established the fastest, and which took the longest? Which were able to survive and reproduce, and which were not? How effective was irrigation/ how often was it needed?

Questions to be Answered by this Project- After many visits to the site and careful analysis of the data collected, information on how wetland riparian herbaceous vegetation will respond to drought conditions will be known. More interestingly, if the drought ends after a couple growing seasons, that could show how plants that survived through the drought will fare in normal rainy season conditions. This would be valuable information to have going forward as the threat of climate change leads to more intense weather and climate alterations. It will be valuable to know which plants to best in versatile conditions and can withstand the most variation over time.

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Soil type comparison (Capay, Clear Lake, San Ysidro, Rincon)

Oscar Morales

Part 1: Project Background and Justification

Why are soils important?

Soils provide structure and foundation for plant utilization, the types of soils in a region determine the hydrology of the ecosystem and also influences the amount of available nutrient there is for plant uptake. Understanding the characterization of soils is useful in implementing the appropriate restoration plans. Having a good soil structure along with the soil being pathogen free is what allows the restorationist to change the vegetation and be confident that the plants will establish and survive the following years. On the other hand, if a soil is degraded and infected with pathogens, it is very difficult for the soil to recover on its own and even more difficult to direct a successional development with ecological restoration (Whisenant, 2002). Overgrazing, deforestation, mining, and intensive cultivation practices are but a few ways how soils are degraded (Whisenant, 2002). Thus in order to have a successful restoration plan we need to cover the fundamental bases and make sure that the soil we are working with is healthy.

The Central Valley

California's Central Valley is made of flat alluvial soil that covers around 19,000 square miles located between the Sierra Nevada and the Coast Ranges; the Central Valley's climate is characterized as a Mediterranean climate having hot dry summers and cool moist winter where rain falling from November through April (Witham et al., 1998). It has been stated that human usage of soil is unsustainable and that soil quality has been declining worldwide, not only that but more than 10% of the world's vegetated land has decreased in productivity due to soil degradation caused by: soil erosion, atmospheric pollution, excessive tillage, over-grazing, land clearing, salinization lead to desertification of the soil (DeClerck and Singer, 2003).

Benefits of soils

The natural development and condition of soils influences the vegetation and at a broader scale, soils are a critical factor in ecosystem development (Urbanska et al. 1997). Soils hold the non-renewable resources of the ecosystem that include nutrients, soil organic matter (SOM), and mineral nutrients; in a healthy ecosystem the resources are lost when vegetation dies off but a healthy soil is able to replenish the resources to new vegetation because of its excellent storage qualities (Urbanska et al. 1997). This buffering capacity is what allow plants to continue their growing cycles from year to year without major repercussions. Only when outside factors influenced by human interventions is when soils become poor and deteriorated.

Factors influencing soil degradation

Negative impacts to soils like in the Central Valley can be seen in the diagram below (Whisenant, 2002). The soil degradation cycle demonstrates that human activities have a deleterious cascading effect that are not evident right away but overtime the effects accumulate until the natural threshold is reached and the soil becomes extremely degraded to a point where it is no longer self-sustaining (Whisenant, 2002). What remains in a degraded soil is "skeletal material" or pieces of undecomposed particles and fragments like single sized sand; the presence of organic matter, micro and macro-nutrients become non-existent (Urbanska et al. 1997). This soil is left barren and the ecosystem's natural resilience to bounce back is lost.

Diagram 1: The Soil Degradation Cycle



Current status of Soils in the Central Valley

In the Central Valley, we are lucky enough to still have a well-structured and healthy soil. The Central Valley soils along with other soil regions were investigated for any change in pH, salinity, phosphorous levels, organic matter, and soil texture. A soil pH ranging between 5.5-8.2 it is considered good, and it becomes a management concern when it deviates out of the set range because it affects the roots ability of nutrient uptake (Singer and Munns, 2002). It was found that about 68% of the sampled soil sites in California had some pH change but the change was not drastic enough to affect plant growth (DeClerck and Singer, 2003). The research article found that compared to the soils from 1945, the soil salinity from 2001 decreased and only about 4% of the sites increased in salinity (DeClerck and Singer, 2003). Phosphorus is an essential macronutrient for plant growth and is a primary component in fertilizers, California soils showed signs of increased Phosphorus concentration but it is not yet clear if the increase of phosphorus is deleterious to soil quality and fertility (DeClerck and Singer, 2003). Soil organic matter (SOM) is a huge contributor to soil fertility, in aggregate stability, and makes the soils less prone to erosion (Seybold et. al 1998). An increase of soil organic matter was found from 1.05% SOM in 1945 to 1.35% in 2001 which actually increased soil fertility (DeClerck and Singer 2003). For crops, soil texture is a primordial factor that influences water availability and holding capacity; soil texture and the amount of clay particles influence cation exchange capacity (CEC) (Arshad and Coen, 1992), CEC determines nutrient availability since many minerals are in ionic forms. In general, the soil conditions of the Central Valley were found to be within the acceptable range but we must be cautious and not take it for granted. We must learn from regions that have had soils been depleted and implement management factors to prevent the Central Valley's rich soil from becoming a barren wasteland.

Comparison of Soil Types found in the Central Valley

Site Conditions

A Capay Soil has a silt, clay, and loam composition; Capay is moderately drained which makes it less prone to flooding along with a low level of salinity and a soil pH range of 6.5-8 (USDA, 2015) slightly more acidic but alkaline as well. A Clear Lake soil is a clay soil that is poorly drained and often generates water tables (Amme, D., 1993), because the soil is made of clay, there is a higher water retention and so water is available for a longer time. Clear Lake soil is poorly drained, its soil pH ranges from 7-8 and it has moderate levels of salinity (USDA, 2015). San Ysidro soil will have a sandy loam or sandy clay loam composition which will allow for this soil to have a moderate drainage capability; San Ysidro's sandy composition makes it have a low water storage capability but also a low salinity with a pH range of 6-8 (USDA, 2015). Rincon soil is comprised of a clay loam soil and has a well drainage capability; Rincon soil has almost no salinity and its soil pH 6.5-8 (USDA, 2015).

Most appropriate vegetation

Capay soil is best fit for annual grasses and forbs, it has been used in agriculture for tomatoes, sugar beets, beans along with dry grains and dryland pasture (USDA, 2015). The natural vegetation for a Clear Lake soil is grasses and forbs, in agriculture Clear Lake soil has been used beans, sugar beets, and tomatoes to name a few (USDA, 2015). Natural vegetation in San Ysidro soils includes annual grasses and forbs, but the soil has been used farming of citrus, row crops, and alfalfa (USDA, 2015). Rincon soil is naturally colonized by annual grasses and forbs (USDA, 2015), in agriculture it has been used similarly to San Ysidro soils.

Challenges and opportunities for restoration

A prairie grassland is extremely difficult to recreate in a restored site, this is because very little is understood about the germination requirements and management processes of native prairies (Amme, D., 1993),. There are also a combination of other challenges that restorationists face that include: prolonged droughts, competition from invasive plant species, cultivation, urbanization, and overgrazing by cattle or other feral animals (Bugg et. al., 1997). Positive public perception on restoration and large producers of Californian native plant seeds allow for opportunities to reestablish portions of native grasslands (Bugg et. al., 1997).

Approaches to restorations case studies

Capay Silty-Clay soil

Because prairie grassland is difficult to achieve, there have been studies like the one conducted by C. Brown and R. Bugg using a two-step process of introducing forbs after establishing grasses. This process was used because by focusing on one type of plant community first, specific herbicides that control broadleaves can be used to ensure the establishment of perennial grasses then forbs can be later introduced. (Brown and Bugg, 2001). In this experiment two trials were conducted on Capay silty-clay soil where background vegetation (previously restored established perennial grasses or tilled ground) was investigated; one trial investigated direct seeding of forbs and the second trial focused on a direct transplant approach (Brown and Bugg, 2001). In the direct seeding approach, it was found that forb

seeds established well under tilled conditions and that emergence was low in conditions where perennial grasses were present (Brown and Bugg, 2001). This may simply be due to competition where the small seedlings cannot compete with well-established plants. In the transplanted experiment it was found that the establishment of the forbs was not considerably reduced compared to the direct seeding trial; this implies that germination, emergence, and early growth are important stages of forb establishment and successful forb introduction can be improved by protecting the plant from competition at such stage by techniques like transplanting or tilling for other species (Brown and Bugg, 2001). Also, I believe that the Capay soil type containing silt and clay allows for higher water retention and contains higher nutrients which is an important factor in restoring a region with native forbs and grasses.

Rincon Silty Clay Loam and Clear Lake Clay soils

In a study focusing in the restoration of riparian native plant species, seedling survival was evaluated under different soil conditions where soil moisture retention, salinity, and an invasive plant species (saltcedar, pigweed, and barnyard grass) density was measured to see which environmental conditions were most appropriate for Cottonwood seedling growth (Bhattacharjee et al., 2008). Although the Rincon soil type was not investigated, a similar clay loam soil type to the Rincon soil series along with a Clear Lake soil series (clay soil) was used. Other soil types used were: sand and sandy loam, loam and silty loam soils (Bhattacharjee et al., 2008). It was found that the seedling survival varied among soil types, which was expected; because soil texture influences growth of Cottonwood seedlings, it was concluded that soil texture may play a major effect on both water drainage rates and capillary rise which determines the seedling's moisture availability which becomes the limiting factor for effective Cottonwood recruitment (Bhattacharjee et al., 2008). The soil with the lowest rate of moisture decline was observed in the loamy sandy and sandy loam soils which translated into higher cottonwood densities; due to its coarse texture it was concluded that the porosity in the texture allowed for Cottonwood roots to grow and expand faster than in finer textured soils (like clay loam or clay soils) (Bhattacharjee et al., 2008). In the silty/clay loam soil similar to Rincon soil series type, it was found that initial Saltcedar densities were high but interestingly enough, the Cottonwood seedlings were able to grow dense enough and outcompete the Saltcedars, this was possible because the Cottonwood and the Saltcedars had similar germination conditions (Bhattacharjee et al., 2008). The issue was with clay soil (a Clear Lake soil type) and pigweed; because Pigweed is able to draw out moisture from the soil more efficiently and shades the Cottonwood seedling, Pigweed was the dominant species in the clay soil region that could possibly outcompete Cottonwood seedlings (Bhattacharjee et al., 2008). Thus implications for restoration practices in riparian areas should be formulated based on abiotic and on site-specific biotic factors; although soil moisture is important, soil texture is what should be paid most attention to as this affects the available moisture for plants (Bhattacharjee et al., 2008).

San Ysidro Sandy soil

A different study examined invasion of non-native species in vernal pools in the Central Valley where the main focus was to analyze the distribution and abundance of the non-natives in relation to the pool size, inundation, soil and nutrient properties, disturbance history, and the native plant community (Gerhardt and Collinge, 2003). A comparison of thirty natural and thirty restored pool sites was done to measure the abundance of the non-native species; the pools are located in the Travis AFB boundary where the soil is a combination of Antioch loam and San Ysidro sandy loam with a argillic hardpan below (Gerhardt and Collinge, 2003). The sandy loam property of San Ysidro soil helps in the fast soil saturation and formation of flooded pools, this is key in forming the inundated areas. What they found was that the non-natives were more abundant in natural pools than in restored pools, also that the non-native

plant cover decreased as the water depth increased; in addition, it was observed that the non-native plant cover was reduced when native plant cover was abundant (Gerhardt and Collinge, 2003). It is a strong possibility that non-native plants cannot tolerate stressful conditions like flooding and cannot outcompete well established native flora. From this study we can take that abiotic constraints (like fire, flooding, and suppression by herbicides or well established plant communities) can limit invasion of non-natives (Gerhardt and Collinge, 2003), thus in restoration of vernal pools for native plant species we can increase the stressful environment where non-natives will not grow but not too harsh so native plants can thrive.

Part 2: Project Goals and Management Plan

Goals

Soil Type	Soil Composition	Restoration Goal
San Ysidro	Sandy loam to sandy clay loam composition great drainage but possibilities of nutrient leaching.	Increase the organic matter composition to decrease leaching while creating soil structure.
Rincon	Clay loam soil that is well drained	Maintain the integrity of the soil and prevent it from deteriorating and from being invaded by non-native species by planting species that are able to compete with the invasive species.
Clear Lake	Clay soil that is poorly drained often generating water tables.	Increase the porosity of the soil to decrease the chances of flooding.
Capay	Silt, clay, and loamy composition with moderately drained soils.	

Restoration Plans

Studies have found out different measures that have been confirmed to successfully accelerate the restoration of soils, one way if restoring sandy soils is by decreasing wind erosion and another way is by improving the soil characteristics in order to promote the growth of natural vegetation (Yan et al., 2013) that would in turn increase the soil structure and it all becomes a cycle. In sandy soils like San Ysidro, but this can apply to any type of soil series and this would be the issue because exposed bare ground would increase the possibility of wind erosion. Thus planting fast growing beneficial crops and native grasses that have a higher root density would be appropriate to stabilize and structure the soil.

A table from *The Science and Practice of Sustainable Sites: Practical Implementation of Soil Protection & Restoration* offers different options in restoring soils.

1. Option 1: this option would be to retain the native plant species and keep it from being disturbed or compacted, this option would be great for the Rincon soil since it is in already good conditions. One way is to only use low impact machinery on the soil or to build fences so people do not walk on the soil and reduce compaction.
2. Option 2: this option is to amend the soil that lacks in structure or nutrients. The use of mulch or nutrient fertilizer would be recommended here but the main concern would be to check what type of soil it is because of leaching issue, a sandy soil would have a different approach than a clay soil.
3. Option 3: in this option one would import topsoil organic content to soils that lack this crucial composition. The soil most appropriate to this measure is the San Ysidro soil because of its sandy composition it lacks high organic matter content.

Each of the described options require and appropriate survey of the soil condition and depending on the condition of the soil, one can adjust the amount of restoration it will require. It has been found that the limiting factor to plant species is the increase of soil disturbance and the spread of bare soil, it is why the use of mechanical soil disturbance like the removal of

topsoil could function as a restorative measure (Schnoor et al., 2015). In sandy soils like the San Ysidro soils, it is important to know the plant community's soil requirements and disturbance regimes because it is necessary to understand whether the plant community favor disturbed sites. A study compared ploughing vs rotavation to mimic historical soil disturbances in sandy soils and found out that rotavation increased the proportion of specialist species along with indicators that conditions had changed enough to favor threatened species; this may be because ploughing only overturned the soil where rotavation crushed and mixed the top soil layer creating a higher soil disturbance (Schnoor et al, 2015).

I believe that the most important limiting factor becomes the hydrology of the soil, a poor drained soil will not allow water to percolate freely into the soil and will tend to flood where a well-drained soil will. This is important to consider in choosing the type of plant cover to restore the site because without prior knowledge to the soil conditions, one might plant a flood sensitive crop in a clay soil causing the crop to die off when the rainy season comes.

Monitoring Plans

Prior to restoration dig test holes to check the depth of soil and its degree of scarification will be done, also it would be recommended to check the compaction of the soil profile at different depths (McDonald, 2011) this then would be useful when comparing the soil in subsequent years. Holes for soil monitoring should be from 10-12" in depth and at least 10 locations should be tested per landscape area (Mc Donald, 2011) this will give a more homogenized status on the conditions of the soil.

Monitoring of the soil would be at least twice a year, before spring and after plant senescence, this will be important in monitoring the soil nutritional content and check the moisture level. I is also useful to measure during these time because it is a time when most plants are dormant, this is will prevent any unwanted disturbance to plants. I believe that this type of monitoring will also keep a record of how much nutrients and moisture is in the soil and how much is used and replenished after.

There is anticipated challenges to such soil restoration plans, for example *The Science and Practice of Sustainable Sites: Practical Implementation of Soil Protection & Restoration* offers some challenges that one might encounter.

1. Is the soil plan practical to achieve?
 - i. Is the size of the site manageable to apply management practices?
 - ii. Is the cost of soil restoration feasible?
 - iii. One will have to decide whether to use compost or haul soil from a different region when amending the soil

These challenges as stated before will depend on the condition of the soil, and on the amount of man power available to restore and manage such areas.

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Arroyo willow (*Salix lasiolepis*)

Abbey Neat

Part 1: Project Background and Justification

Habitat: The Arroyo willow can be seen in various locations, but is most commonly found “along stream banks and in dry stream beds” in montane and wetland plant communities. It is sometimes also found in the desert.

Photo Identification:



Female catkin bud close-up



female catkin



leaf



female catkin bud



male catkin



entire tree

(Top row taken from Calflora - <http://www.calflora.net/bloomingplants/arroyowillow.html>, bottom taken from <http://science.halleyhosting.com/nature/gorge/tree/broadlf/salix/lasiolepis.html>)

Appearance:

Leaves – alternate, 2.5in – 4 in long and 3/4 in wide

Bark – Smooth, yellow, shrub-like

Flower – Catkins, no petals and sepals, two stamens

Fruit - “Two-valved capsules”

Key Identification Indicators:

- This willow is considered a large shrub or small tree, and grows to be 30 feet.
- The male and female flowers differ and are found on separate trees.
- The tree blooms between February and April.

(All habitat, appearance, and identification information from Calflora
<http://www.calflora.net/bloomingplants/arroyowillow.html>)



(photo: Calflora 2015)

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Magnoliopsida

Subclass: Dileniidae

Order: Salicales

Family: Salicaceae

Genus: *Salix*

Species: *Salix lasiolepis*

(USDA 2015)

Background and Justification

Salix lasiolepis (common name – Arroyo Willow), is usually found in mixed Riparian forests in areas with a high water table. This plant varies greatly in size, and can either be found as a large tree or shrub, depending on the water availability (River Partners 2015). This tree is very tolerant of low nutrient soil types, and it able to grow quickly relative to other trees (PFAF 2015). The limiting factors to the growth or potential growth of this willow are exposure to sunlight and water availability. Without one of these two growth functions, the willow will not be fully successful (River Partners 2015). The willow needs to be in a location with a constant water source. The seeds of the willow are both water and wind dispersed. Thus water performs multiple functions for the tree (River Partners 2015). Another threat to the willow growth potential is herbivory of both large animals and insects. Deer often poses potential issues, because it can use the restoration site as a feeding ground (Opperman 2000).

This willow is functionally beneficial to multiple aspects of the ecosystem. It first works for erosion and flood control near the riparian flood banks, due to the dense root system

(GGNPC 2015). In addition, the tree is dioecious, meaning that the flowers are unisexual, and found on separate plants (Calflora 2015). Because of this, it is dependent on bees for pollination. This provides a good habitat for pollinators, and implies that the most successful willows in an ecological community will have a combination of male and female types (PFAF 2015). In addition, the willows are a favorite feeding ground for insects such as caterpillars. Because of this, it also provides a great habitat for birds that feed on these insects. Thus, the arroyo willow supports bird and insect diversity (San Elijo 2015).

Literature Review

Growth and Physical Characteristics:

- The bark of the arroyo willow most commonly ranges between gray and yellow, and is smooth. (Calflora 2015).
- The tree is deciduous and the leaves are gone by late November (Darris 1993).
- This tree size ranges between a small shrub and a tree that is 30 feet at its peak height (Calflora 2015).
- The leaves are dark green and are alternately lobed (Calflora 2015).
- For the beginning years of the tree's life, the willow will grow between 2-4 feet a year (Darris 1993).
- The willow can effectively grow from propagation (Darris 1993).

Reproductive Characteristics:

- This tree has catkins as reproductive organs, meaning that they are incomplete flowers without sepals or petals (Calflora 2015).
- The male and female catkins are found on separate trees. The male catkins are made up of flowers with two stamens each. These are yellow (Calflora 2015).
- The flowering season lasts from February to April (Calflora 2015).
- This tree is both wind and insect pollinated (Sacchi 1988).
- The flowers are epipetalous and not showy, suggesting wind pollination. However, the flowers also have nectaries, supporting the insect pollination. (Sacchi 1998).

Range:

- The range of the Arroyo Willow spans as far south as Baja California and as north as Washington. Eastward, it can be found in New Mexico, Idaho, and Utah (Darris 1993).
- In California, it can mostly be found along the coast and mountain basins in various Riparian areas. The location is quite variable, and it is seen in most parts of California (Darris 1993).

Habitat:

- This tree grows best in damp soils and full sunlight (Calflora 2015).
- It is often found in valleys and arroyos along a river or stream bank. This would include most Riparian ecosystems (Darris 1993).

Spatial and Temporal Scales

- A willow tree tends to persist between 70 and 100 years in a well suited environment (Willow 2015).

- Seed dispersal often happens in the presence of a water source. Because of this, it is not necessarily the size of the landscape, so much as a constant source of water, which determines growth (Willow 2015).
- After transplanting, the arroyo willow takes about three years/growing seasons before it is self-sustaining and less sensitive to disturbance (Zonge 2015).
- Young willows should be planted in areas with less than 5 percent ground cover, because they do not do well with competition in the early life stages (Zonge 2015)
- The necessary spacing from other willows is variable, and dependent on the size of the stream and water table. If the water table is high, then the willows can be planted and exist relatively close together (Zonge 2015).

Requirements:

- The willow thrives in areas where the annual average precipitation is greater than 35 inches (Darris 1993).
- The tree grows in areas below 1500 feet above sea level (Darris 1993).
- The tree prefers areas with damp clay and loam soils, and must have access to a constant water source (Darris 1993).
- The tree is susceptible to herbivory, mostly from deer, and cannot grow or thrive in areas with constant herbivory. (Opperman 2000)

Tolerances:

- The willow can tolerate sandy soils with low moisture content, but may not grow to its full potential (Darris 1993)
- A mature tree (3 years or older) can tolerate sporadic droughts. The cuttings and seedlings rely on the water table, and cannot deal with drought stricken conditions (Zonge 2015).

Animal Interactions:

- The Halictidae, Andrenidae, and Apidae bee families are common pollinators for the Arroyo Willow (Sacchi 1988).
- Certain types of flies were also found to be pollinators of the willow (Sacchi 1988).
- Deer commonly feed on the willow if they are present in the area (Opperman 2000).
- The willow tends to provide shade to support the function and health of the fisheries below it (Darris 1993).

Human Interactions:

- Native Americans often use the willow for basket weaving, and parts of the bark are soft and flexible enough to be used to make rope. (GGNPC 2015).
- The willows are easily propagated. Because of this, hormones from the tree can be taken to expedite the growth of other plants during propagation (GGNPC 2015).
- The base of Aspirin was first taken from the willow. (GGNPC 2015)

Plant Interactions:

- Functionally, the cottonwood and the arroyo willow provide similar benefits to Riparian ecosystems. Both trees require a lot of water to be successful, and are members of the Salicaceae plant family. (GGNPC 2015).

- The only specific competitors would be large trees, that also require a lot of water to function (GGNPC 2015)

Threats:

- Habitat change or conversion due to global climate change threatens the success of this tree. The willow needs constant water to survive. If the source of water dries up, the willow cannot persist (PFAF 2015)
- Herbivory poses a huge threat to the willow. It can survive and thrive with limited amounts of herbivory. Overfeeding will pose a threat to the willow (Opperman 2000)

Propagation Requirements:

- The willow has the potential to be propagated directly from vegetative tissue (GGNPC 2015).
- The cuttings should be 6-8 inches, and the diameter should be ¼ to 3/8 inches (Darris 1993).
- The potting soil should be moist (Darris 1993).
- The cutting should be done during dormancy in the winter, then the planting should be done in the spring (Darris 1993)
- Cuttings are the recommended form of propagation (Darris 1993).

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Part 2: Project Goals and Management Plan

A. Goals

The Arroyo willow functions as a mechanism for erosion control (GGNPC 2015), while also providing a habitat for birds, bees, and other insect species (San Elijo 2015). Because of this, the willow is an important component of the restoration plan of a riparian ecosystem.

1. Survey the existing abiotic conditions

The survival of this tree is dependent on a constant source of water (Darris 1993). It is important that the introduced individuals have access to the water table. The first step should be to survey the water table at different points along the stream, to determine which places can support the dense root system. The willow also relies on moist loamy soils, and access to sunlight (Darris 1993). By survey the existing environmental conditions, it can be determined whether introduction of the willow is plausible in a given area. This step includes establishing which areas have the potential to support the willow, and also should consider the already existing trees and vegetation. Each area with potentially suitable should be characterized as 'viable', 'viable with modification', or 'inviable' to support arroyo willows.

2. Modify the environment to suit the needs of the willow

It is necessary to establish a suitable environment for the willows so that they will be able to persist after establishment. Before introducing the willow species, it is important that the vegetative cover of the areas surrounding the newly introduced willow is less than 5 percent, to limit competition (Zonge 2015). In the first 3-5 years, transplanted cuttings are sensitive to such conditions as grazers and competitors (Zonge 2015). These should be limited or eliminated at the planting site.

3. Establish the willow in areas determined plausible

Using the information above, establish arroyo willow populations in areas that are deemed ready to support the given root system. In the areas that are considered 'viable with modification', create a plan to manipulate the water table or other abiotic factors so that future arroyo willow individuals have a broad potential range of establishment.

Metric of Success

Success can be quantified the number of individuals able to persist after year intervals. A retention rate greater than 50 percent is a viable target (Darris 1993). However, if ideal site conditions are paired with proper propagation techniques, the stands may have the potential to accomplish a 90 percent retention rate (Darris 1993).

B. Restoration Plan for the Arroyo Willow

Establish desired abiotic and biotic factors to support suitable habitat

The first step in restoring this plant species is to establish a suitable habitat. There should be some areas in which not much work or alterations will be necessary to support the species. Other areas will have the potential to support the willow given a few basic changes. This includes establishing some influx of water. If funds permit, an irrigation system would greatly support the growth of the arroyo willow (Darris 1993). The willow catkins bloom in spring

(March), so flooding during this time can support seed dispersal (Cal Flora 2015). This would also establish the preferred clay loam soil for the willows (Hanson 2013). The clay loam soils can be achieved by maintaining the soil water content to the equivalent of 35 inches of rainfall, or greater (Hanson 2013).

Given abiotic factors are suitable for the willow to thrive, it is also important that the environment contains mutualists to encourage the persistence of the willow for future generations. The preferred pollinators of the willow include the Halictidae, Andrenidae, and Apidae bee families (Sacchi 1998). These populations can be built up by creating a suitable habitat to attract pollinators to the site. Plants such as vetch attract bee pollinators. Maintaining the vetch would encourage pollinators to stay in the area (Crown Pollen, 2015). This also means limiting herbivory of the arroyo willow. Deer are a common threatening herbivore (Opperman 2000). This limitation can be done by protecting the cuttings with fences to provide a buffer zone, thus decreasing herbivore access to the tree. Reducing (not necessarily eliminating) the natural herbivores, and supporting the pollinator populations will be the key in the establishment of the arroyo willow populations.

Propagation

Willows are known to be easily propagated from just vegetative tissue (GGNPC 2015). Because of this, the primary generations of the willow species should be propagated in a greenhouse, and then planted near the stream bank. Future generations after the initial establishment can self-regenerate, as the plants grow quickly, given the proper resources (Darris 1993). The propagation will be most successful in the form of cuttings. The cuttings should be 6-8 inches and about $\frac{3}{4}$ inches in diameter (Darris 1993). These cuttings should be cultivated in a greenhouse, then established and transferred to the riparian areas in the spring time. The willows should be planted in an upland area, with 2-3 feet of spacing between each tree (Hanson 2013).

Transplanting

Willow cuttings shall be collected in the wintertime, when the buds of the tree are still dormant. These cuttings should be about two feet long and taken at the most basal section of the branch (Zonge 2015). The cuttings with larger diameters and found at the base of a stem root should be targeted, because they have a high capacity for rapid growth (Zonge 2015). The cuttings should be kept at less than 0 degrees Celsius for around 8 months before planting, to protect the future trees from disease (Zonge 2015). The planting phase should commence in the spring time (Zonge 2015). It is essential to place the base of the cuttings at the water table level. The trees need plenty of moisture in the initial phases of growth, so access to the water table is ideal (Zonge 2015). Soak the cuttings in water for about 8 days before planting, then plant in areas with relatively sparse surrounding vegetation. This ensures no competition for access to the water table. About one foot (or half of the cutting) should be buried underground during the transplant (Zonge 2015).

Promote multiple, connecting patches

The arroyo willow is dependent on pollination for regeneration (Sacchi 1998). Also, willows tend to have a higher survival rate when planted in groups (Zonge 2015). Because of this, the establishment for the willow would be most effective with multiple patches, which are connecting. Corridors between patches allow for increases in recruitment rates for species, as well as increases in the flow of pollen (Damschen 2006). This is good for maintaining genetic variation within the willow populations. In addition, these corridors will maximize the range of the willow around riparian areas, while still maintaining cohesiveness within the population. Also, connectivity of pollinators will promote regeneration (Damschen 2006). Because of this, the willows shall be transplanted in groups, which are connected. It is common for about half of the cuttings to not survive in a given planting area (Zonge 2015). If the target goal is 50 willows along a stream bank, it is recommended to plant 100 willows to reach the goal.

Conserve existing arroyo willow species

The Central Valley already has existing arroyo willow trees. A key to this restoration plan is to establish new trees while still maintaining the old individuals. This includes making sure that the habitat will support sustainability of the willow. The willows are unisexual and dioecious, so it is important to have both the male and female type present in the given area (Calflora 2015). The persistence of one is dependent on the persistence of the other. These older trees are also more likely to avoid disease and pest invasion if in the presence of species and clonal diversity (Zeoli 1968). To encourage persistence, it would be beneficial to plant other species such as cottonwoods or other willow types in areas with the older trees, to establish protection. In addition, factors influencing soil type, access to water, or lack of mutualists could be reasons for this inability to regenerate. These abiotic factors should be tracked and accompany the monitoring process.

Monitoring

Prior to the restoration project, the location and survival rate of the already present arroyo willows should be recorded yearly for two or three years (Zonge 2015). This will ensure that the landscape can support the existing willow species. As previously stated, the targeted yearly survival rate is between 50 and 90 percent (Darris 1993). There will be variation within this window, due to variation in the abiotic factors. In the early life stages of the propagated willows, the tree will grow between two and four feet per year (Darris 1993). In these first two to three years, it is important to limit the grazing near riparian areas, because it could affect the potential growth. After these years, however, grazing may actually benefit the upkeep of the tree species (Zonge 2015). Grazers can be introduced, but should have limited access to the tree. This can be done through fencing, and only allowing the grazers access to the tree a few times per year. The individuals do need to be monitored to ensure regeneration, but should not require intervention. One method of this is to record the amount of willow species that survive to the next growing season (River Partners 2015). This shall be done yearly. Also, recording the changes in height and diameter breast height of each of the species can be another affective form of monitoring (River Partners 2015). This shall also be done yearly during early restoration phases, to ensure that the species will persist without human support. Also, a key component to monitoring is to ensure that the other species aside from the willow are healthy and continue to persist (Zeoli 1968). This community ecology take on monitoring includes recording the surrounding vegetation and presence of harmful invasive species. This vegetative survey should accompany the yearly monitoring process.

Further Research

The restoration plan could be stronger if further research was done on how well willows respond to fire. If burning is a part of the restoration plan, it would be essential to know the effect of fire on the success of the arroyo willow. This includes the ideal fire frequency for the willow to persist without losing seedlings. Also, it is difficult to find information on how the arroyo willow interacts with other plants types. It would be useful to know if an ideal understory (if any), could mutually complement the willow. This restoration plan would be furthered if it was known whether there are major native or invasive competitors that could inhibit willow establishment.

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Black willow (*Salix gooddingii*)

Isabella Santasieri

Part 1: Project Background and Justification

Habitat: “moist or wet soils along banks of streams, lakes, swamps around farm ponds, and pasture sloughs” (USDA NCRS Plant Guide)

https://plants.usda.gov/plantguide/pdf/pg_sani.pdf

Photos of tree parts (USDA NCRS Plant Guide)



Catkin flowers, tree trunk with woody bark, leaf shape.

Appearance and Characteristics

Trunk and bark: “large, short-lived, deciduous tree, it is fast growing and may reach maturity within 30 years. This tree usually obtains a height of 66 feet (20 m) but can grow up to 138 feet (42 m) on some sites. The massive trunks are usually leaning and are often divided. The bark is thick and deeply divided into furrows separating thick, scaly ridges.” (US Forest Service)

Leaves: “blades are variable in size, the larger to 4.7 inches (12 cm) long” (US Forest Service)

Background and Justification

Salix nigra (common name Black Willow) is native to the eastern United States, as well as parts of Canada and Mexico. (USFS 1992) It is most closely related to the California Central Valley species *Salix gooddingii*, which is the most important willow species in the

central valley's riparian habitat (Warner 1984). Black willow is a small to large, short-lived, deciduous, fast growing tree. It may reach a height of 66 ft – 138ft. The bark is thick and deeply divided into furrows, roots are shallow and laterally extensive. (Warner 1984) Black willow is most common in riparian habitats and grown on river margins where it occupies the less sandy soils. It is also common in swamps, growing anywhere light and soil moisture conditions are favorable (Warner 1984).

One of the greatest ecosystem services the willow provides is as a soil-binder. The species is valued and important in restoration and conservation because it's an excellent species for reducing erosion of streambanks because of its flood tolerance. Their fibrous roots help to prevent the soil from being washed away from streambanks (USDA 2010). It is also valued medicinally, ancient pharmaceutical literature describes the bark and leaves of willows as useful in the treatment of rheumatism. Black willow was also once used as a source of charcoal for gunpowder (Warner 1984). Today, black willow wood is mostly used in industry. Due to its light density the wood does not splinter easily and is used for toys, crates, and barn floors (USDA 2010).

One hundred and fifty years ago California Central Valley was endowed with a lush natural wetland environment and since then has been degraded, drained, and converted to land for agricultural use. The Environmental Protection Agency estimates that 90% of wetlands in the state have been lost. Specifically in the California Central Valley 70% of the wetlands were altered by the 1920s (EPA 2013). Riparian forests have also been greatly eliminated or reduced throughout a large portion of the valley and with the disappearance of that habitat the Black Willow disappears as well (Warner 1984).

Fact Sheet

Growing Conditions

- Black Willow flourishes at or slightly below water level and is not appreciably damaged by flooding and silting (USFS 1992).
- Elevation relative to the prevailing water table is important for recently planted cuttings, required for roots to grow long enough to reach moist soils (Pezeshki et al 2007).
- Cuttings generally survived better at low elevations 15cm above the water table as compared with middle 30cm and high elevations 60cm (Pezeshki et al 2007).
- Average survival of cuttings at the end of the first growing season was 70% at low elevation, 48% at mid elevation, and 61% at high elevation (Pezeshki et al 2007).
- The tree is a perennial (USDA 2010).
- The stringent requirements of seed germination and seedling establishment limit black willow to wet soils until maturity (USDA 2010).

Soil

- Black Willow grows best in fine silt or clay in relatively stagnant water (USFS 1992).
- Requires saturated or poorly drained soil from which no other hardwood competitor trees present (USFS 1992).
- The species prefers moderately acidic (lower pH limit is 4.5) to near neutral soils (USFS 1992).
- Extreme soil moisture governs the survival of cuttings planted to restore riparian habitat (Li et al 2005).
- Partial flooding over continuous flooding throughout the year resulted in higher root biomass and productivity (Li et al 2006).

Reproduction

- Flowering begins in February in southern portion of range and continues through late June at the northern limits (USFS 1992).

- Catkins appear at the time of leaf emergence (USFS 1992).
- At about 10yrs of age the tree begins to produce seeds (USFS 1992).
- Seeds usually ripen 45 to 60 days after catkins are pollinated (USFS 1992).
- Seeds ripen and fall in April – July (USFS 1992).
- The optimum seed-bearing age is from 25 to 75 years (USFS 1992). Seeds are dispersed by pollinators, wind and water (USDA 2010).
- Seeds are not dormant (USFS 1992).

Threats

- Deer and other mammal herbivory intensity is of critical importance when looking at effects of damage (Li et al 2005).
- The alteration of riparian zones due to land conversion and water diversion (Warner 1984).
- Insects such as caterpillar and beetles as well as stem and twig borers attack black willow but few cause serious damage (USDA 2010).
- Fire damage (USFS 1992).
- Diseases; willow blight, leaf rust, cankers (University of Maine).

Response to Fire

- Will re-sprout from base of trunk post fire (USFS 1992).
- High severity fires may kill full stands of plant (USFS 1992).
- Low severity may just blacken bark and leave more susceptible to further damage from insect pests (USFS 1992).
- Surface fires will destroy seedlings or saplings (USFS 1992).

Human Interactions

- Industrial
 - o Wood for timber (USDA 2010).
- Medicinal
 - o Tea from bark for joint pain (USDA 2010).
 - o Salicylic acid extracted as fever reducer and pain killer (USDA 2010)

Wildlife Interactions

- Yellow-bellied sapsuckers feed on sap through holes pecked in to bark (University of Maine).
- Provides honey bees nectar and pollen (USDA 2010).
- Elk and beaver browse on willow leaves in the summer and willow twigs in the winter (USDA 2010).

Part 2: Project Goals and Management Plan

Goals:

Salix nigra (common name Black Willow) is native to the eastern United States, as well as parts of Canada and Mexico. (USFS 1992) It is most closely related to the California Central Valley species *Salix gooddingii*, which is the most important willow species in the central valley's riparian habitat (Warner 1984). The goals when restoring Black Willow or its similar subspecies, *Salix gooddingii*, at a riparian site in California's central valley should include observation, site manipulation and modification, and careful monitoring.

Observation:

The first goal, when restoring the site and introducing Black Willow, is to survey the area to gain knowledge and determine if Black Willow even has a chance of survival at the site. After careful consideration the second goal is to alter and enhance the site to better suit conditions that Black Willow requires, such as removal of invasive species or pests and

changing the chemical and moisture composition of the soil. The third and final goal should be to monitor and evaluate the restored Black Willow's success at the site, success can be determined by growth in height, as well as trunk diameter and reproduction of the trees.

Restoration Plan:

The restoration of Black Willow at a site in California's central valley is important and necessary because of the ecosystem services the tree provides. Black Willow has a fibrous root system and acts as a soil binder that prevents soil being washed away from stream-banks (USDA 2010). When determining if the species can survive at the site, the site should match the description of riparian habitat. Riparian sites are characterized by hydrophilic flora and are usually the strip between a river, stream or creek and land. After the site has been classified as riparian and has suitable characteristics for the success of the Black Willow translocation of, seeds or cuttings can be introduced but require some preparation.

Black Willow seeds can be collected from trees over 10 years of age. The optimum seed bearing age is when trees are 25-75 years of age and the seeds would be available for collection when ripe, usually 45-60 days after the catkins are pollinated (USFS 1992). Catkins appear at the time of leaf emergence and seeds ripen and fall from April through to July (USFS 1992). To successfully germinate seeds to develop into saplings for reintroduction, seeds must be collected as soon as the capsules dry and turn yellow-brown, the seeds should be separated from the capsule immediately and planted (University of Texas 2015).

When using cuttings potential problems that may arise include little to no development of cuttings, to avoid this problem it is important to determine if the cutting is dormant or non dormant before beginning presoaking methods, as presoaking non-dormant cutting confers no benefit to the tree. The dormant period of the tree is between leaf fall and bud break (Colorado Riparian Association 2008). If cuttings are taken from the tree during that time they can be classified as dormant cuttings, if they are taken before or after that period the cuttings can be classified as non dormant.

When using dormant cuttings the presoaking technique for enhancing survival of black willow is successful. This pre-planting treatment enhances tissue water content and will promote root development and growth, which will ensure survival of cuttings. Production and size of a substantial root mass is vital to the establishment and success of cuttings at the site. Dormant cuttings should be soaked for 10 days as a pre-planting treatment. In Pereshki's (2006) study it was found that dormant black willow cuttings that were soaked for 10 days produced more roots and had more biomass than did cuttings that were not presoaked. Cuttings should be collected and pre treated in the spring in preparation for transplanting. When using non-dormant black willow cuttings, the planting site should have ample but non-flooded soil moisture content (Pezeshki 2006). Black Willows cuttings are most successful in well-saturated, fine silt or clay soils with a moderately acidic pH at around 4.5 to near neutral soils with a pH of about 7 (USFS 1992). Non-dormant black willow cuttings should be considered only if the planting site is likely to present initial soil conditions that are conducive to success of the species. Non-dormant cuttings express no apparent benefit from presoaking impacting root dry weight, which correlates with a root biomass as an indicator of success. As discussed in Pereshki (2006) the cutting group that was soaked for seven days exhibited no benefits from the treatment and significant consequences were observed in root production, due to presoaking, in the group that was soaked for fifteen days.

After the appropriate pre-transplant techniques have been applied the restoration site needs to be in a fit condition to ensure the success of the transplanted seeds and cuttings. The main success determining component of the site is the soil that the translocate plants will be placed in. As mentioned earlier cuttings require a well saturated, silt or clay soil with a pH

from 4-7. The soil and moisture conditions vary when plants are young seedlings when compared to mature, well established trees. A study conducted by Pezeshki et al (2007) shows that elevation above the water table is prominent determining factor of sapling survival. Cuttings generally survived better at low elevations 15cm above the water table as compared with middle 30cm and high elevations 60cm.

The average survival of cuttings at the end of the first growing season was 70% at low elevation of only 15cm above the water table, 48% at mid elevation, 30 cm and 61% at high elevation 60cm. Established Black Willow's are able to thrive in a broader range of environmental conditions than those in which they naturally occur. Once established these plants do not show a high water requirement (McLeod et al. 1973). Establishment and success of the Black Willow is limited only by the specific requirements of the seedlings rather than the requirements of the adults. If pre treated and grown under favorable conditions until maturity transplants can then survive in a broad range of soil conditions.

Monitoring Plan:

If the restoration is unsuccessful and there is failure of reestablishment of the entire population of transplanted trees, the plan should be reevaluated. A useful tool to ensure success of introduced trees is so spend time growing the cuttings or seeds in a controlled environment but with soil and water features that are unique to the intended restoration site. This method would mitigate the sudden change in sites and allow the plants to continue to grow in soil conditions they are used to but now at the intended restoration site. Monitoring should be continued throughout the stages of development and growth of the transplanted species, monitoring should continue through the first year of development. Management of the introduced patches of Black Willow should occur until the patches begin to reproduce and spread on their own. As stated above the tree reaches full maturity around 10 years of age. Mature and viable seeds are be spread by pollinators water or wind (USFS 1992). After the first year of development monitoring should be continued but at less frequent time intervals. Success of the transplantation and reintroduction can be determined by growth and development. Black Willow trees can reach a height of 66-138ft with a diameter of 2 feet or more (Warner 1984). Depending on the soil condition at the restored riparian site monitoring and management may need to be implemented. Management techniques include checking the soil saturation and pH levels and making adjustments as necessary to provide the best soil possible for Black Willow growth. How long management should continue varies seasonally, with climate change and with the different amount of rain at a given time, the uncertainty can be best mitigated with continued monitoring. Lastly, evaluation is also important post reintroduction to ensure herbivory is not negatively impacting development. Common herbivores, which may cause damage to young saplings, include, caterpillar and beetle species, as well as twig borers (USDA 2010). Common pesticides may be used to control herbivorous insects and careful monitoring can help prevent damage before it begins. On the other hand, Li et al (2005) reported that the above ground herbivory may lead to an increase in the root/shoot ratio due to removal of above ground structures which leads to the stimulation of root growth this is an area of uncertainty and more controlled research and experiments would need to be conducted.

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Red willow (*Salix laevigata*)

Abreanna Gomes

Habitat:

“riverbanks, seepage areas, lakeshores, canyons; < 1,700m. California (except Modoc Plateau, Sonoran Desert); southern Oregon, northern Nevada, Arizona, Mexico, northern Central America.” (<http://ucjeps.berkeley.edu/>)

Appearance:

Trees can reach up to 20 m high. Twigs are yellow- to red-brown, hairy, becoming glabrous and smoothly textured with age. Young leaves are white- to white-and-rusty-hairy with mature blades ranging from 53-190 mm; leaves are long and narrow, base convex to wedge-shaped. Petioles of leaves range from 3.5-18 mm. Staminate flowers have 5 stamens, while pistillate flowers maintain ovaries that are glabrous and stalks ranging from 1.4-2.8 mm. Flowering takes place either with or after leaves form. (<http://ucjeps.berkeley.edu/>) Blooming of flowers takes place February through May. (<http://www.calflora.org>)

Images from CalPhoto



Red Willow (*Salix laevigata*)

Abreanna Gomes

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Magnoliopsida

Subclass: Dilleniidae

Order: Salicales

Family: Salicaceae
Genus: Salix L.
Species: Salix laevigata

Background and Justification

Red willow (*Salix laevigata*) is a small tree native to California that can be found throughout western North America. A key component of riparian habitats, it is located most commonly along riverbanks in moist environments (CalFlora, 2015). Ecological benefits associated with red willow include providing wildlife habitat for different bird species and pollination opportunities for bees and butterflies. Among species that utilize red willow is the western tiger swallowtail butterfly, which uses twigs for nesting and shelter (Moosa Creek Nursery, 2010). Additional ecological benefits include soil stabilization, erosion control and surface runoff prevention along riverbanks. Due to land use changes such as urbanization and agricultural development, riparian areas within California's Central Valley have declined by 99% (Faber and Holland, 1996, as cited in Hankins, 2013). Lowering water tables, due to groundwater pumping and reduced surface flows, have altered habitats significantly, changing hydrological cycles necessary for the promotion of red willow. Despite these changing hydrological conditions, red willow has been found to have a higher water table threshold as compared to other riparian plant species (Groeneveld and Griepentrog, 1985). The ability of red willow to adapt to lowering water tables enhances its restoration success rate, making it an ideal choice for riparian restoration projects.

Fact Sheet

Plant Description

- A winter deciduous tree, red willow is fast growing with slender light green leaves that are shiny on the surface. Flowers are known as yellow catkins (Moosa Creek Nursery, 2010).
- Twigs of red willow range from yellow-to red-brown, becoming glabrous and smoothly textured with age. Leaves are long and narrow, base convex to wedge shaped. The tree itself can reach up to 20 m in height (Jepson eFlora, 2015).
- It blooms February through May (CalFlora, 2015).

Distribution

- Plant communities that red willow comprises include Yellow Pine Forest, Foothill Woodland, Chaparral, Valley Grassland and Wetland-riparian (The Watershed Nursery, 2012).
- Red willow can be found throughout California (except Modoc Plateau and Sonoran Desert), southern Oregon, northern Nevada, Arizona, Mexico and Northern Central America (Jepson eFlora, 2015).
- It is located within elevations of 0 to 5000 ft (The Watershed Nursery, 2012).

Habitat/Requirements

- Red willows are located in high to moderate moisture environments along riverbanks, seepage areas, lakeshores and canyons (Jepson eFlora, 2015). They are intolerant to drought conditions and extended periods of inundation or flooding (River Partners,

2015). Thus, their distance from riverbanks is highly dependent on inundation capacity (Russell et al., 2003).

- While their distribution is correlated with accessibility to water, compared to other riparian species, such as arroyo willow, studies along the Carmel River in coastal central California have shown red willows are better able to tolerate drops in the water table. Despite having better toleration to drops in the water table, red willow still had noticeable impacts, including leaf yellowing and defoliation (Berger, 1990).
- They grow well where slopes are shallow, stream channels are wide and soils are sandy (Russell et al., 2003).
- They are tolerant of mildly acidic and alkaline soils (Thompson, 2015).
- In a study conducted by the Department of Forestry and Resource Management at UC Berkeley along Dry Creek, a tributary of the Russian River in Sonoma County, seedling establishment was highest in finer soils. Establishment was greatest in soils consisting of sediments less than 0.2 cm in size (Mcbride and Strahan, 1984).
- Red willows are also shade intolerant, requiring low canopy environments that provide high sunlight exposure (Russell et al., 2003).

Fire Ecology

- Willows in general are fire resistant, sprouting in response to low and moderate intensity fires. Because of their thin barks, willows remain particularly vulnerable to high intensity fires (Hankins, 2013).
- Repeated spring burnings have been shown to have a negative effect on willows (Quinlan et al., 2003, as cited in Hankins, 2013).

Threats

Pests

- Among insect effects are defoliation, twig or shoot cutting and bark boring. Fungal infections may be caused by bracket or shelf fungi, which enter the tree through injuries caused by insects, wind, etc (Lamb, 1915).

Fluvial Processes

- Through erosion and scouring, fluvial processes can modify riparian habitat from which riparian species can exist. Studies have shown that winter scouring is an important factor in seedling establishment (Mcbride and Strahan, 1984).

Human Influences

- Groundwater pumping and decreased water flows, due to urbanization and agricultural development, have altered riparian habitats, changing water flow regimes. These changes present a risk to riparian vegetation, including red willow. As riparian vegetation decreases, stream bank erosion will increase (Groeneveld and Griepentrog, 1985).

Ecological Benefits

- With their broadly cast root systems, red willows can provide strong stream bank stabilization and erosion prevention. In addition, their trunks and branches can reduce stream flow velocity, thus preventing stream bank scouring (USDA, 2003).
- As red willow cover increases, aquatic species will benefit as well. Fish species such as salmon and steelhead require cool water to survive. Anything above 64 °F can increase their susceptibility to disease (UC ANR, 2015). Increased shade cover provides for stream temperature moderation (USDA, 2003).

- Their flowers attract many butterfly and insect species including the western tiger swallowtail, which uses red willow twigs for constructing nests and shelter (Moosa Creek Nursery, 2010).
- Wildlife habitat is also generated for a variety of bird species, such as the western kingbird, the endangered yellow-billed cuckoo, as well as blackbirds, sparrows, bluebirds, American robins and starlings (Hunter et al., 1989).

Reproduction and Propagation

- In general, willows establish and grow relatively quickly. They have a strong rooting ability and can root along their entire stem (Baley, 2015).
- The recommended cutting size for average conditions is 16 to 20 inches long and one-half to one and a half inches in diameter. Environmental conditions can affect the size of a cutting. When planting larger cuttings, it is best to plant as soon as possible, as they aren't stored easily (Lamb, 1915).
- Hardwood cuttings can be taken during late winter when the tree is dormant and spring buds have yet to appear (Baley, 2015).
- In their natural environment, red willows can live up to 40 to 60 years. Seeds can be propagated by wind, but are only viable for a few days after fruit reaches maturity (Thompson, 2015).

Management

Controlling Weeds

- In order to ensure successful establishment of red willow, weeds must be addressed prior to any restoration activity. Hand removal, tillage, mowing, mulching and herbicide use are possible techniques (JCWC, 2015).

Irrigation

- Irrigation is not normally provided (SRRWG, 2013). Emphasis should be placed on planting willow cuttings within reach of the water table (Hoag, 1993).

Protection

- To protect young willows against herbivores, such as deer, beaver, rabbits and cattle, tree guards can be placed around each tree (SRRWG, 2013).

Monitoring

- Ensuring long-term rehabilitation of a restoration site requires that vegetation be monitored yearly. As not all plantings are expected to survive, some replanting may need to occur. Pruning trees may be necessary to promote smaller and denser growth forms (Hoag, 1993).

Climate Change Considerations

- Within California's Central Valley alone, 99% of riparian habitat has been lost due to land use changes (Hankins, 2013). As climate change continues, these areas will experience additional stressors in the form of more frequent and severe extreme weather events, such as flooding and drought (Seavy, et al., 2009).
- To increase the resiliency of riparian areas, it may be necessary to increase the genetic diversity of the species being planted (Seavy, et al., 2009). This would mean planting additional red willows other than those adapted to the local areas environment.

Other

- Native people used the flexible branches of red willow for building and basketry material, using the bark to make cord and string. Red willow also served medicinal purposes through its bark and leaves (The Watershed Nursery, 2012).

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Part 2: Project Goals and Management Plan

Restoration Plan for Red Willow

A. Goals

Red willow provides an abundance of ecological benefits including soil stabilization, erosion prevention, stream temperature moderation and the provision of wildlife habitat. In order to increase the success rate of red willow restoration, the first goal established should be to identify appropriate habitat that will accommodate species growth requirements and tolerances. The next step should be promoting red willow establishment and persistence, with the goal of creating a self-sustaining species. Depending on site conditions, establishment can take place anywhere from 2 to 5 years (Hoag, 1993). Determining the proper planting techniques, such as the types of cuttings that will be used, when cuttings will be taken and when these cuttings will be planted is critical in increasing planting success rates. In obtaining the goal of streambank stabilization, denser plantings will ultimately be able to provide stronger protection against erosive forces (Hoag, 1993). To measure species progress during early years of plant development, a management and monitoring plan will need to be created. Once establishment of red willow has taken place, the restoration site is expected to provide increased soil stability, shade for aquatic species and wildlife habitat for bird, butterfly and insect species.

B. Restoration Plan

I. Site Preparation

In order to provide for the successful establishment of red willow within the restoration site, care should be taken to remove all growth inhibiting invasive species. Whether planting from seeds or cuttings, red willow requires a low canopy environment that provides high sunlight exposure (Russell et al., 2003). The presence of weeds increases competition and reduces sunlight exposure, especially for red willow seedlings. Depending on restoration objectives, there are a variety of options that can be used to control weeds, including hand removal, tillage, mowing, mulching and herbicide application, all of which will increase water infiltration into the soil (JCWC, 2015). It's important to note however, that disturbance can promote weed germination (Dorner, n.d). Providing a layer of mulch can be an effective way to prevent weeds from sprouting (JCWC, 2015).

II. Planting Methods

1) From Seeds:

While red willow can be planted from seeds, the most common planting method used is to take cuttings (Hoag, 1993). Typically, woody species are harder to germinate by seed and slower at establishment. In addition, seeds are more prone to become outcompeted by invasive weeds during early stages of development (Dorner, n.d). The typical length of seed viability for red willow is 2-3 days after the fruit of the tree reaches maturity, which is indicated by the splitting of the seed capsules (Thompson, 2015). Planting of seeds is recommended to take place either during the late summer, early fall or early spring when the seeds are mature

(JCWC, 2015). With regards to soil factors, soils that are finer in texture, consisting of sediments less than 0.2 cm in size, have been known to promote seedling establishment (Mcbride and Strahan, 1984). Ideal habitats for growth include areas with sandy soils, shallow slopes and wide channels (Russel et al., 2003).

2) From Cuttings:

Due to willow's strong rooting ability to root along their entire stem, willows can establish and grow relatively quickly from cuttings (Baley, 2015). Identifying the proper timing to take cuttings is a critical step in ensuring establishment success. Typically, hardwood cuttings display the strongest ability to root from dormant root primordia within the stem (Hoag, 1993). The ideal time to take hardwood cuttings of red willow is when the plant is dormant, which can be either during the late fall, winter or early spring before the buds start to break (Hoag, 1993). The success rate of cuttings taken in late fall vs. early spring varies, with some studies suggesting one over the other and other studies showing no difference at all (Hoag, 1993).

When preparing cuttings, make sure to remove the apical bud and any lateral branches that will draw energy from the formation of roots (Lezberg, et al., 2008). Although not required, cuttings can be soaked in water prior to planting for the purpose of promoting root formation. The minimum amount of time cuttings should be soaked is 24 hours, but they can also be soaked for up to 10 to 14 days. Removal of willows from water should occur before any roots start to emerge from the stem (Hoag, 1993). If storage of willow is to occur, keep them in temperatures of 33 to 36 degrees F and between 60 to 70% humidity. Labeling can be accomplished by dipping the top ends into a 50:50 mixture of paint latex and water (Lezberg, et al., 2008). For future management and monitoring the date and location from which cuttings were collected can be documented (Hoag, 1993).

Method 1: Pole Planting

Direct planting of unrooted red willow poles is the most common planting method for riparian restoration projects. Where the water table is relatively deep, poles are able to reach moisturized soil and establish roots (Hoag, 1993). The size and length of cuttings should depend upon how deep the water table is and what the erosive factors of the site are (Hoag, 1993). For the diameter of cuttings, they can range anywhere from 0.5 inches or larger (Phytosphere Research, 2013). In determining length, make sure 6 to 8 inches of the cutting are within the mid-summer water table, 3 to 4 buds are above ground, at least half of the cutting is below ground and the cutting is high enough over weed species to receive sunlight (Hoag, 1993). As the cutting becomes larger, it becomes harder to store them (Lamb, 1915). Therefore, pole cuttings should be planted as soon as possible after collection during either late fall or early spring (SRRWG, 2013).

When spacing poles for planting, tree type willow species, such as red willow, should be spaced 8 to 16 feet apart (Hoag, 1993). If increased bank stabilization is required, higher density plantings may occur, as long as cuttings have adequate access to the mid-summer water table. Holes for plantings can be dug through a variety of options including the use of a soil auger, a waterjet stinger, a backhoe or by pushing the cutting into the soil by hand (Hoag, 1993).

Method 2: Rooted Whips

Another option for planting red willow is to use smaller branching rooted whips, which are planted in containers before being planted in the ground. Average cuttings can range anywhere from 0.5 to 1.5 inches in diameter and 16 to 20 inches in length (Lamb, 1915). Whips smaller than 0.38 inches are not recommended, as these will have lower energy reserves within their stems and lower resistance to pathogens and fungi (Hoag, 1993). As with pole plantings, cuttings should be planted either during the spring or fall in order to prevent high heat exposure during the summer (SRRWG, 2013).

III. Plant Sources

In identifying plant sources for taking cuttings, make sure to collect from local sources near the restoration site (Hoag, 1993). Local sources will be more adapted to local conditions, thus the success rate for establishment will be greater. Make note of similar hydrologic influences, elevations and landscape patterns for both the source and restoration site, as these will be important indicators of the adaptability of selected red willows. In addition, make sure to take cuttings from plants that are disease free and the least exposed to stress. Stress can cause stems to have low energy reserves. Low energy reserves inhibit the growth of red willow, thus decreasing restoration success (Hoag, 1993).

C. Management and Monitoring Plan

Management and monitoring of revegetated red willow will be the most critical during the first couple years after restoration (Hoag, 1993). Until the site is able to support a self-sustaining red willow population, management should continue to occur. Typically irrigation of willow is not recommended, as it can promote dependency during situations in which plants are unable to reach the water table (SRRWG, 2013). Control of invasive weeds can be managed by a variety of techniques including hand removal, mowing or mulching. By providing a thin layer of mulch around the planting, weed growth can be suppressed while at the same time increasing water infiltration into the soil (JCWC, 2015). To prevent wildlife browsing from herbivores, including that of beavers, tree guards, a minimum of 3 feet in height, can be placed a minimum of 1.5 feet in diameter around each tree. T-posts to provide support for the tree guards should be incorporated (SRRWG, 2013).

With regards to monitoring, monitoring should take place yearly, assessing red willow progress, weed growth, soil stability and the presence of pollinator species such as the western tiger swallow tail and bird species such as the western kingbird and the endangered yellow-billed cuckoo (JCWC, 2015). Red willow progress should be measured based on yearly growth. Where plantings fail to survive, replanting may need to occur. In measuring streambank stability, the velocity and tractive stress of the waterway can be calculated and compared to acceptable velocity and tractive stress values for particular ground covers. Hardwood tree plantings have an acceptable shear stress of 0.41 to 2.5 lb/ sq ft (Fischenich, 2001). With regards to climate change, a number of questions related to monitoring emerge. Riparian habitats are expected to see increased extreme weather events, such as drought and flooding, which may make restoration efforts difficult (Seavy, et al., 2009). For example, in a drought condition, relying on water table access for willow growth may not be ideal. For this reason, managers may want to look into the benefits and costs of providing irrigation during the first couple years of establishment. Weather or not local species of red willow are able to adapt to these changing conditions will be unknown. Therefore, monitoring of plant growth may take longer than 2 to 5 years (Hoag, 1993). Consideration should be taken by managers to utilize seed and cutting sources other than those locally adapted to the restoration site. This may increase the resiliency of the riparian area against climate change (Seavy, et al., 2009). Throughout all monitoring activities, photos should be taken at selected intervals every year to document species progress (JCWC, 2015).

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Blue oak (*Quercus douglasii*)

Zackery Ziade

Part 1: Project Background and Justification

Pictures of specimen:



Appearance

- Height: 6-20m
- Trunk Size: 36-60cm
- Drought Deciduous
- Wind Pollenated
- Acorns typically 2-3cm in length



o
o Mature in one year

Distribution: This species is native and endemic to California and is most common in valleys with low slopes of the Coast Ranges as well as the foothills of the Sierra Nevada. Typically found in grasslands dominated by perennial bunchgrass. Can typically have multiple trunks and the bark is known to have a light gray color to it. Adaptions to drought, such as thick leaves and high water efficiency aid it in living in California.

Resources

www.calflora.com

www.LasPilitasNursery.com

www.USDAForestService.com

Blue oak (*Quercus douglasii*)

Kingdom: Plantae
Subkingdom: Viridiplantae
Superdivision: Embryophyta
Division: Tracheophyta
Class: Magnoliopsida
Order: Fagales
Family: Fagaceae
Genus: Quercus
Species: douglasii



Background and Justification:

The Blue Oak (*Quercus douglasii*) is a native oak found traditionally in California. Blue Oaks prefer valley floors and lower slope ranges of the California coast. These trees help to create a mosaic of savanna and woodland forest that encircle the California Central Valley (Zavaleta 2007). This deciduous tree typically grows to a height of 20 m tall and has a rounded crown. The leaves of the Blue Oak are described as being shallowly lobed and have a blue-green hue to the top layer (McDonald 1998). This species of oak covers nearly 3 million acres and is one of the largest ancient forest types in California (Zavaleta 2007). Blue Oak Trees perform a number of ecosystem functions. Protection against soil erosion is a key feature of older Oak woodlands. Oak woodlands also harbor higher levels of organism diversity; nearly 60 species of animals utilize blue oaks to nest and take shelter (Bernhardt and Swiecki 2001). It is important to maintain oak forests because they provide shelter for many species. Due to poor seedling recruitment, heavy grazing, and anthropogenic pressure mature Blue Oak populations have been declining for many years (Fryer 2007). During European settlement old blue oak stands were cleared due to their location on prime agricultural land. This process of deforestation that took place in the central valley was only accelerated after the discovery of gold in the late 1800s (Borchert, 1989). Removal of the oak stands has created an opportunity for nonnative grasses and forms to establish in areas what would have been covered by the oaks root system or canopy cover (Borchert, 1989). These newly established non-natives have an easier time out competing oak seedlings in the understory of the old oak trees (Gordon, 1989). The need for management of blue oak stands is a result of poorly managed ecosystems in the central valley and Sierra Nevada mountain ranges. species.

Facts about the Blue Oak:

Project Goal

- To understand recruitment processes in current populations of blue oak trees in along Central Valley region and aid sites by returning ecosystem to its former condition where natural recruitment is able to occur with acorn saplings persisting below the canopy without threat of herbivore or desiccation.

Reproduction

- Acorns typically take about a year to mature and drop to the ground. After that they are carried off by animals or will germinate and become part of a seed bank under the canopy (Borchert et al, 1989).
- Seed germination is aided when organisms like the scrub jays bury acorns under the soil (Bernhardt and Swiecki. 2001).
- Most seeds will begin germination at the first sign of moisture in Autumn (Fryer, 2007).
- Organic debris located under the canopy is important for protection from desiccation of seedlings (Bernhardt and Swiecki. 2001).
- Gap phase replacement is the main form of recruitment for blue oaks (Knapp et al. 2001).
- Mast reproduction; generates many seeds (Knapp et al. 2001).
- Mast years occur every 3 years on average (Knapp et al. 2001).
- Seed germination is rapid with root germination more prevalent in early stages of growth (Campos, 2013).
- Sometimes sites that are suitable for seed germination are not preferable for seedling success, usually due to excess moisture (Bernhardt and Swiecki. 2001).

Range

- Cover nearly 3 million acres in California (Fryer, 2007).
- Form a nearly complete ring around the Central Valley (McDonald. 1999)
- Blue Oak occurs in 39 of the California counties ranging from Riverside County north to Del Norte County (Hogan, 2008)
- Core area of blue oak distribution almost completely encircles the Central Valley (Zavaleta, 2007)
- Typically found below chaparral/ conifer forest and above grasslands (Fryer, 2007).

Habitat

- Common to find blue oaks near or scattered amongst coast live oaks (Bernhardt and Swiecki. 2001).
- Annual grasses such as brome and wild oats can be found as groundcover (Bernhardt and Swiecki. 2001).
- In northern areas the blue oak is found around 500 to 2,000 ft (Standiford)
- Blue oaks on the Central Coast tend to grow between 250 to 3,000 ft (Standiford)
- In Southern California blue oaks have been recorded as high as 5,000 ft (Standiford)
- Soils tend to be rocky, well drained and infertile (Campos et al. 2013).
- Favor shallow somewhat dry soils with a water table at least above 80ft (Campos et al. 2013).
- Prefer sites with water tables that most trees cannot reach, allowing them to take advantage of their large taproot. The taproot can reach around 80 ft (Campos et al. 2013).
- Annual rainfall of blue oak woodlands averages between 10 to 60 inches annually (Fryer, 2007).

Requirements

- Well adapted to dry climates (Zavaleta et al. 2007).
- Soil must be well drained and allow for the blue oak to set a stable taproot (Millikin and Bledsoe, 1999).
- Seedlings need to have access sites free of heavy canopy cover to mature (Gordon et al, 1989).
- Limited watering, except for when unusually low rainfall (McCreary and Koukoura, 1990).
- Limit grazing and major disturbance during sapling phase (Borchert, 1989).

Tolerance

- Mature blue oak trees tend to be tolerant to moderate fire. Extensive root system allows for the tree to regrow after mild disturbance (Bernhardt and Swiecki. 2001).
- Blue oaks have adapted to tolerate drought through deep roots and summer deciduous leaves (McCreary, 1990).

Wildlife interaction

- Studies have shown that 60 species of animals utilize blue oaks to nest and take shelter (Bernhardt and Swiecki. 2001)
- Many rare and endangered species such as Bald eagles and peregrine falcons inhabit blue oak woodlands (Fryer, 2007)
- Local organisms also utilize acorns as a source of food (Fryer, 2007).

Human Interactions

- Blue oak stands have extensive root systems, which limit soil erosion (Gordon, 1989).
- Restoration of blue oak near migration corridors creates temporary shelter (Bernhardt, 2001).
- Native Americans used acorns as a source of food by grinding acorns into a flour substance for meals. Additionally, many Native Americans would set mile brush fires in oak stands to help the regeneration process and overall health of the community (Sullen, 2006).

Threats

- Introduced annual grasses tend to out- compete blue oak seedlings for local resources introducing increased pressure (Borchert, 1989).
- Most seedlings are threatened by grazing from livestock and insect predation. (Borchert, 1989).
- More mature blue oaks are also moderately intolerable to moist shady conditions (Gordon et al. 1984).
- Heavy over story canopies greatly reduce seedlings chance at maturation (Gordon et al. 1984).
- Not currently listed as federally endangered. The population has seen a decline in seedling recruitment, which leaves the species vulnerable after mature trees die. (Knapp, 2001).

Successful Propagation Requirements

- Burial of acorns lead to higher success rate due to limited predation and better moisture contact (Borchert et al, 1989).
- Limited annual grass cover in order to allow for acorn radicals to mature (Gordon et al. 1984)
- If transplanting seedlings the sprouts must be no older than 1 year old in order to avoid damage or impaired taproot growth (Harper and Standiford, 2015).
- It is best to recruit new blue oaks through acorn planting to ensure proper growth (Harper and Standiford, 2015).
- Local seed sources are also important for fit species that adapted to microclimates (Bernhardt and Swiecki. 2001).

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Part 2: Project Goals and Management Plan

Blue Oak Restoration

A. Goals for blue oak.

Regeneration of the Californian endemic blue oak (*Quercus douglasii*) has been widely accepted as problematic due to low gap-phase recruitment success in early stages of growth. Blue oaks produce saplings that wait in canopy understory for gaps to occur, in which case they begin to grow and replace the newly formed gap with a new phase of young growth (McCreary and Tecklin 2004). This characteristic is important to note because blue oaks do not utilize seed banks, which are beneficial during large disturbances. Blue oak stands provide important habitat for nearly 60 species of animals across 3 million acres and forms one of the largest old growth forests in the State of California (Zavaleta 2007). Improving blue oak recruitment can solidify that these important species remain present in the Central Valley. The first goal of restoration is to understand the current recruitment process and determine the factors that are inhibiting successful recruitment. The second goal is to determine site characteristics within California, specifically the Central Valley, that are suitable for blue oak populations. These goals can be accomplished through planting seedlings from acorns and monitoring to ensure that the local environmental conditions are not impeding sapling recruitment. Five-year sapling growth will be used as a key measurement of seedling success as well as 15-year sapling measurements. Overall, the project success will be measured by how many saplings mature into adult trees at 15 years within the estimated 40 trees/ acre estimates (Harper and Standiford 1995). By taking measurements at 15 years data will show that grazing and local competition does not have a tremendous effect on the new mature stand of blue oaks.

B. Restoration Plan

Seedling Preparation:

Selecting local acorns will be crucial because choosing ecotypes near your site will improve seed fitness for local environmental conditions (Bernhardt and Swiecki. 2001). Although ecosystems can be lumped into similar categories, many locations within an ecosystem have varying environmental conditions that make them unique. Acorns found near the restoration site may contain genetic material that is associated with the specific environmental location. Not only do local seeds have a better chance at surviving at the restoration site, the seeds also preserve genetic diversity as apposed to nursery seed which often comes from one tree. Before acorn collection is conducted, it is advised to survey local trees in the Spring months to determine trees with large crop potential (Phytosphere Research 2001). This is an important step because blue oaks typically undergo seed masting events and are known to synchronize with other local trees to produce highly variable seed crops. A masting event is characterized a pulse when a tree creates a large number of seeds every few years (Koenig and Knops 2005). Mast seeding events aid in lowering predation

levels and can improve seed germination success. If a masting event is predicted, collection of acorns should be done between the months of September and October (McCreary and Tecklin 1989). Utilizing PVC poles to dislodge the acorns and tarps to collect fallen seeds ensures minimal damage by insects, desiccation, and impact damage. Once acorns are collected, the best way to test seed health is to conduct a “float test,” which consists of taking the acorns and submerging them in a bucket of water. Seeds that float are considered viable and ready for planting (Phytosphere Research 2001). It is best to plant acorns in December after soil has been saturated with water to a depth of 1 foot (McCreary and Tecklin 1989). During this initial stage the oak tree’s important taproot begins to grow and needs just enough water to begin to establish the root network (Bonner 2003). Because oak species need to establish strong taproots and subsequent root systems, it is advised to plant acorns at the designated site and not use saplings grown in pots (Millikin et al 1999). Soil must be turned over to a depth of 10 inches and acorns must be placed on their side at a depth of a half-inch (Phytosphere Research 2001). To ensure the best acorn success, 3 to 4 seeds should be placed in 40 planting sites at a distance of 30 to 50 feet apart each. Depending on protection measures and quality of the site, this method can lead to a density of 40 trees per acre (Harper and Standiford 1995). Adhering to these procedures should allow acorns to adequately sprout into saplings, after which monitoring and site restoration will aid in growth.

Reintroduction

Blue oak communities are highly variable when it comes to coexisting species composition. The oak stands typically occur with other oak species and tend to form mono specific stands or mosaics within open savanna with shrubby understories. Locations with warm, well-drained soil composed of gravelly loam create the best environment for blue oaks (SAC Valley Conservancy 2008). Irrigation systems are not advised because blue oak trees are adapted to drought conditions and can outcompete most species in times of water stress. During winters of extreme drought, limited watering is advised around the oak tree’s drip-line but water must not saturate the soil (Harper and Standiford 1995). The drip-line is located at the circumference of the oak tree’s canopy. Excess water can lead to oak tree stress leaving it susceptible to pathogen infections, such as Sudden Oak Death (Bernhardt 2001). Surrounding canopy cover should not exceed 30 to 40% in order to limit competition from already established plants (Harris 2013). If grazing is unavoidable, the affected saplings should be protected with barriers. Using fenced enclosures or tree shelters can help provide protection until saplings are well established (Borchert 1989). Herbivory and competition for light and resources will be the biggest challenge for new recruits. Future use of a site must also be addressed to ensure long-term success. Sites that could be suitable for agricultural or urban development may be poor reintroduction sites because future urbanization may lead to the clearing of previously restored habitats. It is advised that proposed sites do not fall within boundaries designated for these types of land use and this be determined by looking up the project site in a city general land use plan.

Conservation

Blue oak stands encapsulate much of the Central Valley and are in danger of poor recruitment for saplings due to many environmental factors. The blue oak is threatened by poor seedling recruitment that can be explained by competition of invasive weeds, grazing, and poor soil conditions at local sites (McCreary 1989). In order to conserve current blue oak stands, competing invasive grasses and forbs must be removed from the understory to allow

for natural sapling to establishment. Additionally, limited grazing at sites can aid in invasive removal. However, if the site is exposed to excessive grazing many saplings will be removed (Borchert 1989). It is important that once saplings begin to grow, grazing is limited until saplings are well above 2m tall (6.5ft) or 15 years to make sure that grazing does not severely damage the new recruits (Phytosphere Research 2008).

Conservation on private land historically has proved to be difficult because many property owners do not realize the importance of local blue oaks (Rissman et al 2007). Additionally, many industries including agriculture and wineries have removed blue oaks in order to grow larger crops. This removal of mature blue oaks, as well as seedlings, ruined the gap-phase recruitments oaks use and allowed for fallow fields to be overrun by invasive weedy species . In recent years, conservation easements have been gaining popularity in their ability to protect blue oaks on private land (Rissman et al 2007). These easements are voluntary agreements that landowners must not remove specific habitat, and in return they receive a tax break for maintaining the protected area.

Protection of current blue oak stands should be the main concern of restoration sites within the Central valley because these sites have already established that they are suitable for blue oak trees to persist. Because the main method of stand regeneration originates from persistent seedling sprouts beneath tree canopies, the removal of noxious weeds as well as excessive grazing can help stands to recruit naturally. Improving these sites now and allowing for natural reproduction to occur enables less investment for restoration work later when these stands begin to die and the gaps in canopy allow for the strong saplings to mature.

Monitoring C

Monitoring will be important in seeds early stages of life because this is when they are the most susceptible to desiccation, herbivory, and competition from other species. Sites should be monitored from March to June directly after seeding to ensure that tree shelters are still intact and that saplings have not been eaten by herbivores (USDA Forest Service). The year after seeds are sown it is advised sites should be visited once every couple of months to check for shelter failure of other sapling pressures. If restoration site is experiencing an abnormally dry winter it is advised to water saplings sparingly. This type of monitoring should continue to be conducted a minimum of 5 years. After young saplings have begun to establish themselves site managers must be aware of herbivory pressure from cattle, deer, and burrowing mammals. These animals are the biggest threat to saplings once their root system has been established (Borchert 1989). After 5 years have elapsed monitoring can be limited to once a year during winter. Winter soil moisture is important because too much water can kill established trees. Making sure roots are not inundated and are well intact can greatly improve chances of survival for trees.

The success of the project will be quantified by measuring the number of saplings that make it through to at least 5 years of age and mature past 15 years. Reaching densities of at least 30 trees/acre out of the estimated 40 will be considered a success in planting techniques. Plants reaching an age of 15 years will determine the success of tree shelters and grazing limitations on saplings. By successfully planting seeds at sites that can maintain seedlings to an age of 15 will show that the site is suitable for future recruitment once saplings mature to at least 20 years of age and begin producing their own acorns (USDA Forest Service). It is necessary for conservation work to be done on blue oaks now while the work is still preventative, rather than reactive. With uncertain climate facing most of the globe old forest such as the blue oak stands will need to have human intervention to compete with new competitors and the changing urban landscape across California.

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Valley oak (*Quercus lobata*)
Brian Arena

Part 1: Project Background and Justification

Valley Oak (*Quercus lobata*)



Photo credit: selecttree.calpoly.edu

Photo credit: selecttree.calpoly.edu

Photo credit: selecttree.calpoly.edu

Valley Oak Leaves



Photo credit: selecttree.calpoly.edu

Valley Oak Bark



Photo credit: selecttree.calpoly.edu

Valley Oak Acorns



Photo credit: selecttree.calpoly.edu

Valley Oak Flower



Photo credit: dendro.cnre.vt.edu

Range: Valley Oaks are “native to and endemic (limited) to California,” with higher concentrations in the Central Valley, the Sierra Foothills, and California Coast.

Appearance: “Height (Source: calflora.org) Canopy Width: 50 feet, Flowers: Inconspicuous with both male and female flowers on same tree (monoecious), Bark: Dark Brown to Light Gray with blocky texture. ”

Similar Species:

(Source: selecttree.calpoly.edu)

Blue Oak



(Source: selecttree.calpoly.edu)



Interior Live Oak



(Source: selecttree.calpoly.edu)



Valley Oak (*Quercus lobata* Née)

Background and Justification

The valley oak, also known as the California white oak, is an endemic species of oak tree that is native to California (USDA Forest Service 2015). The valley oak is also one of the largest oak tree species in all of North America (USDA Plant Guide 2015). Valley oak habitats are very important to wildlife, humans, and the environment. According to the USDA Forest Service, there are sixty-seven different bird species that rely on valley oak habitat, which is more bird species than any other habitat type supports in California (2015). In addition to supporting bird species, valley oak trees play a critical role in cycling nutrients, helping the soil beneath them to become rich with nitrogen, phosphorus, and more (Dahlgren 1994). Conservation of the valley oak ensures continuation of benefits such as these, as well as preserving an iconic tree species for the California Central Valley. The valley oak exists throughout most of California in good numbers, but in certain areas they are declining in number due to encroaching human developments (McCreary 1991). While the exact length of time the valley oak has been present in California is uncertain, some studies suggest that oak woodlands became an important part of the landscape as early as 10,000 years ago (Byrne, Mensing, & Edlin 1993).

Fact Sheet

Basic Characteristics

- The valley oak can grow to anywhere from 40-150 feet in height, with a growth rate of 2-3 feet per year (Selectree 2015).
- The canopy for a valley oak is generally rounded and approximately 50 feet in width (Selectree 2015).
- Valley oaks can live for more than 150 years (Selectree 2015).
- The valley oak is monoecious, meaning it has both male and female flowers on the same tree (USDA Plant Guide 2015).
- Grows acorns anywhere from 0.5 to 1.5 inches long (Selectree 2015) and flowering occurs between March and April (USDA Plant Guide 2015).
- Acorns take approximately one year to mature (USDA Plant Guide 2015).
- As of 1988, it was estimated that the valley oak occupied 109,600 hectares in California. Eighty-six percent of that land was privately owned (USDA Forest Service 2015)

Habitat

- The valley oak is found throughout California, but occurs primarily in the Sierra Nevada foothills and coastal mountain ranges (USDA Plant Guide 2015).
- Can be found anywhere from Shasta County down through to Los Angeles County and even on Santa Cruz Island and Catalina Island (USDA Forest Service 2015).
- Requires moist to dry loam or sand soil, with a tolerance range from highly alkaline to slightly acidic soil (Selectree 2015).
- Has a moderate tolerance for inland salinity, but is not suited for the seaside (Selectree 2015).
- Grows best below 4000 feet of elevation (USDA Plant Guide 2015)
- Not suited for snowy conditions as limbs may break (USDA Forest Service 2015).
- Best suited for Mediterranean climates (USDA Forest Service 2015).
- Optimal growth occurs when the groundwater is approximately 33 feet below the surface (USDA Forest Service 2015).

Propagating with Seeds/Acorns

- The seeds/acorns of oak trees do not keep well over long periods of time, which means they need to be planted shortly after maturing (USDA Plant Guide 2015).

- A healthy acorn for planting is green to brown in color without any holes in the exterior. If the nuts are discolored or have small holes, they should not be used for planting (USDA Plant Guide 2015).
- It is best to gather acorns in the fall and to pick them directly from the tree rather than from the ground (McCreary 1989).
- Seeds will germinate after the first rains (USDA Plant Guide 2015).
- If possible, grow in partial shade or on northern slopes (USDA Forest Service 2015).
- To plant the seeds, dig a hole that is roughly five inches deep and ten inches wide. Place one gram of slow-release fertilizer in the hole and cover it with soil. Then insert between six and ten acorns about one to two inches below the surface and cover with soil (USDA Plant Guide 2015).
- Avoid planting in areas where there are visible gopher mounds or ground squirrels to avoid them taking the acorns. Can plant an inch or two further below the surface to make it more difficult to access, but refrain from planting too deep (McCreary 1989).
- Plant trees in clusters of three to four, spacing them about fifteen to twenty feet apart. Can plant up to forty clusters per acre of open land. When possible, try to plant in a natural pattern instead of in rows (McCreary 1989).
- As an alternative, seeds can also be planted using one-gallon containers with soil that has slow-release fertilizer. As above, plant one to two inches beneath the soil. Transplant the seedlings after the first true leaves mature by digging a hole approximately twice as deep and wide as the container (USDA Plant Guide 2015).

Preventing Herbivory and Competition After Planting

- The mortality rate of newly planted valley oak trees can be up to 100% due to heavy herbivorous activity (USDA Forest Service 2015).
- To prevent herbivores from affecting the seedlings, use some type of simple container to keep animals away after they sprout (USDA Plant Guide 2015).
- Also, consider using a cage, screen cylinder, or rigid transparent tube to keep animals away from the developing seedling. Be sure to remove enclosure once seedling grows to the top (McCreary 1989).
- Valley oak seedlings are affected by surrounding plants or grasses competing for moisture. Keep a two to three foot radius around the seedling clear of vegetation. This can be done by a number of methods, including using mulch, black plastic, bark chips, and more (McCreary 1989).

General Seedling Maintenance

- If there are multiple seedlings from one hole after one season of growth, remove all but one so that it may continue to grow (USDA Plant Guide 2015).
- Seedlings might need to be watered every two to three weeks through their first season. If there is a drought of six weeks or more in the spring, they may need additional watering as well (USDA Plant Guide 2015).
- Once seedlings are six to ten inches tall, there is not as strong of a need to continue removing surrounding vegetation (USDA Plant Guide 2015).

Wildlife Interaction

- Acorns of the valley oak are specifically sought out by wildlife, most likely due to their larger size (USDA Forest Service 2015).
- Valley oak acorns are a diet staple of many species, including: the ground squirrel, yellow-billed magpie, acorn woodpecker, black-tailed deer, cattle, pocket gopher, and more (USDA Forest Service 2015).
- Supports sixty-seven different bird species, including: the swainson's hawk, greater sandhill crane, the yellow-billed cuckoo, and more (USDA Forest Service 2015).

- Leaves of the valley oak provide calcium and phosphorus to black-tailed deer (USDA Forest Service 2015).

Diseases and Threats

- Resistant to both verticillium and oak root fungus (Selectree 2015).
- Vulnerable to: “boring beetles, caterpillars, insect galls and scales, crown rot, mistletoe, and root rot” (Selectree 2015).
- Also vulnerable to: *Armillaria mellea* aka heart-rot fungus, filbert worms, and filbert weevils (USDA Forest Service 2015).
- Seedlings are susceptible to being trampled or eaten by herbivores such as cattle (USDA Plant Guide 2015).

Response to Fire and Herbicides

- Glyphosate or Roundup can be used around valley oak seedlings, but care should be taken to shield seedlings from direct contact, since seedlings can be damaged by direct contact with glyphosate (McCreary 1998).
- If the valley oak saplings are at least ten feet tall, studies have shown that prescribed fires can be used successfully to control surrounding grasses, thistles, or other invasive species (Holmes, Veblen, Berry, and Young 2011).
- Mature trees are considered fire-resistant and acorns stored underground often survive fire (USDA Forest Service 2015).
- There is concern that in times of drought that valley oak trees may not recover from a fire as they normally might (USDA Forest Service 2015).
- Fire can increase susceptibility to diseases such as heart-rot fungi or windthrow (USDA Forest Service 2015).

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Part 2: Project Goals and Management Plan

Goals

The valley oak is one of the California Central Valley's most iconic trees and its restoration will help to benefit the sixty-seven different bird species of bird that occupy its branches (USDA Forest Service 2015). However, much of the information available by the USDA on the valley oak is dated from the 1970s to the early 1990s, including acreage cover estimates (USDA Forest Service 2015). Therefore, the first goal of the restoration of the valley oak should be to update habitat acreage estimates to more accurately determine the present health of the valley oak throughout the Central Valley. After a habitat analysis has been performed, the second goal would be to protect existing valley oak trees in the Central Valley, as there are many counties throughout California that do not have any type of ordinance to protect endemic oak trees (UCANR 2015). The third goal would be to propagate valley oak trees in areas of the Central Valley where conditions are favorable and meet the restoration plan standards set in this document.

A large-scale habitat analysis from one central organization could prove to be time-consuming and costly, but the assistance of local organizations would help to reduce the time frame and still provide a better estimate than those from the early 1980s that are still in use by the USDA today (USDA Forest Service 2015). Counties in California's Central Valley that do

not already have an ordinance related to oak tree protection and that have low oak habitat acreage should consider adopting oak tree ordinances similar to those found in other California counties (UCANR 2015). Elevating the valley oak tree to be protected under ordinance could help to bring the importance of the species to the public's attention.

Restoration Plan

Restoring valley oak trees to an area involves a number of considerations such as tolerances for soil quality and type, how much it rains, the elevation of the land, surrounding vegetation, and more. The first step should be to choose an appropriate propagation site that meets the criteria explained in the remainder of this paragraph. Valley oak trees are native and endemic to California, ergo it is recommended the scope for restoration not extend beyond state lines (USDA Forest Service 2015). The valley oak can be planted at elevations anywhere from sea level up to 6,400 feet (Calflora 2015), but it is best suited for elevations 4,000 feet or below (Selectree 2015). The valley oak should be planted in areas with rich loam soil (USDA Forest Service 2015) that has a pH between 5.2 to 8.2 (Calflora 2015). Valley oak trees are suited for the Central Valley's Mediterranean climate and can tolerate winters without snow and endure through long summers, provided there is at least 13 inches of rain per year (Calflora 2015). Since it is a K-selected species, it is best to plant valley oak trees in areas that have already been colonized or established by r-selected plant species (USDA Forest Service 2015). When possible, grow valley oaks grow in partial shade and on Northern slopes (USDA Forest Service 2015). Finally, the ground should be inspected for any gopher mounds, as these areas should be avoided to prevent acorns that are planted from being eaten (McCreary 1989). Once these general site characteristics have been observed then it will be time to prepare for planting.

The two primary methods for planting valley oak trees are to either 1) plant acorns on-site or 2) plant acorns in a container and transplant them (USDA Plant Guide 2015). In either method, acorns will need to be harvested from existing valley oak trees, preferably nearby the site and from a variety of different individual trees. This will help to widen the gene pool and help to select for traits that ensure viability of the new plant at the desired planting site. The best time to gather acorns is in the early fall while they are still on the tree (Audubon California 2015). Look for acorns that are green to brown in color without any holes in the exterior, as that can indicate a pest species has infiltrated the seed (USDA Plant Guide 2015). To test if an acorn is ready for harvest, see if its cap can be removed easily, which indicates it is ready (Audubon California 2015). After harvesting, put the acorns into water and remove any that float, as that is an indication of a bad seed (Audubon California 2015). If the acorns need to be stored, first clean them with a diluted solution of bleach and water and then put them into a sealed container in the refrigerator with a very lightly damp sponge for moisture (Audubon California 2015). Acorns should not be kept for an extended period of time and should be planted soon after harvest (USDA Plant Guide 2015). It will take approximately six to ten acorns per tree that is to be planted, so collect the number of acorns accordingly (USDA Plant Guide 2015).

If the acorns are to be planted directly on-site, they should be planted either in the month of December or January, preferably once it has started into rainy season (Audubon California 2015). It is best to plant acorns approximately fifteen to twenty feet apart from other trees or planting sites, planting clusters of three to four trees at each planting site (McCreary 1989). When a suitable planting site has been identified, dig a hole roughly five inches deep and ten inches wide, insert some slow-release fertilizer, and then cover it with a small amount of soil (USDA Plant Guide 2015). Then, put between six to ten acorns at a depth of about two inches below the surface and cover with more soil (USDA Plant Guide 2015).

One problem with propagating the valley oak by planting acorns on-site is that the acorns are a diet staple of many herbivores, such as the ground squirrel, black-tailed deer,

pocket gopher and more (USDA Forest Service 2015). This can mean that up to 100% of all planting sites could be compromised by animals such as these unless the acorns are protected (USDA Forest Service 2015). To mitigate the effects of herbivorous activity, some sort of container like a cage, transparent tube, or even a plastic milk jug should be used to keep any animals away until the plant grows to the top of the container, at which point the container should be removed (McCreary 1989). These containers can be up to six feet in height in order to offer to continued protection to the seedling as it grows (McCreary 1989). In addition to herbivores, the valley oak is vulnerable in its initial growth stage to surrounding vegetation competing for moisture (McCreary 1989). Therefore, a two to three foot radius around the planting site should be kept clear of vegetation using something like mulch, black plastic, or bark chips (McCreary 1989). Continue keeping the two to three foot radius clear of other vegetation until the seedlings are between six and ten inches tall (USDA Plant Guide 2015). The initial growth phase for the valley oak involves growing out roots; seedlings should surface around early Spring (Audubon California 2015). If multiple seedlings are growing out of one hole, all but one of them should be removed (USDA Plant Guide 2015).

If seeds are to be planted in a container and transplanted, use one-gallon containers that have slow-release fertilizer and plant the acorns two inches beneath the soil (USDA Plant Guide 2015). The seedlings can be transplanted after the first true leaves mature by digging a hole approximately twice as deep and wide as the container it is in (USDA Plant Guide 2015). As with acorns planted on-site, plant transplant trees in clusters of three to four trees around fifteen to twenty feet from other trees or planting sites (McCreary 1989). For maximum coverage using either planting method, this spacing allows for up to forty clusters of trees, or between 120 and 160 individual trees per acre of land (McCreary 1989). Avoid planting in rows when possible to keep a more natural look or pattern to the trees (McCreary 1989). Make sure seedlings are receiving water at least once every two to three weeks during their first season of growth either naturally via rainfall or by way of drip irrigation (USDA Plant Guide 2015). If possible, use drip irrigation for the first two years of development (Audubon California 2015).

Monitoring Plan

Valley oak trees are most vulnerable during the early years of their life, so it is important that monitoring of the restoration site be most frequent during the first two years after planting. The initial threat is primarily herbivores such as squirrels, black-tailed deer, gophers, and more getting to the acorns that are planted (USDA Forest Service 2015). Even after surfacing, seedlings are susceptible to being trampled or eaten by herbivores such as cattle (USDA Plant Guide 2015). Therefore, the protective enclosure chosen to protect the acorns and seedlings, as described in the section above, should be checked on once every two weeks during the first two years of growth. If more than twenty-five percent of the enclosures are compromised during the first year, consider changing out protective enclosure type to protect remaining planting sites.

Keeping the two to three foot radius surrounding each planting site clear of other vegetation should be another priority during the first year of development (McCreary 1989). Therefore, planting sites should be inspected once per month during the first year of development to insure that no vegetation is growing within the chosen radius. If any vegetation is found within the radius, it should be removed either by hand or by using glyphosate, provided that the glyphosate does not come in direct contact with the seedlings (McCreary 1998).

Making sure that newly planted valley oaks get enough water should be another priority of the monitoring plan. The ideal scenario would include a drip irrigation system that delivers water to the seedlings for the first two years of development (Audubon California 2015). However, if there is not an option to irrigate, pay attention to rainfall in the area to ensure that seedlings are getting water delivery at least once every two to three weeks during

the first rainy season (USDA Plant Guide 2015). In times of drought, if there is no rainfall within three weeks, planting sites must be irrigated or else the seedlings may die (USDA Plant Guide 2015).

After the first two years of monitoring, the frequency of checking on the site can be scaled back to once a year. At that point, the main things to look out for would be for any mortality due to diseases or pests such as oak root fungus, boring beetles, mistletoe, or crown rot (Selectree 2015). If there is more than 50% mortality at the planting site, consider planting more trees to offset losses. Older and larger valley oak trees are fairly resistant to threats such as fire and herbivores (USDA Forest Service 2015). However, one statistic for the valley oak is lacking in research and that is the age of sexual maturity when they begin to produce acorns (USDA Forest Service 2015). Annual check-ins on the planting site would help to determine the average age when the valley oaks begin to produce acorns.

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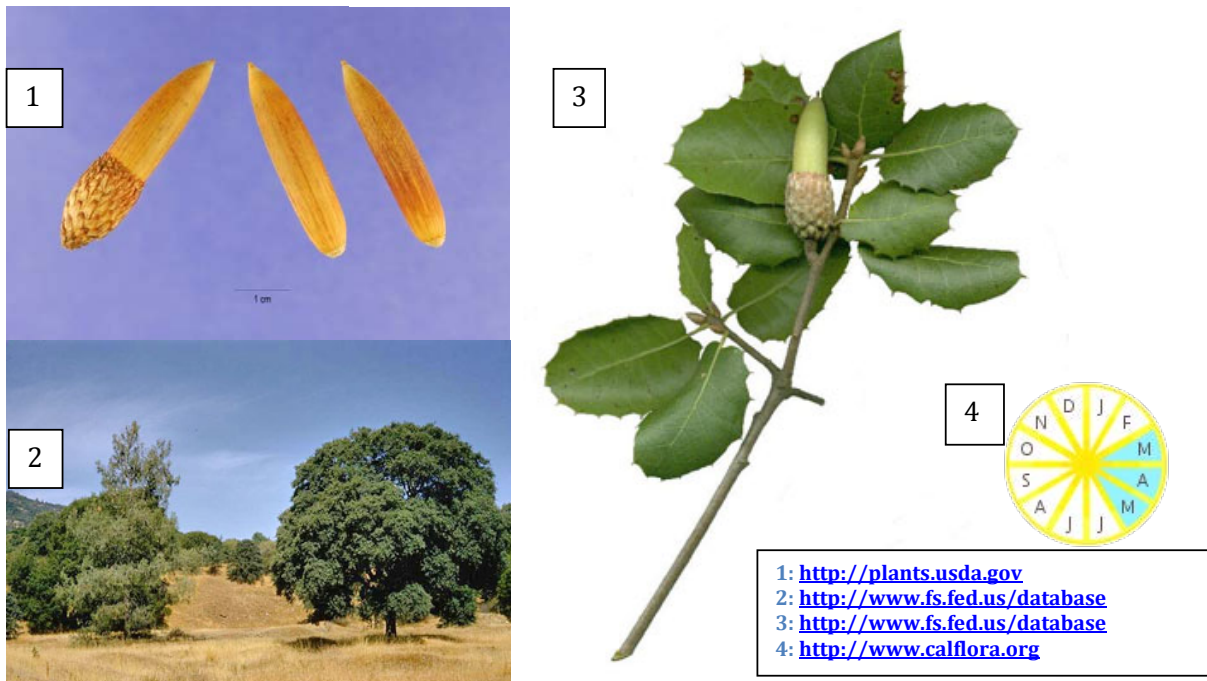
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Interior live oak (*Quercus wislizeni*)

Bradley Santi

Part 1: Project Background and Justification

Interior Live Oak (*Quercus wislizeni*)



Habitat: “Interior live oak mostly grows on harsh sites that other oaks cannot tolerate. Grows strictly in a mediterranean climate. Sometimes grows in riparian and other wetland areas. Grows from 1,000 to 6,200 feet (300-1,900 m) elevation across its range. Landforms with interior live oak include dry valleys, canyons, and foothill slopes. Prefers north-facing or other relatively mesic slopes within these dry habitats.” (USDA plant profile found at <http://www.fs.fed.us/database/feis/plants/tree/quewis/all.html#GeneralDistribution>)

Appearance: “The varieties of interior live oak are distinguished by their growth form. The typical variety (*Q. wislizeni* var. *wislizeni*) grows as a tree, and scrub interior live oak (*Q. wislizeni* var. *frutescens*) grows as a shrub. Typical variety reaches from 33 to 75 feet (10-23 m) tall. Open-grown trees have a dense, rounded crown, with branches that may extend to the ground. Trunks are one to several. Scrub interior live oak typically reaches 7 to 20 feet (2-6 m) tall and is intricately branched.” (<http://www.fs.fed.us>)

Leaf and fruit: “Leaves and fruits of interior live oak are relatively small. The leaves are evergreen and sclerophyllous; the margins may be spine-toothed to entire. The leaves are elliptical and about 1 to 3 inches (2.5-8 cm) long. The fruits are acorns, a type of nut. They are about 0.3 to 0.5 inch (0.8-1.3 cm) wide” (<http://www.fs.fed.us>)

Phenology: Bloom period of Interior Live Oak ranges from March to May. “Male catkins are about as long as the leaves. The smaller, female flowers are born in the leaf axils in clusters of 2 to 4” (<http://www.fs.fed.us>)

Similar Species:

Bradley Santi
**Interior Live
Restoration**

Species:

wislizenii

Location:



<http://www.hastingsreserve.org>

Oak

Quercus

California Central Valley

Background and Justification

Quercus Wislizeni (Interior Live Oak)

Quercus Wislizeni (Interior live oak), a native and endemic species of California and Baja California is common among the Inner Coast Ranges, foothills of the southern Cascade Range, and foothills of the Sierra Nevada (Fryer 2012). Interior live oak is a slow-growing evergreen that grows as a tree or shrub (USDA NRCS 2002). The typical variety of Interior live oak grows as a tree known as *Quercus wislizeni* var. *wislizeni*. The shrub form, and less common form, is known as *Quercus wislizeni* var. *frutescens*. This species is adapted to the Douglas-fir, Ponderosa Pine, Lodgepole pine, redwood, western hardwoods, and chaparral-mountain shrub zones of California (USDA NRCS 2002). Interior live oak species are found along riparian, chaparral, and conifer-dominated areas within each of these broader zones in California (Swiecki 2006).

Oak woodlands and forests dominated by oak trees cover approximately 10 percent, or about 4 million hectares (Swiecki 2006). This species is critical to the health of many ecosystems across California and provides important habitat for wildlife. Interior live oak is an important food and cover source for many birds and mammals such as black-tailed jackrabbit, Audubon cottontail, brush rabbit, Beechy ground squirrel, Sonoma chipmunk, beaver, porcupine, and elk (USDA NRCS 2002). The acorns of these oaks are a valuable food source for deer, other wild ungulates, birds, and small mammals during the fall while preparing for winter (USDA NRCS 2002). Oak woodlands have higher levels of biodiversity than virtually any other Californian terrestrial ecosystem and provided very important wildlife habitat (Swiecki 2006). Resources have identified at least 300 terrestrial vertebrate species, 1,100 native vascular plant species, 370 fungal species and approximately 5,000 arthropod species associated with California oak woodlands, Interior live oak included (Bernhardt and Swiecki 2001). Oak woodlands play a critical role in protecting soils from erosion and land sliding, regulating water flow in watersheds, and maintaining water quality in streams and rivers (Bernhardt and Swiecki 2001).

Over the last 250 years California's oak woodlands have been dramatically reduced due to European and American settlers intensely removing oak woodland cover, especially during the first 50 years following the 1848 discovery of gold (Bernhardt and Swiecki 2001). Clearing our oak woodlands to create more profitable land such as rangeland has been an accepted practice and to this day is still practiced (Bernhardt and Swiecki 2001). Our oak woodlands are extremely important ecological resources and without them many ecosystems could potentially collapse. Woodlands have gradually thinned to open oak savannas which are susceptible to conversion to invasive annuals (Bernhardt and Swiecki 2001). Oak woodland restoration is a critical need in the California central valley because they are so important ecologically. Oak woodlands suffer from low regeneration due to previous and current management practices that, if not corrected, could result in the complete loss of our oak woodlands.

FACT SHEET:

Project Goal:

- To return oak woodland ecosystems, especially Interior live oak woodlands, to conditions in which plant and animals benefit from the ecological significance they provide in the Central Valley. Interior live oak woodlands should be self-sustaining and returned to near historic levels of cover in order to be successful.

Habitat and Distribution:

- Interior live oak occurs from northern California in Siskiyou and Shasta counties, south along foothills of the Coast and Sierra Nevada ranges, and on the Channel Islands. (USDA 2002).
- Grows from 300-1,900 meters elevation across this range (Fryer 2012).
- Sometimes grows in riparian and other wetland areas, especially in southern California, and may be frequent to dominant in riparian zones. (Fryer 2012)
- Often grows on north-facing slopes of dry valleys, canyons, and foothill slopes (Fryer 2012).
- Grows from 1,000 to 6,600 feet elevation, but often to only about 2,000 feet in northern California (Fryer 2012).
- Tends to occur on shallow soils in chaparral and deeper soils in woodlands. These soils are nearly always dry and range in pH from 5.6-7.5. (USDA NRCS 2002).
- Grows very well on dry, shallow, well-drained loams, clay loams, gravelly loams, or gravel (USDA NRCS 2002).

Growth characteristics:

- Slow-growing, variable evergreen that can grow as a tree approximately 75 feet in height or large shrub about 8 to 10 feet in height (USDA NRCS 2002)
- Leaves persist for about 2 years and are mostly oblong-to-elliptic and spiny-toothed to entire around the edges (USDA NRCS 2002).
- Interior live oak is not long lived, living to ages around 150-200 years (Fryer 2012).
- Regenerates vegetatively or through seed after disturbances (USDA NRCS 2012).
- Sprouts vigorously after fire or mechanical disturbances (USDA NRCS 2012).
- Growing season peaks in early spring with most vegetative growth occurring in March (Fryer 2012).
- Sprouting is the most common method of regenerations of interior live oak (Fryer 2012).

Reproduction:

- Interior live oak is monoecious meaning both male and female flowers are borne on the same plant (USDA NRCS 2002).
- Interior live oak pollen is wind dispersed (Fryer 2012).
- There are usually 5 to 7 years between large acorn productions by interior live oak, known as masting (Fryer 2012).
- Seeds are dispersed by gravity and also by animals such as squirrels and scrub jay (Fryer 2012).
- Acorns need about 2 years to develop before reaching maturation (Fryer 2012).

Regeneration:

- Interior live oak sprouts (vegetatively) after top-kill by fire, cutting, or herbicide (Fryer 2012).

- Interior live oak is a fire adapted species, sprouting from perennating buds in the root crown (Fryer 2012).
- Exposure to low temperatures ranging from 32 to 41 degrees Fahrenheit enhances germination of acorns (USDA NRCS 2002).

Plant Care:

- Mature oaks should generally require a “hands off” policy (Sacramento Tree Foundation 2007).
- During drought years Interior live oak may be watered as long as irrigation events are infrequent and deep (Sacramento Tree Foundation 2007).
- Avoid disturbing the soil of the root zone. Mounding soil against the trunk, trenching, compacting, or covering the root zone with asphalt/concrete will likely damage mature oaks or possibly kill them (Sacramento Tree Foundation 2007).
- Avoid changing watering/drainage patterns for saplings because this will cause roots to be less vigorous during the establishment phase ((Sacramento Tree Foundation 2007).
- Allow leaf litter from the tree to create a natural mulch layer around the root zone. Using other mulches such as redwood or cedar chips is not recommended because they do not decompose fast enough (Sacramento Tree Foundation 2007).
- Do not allow large rocks around the root zone because they compact soil and absorb high amounts of radiation, possibly injuring oaks (Sacramento Tree Foundation 2007).

Tolerances:

- Tolerates shade, especially when the plant is young (USDA NRCS 2002).
- Interior live oak is generally adapted to dry summers so it could be planted away from a drip line if necessary (Sacramento Tree Foundation 2007).
- Interior live oak is apparently resistant to sudden oak death disease and as of 2003 was the only red oak species in California which the disease has not been detected in (Fryer 2012).
- Interior live oak tolerates infrequent fires when trees are mature (*Bernhardt and Swiecki 2001*).
- *A clear relationship between Interior live oak and post-fire regeneration has not been established, however some studies suggest fire favors oak regeneration (Fryer 2012).*
- Mature Interior live oaks are intolerant of watering/irrigation because saturated root zones inhibits oxygen to the roots and also allows for harmful soil microbes to live on the roots, ultimately injuring or killing the tree (McCreary and Sabrina n.d).

Wildlife Interaction:

- Serve as important rangelands for wild and domestic ungulates (USDA2012).
- Interior live oak woodlands are primary habitat for feral hogs and Mule deer (Fryer 2012).
- Acorns are a large food source for bears, mule deer, squirrels, acorn woodpeckers, and scrub jays (Fryer 2012).

Plant Interaction:

- Interior live oak hybridization is common with other red oak species such as Coast live oak (*Quercus agrifolia*), Santa Cruz Island oak (*Quercus parvula*), California black oak (*Quercus kelloggii*), and Oracle oak (*Quercus moreha Kelloggii*) (Fryer 2012).
- Occurs in chaparral, oak woodland, and conifer-oak woodland communities that are typically dominated by nonnative annual grasses (Fryer 2012).
- Commonly associated with Gray pine and California buckeye (Fryer 2012).
- Interior live oak requires a clear area around them for good establishment (McCreary and Sabrina n.d.).

- Live oaks are allelopathic, meaning they produce chemicals that prevent other plants from growing near them (Chaney n.d.).

Human Interaction:

- Interior live oak has many ethnobotanical uses and was a staple food for the native peoples of California (Anderson 2007).
- Native Californians leached away tannins from the acorns and made meals, oils, stew, and breads from the acorn mash (Peterson 2002)
- Native Californians regularly burned oak woodlands to create healthy, diverse, and high productive ecosystems (Anderson 2007)

Propagation:

- Young oaks can be established from acorns or seedlings as long as they are protected from rodents and provided enough water until established (Sacramento Tree Foundation 2007).
- Many local nurseries carry container stock of ecotype Interior live oak to be planted for a quick start on establishment (Sacramento Tree Foundation 2007).
- Transplanted Interior live oaks have several disadvantages relative to direct-seeded acorns such as non-vigorous taproot, reduced drought tolerance, and slowed growth (Phytosphere Research 2001).
- Transplants require space in a nursery, care from a grower, and are overall more costly (Phytosphere Research 2001).
- It is difficult to attain commercial amount of container stock of Interior live oaks without adequate time given to a local nursery (Phytosphere Research 2001).
- Acorn collection should be done from Interior live oak stands within a mile or so of your restoration site if possible (Phytosphere Research 2001).
- Matching seed source type may be critical, for example collect seeds from a riparian tree that will be planted on a riparian corridor of the restoration site (Phytosphere Research 2001).
- Acorns are viable most right after collection and viability decreases significantly over time. Acorns are generally only viable during the season they were collected. Acorns can be stored in the refrigerator under moist conditions in a plastic zip-lock bag to slow germination before planting (Phytosphere Research 2001).
- Acorns are ready for collection when seeds easily separate from the acorn cap, this may come in fall or early winter (Phytosphere Research 2001).
- Plant at least 3-4 acorns about 6-8 inches apart and on their side about 2 inches deep to increase chances of at least one surviving (Phytosphere Research 2001).
- Plant Interior live oaks in groups about 15 feet apart, or about 40 groups/acre, to help establish healthy stands (Phytosphere Research 2001).
- Planting should occur in winter to allow seedlings adequate growing time to establish a taproot and grow before the next winter (Phytosphere Research 2001).

Threats:

- Urbanization, land conversion, and creation of poor soil conditions are all threats to Interior live oak.
- Poor management of Interior live oak threatens the loss of the species entirely (Fryer 2012).
- Nearly 750,000 acres of California oak woodlands are at risk from human development before the year 2040 (Garman and Firman 2006).
- Woodlands of California's Central Valley and Sierra foothills face the most immediate threats from development and climate change (Garman and Firman 2006).

- Interior live oak is almost exclusively limited to the San Joaquin and Sacramento regions of California meaning it has very limited range to extend to if more habitat is lost due to climate change and urbanization (Garman and Firman 2006).

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Part 2: Project Goals and Management Plan

Interior Live Oak Restoration Plan

Species: *Quercus wislizenii*

Location: California Central Valley

A. Restoration Goals

Interior live oak plays a large ecological role in California's central valley. Oak tree dominated vegetation types cover about 4 million hectares in California, roughly 10% of the

state, however oak woodlands of California have been increasingly decimated since European settlement and especially the gold rush of 1848 (Bernhardt and Swiecki 2001). Interior live oak was the dominant oak growing along rivers that flowed from the Sierra Nevada mountains down to the Central Valley before rivers were dammed and the fertile land of the Central Valley was cleared for agriculture and ranching (Sacramento Tree Foundation 2007). Sudden Oak Death, a major disease affecting many California oak woodlands, has not been detected in Interior live oak (Fryer 2012). Because of this Interior live oak may play an extremely critical ecological role if California's oak woodlands continue to be lost due to Sudden Oak Death.

The first goal of Interior live oak restoration should be to locate the areas of the California Central Valley still dominated by Interior live oak and collect propagules. The second goal of Interior live oak restoration should be identifying historical or potential Interior live oak habitat and preparing those sites for restoration. The third goal is to implement restoration efforts in areas that have high potential for success. The fourth goal is achieving natural recruitment of Interior live oak, sustaining populations that promote higher diversity and healthy oak woodland ecosystems in the Central Valley of California. Conservation, management, and protection of Interior live oak ecosystems should be a part of the fourth goal, not only to support healthy Central Valley ecosystems, but also to restore Interior live oak to historic levels. These goals are all important for restoring and maintaining healthy Interior live oak woodlands but must be accomplished in steps as they cannot all be addressed at one time.

B. Restoration Plan

1. Current Interior live oak stands & restoration site preparation

Identifying remaining Interior live oak stands is extremely important to reestablish and restore Interior live oak populations to historic accounts. Once good local sources of Interior live oak are identified propagules may be collected. A good source would be a local stand of native Interior live oak within a mile or so of the proposed restoration if possible (Phytosphere Research 2001). These sites should also have many mature trees to collect seed from to ensure a better genetic diversity of oaks are planted at the restoration site to increase chances of trees being well adapted to site conditions (Phytosphere Research 2001). Phytosphere Research (2001) determined oaks can be established by both acorn (seed) and transplants, but transplants have disadvantages when compared to direct-seeded acorns. Transplants have less vigorous taproots, cost more, are difficult to store, are often not derived from the best local sources, and can introduce pests or pathogens to the restoration site (Phytosphere Research 2001). For this reason it is important to have our restoration site planned out and prepare the seed bed where planting are planned.

Once a proper site for planting is chosen the seedbed should be prepared in order to hasten the planting process once seeds are collected. Phytosphere Research (2001) suggests planting acorns as early as you can after collection because stored acorns eventually deteriorate in quality. Having a prepared seedbed allows us to shorten time between collection and planting, thus increasing the chances of germination for seeds. A few weeks before acorns can be planted water should be secured for the restoration site. If the site does not have access to water (irrigation) then it is suggested to wait for the first fall rains to wet the soil, making site and soil preparation much easier (Phytosphere Research 2001). Preparing the seed bed is quite simple but may take a bit of manual labor. A proper seedbed may be prepared by turning over and breaking up the top 25-30 cm of soil using a shovel or your hands, assuming the soil is soft enough (Phytosphere Research 2001). If you are worried about root penetration in your soil due to something such as a hardpan then you may consider augering deeper into the soil, about 60-90 cm, and then filling with the loosened soil, allowing easier root penetration (Bernhardt & Swiecki 2001). Interior live oak grows in soils of all textures but prefers shallow to moderately deep soils and often those such as gravelly loams or sandy loams that are well drained

(Fryer 2012). Production tends to be highest on sites with moderately deep soils without claypans (Fryer 2012).

2. Propagule collection, storage, and planting method

Collecting acorns should be done near sites close to the restoration location, within a mile or so if possible, and should be matched to similar conditions to the restoration site, for example, if the restoration site is a riparian area acorns should be collected from trees located along a nearby riparian area if possible (Phytosphere Research 2001). Using ecotypes collected from areas hundreds of miles away will likely not survive well because environmental conditions are very different and trees will not be well adapted to restoration sites. If a non-local ecotype did survive well at our site it could benefit genetic diversity of Interior live oak and help towards our management goal, however obtaining non-local ecotypes is time consuming and costly and using local ecotypes is generally recommended. Acorns ripen from mid-August to October and collection should be done shortly after ripening (Fryer 2012). Acorns are ready to be harvested when they easily separate from the acorn cap without tearing the seed coat (Phytosphere Research 2001). According to Fryer (2012), collecting acorns and planting must be done in the same growing season because once acorns fall off the tree they only remain viable through the rest of that growing season. Acorns may be stored in refrigeration under moist conditions until they are ready to plant, however viability of the seeds decreases significantly as time passes from acorn separation from the tree (Phytosphere Research 2001).

Before planting acorns it is recommended to sort acorns from good and bad (Phytosphere Research 2001). Acorns that are dried out, shriveled, lightweight, cracked, or have evidence of insect larvae damage such as bore-holes should be discarded (Phytosphere Research 2001). If needed before planting, acorns may be subject to test for viability. Acorns may be subjected to a float test where acorns that float should be discarded and acorns that sink considered viable for planting (Phytosphere Research 2001). If need be acorns may be cut to check the meat of the seed. Healthy acorns have a white or yellowish inside whereas unhealthy acorns have dark-brown, sometimes black insides (Phytosphere Research 2001). When planting, lay groups of 3 to 4 acorns on their side at a depth of 2 inches and space each group 6 to 8 inches apart. This increases the chances of at least one acorn germinating without overcrowding seedlings (Phytosphere Research 2001). Planting too deep will reduce seedling emergence, however planting too shallow may allow for acorns to dry out or be eaten by rodents (Bernhardt & Swiecki 2001).

3. Site Design, irrigation, management, disturbance, etc.

Planting density should be on the order of 80 planted sites per acre, hopefully providing about 40 trees per acre (Harris 2013). It is unlikely that germination will have 100% survival rate, however if we have more than 40 trees germinating per acre a manager should go through and select seedlings that are doing best until the site contains about 40 trees per acre. There is no good evidence supporting how to accomplish this density, just a suggestion of historically oak density around 40 trees per acre in oak woodlands. Seedlings that are growing well should be selected and kept, but those that are underdeveloped or chronically wilting should be removed from the site.

Many aspects must be considered in order to have a successful restoration site. Sites must consider herbivory pressures, disturbance, water security, and many other factors. If this area will be grazed by livestock, which many are, then fenced exclosures and/or tree shelters should be used to help provide protection for seedlings until they are well established and can survive some amount of herbivory (Harris 2013). It is important to protect seedlings from browsing herbivores until they reach heights of approximately 6 – 8 feet (McCreary and Tecklin 2005). Most practitioners recommend using tubes or wire cages to protect seedlings from herbivory because they have relatively low cost, are easily

maintained, and one size can be used until the tree is mature enough (Harris 2013). Competition from exotic annuals should be minimized and can be done through mulching or mowing around seedlings (Harris 2013). Avoid disturbing the root zone by mounding soils/mulch or by compacting soils (Sacramento Tree Foundation 2007). Do not add so much mulch that soils cannot dry out as this may promote fungal disease in the roots (Sacramento Tree Foundation 2007). Rocks should also not be used around Interior live oak because they compact soils and retain heat which ends up injuring roots (Sacramento Tree Foundation).

If the site must be irrigated, drip irrigation is preferred for use on seedlings that have already germinated (Harris 2013). Irrigation should be avoided as much as possible because plants may become water stressed when scheduled irrigation is discontinued, unless irrigation is to ensure plant survival until it can survive on its own (Harris 2013). Sites that are exceptionally dry should be watered with about 1 to 2 gallons per planting site in July and September for the first two years (Anderson 2010).

Disturbance is important for Interior live oak, especially fire. Interior live oak has adapted to fire by sprouting from buds on the root crown, even saplings are known to resprout (Fryer 2012). Native Californians were well aware of the fact that the most diverse, healthy, and productive oak woodlands occurred due to disturbance from frequent, light surface fires (Anderson 2007). Fire clears open space for oaks and reduced competition. Without fire, oaks may be encroached by more shade tolerant species, reducing productivity and development (Anderson 2007). Although it is not confirmed, Anderson (2012) suggests burning in oak woodlands might reduce, and possibly even kill diseases affecting oaks.

4. Sustaining population & conservation of Interior live oak

Many oak woodland restoration projects involve planting acorns however restoring oak canopy may be done by physically protecting oaks that are establishing naturally (Bernhardt and Swiecki 2001). Suppressing competition and herbivory in high quality sites may be enough to allow Interior live oak populations to increase more naturally. These oaks would also be highly suited for the areas they are germinating because they are better adapted to the environmental conditions. There are many keys to protecting oaks that we already have. One way to protect oaks is through regulations. Many counties understand that oak woodlands have great natural and cultural history and therefore require a permit to remove or even prune any oak trees with a DBH of at least 6 inches (Sacramento Tree Foundation 2007). Landscaping may also be a cause for concern when considering Interior live oak conservation because landscaping may damage trees or even allow diseases to infect mature oaks. During landscaping or construction it is important to not disturb the root zone of mature trees by covering with mulch, rocks, or concrete/asphalt, compacting soil, or removing soil from the area (Sacramento Tree Foundation 2007). This activity can damage roots of mature oaks and cause death. We must also consider disease in order to better conserve and sustain Interior live oak populations. Moisture around the root zone poses a threat to mature oaks because it allows pathogens to grow and possibly affect the tree (Sacramento Tree Foundation 2007). This means that we must not water mature oaks or place mulches around the root zone that hold too much moisture and allow unwanted fungal growth or pathogen infestation. Although Interior live oak has not been identified as susceptible to the Sudden Oak Death pathogen it is still vulnerable to other pathogens such as Sunscald and Oak anthracnose, which can harm the tree and ultimately cause death (Swiecki 2006). For this reason it is important to not plant anything within 10 feet of the trunk of a mature tree to reduce chances of contracting disease (Sacramento Tree Foundation 2007).

5. Constraints, areas of concern, further research

Many constraints exist on restoration. Because Interior live oak is highly dependent on mycorrhizal fungi relations, soils are extremely important. Each site will contain different soil conditions, and some sites may not have the correct fungal conditions to support Interior live oak well (Harris 2013). A manager can test for the correct mycorrhizae by sending a soil sample to a lab for analysis. Each soil must be prepared differently for each restoration site, making restoration difficult because these conditions must be identified and addressed. For example, a densely compacted soil or soil with a thick hardpan should be broken up and loosened to allow for better root penetration. Grazing from rodents is much more difficult to control than above ground herbivory (Harris 2013). This poses a problem for establishing oaks in the short term and possibly maintaining oak populations in the long term. Climate change poses a threat to Interior live oak because unknown future conditions are unknown and sites may become unsuitable to support Interior live oak (Harris 2013). Funding, as always, is an overriding constraint because labor, maintenance, and follow-up work often require paying personnel (Harris 2013).

One major area of concern in oak trees is Sudden Oak Death, abbreviated as “SOD.” Although SOD has not been proven to affect Interior live oak according to Fryer (2012), a mutation in the disease, or an entirely new but similar disease, could be carried to California that does affect Interior live oak. A spread of disease is of great concern because Interior live oaks may be some of the only oaks we have left if SOD is not controlled in the near future. To address this problem managers are advised to be very careful with equipment and diligently clean equipment such as shovels, augers, and rakes with a bleach solution to reduce chances of spreading the SOD pathogen to uncontaminated sites. *Phytophthora*, the genus of pathogen that causes Sudden Oak Death, can move via rain splash or wind-driven rain (Rizzo 2002). It is unclear how *Phytophthora* has managed to move across such large distances but it is also believed to travel via infected plant material or soil, ornamental hosts, or firewood (Rizzo 2002). Washing tools and boots with a weak bleach solution before traveling from site to site will help reduce the spread of the *Phytophthora* pathogen.

Further research areas might include identifying the mechanisms that makes Interior live oak resistant to SOD to possibly introduce to other oak species, how fire can be used responsibly to maintain Interior live oak, and how climate change and urbanization might affect Interior live oak populations. Another area of research might include the cultural role oaks play in contemporary society and how they can help bridge the natural and urban world.

C. Monitoring Plan

1. Successful Restoration and project site

Sites that have been planted should be monitored from early March to early June (Harris 2013). Monitoring should include checking for seedlings, removing weeds inside shelters, controlling nearby competitors, and removing shelters from plantings that have failed (Harris 2013). If the trees do not germinate within a month new acorns may be planted in their place to attempt to get germination. Sites should be monitored at least 2 times per monitoring period to ensure plants are remaining healthy and actively growing during the growth period in the spring. Monitoring should be done up to 15 years but after the first 5 years monitoring may be reduced to only once a year midway through spring.

Site history would be important to consider, especially if the site was historically oak woodland. Historical information about the site such as vegetation type, industrial uses, or environmental conditions can help us monitor and determine how successful sites are based on that information. Monitoring questions to consider might be how long on average it takes for Interior live oaks to mature, how many seasons oaks should be watered, how much water Interior live oaks require during those initial growing seasons, and possibly how local ecotypes vs. nonlocal ecotypes perform on the site. These questions are

important because there is not a lot of good information available for Interior live oak that answers these questions.

A new statewide oak survey should be conducted to address how much and where oak woodland is left in California and how our proposed oak woodland compares to those woodlands. After this survey is conducted we can adjust restoration plans accordingly to structure our woodland similarly to healthy woodlands within 5 miles of our restoration site. Comparing restoration sites to nearby healthy oak woodlands will give us an idea of how our restored oak woodlands are doing in comparison to natural stands. This will help us determine success because we would expect the sites to be similar and provide similar ecosystem and community services.

2. Site needs intervention

Sites that have partially established may need assistance to get the restoration back on track. Partially established sites are sites that have lower stand densities than similar oak woodlands nearby. If there are no sites within 5 miles we should compare to the nearest similar stand of Interior live oaks or aim for the threshold of around 40 trees per acre. A stand should be partially established if there are less than 25 trees per acre and no nearby site to compare with. New actions for restoration may follow at site determined “partially failed” to help increase establishment. Actions may include installing irrigation for water stressed seedlings, replanting seeds that have been eaten by herbivores, fixing cages around plants, and removing weeds and competitors. Cages should be tall enough to protect saplings until they are about 6 feet tall but should let sufficient light reach the tree. These sites may need more monitoring and should be monitored up to 5 times per year starting in early March and ending in late September. Once restoration is back on track monitoring may be reduced to 2 times per year in early March and June for up to 15 years if need be. We should attempt to answer questions such as optimal plant density for Interior live oak if this occurs. We should also try to answer research questions such as how source types perform under different conditions. For example, how do acorns from a riparian Interior live oak perform in an upland planting site? This may be a good question to answer at these sites because oak sites that have partially failed may be because our source types or ecotypes were improper for chosen areas at the restoration site.

3. Site failure

Sites that have completely failed and only have a density of less than 10 trees per acre may need to be closed down to public access and grazing and re-planting attempts may be done. Fencing the area or fencing around individual trees until they are about 6 feet tall to reduce herbivory from large browsers may be needed. Planting container stock rather than acorns may be required, meaning irrigation would likely need to be installed after other planting has already occurred. Monitoring should occur once a month for the first 5 years if replanting has been chosen. If the site is back on track and consider “successful” then monitoring may be reduced if the manager sees fit. If the site is determined a total loss and less than 3 trees per acre germinate then materials should be collected from the site, and a new site should be chosen for restoration. A research question to answer under this situation might be a comparison between container stock Interior live oak and on-site acorn planted trees under similar site conditions. This may be easier to study since it might be necessary to plant container stock in order to reach our goal of around 40 trees per acre or a similar plant density as a natural stand within the 5 miles radius.

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Fremont cottonwood (*Populus fremontii*)

Elizabeth Godkin

Part 1: Project Background and Justification

Background & Justification

Populus fremontii is a large deciduous riparian tree species native to California (Jepson Herbarium 2015). While the species occurs through several states, many riparian habitats (and consequently, cottonwoods) have been removed or declined in the last century. A survey in Arizona first in 1914 and then 1944 marked a 90.9% decline of the Fremont cottonwood and other cottonwoods within the survey site; while previously *P. fremontii* had been a cover type, by 1964 the tree remained in scattered bunches (Forest Service 2015). Historically, *Populus fremontii* dominated many riparian stands; however, at present, anthropogenically altered hydrologic cycles from damming and stream diversion have resulted in shifts of species composition towards domination by invasive species (Lite and Stromberg 2005). Smaller, less frequent floods, stabilized flow patterns, and channelization have induced drought stress in many cottonwood populations. To a lesser degree, cattle grazing has prevented the persistence of many seedlings into maturity (Forest Service 2015). Across its range, the historic association with the *P. fremontii* to the discovery of water is unwavering and the cottonwood stands represent a key component of “climax riparian vegetation” in the Sacramento Valley (Forest Service 2015). For these reasons, *P. fremontii*’s persistence through the landscape may serve as an indicator of a local water table’s conditions. Further, cottonwoods help maintain channel morphology by stabilizing the gravel bar and sediment, assist with groundwater recharge, mediate floods, (USDA 2015) and furnish the landscape with numerous habitats for many species of birds and other wildlife (Forest Service 2015).

Literature review

Characteristics of *P. fremontii*

Plant Description

- The cottonwood is a large riparian tree from up to 35 meters tall with whitish cracks on furrowed bark as it ages, and the canopy contains glabrous simple cordate-shaped leaves with crenate margins and petioles half the length of the blade (Jepson Herbarium 2015)

Reproduction

- Cottonwoods are dioecious and produce slender catkin pendants. The wind-dispersed fruit comes in the form of an achene attached to a silky hair; the name cottonwood refers to the tree’s appearance from March through April when the achenes are produced and found in greatest numbers. (USDA 2015)
- As establishment from seed is often difficult, propagation techniques rely on cuttings and seedlings germinated within containers (USDA 2015). Their initially rapid growth renders them ideal for many restoration projects (Forest Service 2015)
- Cottonwoods require bare gravel or a sandy substrate with adequate moisture often characterized by natural flood regimes; as a result, cottonwoods tend to dominate riparian forests of lower terrace deposits and stabilized gravel bars (USDA 2015)

Distribution and Habitat

- While this species distribution extends throughout California and across Nevada, Arizona, Texas, New Mexico and into areas of Mexico, cottonwoods are found in the greatest abundance in the San Joaquin and Sacramento Valleys (USDA 2015). Cottonwood can exist in chaparral-mountain shrub, big sagebrush, pinyon-juniper, and desert shrub communities so long as sufficient moisture is present through the spring (Forest Service 2015)

- While *P. fremontii* can occur in homogenous stands, they tend towards growing in association with *Salix* spp., and other riparian trees and shrubs. (Forest Service 2015).

Tolerances and preferences

- Cottonwoods thrive within a mean annual precipitation range of 1 to 4.5 inches (25.4-114.3 mm). (Forest Service 2015)
- This species occurs through a wide elevation range 0 to 6,500 feet (0-1,981 meters) (Forest Service 2015)
- While cottonwoods tend to occur in areas with steady water supplies, they can also survive with spring water alone. In this kind of incredibly arid setting, the species tends towards a more shrub-like form. (USDA 2015)

Succession

- Hydrologic cycles altered by damming, stream diversion have resulted in shifts of species composition towards domination by invasive species including tamarisk and saltcedar. (Lite and Stromberg 2005).

Requirements

- Smaller, less frequent floods, stabilized flow patterns, and channelization have induced drought stress in many cottonwood populations. Stream diversion and groundwater pumping can reduce riverine surface flows to a level insufficient to support cottonwoods and associated riparian vegetation. (Forest Service 2015)
- The center of the water channel should be the lowest point with smooth slopes extending upwards on either side. Vegetation that resides on stepped banks carved by downcutting often suffer from water stress. (USDA 2007)

Interactions

Cottonwoods add diversity to many riparian corridors of the American Southwest through common associations and habitat creation.

Flora

- While *P. fremontii* can occur in homogenous stands, they tend towards growing in association with *Salix* spp., other trees, and shrubs. Particularly in Californian riparian woodlands, Fremont cottonwood is associated with *Juglans hindsii* (California black walnut), *Quercus agrifolia* (coast live oak), *Quercus lobata* (valley oak), various *Salix* spp. and other species. (Forest Service 2015)
- Cottonwoods are easily and often affected by the hemiparasite, mistletoe and can serve as vectors along riverine corridors (USDA 2015).
-

Fauna

- Within California, cottonwood-willow communities produce the greatest amount of over story canopy coverage compared to all other desert riparian vegetation types. With the wide range of perches, nest sites, and foraging substrates, these areas promote about 2 to 5 times more breeding bird stories than communities with lesser canopies. For this reason, cottonwood has been commonly used to restore, enhance, or create bird habitat in riparian sites. Associated avian species include golden eagle, Swainson's hawk, red-tailed hawk, and Bell's vireo all of which establish themselves in the live crowns of these trees and show a high affinity towards cottonwoods . Through senescence, many cavity-nesting birds reside in the dead trunks and rachi of cottonwood. (Forest Service 2015) While some invasives, such

as saltcedar can replace native cottonwoods both physically and as habitat, many migratory species show an affinity for or require cottonwood stands (Ellis 1994).

- Furthermore, many cottonwood communities provide cover, nesting and foraging spaces for other bird species, elk, deer, ringtail, squirrels, beavers and more rodents. These communities also help perpetuate mesic habitats for upland amphibians and reptiles. (Forest Service 2015)

Uses

- Cottonwood produces moderately lightweight, light-colored wood with a uniform texture and fairly parallel, straight grain. While the wood is relatively soft, the high strength-to-weight ratio proved cottonwood timber viable for some applications. Primary products include lumber, veneer, and pulpwood often used to produce fenceposts, crates and boxes for food storage and pallets or to be used as firewood. Additionally, the wood shavings from Fremont cottonwood are used in livestock bedding, mulches, packing material, and insulation. (Forest Service 2015)
- *P. fremontii* also works well for avian habitat restoration and creation, and is planted as an ornamental shade tree or windbreak.

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Part 2: Project Goals and Management Plan

• Goals

1. Quantify existing populations and estimate overall decline of *P. fremontii* in the Central Valley of California to conserve remnant populations. Identify and measure remnant patches of riparian woodlands in the Central Valley dominantly covered by cottonwood to determine prevalence and establish multiple reference sites with varying site conditions (including differences in degree of urbanization, changes to hydrology, soil type etc.). Identify with Additionally, use multiple estimates of historic populations and observed land use changes to measure the Central Valley metapopulation's decline into the present.

2. Locate potential (unexploited or degraded) corridors of riparian woodlands suited to *P. fremontii* and restore conditions as necessary.

Populus fremontii needs particular hydrologic and geomorphological conditions. Cottonwoods require a moist environment through juvenile stages. Once established, cottonwoods can survive with the bare minimum of spring water (however, species under these conditions tend towards a shrub-like form). Maintaining stands of *P. fremontii* will require removing less water, smoothing incised channels, removing invasive species, and/or eliminating incidents of overgrazing. As cottonwoods' life history are intertwined with riverine and fluvial geomorphological processes, these species require gravel bar's self-maintaining processes of continual creation and erosion.

3. Establish a genetically diverse population of *P. fremontii* supported by it's interactions with the ecosystem.

Propagate and distribute a spatially and genetically diverse population across a constant temporal interval. Prioritize diversity to ensure the success of a reproductively viable, resilient metapopulation capable of migrating between patches.

Enhance *P. fremontii*'s community role as a preferential habitat for numerous migratory birds and ecosystem facilitation of soil. Distribute dense areas for rehabilitation with propagations every 10 meters or more adjacent along the stream bank if site geomorphology permits the juvenile's root depth access to the water table to the translated specimen. Altered hydrologic conditions may not be possible to revert to historic conditions; however in the case of extreme geomorphology, banks will have to be stabilized and recreated into flatter slopes.

- Restoration Plan

1. Conservation and Reintroduction

Identifying the frequency, size, and distribution of remaining patches of riparian woodlands with *P. fremontii* will first determine the degree of intervention necessary to restore the Central Valley's cottonwood population. As 89% of riparian woodlands in the Central Valley have been lost (Schoener 1987), so much of this intervention highlights reintroducing this species to sites invaded by non-native species. Mapping and isolating key areas with the potential for natural wind and water dispersal can aid species longevity and increase resilience. In addition, this quantification can help establish a reference site with which to compare differences in degree of urbanization, changes to hydrology, soil composition, water salinity, invasive domination (i.e. regime shift), or so on.

Using multiple historical accounts of the cottonwood metapopulation's decline into the present and recorded land use changes can measure the species' persistence.

Synthesizing this information could develop the trajectory of Central Valley's riparian woodland habitats.

2. Propagation and Transplanting

Timing the process of cottonwood propagation and transplanting is crucial due to the seasonal hydrologic variation and the short-lived viability of it's seeds (Schoener 1987). Since the seeds only last one to three weeks and disperse from March through April, great care and planning is needed to create a genetically diverse seed bank.

Since cottonwoods produce over 25 million wispy achenes (Stettler 2006), seed collections can be numerous per specimen, but should be balanced with diversity in site adaptations. For example, 100 seeds at each 50 sites would provide an sufficient sample (given that there are numerous trees producing many seeds at each site). The moist gravel bar required for *P. fremontii* to propagate and thrive through it's juvenile stages exists through the movement of meandering rivers. Low alluvial corridors running adjacent to rivers fulfill the demanded access to water and coarser gravel bars provide the proper substrate.

3. Habitat Modification

To maintain stands of *P. fremontii*, precipitation must naturally fall within the time frame of cottonwood dispersal in March through April. While cottonwoods can persist after juvenility in conditions so extreme as to only supply water once every spring, the species will become shrub-like. Where there is ample competition with invasive species such as saltcedar, these should be removed and closely monitored for. Maintaining stands of the species will require close oversight of groundwater levels and the state of the aquifers. Groundwater levels must be monitored and maintained so that output does not exceed inflow. Where subsidence has occurred, soils can no longer store as great a volume of water. This in turn damages the cottonwood's ability to establish. Additionally, overgrazing can eliminate saplings and prevent propagation. The cottonwoods' life history are intertwined with riverine and fluvial geomorphological processes because these species require a gravel bar and inundation for propagation. The self-maintaining processes of continual sedimentation and erosion are regulated by the presence of cottonwoods. In scenarios where channels have been deeply incised, trees will no longer easily establish upon the stream bank. Extreme cases require changing the geometry of a stream bank cross section.

- Monitoring Plan

Maintenance, management, and monitoring of the site(s) will continue across the species' life history. Intensive maintenance will be required until cottonwoods have grown large enough to outcompete other vegetation, resist mechanical damage, and can access water supplies year-round. Transplanted cottonwoods propagated by seed may require competitor removal (especially saltcedar). Once relatively mature, monitoring can become less frequent; however, it should persist through the consequent generation's establishment to ensure the necessary conditions for propagation and long-term success have been created. Strong communities of *P. fremontii* will be indicated by their domination at a density of nearly 400 individuals per hectare growing within patches of riparian woodlands (Stettler 1996). Increasing density of *Populus-Salix* associations along with a growing patch size indicates persistence of gallery communities. As the community grows, other benefits follow. Increasingly stabilized soils can be recorded by measuring decreasing amounts of topsoil lost compared to previous flooding or large storm events. Sedimentation through fluvial meandering regulated by these communities will become slower. These indicators describe the success of a species' restoration, or when intensive management can be supplanted with monitoring.

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California buckeye (*Aesculus californica*)

Gwen Green

Part 1: Project Background and Justification



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Rank	Scientific Name and Common Name
Kingdom	Plantae – Plants
Subkingdom	Tracheobionta – Vascular plants
Superdivision	Spermatophyta – Seed plants

Rank	Scientific Name and Common Name
Division	Magnoliophyta – Flowering plants
Class	Magnoliopsida – Dicotyledons
Subclass	Rosidae
Order	Sapindales
Family	Hippocastanaceae – Horse-chestnut family
Genus	<i>Aesculus</i> L. – buckeye
Species	<i>Aesculus californica</i> (Spach) Nutt. – California buckeye

(*Aesculus californica* (Spach) Nutt. California buckeye. USDA Natural Resource information Center 2015.)

Pictures for ID:

Pictures courtesy of Pacific Horticulture Society, unless otherwise noted
(<http://www.pacifichorticulture.org/articles/california-buckeye-a-tree-for-all-seasons/>)



California Buckeye in bloom



Single inflorescence

Expanding Buds in Late winter

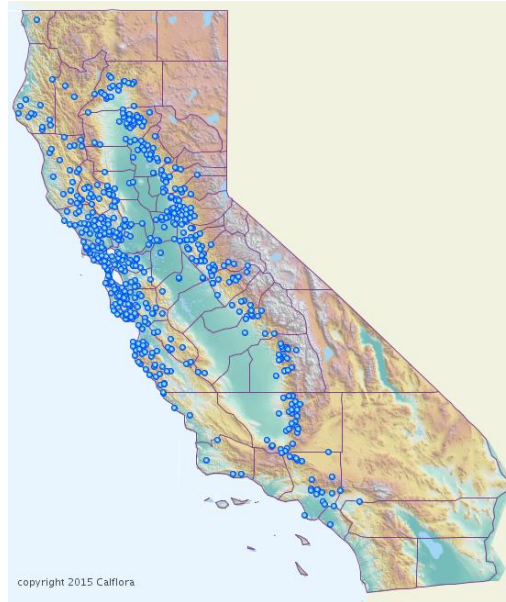


By Dick Baugh

Botanical Details:

Habitat:

Native to California and Southwestern Oregon. Endemic to these regions. Thrives in the” foothills, valley margins, oak savannah and forest, and chaparral openings.” - See more at: <http://www.pacifichorticulture.org/articles/california-buckeye-a-tree-for-all-seasons/#sthash.xAU5yuRg.dpuf>



Height: up to 15-30' often multi-stemmed

Conditions Comments: California buckeye drops its leaves in July or August, but if given ample moisture it will hold them into fall.

Leaf: The leaves of California buckeye are palmately compound with five (rarely seven) leaflets. The leaflets are 6 - 17 cm (2.4 - 6.3 in) long. The petiole is long. The leaf margin of the leaflets is toothed.

Leaf shape: palmately compound

Leaf margin: toothed

Leaf position: opposite

Fall foliage: brown colors

Flowering: April, May, June

Blossom color: white-pink, Fragrant

Blossom description: The inflorescences are upright piston-like (flower candle) The inflorescences up to 20 cm (7.9 in) high. The flower color is white to pink. Gender distribution: monoecious

Fruit: The seeds are surrounded by a green fleshy and spiky capsule. The seeds are brown, glossy and up to 4 cm (1.6 in) in diameter.

Branches: The twigs are light brown with lenticels.

Bark: The bark is smooth, finely fissured and light brown.

Root: Shallow-rooting plant

Location: Sun to half-shade

Soil: moist well-drained soils, medium drought tolerance. Will tolerate poor dry soils

Ph value: slightly acidic to alkaline

Usage: single tree, in America forest tree

Use Wildlife: Chipmunks and squirrels consume the seeds, but bees are poisoned by the nectar and pollen.

Warning: Seeds are poisonous to humans if eaten. Sensitivity to a toxin varies with a person's age, weight, physical condition, and individual susceptibility. Children are most vulnerable because of their curiosity and small size. Toxicity can vary in a plant according to season, the plant's different parts, and its stage of growth; and plants can absorb toxic substances, such as herbicides, pesticides, and pollutants from the water, air, and soil.

Propagation: Seeds and soft wood cuttings. Fall-sow seeds germination easy.

Appearance description courtesy of tree-guide.com (<http://www.tree-guide.com/california-buckeye>) and Lady Bird Johnson Wildflower center the University at Texas, Austin (http://www.wildflower.org/plants/result.php?id_plant=AECA)

Background:

California Buckeye (*Aesculus californica*) is classified as a shrub or mounding tree. Reaching only 15-30 feet high this deciduous shrub provides outstanding fragrant flowers, deep colored foliage and grey bark with an interesting branching character. California Buckeye is endemic to California and thrives in dry foothills and canyon slopes. It can also be found in Chaparral and foothill woodland areas, as well as in the Sierra Nevada and coastal ranges. (Perry 1989 pg. 42). *A. californica* has adapted to its native Californian Mediterranean climate by growing during the wet late winter and spring months and entering dormancy in the dry summer months. (Elna, 1984 pg. 74) California Buckeye is not known to have many pest or disease problems, even when stress with drought. Because the fruit and foliage is poisonous to animals, people and bees it does not have much commercial value. (Benvie 2000. pg. 36) The bark, leaves, stems, fruits, and seeds all contain glycosidal compounds which cause hemolytic action on red blood cells and depress the central nervous system when ingested (Howard 1992 pg.2). But because of its fire resistance, ability to be used on slopes to prevent erosion, and its wide and diverse habitat distribution and tolerances, these trees have grand landscape restorative power and purpose.

Botanical Characteristics:

Small tree or shrub reaching 15-30 feet high, with the crown typically being as broad as its height. These trees are multi-trunked with smooth grey bark on trunks and branches. The leaves are large, dark green and palmately compound and divided into five to seven leaflets with serrated edges (Perry 1989. Pg. 42). The leaves provide splendid summer color when the tree goes dormant to avoid the long dry summer. New growth commences early spring and leaf drop happens again mid-summer to early fall. The flowers are pale pink to white and are arranged in erect panicles eight inches long. They are very fragrant and quite showy. The fruit is large, smooth, light orange-brown and pear or fig shaped. Within, the capsules contain up to six large glossy brown seeds (Benvie, 2000 Pg. 37).

Reproduction:

California Buckeyes reproduces sexually by seed. The average tree produces 100 seeds per year. Being that the fruits are large it is not well dispersed by wind, birds or animals. Being round and heavy they tend to roll downhill and if come into contact with running water the seed is then distributed to a new site. (Encyclopedia of Stanford trees, 2015). Seeds shed between November and February and are viable for one year. Germination will occur within several weeks of shedding or planting if the soil temperature is above 40 degrees F. If the temperature persists below 40 degrees for 2 months or more the seeds are susceptible to fungal infections or desiccation (Gordon, Sampson. 1939 pg. 95). There is no specific information on the rate of seed desiccation but seeds lose viability quickly when stored (Leon, 2015) and should be planted as soon as possible after collection. Asexually it can root from a stump or crown and vegetative propagation is not generally successful once detached from the parent plant.



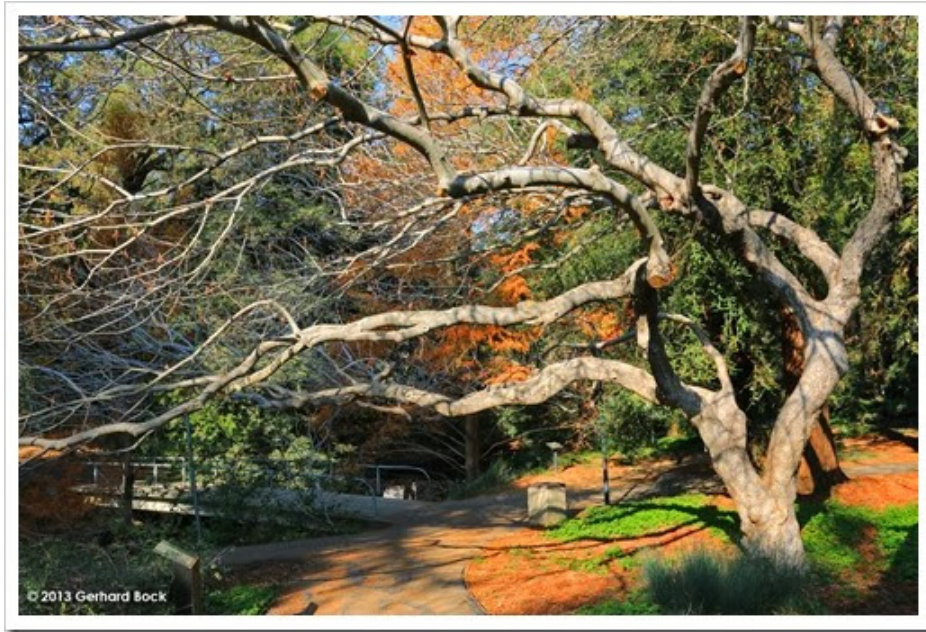
(<http://www.watershednursery.com/wp-content/uploads/2012/08/aesculus-californica-coyote-creek1.jpg>)

Restoration Advantages:

California Buckeye has a long life span. It can live for 250-280 years. This large shrub can be grown in a wide range of habitats. It has been found to live in crowded, moist and part sun locations as well as in full sun, standing alone. It is adaptive in that it can inhabit grasslands and coastal sage scrub areas as well as hilltops, slopes and riparian habitats. It is often accompanied by native oaks and California bay laurels and even mixed evergreen forests with Ponderosa pines. This diverse shrub is tolerant of drought once established, but does require regular water for the first couple of years. The tree avoids loss of water from transpiration through the leaves by dropping them in midsummer. (Encyclopedia of Stanford Trees, 2015)

A. californica, can tolerate a pH as low as 4.0 and as high as 8.0 and can live in clay, serpentine soils. Because these small trees act as soil binders they are useful to prevent erosion in hill top stream or river banks and on steep slopes areas throughout California (Goldner 1984). It will tolerate occasional seasonal flooding and is fire resistant in that California buckeye will recover rapidly following a fire. It will send out new shoots during the first growing season. Growth in subsequent seasons is also rapid, with the plant sometimes exceeding its pre fire mass within a few years (Mooney, Hayes 1973). All of these attributes makes it useful ruderal or stress tolerant (Grime, 1977) specimen for restoration sites.

Although the flowers are toxic to non-native bees, native bees and butterflies are attracted to its pungent large flower clusters and chipmunks and squirrels enjoy the large seed clusters. (Native Plant Database) Despite its toxicity, California buckeye flowers, leaves, and shoots are palatable to livestock and wildlife. It has been listed among the 20 chaparral browse plants most preferred by cattle and black-tailed deer (Hedrick 1951 pg. 112).



Management

California Buckeye (*Aesculus californica*) can be used for restoration of California native upland habitats, creating a buffer for riparian habitat and soil erosion control. This plan will assist managers in the proper collection of species, site preparation, planting, maintenance and monitoring needed to establish *Aesculus californica*. This plan will also address benefits, disadvantages and uncertainties that may accompany the use of California Buckeye in restorative situations.

Goals:

Successful introduction and establishment of California Buckeye (*Aesculus californica*) to restoration area. Specific to Northern California, valley.

Management Advantages:

Wildlife importance:

Despite its toxicity, California buckeye flowers, leaves, and shoots are palatable to livestock and wildlife. It has been listed among the 20 chaparral browse plants most preferred by cattle and black-tailed deer (Hedrick 1951 pg. 112). California Buckeye trees are used as a nectar source for many native butterflies such as Spring Azure and Echo Blue who use the shrub as a larval food source (Williamson, 2014). Native bees and butterflies are attracted to its pungent large flower clusters and chipmunks and squirrels enjoy the large seed clusters (Native Plant Database 2015). *Geographical importance:*

A. californica acts as a soil binder and is useful to prevent erosion in hill top stream or river banks and on steep slopes as well as providing stabilization (Goldner 1984). Because California Buckeye sprouts from the root crown when there is above ground damage it is considered fire resistant, the seeds however will not survive fire (Howard, 2015). It will send out new shoots during the first post-fire growing season. Growth in subsequent seasons is also rapid, with the plant sometimes exceeding its pre-fire mass within a few years (Mooney, Hayes 1973). It can also tolerate seasonal flooding but the maximum is uncertain.

Management Disadvantages:

Toxicity:

Most parts of the California buckeye are toxic to animals and some insects. The bark, leaves, stems, fruits, and seeds all contain glycosidal compounds which cause a rupturing of red blood cells and may weaken the central nervous system when eaten (Homer, 1994), (Little, 1976). The pollen and nectar are toxic to non-native bees, being that bees are the main pollinator of this shrub, this can pose a potential problem in many aspects (Homer, 1994). Losses of adult non-native honeybees and their larvae due to poisoning can be severe (Clark 1937). Human beings have been poisoned by eating honey made from California buckeye (Little, 1976).

Summer dormancy:

The tree avoids loss of water from transpiration through the leaves by dropping them in midsummer (Encyclopedia of Stanford Trees, 2015). Because of this adaptation to survive dry hot summers, the California Buckeye does not provide adequate summer shade or habitat for wildlife. Depending on moisture levels and wind, some trees may have green leaves at the tips or only drop a portion if adequate moisture is obtained (Raiche, 2009). The seasonal summer leaf drop can cause large amounts of litter and be a potential fire hazard (Howard, 1992)



Heinphoto.com

Addition management considerations:

California buckeye is susceptible to spray or injection/cut surface treatments of phenoxy herbicides and picloram (Bovey, 1977), (USDA, Forest Service, 1973). Hand or mechanical brush control is ineffective unless the root crown is removed (Van Dersal, 1938).

Restoration Plan:

Site preparation:

Patch scarification should be done by managers prior to planting to remove all vegetation in the planting area and to allow space for hand planting. (Lof, 2012)(MDNR, 2015). This method will provide open sites for tree establishment without having to remove all landscape material. Patch scarification will eliminate competition for young *A. californica* seedlings, is cost effective, maintains wildlife habitat and requires minimal topsoil removal. (MDNR, 2015) Sites consisting of heavy upland brush may need additional selective herbicides (Holden, 2015, pg. 74) or tracker mowing (U.S. Fish and wildlife service, 2014) to clear vegetation for tree planting. This should be done with adequate time spacing to assure that herbicide is no longer present in the soil upon planting seeds and trees. Seeds should be planted directly into the ground. Soil should be loosened at a depth of 10 inches being sure to remove all roots, rocks and other debris (Bridget, 2015). If seeds are collected from the surrounding area and similar habitat there is no need for soil amendment. Site preparation should be accomplished by mid-July to early September to ensure that plantings are in the ground by late September through early December (Rudolph, 1974)

Growth requirements for best establishment:

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pH Range	5.5–7.5 pH
Precipitation Range	14–14 inches/yr
Planting Density	300–700 indiv./acre
Soil Textures	Coarse
Soil Depth for Roots	36
Minimum Frost-Free Days	175 day(s)
Salinity Tolerance	None
CaCO₃ Tolerance	Low

Physical Characteristics to consider when establishing:

Bloom Period	Summer
Displays Fall Colors	Yes
Shape/Growth Form	Single Stem
Drought Tolerance	High
Shade Tolerance	Intolerant
Height When Mature	40
Vegetative Spread	None
Flower Color	White
Flower Conspicuousness	No
Fruit/Seed Abundance	Medium
Fruit/Seed Seasonality	Summer Fall
Seed Spread Rate	Slow

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Seed Collection and plant stock:

California Buckeye is generally not commercially available. Plants can be obtained by bareroot stock or seed propagation (USDA, 2015). Root crowns sprout readily (Howard, 1992) when roots are preserved. Removal of the crown and bareroot transplanting can be done, but the possible damage to and drying out of roots makes this type of propagation timely, intensive and less practical when compared to seed propagation.

Greenhouse production:

Fruits ripen from September to October and are dropped from November to December (Rudolph, 1974). Seeds should be collected between September and December. Seeds should be collected from surrounding areas and within a similar habitat to ensure preservation of native specimens and successful site adaptation. Collection from more than one site to promote diversity is preferred (Salas, 2015). Seeds should be collected from fallen fruits on the ground or collected directly from the tree. If the seeds are to be propagated in a controlled greenhouse facility, husks should then be removed and the seeds should be refrigerated to prevent desiccation and enable cold stratification which the seeds require to germinate. Seeds should be soaked in water for 24 hours and dipped in a 5% bleach solution for 1 minute upon which they should be placed in a plastic bag with sterile perlite and then be placed back in the refrigerator for approximately 6-8 weeks (Young, 2001). When a radical can be seen, sow each seed in containers filled with standard 50% potting mix and 50% native soil. Germination

rate is approximately 95% within 21 days (Young, 2001). Plant at depth equal to the height of the seed with one seed per pot.

Field seed planting:

California Buckeye does well to be sown directly in the field as well as greenhouse production. Because seeds dry and shrivel quickly it is important to keep the seed moist and plant into the ground as soon as possible (Native Plant Database, 2015). There is no specific information on the rate of seed desiccation but seeds lose viability quickly when stored (Leon, 2015) and should be planted as soon as possible after collection. Again because these seeds require cold stratification it is important to consider temperature at the time of planting. Planting seeds as soon as possible after collection will help provide as much of a natural cycle as possible. Planting 2-3 seeds per hole will ensure higher germination rates taking into consideration seed predation by squirrels and deer. Expect a 60-50% germination rate (Bridget, 2015). Thinning of seedlings may need to be done periodically. Place seeds halfway in the soil, with the light area of the seed facing down into the substrate (USDA, 2015). Keep soil moist until sprouting occurs, at that time provide seedlings with 1 inch of water per week (Bridget, 2015). Germination will occur within several weeks of planting if the soil temperature is above 40 degrees F. If the temperature persists below 40 degrees for 2 months or more the seeds are susceptible to fungal infections or desiccation (Gordon, Sampson. 1939 pg. 95). Because of this possible factor, (depending on the particular site) a combination of direct field planting and greenhouse production is recommended. Space plantings or thin seedlings so they are far enough apart that each tree can reach its full size. This would be approximately 20' x 20' (Leon, 2015). This will ensure full size growth and help prevent disease with adequate air flow.

Seed and plant stock field care:

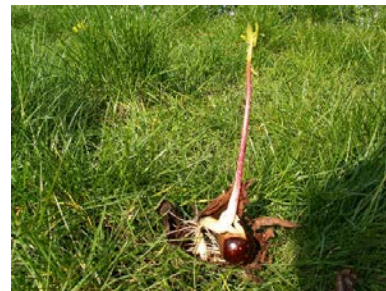
California Buckeye does require adequate water for the first year until established (USDA, 2015). Once established, drought tolerance is high, and no further care should be needed other than monitoring, which is explained below. Soil should remain moist after planting and for the first year of growth. If there is not adequate seasonal rain, supplemental watering will need to be done. California Buckeye requires 13-14 inches of water per year for good establishment (USDA, 2015). This shrub is not very shade tolerant so seeds should be planted in a full-sun to light shade area. Tree density should be approximately 300-700 per acre if establishing a California Buckeye upland forest (Garden Guides, 2015). Fertilization is not necessary if site preparation is followed as instructed.



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<http://en.academic.ru/dic.nsf/enwiki/698646>

Companion tree recommendations:

Quercus spp. Oak (Howard, 1992)

Q. wislizenii Interior live oak (Howard, 1992)

Q. douglasii Blue oak (Howard, 1992)

Calocedrus decurrens, California incense cedar (Pacific Horticulture Society, 2015)

Torreya californica. California nutmeg (Encyclopedia of Stanford Trees, 2015)

Monitoring Plan:

Evaluation and annual inspection of vegetation should be done for a period of five years (Condit, 2010, pg. 2). Close monitoring of tree establishment should be done every 3-4 months for the first year. Inspection should be done by site manager and a certified arborist to ensure sufficient investigation and monitoring of the following:

- Tree/shrub establishment (Condit, 2010)
- Pest and diseases (Farr, 1989)
- Under or over population and possible replanting and/or thinning. (Bridget, 2015)
- General tree/shrub maintenance including removal of dead and dying branches. Removal of diseased branches or if heavily infected removal of entire tree/shrub. (Garden Guides, 2015)
- Detailed documentation can be taken about grow rate, propagation success and other details to add further knowledge to future restoration plans. (Condit, 2010)

Inspection and prevention:

Inspection of trees should be done to notice any changes and abnormalities to prevent decline. Contacting your local extension if you are unsure of the problem should be done promptly after carefully logging any changes seen in the tree (Damask, 2015). Fungal diseases can be treated with sulfur based fungicides and neem oils (Damask, 2015). Avoiding overhead water can be effective in reducing the risk of fungal diseases (University of California, 2012). Releasing natural enemies such as tachinid flies and lacewing larva can be an effective natural control of leafrollers (Damask, 2015). Reduction of stress and regular applications of a broad spectrum pesticides can reduce and/or prevent insect infestation. The installation of monitoring strips can be useful in identifying the pest (UC IPM, 2015). A list of common fungal and insect problems associated with the California Buckeye is as follows.

Fungal Diseases:

Sudden Oak Death. (*Phytophthora ramorum*) (Farr, 1989)

Powdery Mildew (*Sphaerotheca fuliginea*) (McGrath, 1997)

Leaf Blotch, Guignardia blotch (*Guignardia aesculi*) (Hudson, 1987)

Taphrina leaf curl (*Taphrina* spp.) (University of California, 2012)

Leaf, shoot, or twig blight (*Anthraco*) (Dreistadt, 2004)

Pests:

Fruit tree leafroller (*Archips argyrospila*) (Dreistadt, 2004)

Oak ambrosia beetles (*Monarthrum* species) (Donaldson, 1998)

Oak bark beetles (*Pseudopityophthorus* species) (Donaldson, 1998)

Japanese beetle (*Popillia japonica*) (California Dept. of food and Agriculture, 2015)

White-Marked Tussock Moth (*Orgyia leucostigma*) (Plantwise, 2015)

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Coyote bush (*Baccharis pilularis*)

Leticia Macias

Part 1: Project Background and Justification

Scientific name: *Baccharis pilularis*

Common names: Coyote brush (Bush), Chaparral broom, Dwarf baccharis



small, dentate, thick, waxy leaves.
white flowers

Photo: nwplants.com



Fig. 2 & 4 Evergreen shrub with

Photo: Paul Slitcher

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Background and Justification

Coyote Bush: *Baccharis pilularis*

Class: Magnoliopsida

Order: Asterales

Family: Asteraceae

Genus: *Baccharis*

Species: *pilularis*

Common names: Coyote brush (bush), Chaparral broom, and Dwarf baccharis

Coyote Bush (*Baccharis pilularis*) is a native California slow growing, evergreen shrub or groundcover that is adaptable to a variety of environmental conditions. It thrives in different types of ecosystems such as, coast and canyon regions. Coyote Bush provides habitat and supports a variety of insects that host, in addition, a variety of microorganisms. It is well known for being an excellent drought and heat tolerant species, a remarkable feature of coastal sage scrub plant communities. Moreover, its popularity is extended by being mainly used for restoration purposes due to its resilience to poor conditions, slope stabilization, and by being a pioneer species. Coyote Bush only requires good drainage and moderate summer watering to proliferate. Coyote Bush increases native diversity and regenerates quickly from fire or clearing. It is a

common plant due to its dense, large root system, and wax-covered leaves that make it adaptable to almost any challenging environmental condition.

Growth Characteristics:

- Native plant, evergreen, short spreading groundcover or shrub, with a height reaching 50cm (Norris 2007)
- Grows better with water once a month, perfect for low maintenance areas (Norris 2007)
- Adaptable to a variety of soil and climatic conditions (Sunset 2007)
- Reliable bank and flatland cover (Norris 2007)
- Dense root system (10 ft. down approx.), high root: shoot ratio (FEIS 2015)
- Pioneer species (Warner 1984)
- Mortality depends on adequate moisture (watering should be done twice during the first week and once established every 4 to 6 weeks) and best establishment depends on wet years in grassland areas (Warner 1984)
- Does not regenerate under closed canopy (Schmidt Greenberg, 2012)
- Rapid growth during spring, slows down with declining soil moisture in late May. Soak deeply after planting. Water twice during the first week; after that adjust frequency and amount to local weather conditions. It appreciates an occasional misting to clean its foliage (FEIS, 2015)

Reproduction:

- Life form: Phanerophyte, meaning that is an evergreen perennial that bears its buds more than 25 cm above soil level (Norris, 2007)
- Lifespan: 10-15 years (Norris, 2007)
- Sexuality: Dioecious (Norris, 2007)
- Flower season: Late summer/fall (Norris, 2007)
- Color: Yellow (Norris, 2007)
- Fruit type: achene, male cultivars are grown so don't have seed (Norris, 2007)
- Fruit Season: fall/winter (Norris, 2007)
- Color: creamy "fuzzy" (Norris, 2007)
- Pollination: late September, early October by insect species, such as: Argentine ants (*Linepithema humile*), parasitic hymenoptera (*Agathis gibbosa*, *Synopeas* spp, and *Dolichogenidea* spp), and honey bees (*Apis mellifera*) (FEIS, 2014)
- Seed dispersal: by wind, and mammals. Generally dispersed from October to January (NPIN, 2015)

Range:

- Native to Northern California coast (Jepson, 2015)
- Physiographic regions: outer Coast Ranges from northern Baja California, Mexico; San Diego County, Ca., Oregon. Also occurs in Islands and isolated populations in the Sierra Nevada foothills (FEIS, 2015)
- Dominant shrub in northern coastal scrub communities and in low frequency on coastal beach communities, coastal sage scrub, chaparral, and closed-cone pine forest, and mixed evergreen forests (FEIS, 2015)

- Found in high deserts to coastal areas. It tolerates heat, drought, dry winds, salt spray but not foot traffic (FEIS, 2015)

Habitat requirements:

- USDA: 8, Sunset zones: 5-11, 14-24 (Jepson, 2014)
- Soil: tolerant to poor soils, pH: 5-8, medium to coarse-textured soils, well drained soils (Crustsinger, Carter, Rudgers, 2013)
- Drought: tolerant to drought conditions (Jepson, 2014)
- Sun: shade intolerant, full sun (Jepson, 2014)
- Germination: better in mineral soil, 50-30 days, no specific temperature requirements. Higher germination rate on late fall or early winter rains (FEIS, 2015)
- Fertilizer: in fall and early spring with granular fertilizer: 16-4-8 (Jepson, 2014)
- It grows with no water near the coast, monthly watering on inland areas make it look better (Norris 2007)
- Grows as a ground cover in salt and windy areas such as dunes and plains and as a tall shrub in protected areas, such as slopes and canyons (Norris 2007)

Pest and Diseases:

- Black sooty mold and aphids can be prevented and eliminated by promoting air circulation on the plant's woody canopy (Schmidt and Greenberg, 2012)

Propagation requirements:

- Asexual regeneration, may grow roots in branch nodes when in contact to soil (Schmidt and Greenberg, 2012)
- Propagate better from male cuttings because female plants produce a cottony substance (Schmidt and Greenberg, 2012)

Plant associations:

- Coyote bush is associated with: Mixed conifer forest, Redwood forest, Pine-cypress forest, Ponderosa shrub forest, Oregon Oakwood, California mixed evergreen forest, California Oakwood, Chaparral, Montane chaparral, Coastal sagebrush, California steppe- Kuchler plant associations (FEIS, 2015)
- Coast live oak, California bay, and other shade tolerant species replace coastal sage scrub and other coyote brush dominated areas when fire and grazing are excluded (McBride and Heady, 1961)
- Associated species: San Diego bush monkeyflower (*Diplacus auranticus*), Monterrey coast Indian paintbrush (*castilleja latifolia*), Pacific dewberry (*Rubus vitifolius*), Open lupine (*Lupinus varicolor*), Cow parsnip (*Heracleum lanatum*), seaside woollysunflower (*Eriophyllum staechadifolium*), salal (*Gaultheria shallon*), Western pearly everlasting (*Anaphalis margaritacea*), Coastal wormwood (*Artemisia suksdorfi*), and sea side fleabane (*Erigeron glaucus*) (Jepson, 2014)

Plant interactions:

- Excluded or reduced by competition from fast growing grasses or other shading species (McBride and Heady, 1961)
- Areas with exposed mineral soil gives an advantage over perennial grasses and chaparral shrubs (McBride and Heady, 1961)
- Facilitates the establishment of other coastal sage, scrub species in grasslands (McBride and Heady, 1961)
- Companion plantings: Butterfly bush, California sycamore, White birch, and Crimson bottlebrush (Norris, 2007)

Wildlife effects:

- Shrub cover increases numbers of rabbits and small mammals that reduce herbaceous vegetation and favor shrub development (FEIS, 2015)
- Flowers attract pollinators and other beneficial insects (Halligan, 1974)

Effects on wildlife:

- Deer resistant (Halligan, 1974)
- Trampling and grazing limit coyote brush establishment in grasslands (Halligan, 1974)
- Has low protein value and low palatability to herbivores (Halligan, 1974)

Fire ecology:

- Moderately fire tolerant/resistant when watered, able to resprout from roots (Russell and Tompkins, 2004)
- Establish well from seed following fire (Russell and Tompkins, 2004)
- Fires does not reduce shrub density but crown cover (FEIS, 2015)
- Detrimental when high temperatures are present at stem bases (Russell and Tompkins, 2004)
- Post fire recovery is by sprouting in Oak woodlands and Chaparral areas (FEIS, 2015)
- Post fire sprouting is important for regeneration in coastal sage scrub communities (Russell and Tompkins, 2004)
- Further information on tradeoffs or feedbacks remains unknown due to a gap on literature.

Successional status:

- Colonizes actively in eroding or alleviating areas, succession varies with habitat type (Warner, 1984)
- Invades and increases in the absence of fire or grazing, correlated with the amount of spring rainfall (McBride and Heady 1961)
- Does not regenerate under a closed shrub canopy (Warner, 1984)
- It generally takes about 50 years to transition from a Coyote bush dominated scrub to mixed evergreen forest (Warner, 1984)
- Reversible with periodic fire (FEIS, 2015)

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Part 2: Project Goals and Management Plan

Goals:

The restoration of Coyote Bush to California's Central Valley is an integral element of its native vegetation due to its resilient features. The first goal of Coyote Bush restoration is to increase native plant population and therefore ecosystem health. Native plants such as Coyote Bush are considered secondary pioneer plant species in coastal sage scrub, grasslands, and chaparral communities. Coyote bush is well adapted to the variable California's Central Valley climate due to it promotes the establishment of other species and serves as a nurse plant for shade tolerant tree seedlings, particularly coast live oak and California bay (Norris, 2007). Tree development consequently excludes or eliminates Coyote Bush species, a tradeoff for its nursing characteristics. The second goal is to minimize negative impacts on water supply of California's Central Valley by promoting soil water infiltration, decrease soil compaction, and reducing the overall use of water intake over long periods of time, in comparison to other non- native species. Coyote Bush is considered a stress tolerant plant meaning that can withstand severe droughts once established for about four to six weeks and still have a long lifespan

(about 10 to 25 years) (FEIS, 2015). The third goal is to prevent erosion of Central Valley and to create wildlife habitat. Coyote Bush colonizes actively eroding or alluvial areas with a preference for exposed mineral soils. Also, it provides micro-habitat for other plants and supports a variety of small mammals and insects that host in addition, a variety of beneficial microorganisms (FEIS 2015). These goals will be accomplished through transplanting Coyote Bush species in areas sufficiently fertile or suitable for the requirements of this native shrub.

Restoration Plan:

In the establishment of restoration of evergreen perennials such as Coyote Bush in the wild, several requirements have to be met. Coyote bush is a dioecy species, meaning that it has male and female in different plants. Seeds are generally dispersed from October to January and should be collected with a cloth and stored in a warm ventilated room in sun without wind or refrigerated container (FEIS 2015). Sometimes the pappus (a ring of hairs around the fruit) is removed before planting (Jepson, 2014). Germination occurs after late fall or early winter rains and requires mineral soil for better development. Growth slows with declining soil moisture in late May (Warner, 1984). Coyote bush seeds ought to be sown in fall or early spring using sandy soil or vermiculite, perlite, and sphagnum moss mix and it has no stratification or temperature requirement (Jepson, 2014). Flowering occurs from July to October, and fruit ripens from September to November. Rains in September typically allow a high rate of leaf addition. Seasonal development is slightly later in inland than in coastal populations (FEIS 2015). Furthermore, it is able to regenerate asexually from the root crown and roots and can also grow roots where branch nodes contact soil surface (FEIS 2015). Shrubs like Coyote Bush can be established by seed, bare root plantings, and containers. Seeds are susceptible to herbivory and are sensitive to drought conditions (FEIS 2015). For restoration purposes, Coyote Bush is more successful when planted from containers if the sex ratio of 1:5, males to females is used (Norris, 2007). Fully development and maturity is reached at the first to second year of establishment if the initial requirements are satisfied. To enhance survival and transplanting success, it is recommended to use DeePot containers that measures 2 and a half inches in diameter by 10 inches long appropriate for shrub species (FEIS 2015). Moreover, root growth rates are relatively fast with an average of ten times faster than shoot growth, therefore, plants should be spread 8 to 10 feet on center apart (FEIS 2015). Coyote bush occurs on a range of soil types such as, serpentine and slightly saline soils but is best adapted to medium to coarse textured (well drained) soils. Although Coyote Bush does not require frequent watering, it should be watered twice during the first week and once established every 4 to 6 weeks to ensure healthy growth, higher rate of plant biomass, and to increase its resistance to fire (FEIS 2015). Coyote bush is a shade intolerant species with preference to open areas and an active colonizer (Jepson 2014). As a consequence, it does not regenerate under a closed shrub canopy leading to a lower success rate of seed and overall development (Jepson 2014). Coyote bush is adapted to experience moderate temperatures with summer fog, sea spray, and heavy onshore winds and can be exposed to cold winters and hot summers which works perfectly for California's Central Valley climate (Schmidt, Greenberg 2012). Special considerations should be met in the area when planting Coyote bush such as, full sun exposure as it is in south facing areas to ensure successful establishment (FEIS 2015). It thrives in middle, upper, and upland areas due to its adaptation to dry conditions with minimal moisture inputs (FEIS 2015). Root and shoot damage by small mammals can be a threat for small and/or young Coyote

bush species, therefore root protectors or tree shelters should be considered at time of implementation (FEIS 2015). As a result of decreased burning and grazing on Ca, Central Valley, this plant has become intrusive to native grassland ecosystems (FEIS 2015). Coyote bush establishes well from seed following fire. A combination of mechanical and chemical techniques should be used to the successful reduction of these species. Mechanical removal is the best method for removing the shrub from the area. Wood should be cut and dried prior to removal for burning. It is not recommended to chip this material do to the poisonous nature and its ability to reproduce from root fragments. Applying Triclopyr at basal stems has been an effective chemical treatment. It can be applied as a 25 % basal bark in an oil carrier after cutting older plants (Waterboards 2015). Additional information of risks and uncertainties for this species is currently unknown due to a gap in literature.

Monitoring Plan:

The frequency of activities required for monitoring of Coyote bush species will depend on the amount of invasive species present, shading conditions of the area, and the type of plantings installed (Waterboards 2015). These conditions are fundamental to ensure the success or failure of Coyote bush species in the area. If planting by seed, monitoring will be required 2 to 4 times per month between the first 6 months (preferably on fall), and once per month (spring to summer season) after the first 15 months of establishment (FEIS 2015). For reasons described in the restoration section, seedling plantings are labor intensive and require an extended monitoring period. If planting in containers, monitoring will be required 2 to 3 times per month between the first 3 months (preferably on fall to winter), and once every 4 months (spring to summer season) after the first year of establishment (FEIS 2015). Qualitative assessment of health and vigor of Coyote bush plantings can be considered excellent when there is no evidence of stress (no yellow leaves), and no pest or pathogen damage is present. Also, evidence of new growth and flowering set on majority of the plants (75 %) are observed (FEIS 2015). Consequently, assessment of health and vigor can be considered poor when high levels of stress are found (yellow leaves greater than 10%), high levels of pest or pathogen damage are shown, and no evidence of new growth, flowering or seed set occurs on the plants (less than 25%) with these characteristics (FEIS 2015). Maintenance activities should include replacing dead plants, maintaining tree and root shelters, monitoring and removing invasive species around the area (Schmidt. L. Greenberg). Dead plants can be replaced annually to the extent possible during the 3 year maintenance period following site installation to help achieve plant survival (FEIS 2015). Coyote bush species that are well adapted to the area and are rapidly establishing should be used to replace dead plants (Schmidt. L. Greenberg 2015). A critical evaluation of the vigor and growth of Coyote bush should be taken in consideration as well as survival rates and non-native reestablishment in the area. Further information on thresholds and other specific data related to monitoring of Coyote bush species are currently unknown due to a gap on literature.

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California coffeeberry (*Rhamnus californica*)

Stephanie Wen

Part 1: Project Background and Justification

California Coffeeberry (*Frangula californica*)

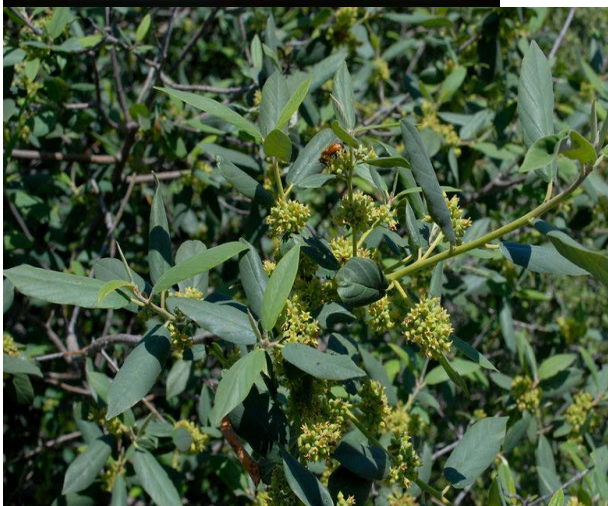
Habitat: “Frequent member of coastal chaparral and sage scrub community. Also locally abundant on cool, fog dominated sites along the central Coast Range where it occurs beneath mixed-hardwood”

(<http://www.parksconservancy.org/conservation/plants-animals/native-plant-information/california-coffeeberry.html>)

Pictures at different phenological stages (All from CalPhotos):



Berries can range from green to red to purple-ish to black. The leaves are usually long and waxy, leathery like.



Appearance:

Stem: Bark bright gray or brown; twigs glabrous (without hair, smooth) to finely hairy

Leaves: Light green when young, maturing to dark green, often with red tips; smooth, leathery, 2-4 inches long; edges curl under during dry summers to conserve moisture. Ovate to elliptic

Flowers: White, star-shaped, sepals only, from green buds, in clusters at tip of branches. Bisexual. Five petals, five sepals

Habit: 2-6 feet tall, compact evergreen shrub with red-purple stems

Fruit/Seeds: Clusters of berries, beginning green, ripening to orange/red and finally black in August - October

(<http://www.parksconservancy.org/conservation/plants-animals/native-plant-information/california-coffeeberry.html>)

Similar Species:

***Rhamnus crocea*; Redberry**

****pay close attention to leaf shape, the flowers look extremely similar and the berries are also similar but a bit redder and bigger****



(Photos from CalPhotos)

California Coffeeberry (*Frangula californica*)

Kingdom: Plantae
Order: Rosales
Family: Rhamnaceae
Genus: Rhamnus
Subgenus: Frangula

Background and Justification:

Frangula californica (common name: California coffeeberry) was once known as *Rhamnus californica*. It is a native evergreen shrub that ranges from the Oregon Coast to most of California into Arizona and Baja (Las Pilitas Nursery, 2014). It is a coastal chaparral in woodlands and forest communities (McMurray, 1990).



The coffeeberry is mostly distributed around big game and livestock because the fruits are consumed by a variety of wildlife species, especially birds (Golden Gate National Parks Conservancy). Its fruits are readily eaten by species during the fall because of its “juicy” fruit and are more palatable than other plants during this time of year (McMurray, 1990). The coffeeberry attracts different species to its fruit by the stem age and the different community associates (McMurray, 1990). The nutritional value for livestock and big game are satisfactory food sources because it provides little foliar protein in the coffeeberry’s leaves from November through March; from April to August, the foliar protein is at its peak (McMurray, 1990). The coffeeberry is also extremely useful for erosion control on dry, steep hillsides (Golden Gate National Parks Conservancy).

FACT SHEET:

Project Goal:

- To introduce the California coffeeberry to restoration site to provide hedges for aesthetics and wildlife with little maintenance.

Growth Characteristics:

- California coffeeberry can grow up to 2-6 feet tall (Golden Gate National Parks Conservancy)
- compact evergreen shrub with red-purple stems (Golden Gate National Parks Conservancy)
- this evergreen shrub can grow up to 6-8 feet, and sometimes even 10 ft. (Las Pilitas Nursery, 2014)

Reproduction:

- seed production begins by 2-3 years (McMurray, 1990)
- widespread seeds occurs through animals, particularly birds because they harvest the fruit crop (McMurray, 1990)

- when seeds get dispersed, each seed displays chlorophyllous cotyledon; meaning germination is about to happen (McMurray, 1990)
- seeds are short lived and will germinate in favorable temperatures and moisture conditions (McMurray, 1990)
 - 1 month: stratification at 41 degrees Fahrenheit
 - 3 weeks in incubator at 73 degrees, 65% of California coffeeberry seeds germinated

Range:

- California coffeeberry is native from the Oregon Coast ranges to most of California into Arizona and Baja (Las Pilitas Nursery, 2014) and even Hawaii (McMurray, 1990).
- In fog-dominated areas along the central Coast Range, the coffeeberry thrives better among mixed hardwood forests that are dominated by coast live oaks (McMurray, 1990).

Habitat/Tolerances:

- frequent member of coastal chaparral and sage scrub community (Golden Gate National Parks Conservancy)
- needs to be in a cool, fog-dominated site; preferably along the central Coast range (Golden Gate National Parks Conservancy)
- grows in sun or shade (McMurray, 1990)
- will grow in sand or heavy clay soils (McMurray, 1990)
- quite resistant to fire mortality (McMurray, 1990)
- can survive weeks without water, once it is mature (Songster, 2010)
- Adaptable to different soil conditions (Songster, 2010)
- requires little water in most areas (McMurray, 1990)
- The coffeeberry's fruits begin to ripen during the months of August to October; there will be cluster of berries ranging from green (beginning) to the ripening of orange and red and finally black (Golden Gate National Parks Conservancy).

Succession:

- long lived and moderately shade-tolerant shrub (McMurray, 1990)
- is highly persistent within chaparral, hardwood woodland and open conifer forests (McMurray, 1990)

Wildlife Interactions:

- Coffeeberry is a staple browse for big game and livestock; specifically sheep, goats, and deer (especially during the winter), not so much cattle (McMurray, 1990)
- California coffeeberry's fruits are mainly used by birds (McMurray, 1990)
- the fruits are often eaten by band-tailed pigeons, black-tailed deer, and black bears (McMurray, 1990)
- the flowers provide nectar and pollen for bees, butterflies, and other insects that have overlapping bloom periods (MoreMesa), (Hoover. et al., 1999)

Plant Interactions:

- some are commonly associated with chaparral whitethorn (*Ceanothus leucodermis*), toyon (*Heteromeles arbutifolia*), skunkbush sumac (*Rhus trilobata*), redberry (*Rhamnus*

crocea), hollyleaf redberry (*R. crocea* var *ilicifolia*), and poison-oak (*Toxicodendron diversilobum*) (McMurray, 1990)

Human Interactions:

- Humans utilize the California coffeeberry in their gardens and lawns as hedges that require minimal maintenance (Scotts, 2011)
- neat leaved and compact branching growth would be used effectively as hedges, busy plants or shrubs (MoreMesa)

Threats:

- California coffeeberry is part of the chaparral community (common in the valley), which often tends to burn rapidly and more often in areas close to humans; however they do tend to regrow quickly after fires (McMurray, 1990)

Propagation Requirements:

- It is also easily propagated from their seeds; their seeds should be collected in the fall, prior to the fruits being completely ripe; the pulp should be removed before sowing (Golden Gate National Parks Conservancy).
- The seeds should be stored at 41 degrees F in a sealed container; the seeds can last for many years (McMurray, 1990).
- The propagation of the coffeeberry from the stems is difficult due to the soft or hardwood cuttings at the nodes (McMurray, 1990)

Fire Interactions:

- After a fires, the California coffeeberry sprouts from surviving adventitious buds on the root crown and is able to reestablish after a fire because the top of the plant gets burned but the roots survive (McMurray, 1990).
- During extended fire free intervals, the California coffeeberry is able to outlive, overtop, and shade out many shorter lived species (McMurray, 1990).
- The California coffeeberry is an obligate sprouter, meaning they're not completely destroyed by fires and are able to resprout; unfortunately, the seeds from the California coffeeberry are lost due to the fire. Obligate sprouters follow a limited set of criteria; the seeds must be established in mature chaparral and amongst short lived species. (Pratt, 2007)
- Most seeds aren't well adapted to resist fire, but the seeds that do survive will germinate in a postburn environment (McMurray, 1990).

Herbicides:

- California coffeeberry is sensitive to almost all forestry-registered herbicides (McMurray, 1990)
- If the sprouts are treated following a burn, the entire plant is usually killed by retreatment (McMurray, 1990)

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Part 2: Project Goals and Management Plan

California Coffeeberry (*Frangula californica*)

Goals:

The California coffeeberry can live for many years. It is a resilient and versatile plant. It thrives in Mediterranean climate and has few requirements. It can survive in poor soil, little water and withstand sun or shade (McMurray, 1990). California coffeeberry produces berries that are highly preferred by a variety of bird species, making the California coffeeberry a good choice for wildlife plantings (McMurray, 1990). Maintaining the California coffeeberry benefits wildlife as well as the structure and integrity of the land due to its ability to secure loose soils (Golden Gate National Parks Conservancy). California coffeeberry can provide hedges for aesthetics and provide fruit for wildlife with little maintenance on the restoration site.

Objectives

Establishment Phase:

Planting California coffeeberry in coastal chaparral and sage scrub communities will reduce erosion, improve native vegetation, and supply food sources for wildlife/livestock. (McMurray, 1990). To establish successful growth of California coffeeberry, eradicating invasive species to provide open space for California coffeeberry and other native species to thrive. California coffeeberry should be planted during the fall.

Coastal Chaparral: The climate ranges from hot, dry summers and rainy, mild winters (261 California Coastal Chaparral Forest Shrub Province). The vegetation supports shrubs and several tree species that are well adapted to seasonal and periodic droughts (Plant Communities: Chaparral). The California coffeeberry is a dominant species in this type of community.

Sage Scrub Community: Has a relatively drier soil than coastal chaparral. The California coffeeberry is also a dominant species, the roots of the California coffeeberry are half as deep as it would be in a chaparral community (Plant Communities: Coastal Scrub). California coffeeberry is most active, in this community, after a rainy season in November and December (Plant Communities: Coastal Scrub).

Maintenance and Monitoring Phase:

Although California coffeeberry does not require a lot of maintenance, a future monitoring program should be implemented. Monitoring seedlings should be more frequent because it is vital for the success of California coffeeberry; as California coffeeberry matures, monitoring California coffeeberry should occur less. In addition, regular fire regimes should be put in place to allow a diverse plant community. But it is also important to keep invasive species away from returning after fires.

Restoration Plan:

Implementation

Task 1: Collect Seeds

California coffeeberry seeds should be collected in the fall, approximately 2 weeks before California coffeeberry is fully ripe (McMurray, 1990). A way to prolong the seed life before planting is to store the seeds in a sealed container at 41 degrees F; this allows the seed to

usable for several years (McMurray, 1990). California coffeeberry should be sampled in different locations with similar conditions like California's Central Valley.

Task 2: Preparing Site

The site should be prepared for success by eradicating exotic species and weeds with forestry-registered herbicides such as pre emergent herbicides (in DCPA (Dacthal), dithiopyr (Dimension), isoxaben (Gallery), oryzalin (Surflan), proflam (Barricade) are some just to name a few) and post emergent (Glufosinate (Finale), diquat (Reward, pelargonic acid (Scythe), and new herbicides that contain clove oil (Matran, EcoEXEMPT)) (Wilén & Elmore, 2007). The California coffeeberry does not require a lot and can thrive sun and shade and is drought tolerant once it is mature (Songster, 2010). The soil conditions also do not have to favor California coffeeberry because it is extremely adaptable (Songster, 2010). Soil texture that is suitable for California coffeeberry ranges from fine, medium, to coarse and the pH varies from 5.4 to 8.2 (CalFlora, 2015).

Task 3: Preparing Seeds/Seedlings

California coffeeberry seeds are short lived; however there are certain methods that can prolong the life of seeds (McMurray, 1990). The seedlings are produced by California coffeeberry at the age of 2 to 3 (McMurray, 1990). If they are dried at room temperature, they will not last more than 9 months (McMurray, 1990). Seeds are more common in older California coffeeberry because the fire free interval allows for the buildup of seed population (McMurray, 1990).

Treated Seeds: Using treated seeds allows California coffeeberry seeds to be protected from fungicides that cause seeds to rot (National Gardening Association Editors). The success rate of treated seeds will be higher than untreated seeds.

Untreated Seeds: Using untreated seeds lowers the success rate of California coffeeberry because there are chances of the seeds/seedlings rotting. Waiting for soil to be warm, 60 degrees F, can decrease the chances of rotting seeds/seedlings in moist weather conditions (National Gardening Association Editors).

Inoculate Seeds: Depending on soil conditions, even though coffeeberry is not high maintenance, having inoculated seeds will enhance the chances of the California coffeeberry seed producing fruit and surviving. Inoculate seeds are more effective in poor soil conditions (National Gardening Association Editors).

Transplanting: When transplanting California coffeeberry, it is important to avoid tearing the roots (The University of Arizona and Cooperative Extension, 1998). The method of transplanting is a delicate process and should be handled by their leaves and not by the stems (The University of Arizona and Cooperative Extension, 1998). The California coffeeberry should be grown for one to two years before transplanting (McMurray, 1990).

Task 4: Planting

California coffeeberry can be planted in fine, medium, or coarse soils (McMurray, 1990). They should be planted during the fall, after the fruits begin to ripen in August to October (Golden Gate National Parks Conservancy). In all cases, planting other species to provide for shade will increase California coffeeberry's survival rate (Maloney, 2007). **Treated Seeds:** Treated seeds should be planted in the fall because dispersal is most common at this time. California coffeeberry should be planted at a depth minimum of 13 cm (CalFlora, 2015).

Untreated Seeds: Untreated seeds should also be planted in the fall, but more so during the drier soil conditions to prevent the seed from rotting (CalFlora, 2015).

Inoculate Seeds: California coffeeberry inoculate seeds should be planted by having a depth minimum of 13 cm (CalFlora, 2015). It should be placed 1-2 inches apart depending on the size of the seed; stabilizing the soil and mildly watering the area (The University of

Arizona and Cooperative Extension, 1998). A 1 to 2 year old transplant can be successful and grow 8 to 12 feet (McMurray, 1990).

Task 5: Monitoring Plants

California coffeeberry seedlings should be monitored quite frequently. Although the California coffeeberry is extremely adaptable to soils, the soil must be suitable, meaning moist enough for survival, but not too dry because immature seeds and seedlings will have a hard time growing (McMurray, 1990). They start out being monitored every 4 months to see if the seedling growth has been interrupted by rotting of the seeds/seedling or animals disrupting the seedling's environment. Since the seed/seedlings should be planted in the fall, observing the seedlings around April can help indicate the health of the plant as it should be half developed (McMurray, 1990). By May, the California coffeeberry leaves should be fully developed and signify that the California coffeeberry is healthy (McMurray, 1990). And in June, the leaves should be fully developed and the California coffeeberry's fruit should begin to ripen (McMurray, 1990). As they mature, California coffeeberry does not require a lot of maintenance, but they should be monitored to determine its success rate as well as detecting any problems that need to be resolved, especially in the first year (Las Pilitas Nursery, 2014). The thresholds of action are planting the seeds in the fall and allowing the winter rain to nourish the plant, observing the plant growth during April will give a better understanding of whether or not the plant has been successful in its growth (McMurray, 1990). And can be adjusted accordingly for plant growth (McMurray, 1990).

When California coffeeberry is mature, little maintenance is required because it is extremely drought tolerant and can adapt to sun and shade (Golden Gate National Parks Conservancy). However, they should still be monitored from seeds to about 5 years of maturity in plants (McMurray, 1990). Complete failure of reestablishment of population would be unlikely. But if failure was to occur, examining the soil quality and amount of water provided would be key in making sure the next set of California coffeeberry had a suitable habitat. There is also the possibility of not having enough funding to plant California coffeeberry, as the funding would perhaps go to another plant that provided more ecosystem services (McMurray, 1990). Species establishment at only small sporadic locations would result in the California coffeeberry being able to adapt to its surroundings and being able to stabilize the surrounding soil and prevent erosion if it is occurring in the area (McMurray, 1990). The California coffeeberry would be economically feasible because the plant does not require a lot of care or resources (Golden Gate National Parks Conservancy).

Task 6: Maintaining California coffeeberry population

California coffeeberry is a versatile plant; minimal care is required because it maintains itself (Golden Gate National Parks Conservancy). The California coffeeberry can reproduce sexually and through vegetative means. California coffeeberry will maintain its population mainly through sprouting. In cases of disturbances, like fires, the California coffeeberry can regenerate itself through the surviving adventitious buds on the root crown (McMurray, 1990). Long periods without fire allow the long-lived sprouters to revitalize their population by having their root crowns produce new sprouts (McMurray, 1990). California coffeeberry can also be distributed through livestock and wildlife like sheep, goats and deer (McMurray, 1990). The fruits from California coffeeberry can also aid in maintaining the population. Due to the abundant fruit that ripens from August to October, and are readily available in the fall; birds especially utilize the fruits and use their excrements containing seeds tend to fall under the parent plant and can be used to help maintain California coffeeberry population (McMurray, 1990).

Task 7: Creating a Site Disturbance Regime

Fire: California coffeeberry are long-lived shrub that can endure harsh conditions. It is resistant to fire mortality and fires in these communities are usually top kills, which allows most plants to survive the fire (McMurray, 1990). California coffeeberry responds to fire through its ability to quickly sprouting and reestablishing itself. Seedlings support the population after fires depending on the fire intensity, topography, and community type (McMurray, 1990). California coffeeberry seedlings can be triggered by the heat from the fire and increase germination, especially in conditions with charred wood (McMurray, 1990).

Non-fire regime: California coffeeberry are also disturbed by any forestry-registered herbicides (McMurray, 1990). The forestry-registered herbicides can destroy sprouters, specifically after burns (McMurray, 1990). Reapplying herbicides will kill California coffeeberry indefinitely.

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California blackberry (*Rubus ursinus*)

Brandon Putz

Part 1: Project Background and Justification

“Habitat: Canyons, coastal, streambanks, disturbed” (http://www.calflora.org/cgi-bin/species_query.cgi?where-taxon=Rubus+ursinus)

Photographs of *Rubus ursinus*



Rubus ursinus flowering
(<http://science.halleyhosting.com/nature/plants/5petal/rose/rubus/ursinus/ursinus3c.jpg>)

Rubus ursinus fruiting
(<http://eaglelandingpark.org/PC280001.JPG>)



Leaves and spines of *Rubus ursinus*
(http://www.yerhabuenanursery.com/images/new_botimages/large/0527_j.jpg)

Appearance and Identification of *Rubus ursinus*

“Stem: 2–10 mm diam, not angled, ± glabrous to hairy, ± with stalked glands, glaucous, persisting 2 years, rooting at tips.

Leaf: simple or compound, leaflets 3(5), terminal triangular-ovate, irregularly coarse-toothed, tip acute, abaxially sparsely to densely gray-hairy, stipules thread-like to linear, ≤ 1 mm wide.

Inflorescence: cyme, flowers 1–5.

Flower: generally unisexual; sepals hairy, prickly, ± with stalked glands; petals 6–8(11) mm in pistillate, 10–15(18) mm in staminate, elliptic to round, white; filaments thread-like; pistils > 30, styles long, slender, ovaries glabrous or hairy.

Fruit: blackberry-type, black.” (http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=42267)

Similar species: *Rubus armeniacus*

Also known as Himalayan blackberry, it is a very aggressive weed that grows throughout



Rubus armeniacus, leaves are palmately compound, redish stems, thick spines.
(<http://www.biopix.com/photos/jcs-rubus-armeniacus-10521.jpg>)



Aggressiveness of *Rubus armeniacus*.

([http://sfwma.org/The%20San%20Francisco%20Six%20-%20The%20City's%20Most%20Invasive%20Weeds/slides/Rubus%20armeniacus%20\(syn.%20R.%20discolor\)%20-%20Himalyan%20blackberry.jpg](http://sfwma.org/The%20San%20Francisco%20Six%20-%20The%20City's%20Most%20Invasive%20Weeds/slides/Rubus%20armeniacus%20(syn.%20R.%20discolor)%20-%20Himalyan%20blackberry.jpg))

California. (Calflora)

California Blackberry (*Rubus ursinus*)

This is a typical flower of *Rubus ursinus*, California blackberry.

Photo:

http://biology.burke.washington.edu/herbarium/image/collection/wtu25000-25499/md/wtu025040_md.jpg



Background and Justification:

Rubus ursinus, also known as California blackberry, is a widely distributed native perennial subshrub found throughout the west coast of the United States. (Calflora 2015). Although preferring climates along the coast, *Rubus ursinus* does well in riparian communities dominated by willow (*Salix spp.*) (Tirmenstein 1989). *Rubus ursinus* is a species with quite a lot of vigor. It is usually part of primary succession, establishing itself quickly after a disturbance, such as fire or even mudflows resulting from Mount St. Helens (Pond 2003). Although *Rubus ursinus* is a dominant plant initially, canopy cover suppresses it, as trees grow taller and taller in a succession event (Pond 2003).

As *Rubus ursinus* grows, it provides benefit to all kinds of wildlife. These benefits come in the form of food, shelter, and a place to nest; Many small mammals and birds will use these blackberry thickets created by *Rubus ursinus* for protection and a source of food, and there are many birds that will use these thickets for their nests (Tirmenstein 1989). This useful habitat not only protects the animals that use it, *Rubus ursinus* is a native way to protect soil from erosion as well (Tirmenstein 1989).

Rubus ursinus may be a widely distributed species that is doing fairly well; however, there are threats to it. The main threat being competition from invasive species, such as *R. armeniacus* and *R. discolor*. These blackberry's are much more aggressive than *Rubus ursinus*, growing taller and faster, and dedicating more resources to reproduction (McDowell and Turner 2002). Without the pressure from other *Rubus* species, *Rubus ursinus* is a dominant species in early successional stages, which can push other exotics out of a restoration site (Pond 2003).

Literature Review:

Facts on *Rubus ursinus*

--Possible Goals for *Rubus ursinus* at our Site:

- Goals include;
- The establishment of *Rubus ursinus* in codominance with Oaks (*Quercus spp.*) in the upland area and Willows (*Salix spp.*) in the riparian area (Tirmenstein 1989).

- Establishment without pressures of Himalayan blackberry (*Rubus armeniacus*).
- The avoidance of hybridization with *Rubus armeniacus* (Clark 2012).

--Growth Characteristics of *Rubus ursinus*:

- Rubus ursinus* is a perennial subshrub (Calflora, 2015).
- Can promptly re-establish after a disturbance such as fire through sprouting via root or stem suckers (Tirmenstein 1989).
- Commonly uses seed for reproduction, in spite of ability to regenerate through root and stem suckers (Tirmenstein 1989).
- Rubus ursinus* is low growing, reaching up to 6m in length, slender, curved, unflattened prickles; usually no more than 50cm tall (Pond 2003).
- Rubus ursinus* is winter deciduous (Tirmenstein 1989).

--Habitat/Range:

- Distribution of *Rubus ursinus* ranges from all the way from British Colombia to Northern Mexico (Pond 2003).
- Found from sea level at the coast to inland areas, like the central valley (Pond 2003).
- Often found in codominance with conifers along the coast, but in the central valley, *Rubus ursinus* is often found with oaks and willows, in a riparian setting (Tirmenstein 1989).
- No preference to neither wetlands nor non-wetlands, it is equally likely to occur in both; occurs in many communities, notably foothill woodland, valley grassland, and wetland-riparian (Calflora).

--Disturbance Response:

- Responds well to disturbances such as fire, as it can quickly re-establish through root suckers (Tirmenstein 1989).
- It responds well to floods; however, only if the top of the plant is still above water (River Partners 2015).
- Rubus ursinus* struggles with periods of extended drought (River Partners 2015).

--Dependence by other Animals:

- Many animals depend upon *Rubus ursinus*. Important species of birds that consume the blackberries include: California quail, ring-necked pheasant, blue grouse, and the summer tanager (Tirmenstein 1989).
- Important species of birds that live in the protective branches are: towhees, Jays, northern mockingbird, and thrashers (Tirmenstein 1989).
- Many small mammals also use the shrub for cover and food; such as: chipmunks, skunks, gray and red foxes, and squirrels. Black-tailed deer also use *Rubus ursinus* for forage (Tirmenstein 1989).
- Provides ideal nesting habitat (Tirmenstein 1989).

--Reproduction in *Rubus ursinus*:

- Rubus ursinus* produces a blackberry as its fruit (aggregate fruit), as there are many separate carpels, each producing its own fruit (Cham. & Schldtl. 2013).

- Insect pollination and self-pollination in *Rubus ursinus*, with dispersion through animals (River Partners 2015)
- *Rubus ursinus* is affected by water stress more so than invasive species like *R. discolor* when it comes to reproductive canes (McDowell and Turner 2002)

--Propagation and Conservation Genetics:

- *Rubus ursinus* is capable of self-fertilization (Tirmenstein 1989).
- The best way to propagate *Rubus ursinus* is in plug flats, through transplanting cuttings. Cuttings are treated with various chemicals prior to planting in plugs, in which they are planted at a depth of 3 inches, and are left to grow for 70 days in a fully controlled green house (Pond 2003).
- It was found that spontaneous hybrids may occur with *Rubus ursinus* and exotic *Rubus* species. "These hybrids also retain the ability to increase their fitness via sexual recombination and natural selection" (Clark 2012).

--Disease in *Rubus ursinus*:

- *Rubus ursinus* is affected by Tobacco Streak, Tomato Ringspot, and Raspberry Bushy Dwarf viruses (Finn and Martin 1996).
- Tobacco Streak and Raspberry Bushy Dwarf viruses can have serious effects on *Rubus ursinus*, such as crumbly fruit, decreased yields, and decrease in plant growth. However, it is suggested *Rubus ursinus* is nearly immune to Tomato Ringspot (Finn and Martin 1996).
- Tobacco Streak virus is common in naturally occurring stands of *Rubus ursinus*, Tomato Ringspot and Raspberry Bushy Dwarf viruses are not (Finn and Martin 1996).

--Threats to *Rubus ursinus*:

- Pressure from *Rubus armeniacus*, and other invasive *Rubus* species may threaten *Rubus ursinus* restoration; and accomplishing this through competition or hybridization (Clark 2012).
- Current drought may make it difficult to establish *Rubus ursinus* (River Partners 2015).

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Part 2: Project Goals and Management Plan

Goals for *Rubus ursinus* Restoration:

Rubus ursinus is a successful, hardy shrub that ranges from Canada to Mexico, and is ecologically significant throughout this range, including California (Tirmenstein 1989). As an important source of shelter and food for wildlife, and stabilization for stream banks, and disturbed areas, *Rubus ursinus* reintroduction will be a valuable asset in the restoration projects throughout the central valley (Tirmenstein 1989). With the many benefits that come with the restoring of *Rubus ursinus*, a set of goals must be put in place to make sure what goals are to be met with the restoration of *Rubus ursinus*.

The first goal for *Rubus ursinus* restoration should be to survey the site in question for *Rubus ursinus* and other species in the *Rubus* genus. There are many species of *Rubus* throughout the central valley; however, not all of these species are problems. A survey will be necessary to see if there will be any conflict between the species desired, *Rubus ursinus*, and other species that are potentially problematic, such as *Rubus armeniacus*.

The second goal is to determine when, from where, and how *Rubus ursinus* will be propagated. This is important for the success of new individuals at a site, as propagated plants can significantly increase the ability of the plant to succeed (Pond 2003).

The third goal for *Rubus ursinus* will be to establish the plant in riparian areas throughout the central valley, and depending on the site, the percent cover for *Rubus ursinus*. *Rubus ursinus* will also do well in wetland habitat; however, this can cause flooding risks if the blackberry thicket gets too dense (DiTomaso 2010). This clogging of waterways needs to be avoided, and will be need to be managed and will be outlined in the management and monitoring section.

Restoration Plan for *Rubus ursinus*:

For goal one, a survey of the chosen site in the central valley will be chosen. Once the site is chosen, a survey of the *Rubus* species will be conducted. The plants can be surveyed on an individual basis due to the distinctive nature of the genus *Rubus*. The survey will be carried out by identifying adult plants using plant characteristics or resources like The Jepson Manual second edition or Calflora if the plant is not immediately identifiable. Once the plants are identified, it can be determined whether or not *Rubus ursinus* can co-exist with the other species of *Rubus*. If *Rubus armeniacus* is present at the site, it will need to be removed, which will be outlined in monitoring and management.

For goal two, the area in which the samples and cuttings of *Rubus ursinus* for propagation must be chosen, and these cuttings should be taken from a near by region within the central valley. The final piece for this goal is the propagation, and planting of *Rubus ursinus* at the chosen restoration site. Once the survey of the site is concluded, and if any specimens of *Rubus ursinus* are present at the site, they will be used for propagation. If there are no plants present, plants from a near by region should be chosen. This is because there is a higher chance these near by individuals may be more locally adapted than a population that is farther away.

The method of propagation that we will be using is vegetative propagation, not from seed. This type of propagation was chosen so that *Rubus ursinus* would be easier to manage as it establishes (Tirmenstein 1989). To collect the specimens, make cuttings 15 inches long, with at least 15 nodes along the cutting (Pond 2003). To prepare the cuttings for the flats, cut the cuttings once more to 5 inches in length each, and cleaned in a mild bleach solution to assure that there is no contamination of the plug flats (Pond 2003). After the cuttings are cleaned, they are treated with Hormex rooting powder, and are planted 3 inches deep, with 100 cuttings per flat (Pond 2003). The propagules will be kept in the flats until their roots are fully developed, after which they will be transplanted into their own 2”X10” container (Pond 2003). Once they have been successfully transplanted into their individual containers, the plants can then be kept in a shadehouse until it is time for them to be planted (Pond 2003).

The site survey should happen in the spring and summer, while *R. ursinus* is flowering and easier to identify (Calflora 2015). Collection of cuttings from specimens found at Centennial Park (or collected from else where) should be taken during the fall, as the cuttings will need plenty of time to grow their roots from the vegetative parts of the plant, but still be healthy when it is time to plant them come spring (Pond 2003). *Rubus ursinus* grows quickly in the spring, and is flowering by April; so, planting the propagated plants in the late winter will be ideal to assure proper establishment (Tirmenstein 1989).

Finally, for goal three, a suitable riparian habitat will be chosen for *Rubus ursinus* reintroduction, and an appropriate percent cover in the riparian habitat. The amount of cover necessary will vary from site to site; however, successful blackberry coverage is usually between 25 and 50 percent in the shrub layer (Tirmenstein 1989). With between 25 and 50 percent cover in the shrub layer, the blackberry thicket should provide ample protection for small animals and birds, while also supplying them with food, in the form

of blackberries. However, with this much *Rubus ursinus* at the site, monitoring will need to be in place to ensure the thicket doesn't push out other plants the restoration project is attempting to restore, which will be outlined in the monitoring section.

Managing and Monitoring Plan for *Rubus ursinus*:

After *Rubus ursinus* has been successfully established, it will need to be monitored on a regular basis, at least once a year; this is because in disturbed sites, *Rubus ursinus* has the ability to colonize and dominate disturbed site quickly (Tirmenstein 1989). If this were to occur, it could damage the restoration efforts around the other newly introduced plants. Left unchecked, *Rubus ursinus* can grow very quickly, in an almost weed like fashion; as a result, plants may need to be trimmed to make sure that they are not shading out neighboring plants (DiTomaso 2010). While *Rubus ursinus* is being monitored, it will be necessary to monitor how close the plants are in proximity to a stream, or if individuals have colonized the water channel; if so, they will require removal. According to the California Department of Water Resources, any obstruction to the flow of water will need to be removed to reduce flooding (Ca Department of Water Resources).

Although *Rubus ursinus* is hardy, it can encounter some problems. Other species of *Rubus*, such as *R. armeniacus*, can out compete *Rubus ursinus*. *Rubus armeniacus* is very invasive, and can easily out compete *R. ursinus* and many other plants; for this reason, it must be managed as well (DiTomaso 2010). To contain *R. armeniacus*, the best choice of action for projects in the central valley would be to apply herbicide to the invasive *Rubus* species (DiTomaso 2010). When applying an herbicide, it is best to correctly ID the plant; *Rubus armeniacus* is easily identifiable by its thick red stem and large spikes down the length of the stem (Calflora 2015). For herbicide application, DiTomaso suggests that herbicide be applied directly to the plant during summer months so that the plant will transport the herbicide into the roots and kill the plant there (DiTomaso 2010). Herbicides like roundup (Glyphosate) can provide good seasonal control of *Rubus armeniacus*, but herbicide will need to be applied directly to the plant to get rid of the plant entirely (DiTomaso 2010).

Another threat to *Rubus ursinus* is the hybridization of *R. ursinus* and *R. armeniacus*, resulting in very competitive hybrids (Clark 2012). These hybrids are viable, and have the ability to increase in fitness through natural selection (Clark 2012). However, these hybrids can be managed the same way as *R. armeniacus*, through herbicide use in the summer to kill off the hybrids (DiTomaso 2010). The *Rubus ursinus* x *armeniaceus* hybrids are easy to identify by their compound leaf leaflets. The *R. ursinus* has three leaflets, while *R. armeniacus* has five leaflets. The hybrid of these two has three leaflets; however, the non-terminal leaflets will be highly lobed in one location, as to give the appearance of five leaflets (Clark 2012).

There are also diseases that can affect *Rubus ursinus*, such as Tobacco Streak and Raspberry Bushy Dwarf viruses (Finn and Martin 1996). These viruses can have serious effects on *R. ursinus*, as it can cause the fruits to develop incorrectly and be crumbly, and slow the growth of the plant (Finn and Martin 1996). According to the paper by Finn and Martin, these viruses are transmitted through seed, and Raspberry Bushy Dwarf virus can be found in 0-8% of cultivated plants (Finn and Martin 1996). Plants would be propagated from specimens known not to have the virus, and propagated vegetatively to avoid transmittance of the disease. Plants found with symptoms of the diseases will be top killed or removed completely to further avoid transmittance of disease.

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California grape (*Vitis californica*)

Zachary Sutter

Part 1: Project Background and Justification

The California Grape is a wild vine that grows deciduously.

Appearance:

- **Stem:** tomentose when young, becoming less so; nodal partitions generally 3–4 mm thick
- **Leaf:** stipules generally < 3.5 mm; blade lobes 0–3, shallow, margin crenate to slightly serrate, lower surface ± tomentose
- **Flower:** unisexual
- **Fruit:** generally > 8 mm wide, spheric, purple, glaucous; skin separating from pulp

Fruits and Seeds:



Flowers:



Seedling



Leaves during Autumn



Photos from CalPhotos

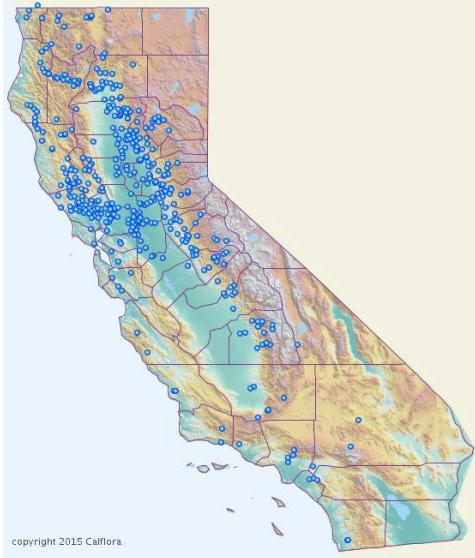
Identification information from Jepson

Mature Plant



Habitat and Distribution:

The CA grape is native to California, but can also be found in Oregon. Its preferred ecological areas are streamsides, near springs, and in canyons.



The California Grape (*Vitis californica*)

Kingdom: Plantae



Phylum- Angiospermae
Class- Magnoliopsida
Order: Rhamnales
Family: Vitaceae
Genus: Vitis
Species: *Vitis californica*

Background and Justification:

The California Wild Grape is a deciduously growing vine that occurs naturally in Southwest Oregon and throughout California. Its preferred habitats are riparian forests, canyons, and forests near sources of water such as rivers or streambeds. As it is a vine, the CA grape prefers to grow on oaks, cottonwoods, bays, or buckeyes (Brewer). Like most California riparian plant species, the CA grape is fairly drought-tolerant and resistant to occasional flooding after being established in soil.

Vitis californica is a significant and beneficial plant to riparian ecosystems. It provides shelter and food for many animals including coyote, opossum, skunks, California quail, and mountain bluebird among other creatures (Brewer). Many of these animals are also endangered or threatened from loss of habitat. Additionally, *Vitis californica* has been extremely useful in agricultural grape production. Due to its hardy drought-tolerance as well as resistant to the vineyard-ravaging Phylloxera pest, it makes an ideal rootstock for many wine and table grapes (Granett, 1991).

Destruction of riparian ecosystems poses a major threat to wild California grape communities. Overgrazing of cattle and building development have degraded the soil structure of such communities, resulting in uninhabitable conditions for riparian plants (Kaufman, 1983). Another threat to CA grapes is the advent of invasive nonnative plants, especially the very tenacious grass *Arundo*, which has spread throughout must rivers and streams in California (Bell, 1998). Another non-native species is the Blackberry-leafhopper, which spreads a disease to wild Grape populations and has affected a significant number of the wild grape communities (Williams, 1984). A concentrated restoration practice is needed if we wish to see the survival of this important California native plant.

Fact Sheet

Project Goal:

- To facilitate the reintroduction and management of California Wild Grape in riparian communities that have been disturbed by the introduction of invasive foreign species.

Growth:

- Mature in about 40-50 days from seedling (Strik, 1993)
- At full maturity, their height x Width will be at 25'-40' (Bornstein, 2005)
- CA Grape is a Perennial Dicot Species (CalFlora)
- Life expectancy is long, and they can live from 50-100 years (1993)

Reproduction:

- Propagation occurs by seeds
- CA grapes bloom in May through June (CalFlora)
- Flowers are unisexual and dioecious, with pentamorous whorls (Gleason)
- Flowers are small and bunched into large inflorescences that are then wind-pollinated (Wine and Spirits)
- Pollinated flowers will form into a Grape, which is a form of berry
- Grape berries then attract birds and mammals and the seeds become propagated.

Range: (all data from USDA)

- Endemic to California and Southern Oregon.
- It is distributed in the Coast Ranges from Douglas County, Oregon, south to San Luis Obispo County, California; in the Klamath Mountains, the Cascade Range, and the Sierra Nevada from Siskiyou to Kern counties, California; and in the Central Valley

Habitat:

- Riparian forests, canyons, and forests near sources of water such as rivers or streambeds (Padgett, 2003)

Succession:

- Thrives best in conditions where there are mature or near-mature trees and sparse ground cover (Olson, 1997).

Growth Requirements: (All information from CalFlora) -pH -salinity -moisture - composition (clay, sand, loam)

- Elevation: 0 to 1640 meters
- Annual Precipitation: 13 to 91 in
- Wet Season: 4-8 months
- Temperature range: $\leq 65^{\circ}\text{F}$
- December low: 26°F
- July High: 98°F
- Require full to part sun (Bornstein, 2005)

Soil Requirements: (All Information from CalFlora)

- pH: 5.5-8
- Not tolerant to saline conditions (max salinity: 1 mmhos/cm)
- Minimum soil depth: 31 cm
- Not tolerant to Calcium Carbonate (Max CaCO_3 is 0%)

Tolerances:

- CA Grape are resistant to occasional flooding, and in fact, flooding is a requirement for the introduction of nutrients to riparian soils (Bell, 1998)
- Plants must be established before flooding occurs, as seedlings of less than one year will not survive (Bell, 1998)
- Has a high-degree of drought tolerance, but can be harmed if drought lasts for a greatly extended period (Epron, 1993).
- Considered to be one of the most drought-tolerant *Vitis* species (Padgett, 2003)

Wildlife Interaction:

- *Vitis californica* provides shelter and food for many animals including coyote, opossum, skunks, California quail, and mountain bluebird among other creatures (Brewer).
- Propagation is mostly through birds, and the CA grape is an important food source for them (Bell, 1998)

Plant Interactions:

- Relies on trees such as oaks, cottonwoods, bays, or buckeyes for upward growth (Brewer).
- Valley oaks and cottonwoods can succumb if the vine climbs into the upper canopy (Brewer).

Human Interactions:

- Has been used worldwide as a rootstock for commercial wine and table grape production due to its hardiness and resistance to Phylloxera after first phylloxera-hybrids became susceptible (Granett, 1991).

Threats:

- *Arundo donax* an introduced non-native grass species that has disrupted many riparian systems in California due to its high resilience and fast vegetative growth (Bell, 1998).
- There is a tendency for CA Grapes to die out in IRF model restoration sites where many species are introduced at once (McClain, 2011).
- Diseases and pests that are commonly found in agricultural grape production, such as Pierce's disease or Phylloxera have migrated to wild grape populations (Granett, 1991).
- Non-native pest, the Blackberry-Leafhopper transmits a pest that has significantly affected wild CA grape communities in some areas (Williams, 1984).

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Native bulbs (Brodiaea sp, Dichelostemma sp., Tritoleia sp)

Whitney Krupp

Part 1: Project Background and Justification

Bulbs and corms are popular garden plants associated with showy spring and summer flowers. They are likely to garner easy support in conservation and restoration efforts. In California's wildlands, native bulbs have a rich history of cultivation and use by native tribes: bulbs and corms were often eaten and fibrous outer hairs on corms were used as brushes (USDA PLANTS). Brodiaeas and blue dicks (*Dichelostemma capitatum*) are popularly called "Indian Potatoes," highlighting their place as a key food source for California tribes (Lowry). Today, native bulbs are declining in diversity: some, like the soap plants (*Chlorogalum sp.*) are still fairly common while others like crown brodiaea (*Brodiaea coronaria*) are disappearing due to pressure from agricultural and urban development (USDA PLANTS). In the central valley, bulbs are likely to occur in grassland and riparian habitats with some species preferring vernal meadows. Little is known about life cycles, pathogens, and pests of California native bulbs, especially in the context of wild or restored systems. This guide will consider the known biophysical factors necessary for the successful restoration of eight native bulbs (*Triteleia laxa*, *T. hyacinthine*, *Chlorogalum pomeridianum*, *C. angustifolium*, *Dichelostemma capitatum*, *Brodiaea californica*, *B. coronaria*, and *B. elegans* to Central Valley habitats.

Fact Sheet

Species Characteristics

Many bulbs have ranges significantly larger and more varied than the climate and habitats of the Sacramento Valley. The following table lists characteristics of bulb species and cultivars found in low-elevation, inland Mediterranean climates, and in grassland, riparian, wetland, and vernal pool habitats.

Common Name	Scientific Name	Habitat/ Soil Type	Bloom Time	Soil pH	Min soil depth (cm)	US Hardiness Zones
Ithuriel's spear	<i>Triteleia laxa</i>	Grassland	April- July	5.5-7.6	27	8a-10b
		Clay soil				
Wild hyacinth	<i>Triteleia hyacinthine</i>	Grassland,	March- July	5.4-7	39	6a-10a
		Vernal meadow,				
		dry slopes				
		Sandy or loamy soil.				
		Shade intolerant				

Soaprot	<i>Chlorogalum pomeridianum</i>	Grassland	May - August	5.5-8.2	13	7b-10b
Narrow leaf soaprot	<i>Chlorogalum angustifolium</i>	Grassland Heavy soils	April-July			9a-9b
Blue dicks	<i>Dichelostemma capitatum</i>	Wetland Riparian	Feb-April	5.2-8.2	13	7b-10b
California brodiaea	<i>Brodiaea californica</i>	Grassland Rocky/gravelly soils	April-June			
Crown brodiaea	<i>Brodiaea coronaria</i>	Vernal pools Grassland	April-June			7a-9b
Harvest brodiaea	<i>Brodiaea elegans</i>	Grassland	April-August	5.4-6.8	29	6b-10b

Sources: CalFlora, USDA PLANTS database, Jepson eFlora

Depth to Water Table & Waterlogging

- Long periods of waterlogging rot corms, though it is unknown exactly how long it takes for rot to set in. Ensure that plants have a summer dry season. Even wet-adapted species (wetland/riparian/vernal pool species as designated in the table) do poorly in wet summer conditions—e.g. conditions wet enough to sustain turf grass. (USDA PLANTS)
- All species prefer well-drained soil, especially for establishment.
- The water table should stay below the corm zone (4-6 inches below the soil surface) with only temporary inundation, as from rain or short flood events.

Germination controls

- *Triteleia laxa* germinates best when its seeds are cold-shocked at 3C for 8 weeks (Han, 1993)
 - Seed-based reproduction may decrease with warming winter temperatures under global warming
- *Brodiaea* and *Triteleia* do not require stratification (USDA PLANTS)
- *Dichelostemma* may require 1 month of stratification if seeds are not planted in autumn (USDA PLANTS)

Seed bank and vegetative reproduction

- *Chlorogalum* disperses seed via autochory, relying on gravity as a main motive force (Reeves, 2006)
- Dormant seeds are produced by bulb and corm-forming species, often germinating en masse after fire or other surface disturbance clears established vegetation (USDA PLANTS, Reeves, 2006)
- Bulbs may remain dormant and viable for up to 10 years (Reeves, 2006)

- Corms of all families need to reach a minimum size before flowering is induced (Han, 1991)
 - o Possible exception: flowering may be forced by fire

Establishment protocols/best practices

Family	Planting from Corms/Bulbs	Planting from Seed
<i>Triteleia</i>	Plant in full sun in fall, 2-4 inches apart & 4 inches deep Irrigate, weed, and protect from animals (mammals, insects, birds) for 1 year Ground should be kept damp: do not water after a rain Waterlogged soil rots corms Stop watering after leaves turn yellow and dry up Let the corms bake through the summer Establishment is complete after 1 year	Recommended to germinate in a greenhouse and plant in the ground after 3 years Plant in fall, before Oct. 1 Use pots 6" or larger 100 seeds per pot sprinkled on top of soil and covered lightly with soil; put ¼" gravel on top Store in part shade; keep soil slightly damp Fertilize late winter and early spring Stop watering when leaves yellow Separate corms & transplant after 2 years Grow to bloom in new container before transplanting
<i>Chlorogalum</i>	Plant in fall (before Oct 1) in full sun shallow enough that the top is exposed Do not water: wait for rains Soaproot is generally competitive and almost weedy in its preferred climates, so establishing mature corms requires little additional attention	Plant in fall before Oct 1 in 1-gallon container at least 6 inches deep Pre-irrigate and let drain overnight Use sandy potting soil Scatter seed over soil surface, cover lightly with soil and ¼" layer of gravel Do not irrigate: leave outside and rain-irrigate only Containers should get midday shade with morning and afternoon sun

		Repot during summer dormancy after 1 year, grow for an additional year before transplanting into the ground
<i>Dichelostemma</i>	Depending on corm size, plant 1-4 inches deep (larger corms deeper) 1 inch apart Plant in autumn with full afternoon sun Water in but allow rain irrigation over winter	If planting in fall, seeds germinate readily Plant by scattering over soil surface and lightly raking in until seeds are as deep under the surface as they are long Plant in full to partial sun Water in and keep soil moist through spring; stop watering when leaves yellow Plants will take several years to mature If planting in pots, keep pots in a mostly shady location Transplant into soil after 2 years, in the fall
<i>Brodiaea</i>	Plant in fall in full sun, 2-4 inches apart and 4 inches deep Keep ground damp, stopping irrigation when leaves yellow Establishment is complete after 1 year	Plant in fall before October 1 Use 6" deep pots or deeper Broadcast seed ~100 seeds per pot and cover with thin layer of soil and ¼" gravel Keep in partial shade Keep pots damp and fertilize in late winter and early spring Stop watering when foliage yellows Let grow for 2 years before transplanting into new pots in the fall Grow until flowering maturity before planting in the soil in fall

Sources: USDA PLANTS database.

Protecting all establishing seedlings and corm sprouts from mammals, insect pests, and birds is important. Small corms and seedlings can be especially vulnerable to gopher herbivory: if gophers are present, line transplant sites with chicken wire mesh. Once establishment is complete, (after one calendar year from planting) plants can withstand animal interference such as trampling, herbivory, and digging. Weeding is also key during establishment, as bulbs are readily outcompeted by fast- and early-sprouting annuals (USDA PLANTS).

Seasonality and phenology

Fall

- Corms go dormant in early fall, which is a good time to harvest them for planting (USDA PLANTS)
- Corm growth, rooting, and seed germination begin with late fall rains (around October 1) (Schlising and Chamberlain, 2006)

Winter

- Germination occurs within 4 weeks of planting *Triteleia laxa*
 - Cotyledon emergence by 8 weeks after planting
 - Total germination percentage of 82-98% for a late November planting in Chico, CA
 - Leaves are identifiable by February (Schlising and Chamberlain, 2006)

Spring

- Seedling rooting and corm development begin around 18 weeks after germination (March-May) (Schlising and Chamberlain, 2006)
 - Leaf elongation of *Triteleia laxa* continues until March-April
- In *Triteleia* and *Brodiaea* new corm development happens before flowering and flowering scape grows from the old corm (Schlising and Chamberlain, 2006)
- Flowering begins from February-May, depending on species (see species characteristic table)
- Foliage yellows as flowering begins (USDA PLANTS)

Summer

- Foliage continues to yellow and die back
 - Dieback also happens in times of stress (USDA PLANTS)
- Flowering stalks die back after flowering (June-August, see species characteristics table)
- Plants survive as buried storage structures (bulbs or corms) (Schlising and Chamberlain, 2006)
 - Their phenology therefore roughly resembles that of annual plants

Pollinator interactions

- *Triteleia laxa* successfully pollinated by introduced honeybee *Apis mellifera* (Chamberlain and Schlising, 2008)
 - Also capable of self-pollinating, but produces significantly fewer seeds relative to outcrossing via pollination (Schlising and Chamberlain, 2006)
 - Average of 2 seeds/plant produced with selfing versus 13 with outcrossing
 - Flowers remain open for 4-5 days, allowing day-active *A. mellifera* to be a successful pollinator (Schlising and Chamberlain, 2006)

- Because of their evening bloom time, *Chlorogalum* species rely on native bees for pollination; however, they are also self-fertile (Stockhouse et al, 1978; study done on *Chlorogalum pomeridianum*)
 - o Flowers are closed during the day, opening around sundown every night and closing around sunrise
 - o Flowers become self-fertile approximately 30 minutes after they open; prior to that, they can only be outcrossed
 - o *Apis mellifera* visited the plants before flower opening, removing nectar without accessing pollen
 - o Key large native bee pollinators are *Bombus sonorus*, *Bombus vosnesenskii*, *Xylocopa tabaniformis orpifex*
 - o Other pollinators include yellow jackets, mining bees (*Lasioglossum sisymbrii*), and Allen's hummingbirds (Reeves, 2006).

Pathogens

- *Triteleia laxa* has an unnamed pathogen that causes scape death before flowering, found in the Sacramento Valley (Schlising and Chamberlain 2006)

Disturbance Responses & Management Actions

Fire

- *Triteleia*, *Chlorogalum*, and *Brodiaea* were burned by native tribes as a management tool: flowering and seed set increase after fire, though seed set will not happen without successful animal pollination. Post-fire, most first generation seeds are nondormant (Anderson, 2000; Reeves, 2006)
 - o These families have evolved to tolerate frequent, low-temperature, stand-clearing fires
- *Dichelostemma* does not increase flowering post-fire but does emerge and flower from dormant/protected corms after fire events
 - o Most likely a response to lack of light competition and additional soil nutrients after the ground layer is burned away (Anderson, 2000)
- Corms and bulbs may sit for a decade or more and wait for fire or other favorable environmental conditions before breaking ground. (Anderson, 2000)

Grazing and digging

- Bulbs maintain or slightly increase in abundance in response to grazing and digging disturbance (e.g. activities of feral pigs), though they may be outcompeted by exotic species in recapture of light and space (Tierney and Cushman, 2006)
- Digging actions that separate large bulbs and corms from attached small ones increases the density of sprouts in that area (Anderson and Rowney, 1999)
 - o Potential management tool to increase the number of propagules post-establishment
- Bulbs can survive surface upheaval that might negatively affect the seed bank but are increasingly likely to be damaged with deeper disturbance—i.e. 4-6 inches deep or deeper. Recently planted corms are sensitive to shallower disturbance (e.g. 1-2 inches in depth). (Konaten, 1996)
- Bulbs are sensitive to gap size and shape during disturbance, naturally revegetating fastest when bare ground is small in size (156cm² bare ground or smaller) and roughly rectangular in shape (Kotanen, 1997)
 - o Revegetation success is controlled mainly by competitive interactions with coinvasaders such as annual grasses. If competition can be controlled, gap dimensions affect revegetation rate

- *Chlorogalum* is eaten by a collection of small rodents, including California ground squirrels and pocket gophers (Reeves, 2006)
 - Other herbivores may include rabbits, deer, and other rodents
 - Livestock may also graze it if it is available, though no data exists to confirm this
- *Brodiaea* is palatable to the same herbivorous groups as *Chlorogalum* (Wilson, 1960)
- Palatability may decrease after flower set as foliage yellows and dries
- Grazing early in the growing season, in moist soil, may lead to the uprooting of corms (Wilson, 1960)
 - Some grazers eat young corms
- Pocket gophers (*Thomomys bottae*) have been recorded eating *Triteleia laxa* corms in the Sacramento Valley (Schlising and Chamberlain, 2006)

Herbicide Sensitivity

- Bulbs and corms are sensitive to broad-spectrum herbicides (Valentine, 2004)
- Insensitive to foliar-applied herbicides after leaf die-back (Valentine, 2004)
- Especially sensitive to systemic herbicides that affect monocots during new corm growth shortly before flowering (Valentine, 2004)

Climate Change

- Rainfall redistribution and drying of wetland/vernal habitats may impact wet-adapted corms
 - More concentrated rainfall may promote waterlogging, which rots corms if soils do not have adequate drainage (USDA PLANTS)
- Longer, hotter summers may push leaf wither earlier in the year and corm/seed activity later
 - This would decrease the growing period each season, resulting in less biomass accumulation and potentially a delay in flowering if corms take longer to attain minimum mass to induce flowering (Han et al, 1991)

Tillage

- Native tribes managed bulbs through tillage, promoting sprout density by breaking off cormlets which would sprout into new plants (Anderson, 2000)
 - Light, shallow tillage can therefore promote native bulb patches

Native Bulbs (information from CalFlora, Jepson eFlora, USDA PLANTS Database)				
<i>Triteleia hyacinthina</i> white brodiaea	<i>Dichelostemma capitatum</i> Blue dicks	<i>Chlorogalum</i> spp soaproot	<i>Triteleia laxa</i> Ithuriel's spear	
 Neal Kramer, 2007	 Cal Academy of Sciences, 2011	 David A. Tharp 2003  Christina Raving 2002	 St Mary's College of CA, 1995	
Umbel inflorescence of 10-40 flowers in capitate clusters. White sepals/petals with green midvein. Basal leaves 10-40cm long, 4-22mm wide.	Lynn Watson, 2007 Dense, umbel-like infl. w/ wide bracts on fleshy stem. Blue to pink, purple, or white perianth, 6 fertile stamens and membranous, petal-like tissue around anthers, 2-3 basal leaves, may be keeled	Bulb covered in coarse hairs, leaves 20-70cm with wavy margin, inflorescence with many branches, white sepals/petals with green or purple midvein (<i>C. pomeraldium</i>) green to yellow midvein (<i>C. angustifolium</i>)	Umbels of 8-48 funnel-shaped flowers with 6 fused petals, 2-3 basal linear leaves. Corms covered in fibers.	
Grasslands, pine forests, vernal meadows, foothill woodlands.	Pine forests, creosote bush scrub, wetlands/riparian areas, Pinyon-juniper woodland	Valley grassland, coastal scrub, foothill woodland, evergreen forests, chaparral	Open forests/woodlands, grassland. Tolerates clay soil.	
Bloom March-July Leaves wither w/ flowering.	Flowers February-April	Flowers May-August; flowers open in evening	Blooms April-July. Leaves wither when flowering.	

Part 2: Project Goals and Management Plan

Goals

Short-Term

- Increase the total population of *Brodiaea californica*, which is native and endemic to California and currently only found in 16 counties.
- Add new populations of *Chlorogalum*, *Dichelostemma* and *Triteleia* species to enhance their range and presence in ecological communities.
- Enhance grassland, vernal pool, riparian, and wetland area diversity at the levels of genotypes, species, and ecological strategy by fostering native bulbs.

Long-Term

- Create refuge populations of *Brodiaea coronaria*, which is under pressure from habitat loss due to agricultural and urban development.
- Conserve and restore vernal pool communities while creating *B. coronaria* habitat.
- Foster restoration and conservation of wetland and riparian habitat through *Dichelostemma* restoration.
- Promote native pollinators such as *Bombus sonorus*, *Bombus vosnesenskii*, *Xylocopa tabaniformis orpifex*, *Lasioglossum sisymbrii*, and *Selasphorus sasin*.
- Incorporate traditional knowledge into wildland management by teaching traditional tillage methods to restorationists.

Efficacy of Goals

Short-term goals can be achieved by the end of the establishment period of one year's worth of planted bulbs. Long-term goals require maintenance of bulb populations over many years, relying on the persistence of those populations. The easiest goal to achieve is the final one—incorporating traditional management into restoration practices—because its success involves only human interactions of teaching and learning techniques, regardless of any resultant changes to plant communities; that said, formal adoption of those practices by restoration agencies would hinge on their success at positively impacting bulbs.

The other goals are directly dependent on the successful establishment and growth of bulb populations. They require that those populations become self-sustaining, self-reproducing, and resilient. For true long-term viability, bulb patches must be able to vegetatively and sexually reproduce, recruiting enough new individuals to keep the effective population size above the minimum viable population threshold. They also must be prevented from overcrowding and succumbing to population failure driven by intraspecific competition.

Restoration plan

The following plan is designed to be implemented on a singular multi-acre project scale, taking into consideration the potential for habitat variation from grassland to wetland/riparian to vernal pools within a potential site. Not every species considered is appropriate for every habitat or project site, and species must be carefully matched with the environmental characteristics of a site at the time of restoration. The plan can also be applied to a smaller site of just one patch of bulbs. It relies heavily on rainfall irrigation and the presence of pollinators,

neither of which are guaranteed to be present on-site at the time or frequency required. Where possible, alternative management strategies are suggested.

Propagule Supply

Propagules should be sourced, as much as possible, from several local populations. Bulbs reproduce clonally and by gravity-driven seed dispersal so within-patch genetic diversity is generally low (USDA PLANTS). It is therefore advisable to take propagules from as many different populations as possible to help ensure genetic diversity and increase the chances of long-term survival and adaptation.

Triteleia laxa is morphologically variable in plant height and flower size and color. Different phenotypes dominate different zones in its geographic range, from the lowlands to mountain slopes, so it is especially important to use lowland-adapted propagules to best ensure establishment and maintain the integrity of regional gene pools (Kotanen 1996). *Chlorogalum* species can be competitive to the point of weediness: using nonlocal propagules introduces the risk of domination by introduced genes (USDA PLANTS). Local patches with noninvasive genomes are likely plentiful and should be utilized. *Dichelostemma* and *Brodiaea* are fairly uncommon in the Central Valley, so propagules may necessarily come from farther afield (Calflora).

Transplanting tubers is the recommended method of establishing bulbs. Field tests with *Dichelostemma* indicate that harvesting 50% of the mature plants in a patch yields the greatest number of corms and cormlets as well as the heaviest cormlets (Anderson 1999). Knock off any attached cormlets and rebury them: this enhances the source population by spreading cormlets out spatially and allowing them to resprout where they face less resource competition with other corms.

Corms harvested for direct transplantation should be installed in the site as soon as possible after being gathered. Plant corms in the fall, before October, 2-4 inches apart in full sun. Because of their short dispersal distance, bulbs tend to grow in discernable patches and such spatiality should be reflected when transplanting.

Plant *Triteleia*, *Brodiaea*, and *Dichelostemma* 4 inches deep, *Chlorogalum* so that the top of the bulb protrudes above the soil. Protect plants with cages, sleeves, or light fencing and screen cover for one year. Weed aggressively during this time, especially in advance of the fall rains, when bulbs will resprout, and 6-8 weeks after planting when cotyledons emerge (Schlising and Chamberlain, 2006). With the exception of *Chlorogalum*, which can be exclusively rain-irrigated, bulbs should be kept moist until leaves turn yellow in the summer. Bulbs take one calendar year to fully establish (USDA PLANTS).

If tubers cannot be acquired, bulbs can be propagated through seed broadcast at a rate of approximately 1600 seeds/square foot (USDA PLANTS). However, bulbs take 2-3 years to mature from seed and are vulnerable to drought and damage from insects, mammals, and birds during that period. A more effective strategy is to raise plants to maturity in a greenhouse before transplanting into the restoration site. Seed should be sourced from local populations, following the same sourcing guidelines as corm harvesting, or from native plant nurseries with careful attention to their source (USDA PLANTS). If sourcing from field populations, harvest seed directly from plants or from the soil surface. Bulbs make dormant seeds that germinate after disturbance and are mostly found in the soil seed bank (USDA PLANTS, Reeves, 2006). Bulb seed is viable for approximately ten years after production, so seeds need not be planted the same year they are harvested (Anderson, 2000). When growing from seed, *Triteleia laxa* germinates best after cold stratification for 8 weeks at 3C (Han, 1993). If seeding does not take place in the fall, *Dichelostemma* may require 1 month of cold stratification (USDA PLANTS).

Establishment

Establishing bulbs from seed and field-sourced tuber transplants takes 4 growing seasons, offset one of two ways. In the first regime, seed and tuber propagules are gathered in the same growing season; in the second, seeds are gathered 4 years prior to field corms and both seed- and field-sourced corms are planted in the same growing season.

In the first regime, transplant mature, field-harvested tubers and broadcast seeds in nursery pots at a rate of 100 seeds per 6-inch pot during the initial growing season. The next year, transplant germinated seeds into gallon-size pots and, if the bulbs in the field have established well, till lightly to break off cormlets (USDA PLANTS). In the fourth season, transplant mature plants from nursery pots. After the seed-sourced plants are established, introduce an annual or biannual (every other year) tilling regimen.

In the second regime, start seedlings 3 years before field-bulb transplanting so all mature corms are transplanted in the same growing season. This has the advantage of allowing all bulbs to be planted into a similar species assemblage, instead of planting seed-sourced corms into a post-restoration community that could hinder establishment.

Tilling is done by digging to corm depth with a narrow (approximately 1-2" diameter), stick or stick-like implement in the fall, after seed set (USDA PLANTS). Its action breaks cormlets off from parent corms and spreads them underground. It can be used to increase patch area, density, and total number of individuals. Because tillage can be used to expand patches over time, initial establishment density is not of critical concern if tillage is an option. If not, or if only one or two individuals survive, a second year of planting may be necessary.

Potential problems for establishment and survival of bulbs are water shortages, lack of supporting pollinators, and pathogens. If autumn rains are light or absent, establishing bulbs should be irrigated to mimic average seasonal rainfall.

Long-Term Management Practices

Burning

Bulbs can benefit from a burning regimen with at least 3 years of rest between burns to give plants time to mature and set seed (USDA PLANTS). After burning, dormant seeds sprout en masse, creating a surge in the number of genetically diverse individuals in a patch (Anderson, 2000; Reeves, 2006). Burning regimes are most successful if animal pollinators are present to facilitate post-burning sexual reproduction (Reeves, 2006).

Pollination

Triteleia laxa can be pollinated by *Apis mellifera*, the common, introduced honeybee (Chamberlain and Schlisig, 2008). *Chlorogalum* requires large native bee species (*Bombus sonorous*, *Bombus vosnesenskii*, *Xylocopa tabaniformis orpifex*), yellow jackets, mining bees, or Allen's hummingbirds for pollination in the evenings when their flowers open (Stockhouse et al, 1978). Without animal pollination, *Chlorogalum* becomes self-fertile. If outcrossing is desired, pollinator species can be introduced to the area, or their activity can be simulated by humans (Stockhouse et al, 1978). However, all bulbs are capable of reproducing vegetatively, so pollinators are not necessary for survival as long as clonal genotypes are well adapted to the growing conditions. Exclusively relying on vegetative reproduction decreases population resilience.

Pathogens

In a 5-year study of *Triteleia laxa* in the Sacramento Valley, Schlising and Chamberlain discovered an unidentified pathogen that rotted scapes before they could flower. The cause and prevalence of the pathogen remains unknown. Some *T. laxa* clones can successfully flower despite infection, though they have fewer flowers and fewer seeds per flower than uninfected individuals (Schlising and Chamberlain 2006). If the pathogen is found on a restoration site, gathering seed from areas with known infection will increase the likelihood of introducing resistant individuals.

Monitoring plan

Pre-Restoration

Before restoration begins, the site should be assessed for its extant species assemblage, focusing especially on plants; pollinators; and animals that feed on bulbs, such as livestock and pocket gophers (Geomys bursarius) (Anderson, 1999).

Restorationists should determine the average date of the first rain of the season to help determine when to till, harvest, and transplant.

Post-Restoration

After planting, monitoring can be incorporated into plant care. When tilling, corm weight should be recorded. Corms 1g or heavier are generally considered mature and capable of producing flowering stems (Han, 1991, Schlising and Chamberlain, 2006). Germination and sprouting percentage can be measured during emergence, approximately 8 weeks after planting, with an expectation that 80-90% of propagules will germinate (Schlising and Chamberlain, 2006). If germination is significantly lower, steps should be taken to determine why. Soil moisture data should be taken and compared to on-site historic averages on a weekly basis during the establishment year; supplemental irrigation should be applied when soil moisture dips below the average (USDA PLANTS).

*After emergence, aboveground vegetation should be visually expected for yellowing and drying. All bulb species considered in this paper go dormant during the summer months, but unseasonable drying of leaves is an indicator of stress (Schlising and Chamberlain, 2006). In *Triteleia laxa*, scape development should be monitored for signs of rot, which would indicate infection by the pathogen found by Schlising and Chamberlain. If rot is found that appears symptomatic of the pathogen¹, the corm should be removed from the site to help prevent further spread. Plants should be inspected for damage by animals—e.g. by grazing or trampling—and protective structures checked for integrity and function. These observations should be made on a regular weekly to biweekly basis to avoid loss of propagules from accumulated stress and damage.*

*During flowering (April-August), pollinator interactions should be noted. *Chlorogalum* should be observed in the evening, when its flowers open, but other bulbs should be observed during the day (Stockhouse et al, 1978; Chamberlain and Schlising, 2008).*

The most intensive monitoring is done during the establishment year, especially in the time around emergence and flowering. Corm, pollinator, and pathogen monitoring are longer-term, continuing annually after the establishment year. Corm monitoring is attendant with tilling while observations of pollinators and pathogens are independent

¹ Pictures of rotted scapes are included in the published paper by Schlising and Chamberlain. For more information, see the list of references.

of other management practices. Once patches are of the desired size and maturity, tilling can be stopped and monitoring cut down to one of every two to three growing seasons. This allows each generation of plants to be monitored while conserving time and money. If patches decrease significantly in size or density, they should be tilled and weeded as appropriate.

Contingency Planning: Failure to Establish

If populations fail to establish, careful note should be taken about the circumstances under which they failed. If the propagule supply is determined to be the cause, propagules should be harvested from different plants in the next season, or reared differently (e.g. try transplanting greenhouse-grown corms instead of field-grown ones). If only a few individuals establish in a patch, tilling can be used to grow the patch over several years. Supplemental planting may also be used to increase genetic diversity.

Unknowns & Areas of Future Research

There is a staggering lack of research about restoration of native bulbs in California wildlands. Soil pH tolerance for *Brodiaea* is currently unknown: if a prospective restoration site has a range of soil types with different pH, patches of *Brodiaea* could be planted in each to generate a rough tolerance range. Bulb response to pesticides is also unknown, though this is more appropriate to test on nursery-grown seedlings to reduce risks of drift to other desirable species and losses of mature corms. If corms are being reared from seeds in a greenhouse, flats can be tested against herbicides likely to be used in restoration at field-typical application rates. Water table requirements for bulbs are also unknown, but determining such complex dynamics is likely to be outside the scope and budget for a restoration project.

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Narrow Leaf Milkweed (*Asclepias fascicularis*)

Greg Webber

Part 1: Project Background and Justification



General Information

Family: Asclepiadaceae

Genus: *Asclepias fascicularis* (formerly *A. mexicana*)

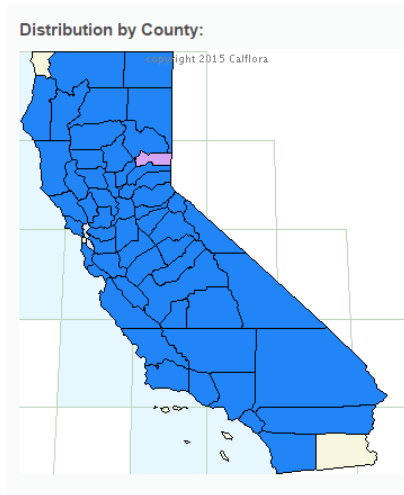
Common: Narrow Leaf Milkweed

Background and Justification:

Asclepias species occur across all lower 48 states with 15 species native to California (B. a. M. E. Borders, 2011). *A. fascicularis* displays large clusters of fragrant flowers that attract many insects. These herbaceous perennials are specifically known for their role in the lifecycle of the monarch butterfly (Holstein, 2011; Powell, 2002; Schmidt, 1980; Wikimedia, 2015). Recent declines in milkweed populations due to increases in agricultural efficiencies are cited as factors in the decline of Monarch populations, but most Milkweed species are not yet classified as endangered (Luna & Dumroese, 2013; Oberhauser et al., 2008). Of California's Milkweed species, *A. fascicularis* is most common as is found everywhere from high mountains to valley bottoms (Calflora, 2015).

Range and Distribution:

The range of *A. fascicularis* extends from Washington to Baja, east to Utah and west to the Pacific Coast. There are recorded specimens for all California counties except Del Norte, Imperial and Sierra (Calflora, 2015).



(Calflora,



(Calflora,

Form:

Stems: slender 2-5 feet. Leaves: linear-lanceolate in whorls of 3-5, often opposite at top and bottom of stem. Umbels: many in whorls, densely many flowered on peduncles longer than the pedicels with oblong corolla lobes. Fruit: forms follicles 3-4 inches long (Jepson, 1951). Seeds disperse on the air via silky hairs attached to individual seeds (Calflora, 2015).

Reproduction and Cultivation:

A. fascicularis blooms from July to September and is pollinated by many native insect species including the Tarantula Hawk Wasp (*Pepsis* sp.) (B. a. M. E. Borders, 2011). Seed should be collected as the follicle ripens, but prior to seed dispersal. Follicles can contain up to 60-100 seeds depending on species (Betz & Lamp, 1992). Field planting of seed can be carried out in the fall with subsequent germination occurring in the spring. Planting in the nursery can be accomplished with scarification, but some sources indicate that potted milkweed plants do not transplant well (Luna & Dumroese, 2013). Milkweed can reseed into both disturbed and undisturbed areas successfully after reintroduction (Calflora, 2015). Narrow Leaf Milkweed may also be cultivated from root cuttings best taken during dormancy and planted immediately in the fall or winter (Luna & Dumroese, 2013).

Habit and Adaption:

Narrow Leaf Milkweed is widely adapted from riparian fringes to dry chaparral and forested areas, from lowlands to ultimate height of 7,000 feet. *A. fascicularis* can survive in both heavy clays and sandy soils, but generally prefers sunny conditions (Calflora, 2015). This high adaptability is seen as a key to the species ability to thrive in gardens and native conditions alike. While Narrow Leaf Milkweed is hardy to 18° F in winter, (USDA Zones 6a-10b), it may die back in colder months. Acceptable soil pH occurs from 5.8-8.2. Allowable annual precipitation rates vary wildly: 9-107 inches. Bloom times extend from June-September and may reseed freely to create a large colony (Calflora, 2015; USDA/NRCS, 2001). Some studies suggest that fire can create opportunities for Milkweed to fill newly cleared land (Baum & Sharber, 2012).

Insect Interactions:

All *Asclepias* species are known to be pollinator attractors and hosts to Monarch Butterfly larvae. Cardenolide compounds found in the milkweed are thought to act as a deterrent to predators of Monarch larvae in adolescent and adult stages (Marty, Gee, & Krieger, 1982; USDA/NRCS, 2001). While several other native Lepidoptera species use Milkweed as well, there are some pest species also associated with the genus that need to be considered. Cal Flora notes that milkweed may host Glassy Winged Sharp Shooters which can carry Pierce's disease, a bacteria deadly to Grapes and Citrus. Also, due to concerns with Light Brown Apple Moth, California Ag. Regulations require nurseries to treat Milkweed with Bt, thus requiring a year of decontamination prior to use as Monarch habitat (AnniesAnnuals&Perennials, 2015). Also, Oleander aphids (*Aphis nerii*) are known to heavily infest Narrow Leaf Milkweed in nursery and wild settings (B. Borders). Other known predators of Milkweed include: Common Milkweed Beetle, Small Milkweed Bug, Large Milkweed Bug, Common Milkweed Stem Weevil, Milkweed Leaf Miner, Aphids (Green Peach, Black, Red, Cotton and Oleander), Thrips, Orange Margined Milkweed Moth, Harlequin Caterpillar Moth, and as previously mentioned, the Monarch Butterfly (Betz, Rommel, Dichtl, & Warwick, 1997).

Animal Interactions:

Mild toxicity of Milkweed makes it largely unpalatable to most mammal species (B. Borders; Oberhauser et al., 2008), though occasional browsing should be expected.

Human Interaction:

Milkweeds were used for cordage by Native Americans, but may cause skin irritation if handled (Calflora, 2015). The common name comes from the milky sap produced by the plant to dissuade predation. Though mildly toxic, the sap is generally not potent enough to warrant concern. Some western tribes even used the milky sap to create a chewing gum like substance. Modern day Monarch decline has raised awareness of the importance of Milkweed in the wild, home and farmed environments. Recent developments in GMO crops and the Round-up ready gene have largely been viewed as responsible for the rapid decline of *Asclepias* species across the nation (Oberhauser et al., 2008).

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Part 2: Project Goals and Management Plan

Introduction:

Narrow Leaf Milkweed (NLM), or *Asclepias fascicularis* is one of the most abundant and widely adapted milkweed species in California. However, due to a long history of invasive plant competition, land development, and agricultural management practices geared to eradicate weedy pests, most Milkweed populations are declining (B. Borders & Lee-Mader, 2014; Pleasants & Oberhauser, 2013). NLM is an early successional species adapted to ruderal zones where soil has experienced recent disruption like road sides, gravel bars, and recently eroded or excavated slopes. Milkweed seed disperses in the wind, but can also reproduce from rhizomes (B. a. M. E. Borders, 2011; Calflora, 2015). NLM is a key source of forage for pollinators and is known for being host plant for Monarch Butterfly larvae (Bhowmik, 1994). As a whole, milkweed populations make up an important component of native forb communities and an important source of forage for many insect species, as such, they should be included as a part of native restoration projects (Betz, Romnel, Dichtl, & Warwick, 1997; B. a. M. E. Borders, 2011; Holstein, 2011).

Background and Significance:

For the majority of the 20th century, milkweed was considered an agricultural weed, and as such, research focused on the species' detriments to agriculture and the best management practices to contain its spread in the agricultural environment (Calflora, 2015; Martin & Burnside, 1980; USDA/NRCS, 2001). It is not until the decline of Monarch butterflies over the last twenty years that research into milkweed restoration has been begun in earnest, but still many gaps in information remain. Though known to be a successional species in a fire adapted environment, the species reaction to fire disturbance is not documented to the point of providing actionable intelligence (Ulev, 2005). Also, while there is research into select species of Milkweed, a general lack of research into *A. fascicularis* specifically means that restoration practitioners need to rely on data and practices derived from a wide variety of *Asclepias* species.

As a species adapted to a wide variety of climates across its range, it will be important to document and collect a large variety of *A. fascicularis* genotypes for occurrence studies and selection catalogs. While seed is readily available through reliable sources, wild harvested seed can be collected as a means to

increase locally adapted populations in restoration efforts (B. Borders & Lee-Mader, 2014; Hedgerow, 2015). Furthermore, studies of *Asclepias* in California agricultural lands, urban margins and wild areas would help to develop a more complete picture of the state of the species in the state and the possible restoration practices to adopt. It may be that Ag management and utility corridor management policies could play as significant a role in population management as active restoration (Hopwood, 2008; Jones&StokesAssociates, 1997; Pleasants & Oberhauser, 2013).

Restoration Goals:

- 1) First, managers need to identify potential habitat for restoration efforts. Suitable sites not only need to include the specific environmental conditions for NLM, but also be readily available for conservation activities.
- 2) We must next determine the specific management goals tied to Narrow Leaf Milkweed restoration. Though there may be a conservation argument to increasing Milkweed itself, it is unlikely that law makers, land managers and the public will be interested in what is essentially a mildly noxious weed (Calflora, 2015). It is more likely and more productive to consider milkweed restoration as a step to providing habitat and forage for pollinator species and Monarch Butterflies. Recognizing the goals of each will be important, as each category entails specific spatial and temporal requirements that have implications for the use of conventional land management policies. Monitoring strategies will be considered in this section as they are critical to creating an adaptive management strategy that meets stated goals.
- 3) Finally, specific management and propagation strategies need to be studied for effectiveness in the realization of restoration strategies.

Site Selection Overview:

Agricultural Opportunities:

It is critical to recognize that NLW has been seen by the agricultural industry and academics as pest species. Historical research efforts were geared to measuring the effects milkweed has on crops, as well as the best methods for eradicating the pest (Martin & Burnside, 1980). Furthermore, the success of Glyphosate resistant GMO crops and increased agricultural efficiency is seen as a major reason for trends in Milkweed and Monarch Butterfly decline nationally (B. Borders & Lee-Mader, 2014; Pleasants & Oberhauser, 2013). One key step in regaining Narrow Leaf Milkweed populations in the central valley would be to increase sustainable practices in the 25.4 million acres that California currently dedicates to farming (Tolomeo, Krug, & DeWalt, 2012).

Organic production methods are sustainable land use tactics with potential to reintroduce NLM to agriculture. Though not widely adopted for financial reasons, there is strong evidence that organic production generally increases biodiversity in Agricultural lands (Bengtsson, Ahnström, & WEIBULL, 2005). Further research into whether a general increase in diversity includes Milkweed specifically, and whether sustainable methods allow NLM to

reproduce in the Organic Ag. Environment. Furthermore, the discrete goals of boosting pollinators or boosting Monarch Butterfly populations will affect the timing of management activities for NLM, as one goal requires flower production, and the other is dependent on butterfly migration patterns (B. Borders & Lee-Mader, 2014).

Hedgerows in agriculture have been gaining popularity for their ability to reduce herbicide use, increase beneficial insect populations, and improve soil and water quality in and around Agricultural lands (Brodt, Klonsky, Jackson, Brush, & Smukler, 2009; Forman & Baudry, 1984; Hedgerow, 2015). These bands of native plants would provide great ruderal habitat for NLM, and suit both the pollinator habitat and Monarch Butterfly populations (B. Borders & Lee-Mader, 2014; Morandin & Kremen, 2013). Given the expansive areas dedicated to agriculture in California's central valley, further geospatial analysis into how much land is actually available in the margins, and what percentage should be covered in milkweed is needed.

Wild Land Restoration Opportunities:

Due to Narrow Leaf Milkweed's wide adaptability to both dry upland and riparian conditions, it is a key forb species for landscape restoration managers in California (Calflora, 2015). It is highly recommended however, that NLM be incorporated into a functional communities mixture at a rate of 1-14 % as planting only Milkweed would limit habitat adaptability and benefits; furthermore, community diversity ensures a higher level resilience and tolerance to disturbance while spreading out forage and covering opportunities across the year (B. Borders & Lee-Mader, 2014). Periodic

Utility and Transportation Corridors:

Another great landscape for NLM restoration are utility and transportation corridors. The same hedgerow techniques applied to agricultural margins above have already been applied to roadsides in Minnesota (B. Borders & Lee-Mader, 2014). Research into the opportunities and constraints that other utility corridors such as rail lines, canals and interstate highway margins may provide is still needed. Studies of right of way management techniques and their effects on butterfly populations in Pennsylvania show that the effects of clearing the forests for transmission lines with herbicides or mechanical techniques improves butterfly populations by increasing the presence of open habitat (Bramble, Yahner, & Byrnes, 1997). Yet this study can only point to a general positive relationship of utility corridors and butterfly populations, but falls short of informing what steps should be taken in California's varied network of utility lines. Again, selecting a regionally appropriate plant community mix will be key to success, but the generally harsh conditions of transportation corridors and the wide adaptability of NLM may coincide quite well.

Management Goals Overview:

As stated earlier, the specific restoration goals for Narrow Leaf Milkweed should not only be incorporated into broader functional communities, but

should also be integrated into larger site goals such as erosion control, increasing pollinator habitat, and boosting Monarch populations. Though NLM decline has been historically linked with Monarch decline, monitoring and management practices need to prove that current restocking strategies are meeting end goals whether they be soil improvements, pollinator support, or Monarch reproduction (Pleasants & Oberhauser, 2013).

Monarch Strategy Goals:

To help re-establish Monarchs, the need for healthy milkweed patches of various species need to be present along known migration routes for Monarchs (Borders, 2011). Furthermore, with a multigenerational lifecycle that incorporates migration patterns there is a clear need for Milkweed host plants for all season except late fall and winter when Monarch are overwintering and inactive (Oberhauser & Solensky, 2004). Predicting when and where monarchs will mate is difficult, but monitoring of eggs or larvae at restoration sites will be necessary to judge the success of restoration goals. Also, the monitoring of eggs and larvae will be critical for timing management techniques like mowing that have the potential to destroy host populations during early lifecycles. Long term Butterfly and Milkweed monitoring in the Central Valley are needed to ascertain effectiveness of restoration efforts and thresholds of action.

General Monitoring Strategies:

For general Milkweed monitoring strategies, there are a variety of monitoring techniques that need to be considered. When large patches of Milkweed are present on site, monitoring once in spring and once in summer for aphid infestation will help managers determine action thresholds (Betz, Rommel, Dichtl, & Warwick, 1997). For areas that are being controlled through mowing, there is an increased likelihood that seed production will be reduced and that vegetative re-sprouting is critical for survival on the site (Bowles, McBride & Betz 1998). As Milkweed are almost all self-incompatible, mower exclusion or periodic seed planting could help decrease reliance on clonal reproduction and increase genetic diversity, and wind dispersal effects on the site. Due to a lack of comprehensive data about Milkweed and associated species across the Central Valley of California, restoration technicians should create their own monitoring schedule based on their specific goals.

Disturbance:

As a ruderal species, NLM will be able to fill niches left by erosion, fire and channel scouring (Baum & Sharber, 2012; Calflora, 2015; Brianna Borders; Calflora, 2015; Calflora, 2015). Therefore, monitoring for disturbance will provide managers with opportunities to fill voids in the ecosystem with beneficial species.

General List of Variables to Monitor:

- Spring: monitor levels of aphids, ensure new re-sprouting form dormant plants, and begin monitoring of monarch eggs and larvae.
- Summer: monitor levels of aphids, continue Monarch monitoring, begin flower and seed pod maturation timelines.

- Fall: continue flowering and seed pod maturation timelines, monitor for aphids especially in milder regions, begin watching for dormancy.
- Winter: note extreme weather patterns, flooding and erosion patterns on site to determine reseeding opportunities and potential mortality.

Propagation Practices:

Seed: Individual seed pods containing up to 100 seeds mature gradually over the harvest period and demand that collections be drawn out over the course of a few weeks in the fall (Betz & Lamp, 1992). Monitoring records will greatly assist these efforts. Seed is best harvested when the pod splits open, but before the seed floss unfurls prior to wind dispersal. For small restoration efforts, hand harvesting and cleaning can be carried out, but for larger projects, large scale seed production can be successful (Pleasants & Oberhauser, 2013). Seed application can be carried out in late fall for untreated seed, or winter for scarified seeds, but seed longevity generally lasts less than 2 years so fresh seed supplies are important (Comes, Bruns, & Kelley, 1978). Drill seeding and broadcasting are both viable methods for seeding, but some evidence suggests drill seeding is a better option (B. Borders & Lee-Mader, 2014).

Root Division: Many species of *Asclepias* demonstrate the ability to sprout from root materials, and it is not uncommon to find a patch of several Milkweed plants produced by asexual reproduction of one mother (Brianna Borders; Calflora, 2015). Since most Milkweed plants are self-incompatible, it is critical to select seed from a fairly large geographic area to ensure genetic mixing of seeds (Ulev, 2005). Root cuttings can be taken and rooted to create clonal plants of a single mother if dense plantings of NLM are desired. The cons of this technique would be the limiting of fertile seed production and genetic diversity in exchange for rapid plant establishment. Conditions where this technique may help would be to improve erosion protection in a newly exposed site.

Conclusion:

It is critical to reinstate NLM as a component of a native grassland and forb community to create a sustainable management strategy. Hedgerow Farms in Winters Ca in cooperation with The Xerces Society for Invertebrate Conservation, created a wild land seed mix formulated for pollinators that includes *A. fascicularis* (B. Borders & Lee-Mader, 2014; Hedgerow, 2015). These diverse communities require strict limits on herbicide use to be effective in bolstering pollinator communities. The use of NLM as a constituent member of hedgerow species can be widely utilized in a variety of marginal land areas like drainage ditches and roadsides to larger prairie restoration sites. By including Narrow Leaf Milkweed restoration as a subset of larger efforts to help more charismatic species like Monarch Butterflies or Bees, a broader level of NLM restoration can be achieved.

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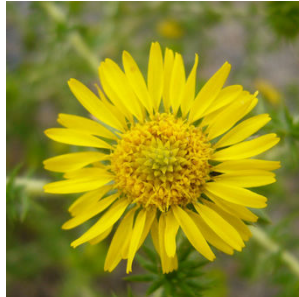
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Tarweeds (*Hemizonia* sp., *Calycadenia* sp, *Centromadia* sp)

Michaela Owens

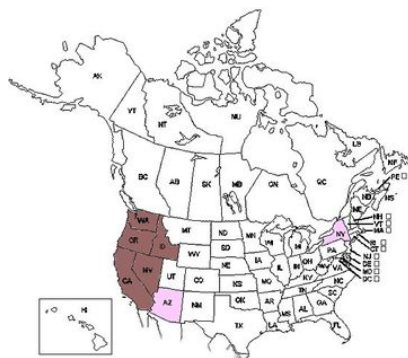
Part 1: Project Background and Justification

Pictures at different stages: (Encyclopedia of Life; eol.org)



Appearance: It is a yellow-flowered annual plant that is sticky and aromatic. It is hardy and competitive in the dry climates of California (eol.org).

Habitats it is found in: It is native to southwestern Northern America, specifically to the Cosumnes River Preserve in California. It prefers dry grasslands and seasonal wetlands where it thrives on a wide variety of soil types. It has been known to move into dryland cereal and irrigated crops (eol.org).



Michaela Owens

Tarweed (*Hemizonia* sp., *Centromadia* sp., *Madia* sp.)

Project Background and Justification

Tarweed is an annual native California grass that is best suited in areas with hot, dry summers such as the Central Valley and surrounding foothills. California's

grasslands drastically changed with the arrival of Europeans. Many annual grasses and forbs were accidentally and intentionally introduced from the Mediterranean area. Grazing pressure on the range increased with heightened numbers of domestic livestock, which led to a reduction in soil moisture used by plants. In addition, the summer fires that went through the perennial grasslands were controlled. All of these changes made the spread of tarweed more favorable. Tarweed is an important protein source for ground squirrels and the pollen of tarweed flowers is an important food source for honeybees. Tarweeds are unique in that they are deep rooted, which allows them to use the stored water in the soil that other short-rooted annual grasses cannot. Control of tarweed is done by either reducing tarweed densities or by depleting soil moisture. To reduce densities, mechanical (mowing) and chemical (herbicides) strategies are used. These techniques must be used over at least a five year period due to the extensive seedbank of the many tarweed varieties. To deplete soil moisture, nitrogen fertilizer is used to increase the production of the competitors of tarweed, which makes them diminish the soil moisture that maintains the growth and survival of tarweed. Controlled fires can also be used to control tarweed, but due to the site location is not recommended (Perrier, Williams and Menke, 1982).

Literature Review- Fact Sheet

Specific Variety Conditions (CalFlora)

Scientific Name	Common Name	Status	Life form	Bloom Period	Habitat/Community
Centromadia parryi	Pappose tarweed	Native	Annual herb	May-November	No info
Centromadia pungens	Common tarweed	Native	Annual herb	May-September	Wetland-riparian
Hemizonia congesta	Hayfield tarweed	Native	Annual herb	August - October	Valley grassland, foothill woodland, northern coastal scrub, southern oak woodland
Hemizonia congesta spp. calyculata	Mendocino tarplant	Native (rare species)	Annual herb	July-November	Valley grassland, foothill woodland
Hemizonia congesta spp. clevelandi	Cleveland's tarweed	Native	Annual herb	August - October	Valley grassland, foothill woodland, southern oak

i					woodland
Hemizonia congesta spp. congesta	Hayfield tarweed	Native	Annual herb	April-November	Northern coastal scrub, valley grassland
Hemizonia congesta spp. lutescens	Hayfield tarweed	Native	Annual herb	August - October	Valley grassland, northern coastal scrub
Hemizonia congesta spp. luzulifolia	Woodrush tarweed	Native	Annual herb	August - October	Valley grassland, foothill woodland
Hemizonia congesta spp. tracyi	Tracy's tarplant	Native (rare species)	Annual herb	May-October	Coastal prairie, Yellow Pine forest, Redwood forest
Madia anomala	Plump seeded madia	Native	Annual herb	April-June	Foothill woodland, mixed evergreen forest
Madia citrigracilis	Shasta tarweed	Native	Annual herb	June-August	Yellow Pine forest, Northern Juniper woodland
Madia citriodora	Lemon scented tarweed	Native	Annual herb	April-July	Yellow Pine forest, Northern Juniper woodland
Madia exigua	Little tarweed	Native	Annual herb	April-June	Multiple habitats
Madia glomerata	Mountain tarweed	Native	Annual herb	June-August	Yellow Pine forest, Red Fir forest
Madia gracilis	Gumweed	Native	Annual	April-July	Foothill woodland,

	madia, grassy tarweed		herb		mixed evergreen forest, northern oak woodland
Madia sativa	Coastal tarweed	Nati ve	Ann ual herb	May- August	Many habitats
Madia subspica ta	Slender tarweed	Nati ve	Ann ual herb	April- June	Valley grassland, foothill woodland

General Plant Description

These tarweed varieties all have sticky, strongly scented leaves. A mature plant will range from 1-1 ½ feet (30-45 cm) high. They all have upper and lower leaves in which the upper leaves are flattened against the stem, glandular, and hairy, while the lower leaves are distinctly lobed and “lance-like.” The flower petals can either be yellow or white (depends on the species) and all have three-toothed edges. They also vary in number of petals with the lowest number of petals being three (UC IPM).

Reproduction, Growth, and Dispersal

Germination will begin in the fall with the first rains and extend through April. Once winter has come to a close, a deep taproot will be established as well as a rosette containing about a dozen broad leaves. Compared to other winter annual grasses, tarweed roots go deeper, which reduces competition for soil nutrients and water. Between late spring and early summer, the shoots will lengthen to about 1-2 feet high and branch out with “bract-like” leaves. In August and September, the plant will make composite heads containing 3-5 ray flowers and 3-12 disk flowers. The ray flower only has a carpel but the disk flower has anthers that produce large amounts of pollen, which is an important food source for honeybees. The ray and disk achenes will mature at the close of September. Dispersal of achenes will continue into winter and is achieved via rain, wind, and wildlife. The plant produces five times as much fertile ray achenes than disk achenes, however most of the germination in the fall is from disk achenes. Once spring has ended, only the woody stems and thicker branches remain and stay as such until the next rainy season (Perrier, Williams and Menke, 1982).

Interactions

Many livestock eat tarweed plants in the winter and early spring, which is the period of time when they are young and succulent. Once the plant begins to increase in height and resin covering, herbivory rapidly declines. Grazing almost completely stops once it reaches maturity and is completely covered in resinous exudate. Even at this stage though, it is a vital protein and water source for ground squirrels. As mentioned above, the anthers produce an abundance of pollen, which is an important food source for honeybees. The summer annual varieties are usually the only

growing green plants that are moderately high in protein. To depress herbivory, summer annuals have evolved mechanisms such as spines and aromatic resins. Because of this, few animals are able to feed on these summer annuals (Perrier, Williams and Menke, 1982).

Competition

Tarweed mainly competes with winter annuals by lessening soil moisture in late spring. During the growing season, there may also be some amount of competition with other winter annuals for soil nutrients and water (Perrier, Williams and Menke, 1982).

Tarweed is commonly seen in the early successional stages of annual grasslands. This tells us that they are more compatible with less productive species that are commonly found in these stages and thus, has been coined as an “invader” species. An abundance of water is left over for the tarweed to utilize because the shallow-rooted, short-statured, early maturing alien annual grasses use less light and water. Tarweed is most competitive in deep, fine rooted soils since they rely on stored soil moisture (Perrier, Williams and Menke, 1982).

Annual variations in climate, specifically rainfall and temperature, determine if annual grasses or annual forbs/legumes are dominant. The degree of competition between tarweed and other winter annuals is less in grass dominant years and more in forb/legume dominant years. A reduction in tarweed densities is caused by the nitrogen fixing ability of annual legumes, which increase soil fertility, which then increase forage production and water use (Perrier, Williams and Menke, 1982).

General Overview of Management and Restoration Techniques

The most cost effective way to restore tarweed populations is by directly planting seeds to about ¼” deep in early spring (Ross, T.C., 2012). A drip irrigation system is recommended to be used until the plants have established their deep taproot (Alexander, 2003). Once the plants have established, it is important to monitor their success over a period of about 3 years. If plants are not continuing to successfully establish, changes need to be made to the original plan (Randall, 1995).

Part 2: Project Goals and Management Plan

A. GOALS

The various tarweed species are most commonly found in upland areas with only one species, *Centromadia pungens*, which is found in wetland-riparian areas (Ross, T.C., 2012). Tarweed species are most commonly found on recently disturbed areas at elevations between 0-12,000 feet (Ross, T.C., 2012). They can grow in a wide variety of soils including coarse, gravelly, and silty/clayey soils and in full sun (Ross, T.C., 2012). All tarweed species develop a deep taproot which makes them able to access water that other short-rooted plant species cannot. This gives them an increased probability of successful establishment (Perrier, Williams, and Menke, 1982). These various characteristics make the many tarweed species occur at early successional stages (Perrier, Williams, and Menke, 1982). The main goal for tarweeds is to successfully establish a wide range of tarweed varieties by collecting seeds from multiple reference sites in the Central Valley. To ensure ongoing success,

a disturbance regime of mowing to 4" every May, using herbicides, and controlled fires needs to be implemented (Perrier, Williams, and Menke, 1982).

Objectives

Establishment Phase

- Plant a variety (5-8) of tarweed species that can be found in upland areas, such as the *Hemizonia* genus, the *Madia* genus, and the *Holocarpha* genus. These will increase vegetation and be an important food source for wildlife (CalFlora).
- Install a drip irrigation system that will be able to reach deep soil layer so that tarweed taproots can access the water.
- It is unknown as to the frequency of monitoring plant establishment and recruitment for tarweed species specifically, but for other weedy plants similar to tarweed, monitoring monthly for three years was put into place.

Maintenance and Monitoring Phase

- Once the tarweed populations are established, set up a disturbance regime of mowing to 4" every May and/or spraying them with herbicides to make sure the tarweeds do not become invasive (Perrier, Williams, and Menke, 1982). Intermittent controlled burning can also maintain the population due to tarweed's ability to self-sow and persist (Ross, T.C., 2012).
- Make sure the surrounding shrubs and trees do not get too high in density as they may shade out the tarweeds and inhibit their establishment and recruitment success rate (Ross, T.C., 2012).

B. RESTORATION PLAN

Step #1: Collection of Seeds

Collection of tarweed seeds should take place in late summer to early fall (Deur, 218). Gathering the seeds can be done in two ways. The first is by stripping the seed heads by hand. An alternative, more efficient way is to cut the plant near the soil level and beat the seeds into a bucket or onto a tarp laid over the ground (Deur, 218).

Step #2: Preparation of the Site

To ensure successful establishment of tarweed populations, the site must be prepared before planting can occur. First, tarweeds require full sun so any debris needs to be removed (Deur, 219). Second, tarweeds have deep taproots so the soil needs to be deep and well-drained (Deur, 219). Lastly, the site needs to be completely cleared of any weedy perennial species as they may out-compete some tarweed species and inhibit successful establishment (Ross, T.C., 2012).

Step #3: Install a Drip Irrigation System

There are two main reasons why a drip irrigation system needs to be installed. First, the climatic and environmental conditions in this area are very unpredictable and second, it is much more cost efficient and effective than hand watering (Alexander, 2003). One study had a 95.7% survival rate when a drip irrigation system was used (Alexander, 2003). A constant slow drip will keep the soil moist without flooding the soil with water.

Step #4: Preparation and Planting of Seeds/Transplants

Depending on the budget, seeds can either be directly planted on-site or grown in a greenhouse and transplanted to the site.

Directly planting: Seeds should be planted in early spring when there is a plentiful amount of soil moisture for them to establish (Ross, T.C., 2012). Seeds can be planted in one of two ways. They can either be broadcasted onto the site, which is less efficient, or planted using a seed drill at a depth of $\frac{1}{4}$ ", which is more efficient (Ross, T.C., 2012). A rate of 10 pounds per acre should be used in order to create a dense strand (Ross, T.C., 2012).

Transplanting: If the budget allows, in late winter grow the plugs in a greenhouse and transplant them to the restoration site in spring (Ross, T.C., 2012). For the best results, cover the soil with weed fabric that has holes with 1 foot by 1 foot spacing (Ross, T.C., 2012). Place one transplant per hole (Ross, T.C., 2012).

C. MONITORING PLAN

Step #1: Monitor Plant Success

It is important to monitor areas where tarweed species are introduced to see if the densities are increasing (Randall, 1995). Since the tarweed populations will be controlled, it is also important to monitor to make sure the methods in use are executing the desired effect (Randall, 1995). Monitoring should take place over a few years because it will take a while for the populations to acclimate to the environmental and climatic conditions. Each successional year should show an increase in plant survival and success.

Step #2: Maintain the Tarweed Populations

Once a population of tarweeds has successfully established and survived to maturity, one should go out and monitor the population once every few years. Germination occurs anywhere from late fall to early spring, depending on climatic conditions (Randall, 1995). Rosettes will then bloom and flower from June to late summer (Randall, 1995). Based on this information, monitoring should take place monthly between early spring and late summer once every few years to make sure the plants are flowering. Another indication of success is the presence of honeybees, which are the main pollinators of the tarweed varieties (Perrier, Williams, and Menke, 1982).

Step #3: Set up a Disturbance Regime

Burning: Controlled burns will help to control tarweed populations, but only in the short-term because they can easily self-sow and persist (Ross, T.C., 2012).

Herbicides: Herbicide use is a good option for controlling tarweed populations. For the best results, apply picloram at a rate of 0.25-0.50 pounds of active ingredient per acre (Randall, 1995). In terms of timing, it needs to be applied before the seedlings germinate, which is in early spring (Randall, 1995).

Mowing: A regime of mowing to 4" every May will also help to control and maintain tarweed populations (Perrier, Williams, and Menke, 1982). It is important to note that a combination of these disturbance regimes can be used in concert if necessary.

Areas of Concern

Tarweed is known to give off a strong-scented resin from the leaves and stem (Randall, 1995). Because of this, many herbivorous wildlife cannot feed on tarweed once the plant reaches maturity and produces the resin (Perrier, Williams, and Menke, 1982).

Further Research

It has always been recommended to try to avoid herbicide use due to their chemical entities, so additional research on how to reduce or eliminate herbicide use should be done (Randall, 1995).

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Summer lupine (*Lupinus formosus*)

Kaili Brande

Part 1: Project Background and Justification

Habitat:

Prefers the dry slopes under yellow pine forests, red fir forests, lodgepole forests, and subalpine forests. Can also live in foothill woodlands, valley grasslands, or chaparral. Often inhabits clay soils. Populous in the San Jacinto, Santa Rosa, and San Gabriel Mountains. (http://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=5147, <http://www.calflora.net/bloomingplants/summerlupine.html>)

Photos:

Two major varieties (bloom June-October):

(http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=26017)

(<http://www.calflora.org/entry/plantchar.html?crn=5147>) (All CalPhoto below)

Lupinus formosus var. *formosus* E Greene:
C. P. Smith:



Lupinus formosus var. *robustus*



Pre-flowering stage (*Lupinus formosus* var. *formosus* E Greene):





Appearance:

Both varieties:

“**Stem:** spreading to erect.

Leaf: cauline; stipules 4–15 mm; petiole 2–7 cm; leaflets 7–9, 25–70 mm.

Flower: 10–18 mm; calyx upper lip 7–11 mm, 2-toothed, lower 8–12 mm, entire to 3-toothed; petals purple, banner back glabrous, spot white or not, keel glabrous, upcurved.

Fruit: 3–4.5 cm, hairy.” (http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=31876)

Lupinus formosus var. *formosus* E Greene: *Lupinus formosus* var.
robustus C. P. Smith:

Stem: 3-4 mm in diameter
diameter

Stem: 5-7 mm in

Flower: 10-14 mm

Flower: 16-18 mm

Part 1: Project Background and Justification

Habitat type in the overall project:

Valley Floor grassland

A. Background and Justification

Lupinus formosus, otherwise known as summer lupine, serves as a beautiful native wildflower that can visually enhance landscapes and help California retain its natural vegetative heritage. By conserving this lupine species alone, we can help create more suitable habitat for the endangered Mission Blue Butterfly, whose numbers have dramatically declined in Northern California in recent decades (Golden Gate National Parks Conservancy n.d.). Additionally, this lupine’s presence can likely provide pollination opportunities for bees (The Watershed Nursery n.d.). Underground, due to the plant’s ability to fix nitrogen and to thrive in post-disturbance landscapes, the plant is a valuable natural resource that can help facilitate succession in a community (Goergen et al. 2009). It often has shown to increase soil productivity and soil nitrogen content, making it a potential tool in restoration of degraded native grasslands in California (Potthoff et al. 2009; Goergen et al. 2009). Throughout California, and more specifically within the Central Valley, this lupine species has experienced widespread decline in both human-dominated areas (through urbanization and habitat conversion) and in undeveloped areas

(through overgrazing of livestock and fire suppression) (Shapiro 2002; Cushman 1993). Additionally, intentional planting (or accidental invasion) of non-native woody tree species has led to the lupines' decline, as the shade the trees create blocks lupines from proper sunlight and growth (National Park Service 2011). As early as the mid 1800's, early chroniclers noted that the valley could fluctuate between an extensive blooming wildflower cover, and a barren and "desert-like" landscape (due to lack of irrigation and normal seasonal fluctuation) (Shapiro 2002). In 1973, one account noted that the lupines still had a strong presence in the Sacramento Valley, but by 2002, the species had become nearly extinct regionally (Shapiro 2002). It exists now in patches of valley and foothill prairie areas, and in sandy soiled areas (Shapiro 2002).

B. Literature Review

Specific Characteristics of Species:

Environmental Tolerances and Preferences

- *Lupinus formosus*' preferred elevation is 7 to 3000 meters, and a temperature average ("range") of 64 °F, with a 24 °F low in December and a 96 °F high in July. It prefers a wet season of 4-8 months, and a warm season of 1-6 months. Preferred precipitation is 13-53 inches. Possible Hardiness Zones are 7b to 10a (5 to 35 °F). According to certain test locations, the plant prefers a soil pH of 5.3-7, needs a minimum depth of 39 cm, and requires little to no salinity and CaCO₃ in the soil. (Calflora.org n.d.)
- Elevation can range from 0 to 9850 feet, with clay soils. Prefers dry or light water levels, and either full sun or part-shade. (The Watershed Nursery n.d.)
- Possible USDA Hardiness Zones range from 6a (to -23.3 °C/-10 °F) to 10b (to 1.7 °C/35 °F). *Lupinus formosus* is drought-tolerant and can be useful in xeriscaping. (Dave's Garden n.d.)

Germination/Growth Information

- The average number of live seeds in one bulk pound is 7,200. (S&S Seeds n.d.)
- To plant lupines (in a garden setting), soil must be well drained, and seeds should be soaked overnight or have their surfaces scratched in order to increase seed coat penetration when planted. Seeds can also be chilled in the refrigerator for a week before planting. (Badgett n.d.)
- To increase lupine blooms (in a garden setting), use a high-phosphorus fertilizer, but to increase foliage growth, use high-nitrogen fertilizer. Planting a flowering ground cover under the lupines is recommended to keep the lupine roots cool; this also allows the ground cover plants to benefit from increased nitrogen in the soil (from the lupine). (Badgett n.d.)
- In order to establish a native wildflower cover (including *Lupinus formosus*) in a field or grassland, the site must be prepared by removing as many perennial and "aggressive" annual weeds as possible. In the first and second years after planting the wildflowers, continued removal of invasive weeds is most important. The native plants should be protected from herbicide sprayings and other disturbances, except in the case of spot-treatment of herbicides on certain weeds. (Natural Resources Conservation Service 2012)

Key Mutualists and Competitors

- Can attract butterflies (i.e. Mission Blue Butterfly) and bees, and is resistant to deer. (The Watershed Nursery n.d.)
- *Lupinus formosus* serves as one of three host lupine plants for the Mission Blue Butterfly species, added to the Federal Endangered Species List in 1976. There are a few remaining population of the butterfly around the San Francisco Bay area. Adults spend their lives within patches of the host plant, looking for mates and hiding underneath the vegetation when the weather gets cool or wet. Adults lay their eggs on the dorsal side of new lupine leaves and sometimes on the stems, flowers, or seed pods. When the eggs hatch, the larvae feed on the lupine's leaves; and when the next spring arrives, pupation occurs in the base of the plant. (Golden Gate Parks Conservancy n.d.)
- The "Mission Blue Butterfly habitat" consists of coastal grassland or scrub in which some of the three host lupine plants live. This habitat is threatened by non-native, invasive shrub and tree species, originally introduced from Africa, the Mediterranean, and other areas. The shrub plants include French broom, Pampas grass, Cape ivy, and thoroughwort; the tree species include blue gum, Monterey cypress, and Monterey pine. (National Park Service 2011)
- Although the three species of lupine (including *Lupinus formosus*) that host the Mission Blue Butterfly are usually good competitors with invasive non-native grasses, they are more susceptible to invasion of woody species (such as gorse, blue gum, and broom). These plants create too much shade for lupines to grow successfully. (Cushman 1993)
- For the San Joaquin "bioregion", California Native plants that can grow with *Lupinus formosus* include: California peony, coastal tarweed, deer brush, southern California dudleya, common California figwort, Star flowered false solomon's seal, spinescale saltbush, snowberry, wild hyacinth, canyon sunflower, and various others. For the Sacramento Valley "bioregion", *Lupinus*-compatible California Native plants include: the first four listed above, snowberry, California evening primrose, canyon sunflower, fringed onion, few-flowered blue eyed mary, spencer primrose, douglas iris, hop sage, and many others. (California Native Plant Link Exchange n.d.)

Pathogens

- Diseases that can affect *Lupinus* species (North America) include fungal diseases, viral diseases, and problems due to insects. For fungal diseases, most occur in cool, wet weather (the opposite of *Lupinus formosus*' preferred conditions), and include basal/root rot, downy mildew, gray mold/flower and leaf blight, leaf spots, powdery mildew, rust, and stem/root rot. In some cases, fungicide may be applied, or the diseased part of the plant should be removed. For viral diseases, most are spread through contact with other diseased organisms or through contaminated tools, and these include mosaic, ringspot, and tomato spotted wilt viruses. In most cases, controlling the virus depends on making sure seeds or plants are virus-free, and eliminating nearby diseased plants. Finally, insect problems can involved either aphids or garden millipedes. Aphids can be controlled by using either horticultural oil,

insecticidal soap, or Malathion. (The Connecticut Agricultural Experiment Station 2007)

- The greatest damage to lupines (worldwide) is caused by anthracnose (fungal disease in wet climate), fusarium wilt and root rot (warm weather and unstable water), bacteria, and viruses (especially mosaic forms). Some lupines, especially those with low-alkaloid levels (*Lupinus formosus* has high levels), are more susceptible to species of damaging insects, mites, and nematodes. (Golubev et al. 2006)

Toxicity

- *Lupinus formosus* contains a piperidine alkaloid that can be toxic to cattle, sheep, and goats when consumed. Most notably, when pregnant livestock eat the plant, it can lead to fetal malformation, including heart problems, cleft palate, and other congenital contractures. It can also cause fluid buildup in the placenta, and even fetal death and abortion. Local livestock industries should be wary of foraging on *Lupinus*-covered areas. (Bunch et al. 1992)

Specifics of Ecosystem:

Plant Community Types

- Lives in Yellow Pine Forest, Red Fir Forest, Lodgepole Forest, Subalpine Forest, Foothill Woodland, Chaparral, and Valley Grassland. It prefers the openings between chaparral and oak trees. It is native to California and only found slightly outside the state's borders. (The Watershed Nursery n.d.)
- Can be found to live in Alameda, Butte, Calaveras, Contra Costa, Colusa, El Dorado, Fresno, Glenn, Humboldt, Inyo, Kern, Lake, Los Angeles, Madera, Mendocino, Merced, Mono, Monterey, Mariposa, Marin, Napa, Plumas, Riverside, Santa Barbara, San Bernardino, San Benito, Santa Clara, Santa Cruz, San Diego, San Francisco, Shasta, San Joaquin, San Luis Obispo, San Mateo, Solano, Sonoma, Stanislaus, Tehama, Tulare, Tuolumne, Ventura, and Yolo counties. (S&S Seeds n.d.)
- The lupines that host the Mission Blue Butterfly (including *Lupinus formosus*) are often found in recently disturbed areas and are most populous in grasslands that have thin, rocky soils. (Cushman 1993)

Relation to Water/Water Table

- Plant is drought-tolerant, and prefers drier soils and open grasslands (as opposed to riparian areas). It can also tolerate heavier soils, but water must be kept at a minimum level. (Thus this plant is not likely to survive flooding events.) (Theodore Payne Foundation 2010).

Relation to Fire/Relation to Soil

- The study's *Lupinus* species (and likely other lupines) tended to increase population density following a fire event, as their germination is stimulated by heat and other chemicals released during fire. Greatest cover and productivity was usually reached by the third year after the fire event. (Goergen et al. 2009)
- The study's *Lupinus argenteus* (and perhaps other lupines) have the potential to increase inorganic nitrogen and nitrogen mineralization in the soil after fire events. Because legumes like lupines are N₂-fixing organisms, their

effect on soil N paired with the effect of fire on soil N increases total soil N to a greater extent than fire does alone. (Goergen et al. 2009)

- Presence of such *Lupinus* species in sagebrush ecosystems was found to lead to increased biomass and plant cover of neighboring plants, thus “facilitating” the plants in an otherwise harsh environment. By producing their own nitrogen and thus stimulating microbial activity, they seemingly create better living conditions for various neighboring plants. (Goergen et al. 2009)
- In a study that applied both a high C/N-ratio litter mulch layer and a high number of annual *Lupinus bicolor* plants to a California grassland restoration site (in Carmel Valley), the increased presence of the *Lupinus bicolor* proved to increase levels of soil microbial biomass carbon (SMB-C) and overall soil fungi. Yet neither the *Lupinus* nor the litter mulch layer caused increases in plant community composition or biomass. Thus the study suggests that repeated plantings of legume plants (such as *Lupinus* species) can potentially increase carbon levels and fertility in soil. (Potthoff et al. 2009)

Spatial Scale:

- Height of plant is 1-3 feet, the flower size is ¼-1 inch, the inflorescence size is usually greater than 5 inches, and the flowers are clustered. (S&S Seeds n.d.)
- Height of plant is usually 24-36 inches, or 60-90 centimeters. Plants must also be spaced 24-36 in or 60-90 cm. (Dave’s Garden n.d.)
- Plant’s height by width is 1-3 feet H by 2-4 feet W. It either can grow upright or can be “low and creeping.” (Theodore Payne Foundation 2010)

Temporal Scale:

- Blooms in Mid Spring, Late Spring, or Early Summer. (Dave’s Garden n.d.)
- The plant’s blooming months (from Calflora) are June through October. It has a perennial life cycle. (S&S Seeds n.d.)
- Because *Lupinus formosus* is a perennial plant (like *Lupinus variicolor* in the study), it will have additional opportunities to reproduce in following years, so in its first year, it allocates a greater proportion of energy to growing its roots and leaves systems, than to its reproductive structures (compared to allocations by annual plants). It is also slower growing in terms of biomass, compared to annuals in that first year. This makes perennials like lupines, comparatively, more often found in long-term stable environments. (Pitelka 1977)
- It is recommended to plant the seeds in autumn so that the planted seeds can be “chilled” in the winter before sprouting in spring. (Badgett n.d.)
- In order to restore fields or grasslands to a cover of native wildflowers for pollinators, *Lupinus formosus* is a suggested flower that is a “Mid Season Blooming Species.” Most of the wildflowers should be planted in late fall for best success. (Natural Resources Conservation Service 2013)

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Part 2: Project Goals and Management Plan

A. Goals

Large-Scale (California's Central Valley)

* Restore the *Lupinus formosus* species to several areas of the Central Valley (such as the Sacramento Valley) where lupines have become extinct regionally. Create sustainable population sizes of ideally medium-density to ensure population viability.

→ Tradeoff: Increasing this species' presence may pose local livestock health risks (Bunch et al. 1992). It may also cause certain formerly recreational areas to become "off-limits" temporarily or permanently to ensure full restoration.

→ Interactions: Depending on the specific area, *Lupinus formosus*' success of reestablishment will largely depend on the current community of native (and/or invasive) species already there. Other plant species' direct competition for soil resources will be an important factor.

→ Potential for Success: The above-mentioned interactions will mean greater success in certain areas (especially with high proportions of native species), and lowered success in other areas.

* Establish these *Lupinus formosus* populations to an extent that areas that have historically hosted the Mission Blue Butterfly can experience notable butterfly population increases.

→ Interactions: This goal is dependent upon a continual, mutually positive relationship between *Lupinus formosus* and the Mission Blue butterfly. This relationship may prove strong in certain areas of the Central Valley, but in other areas, additional environmental conditions such as climate and predators may lessen the habitat's suitability for the butterfly, making *Lupinus formosus*' role as a host plant not attractive enough to keep the butterfly in the area.

→ Potential for Success: Success will mostly vary depending on the habitat suitability of certain areas for this butterfly's inhabitation.

Small-Scale (specific parcel within Central Valley)

* Restore *Lupinus formosus* within the specific parcel, so that a population size of approximately medium-density can thrive sustainably.

→ Tradeoff: Restoring *Lupinus formosus* to the specific parcel will alter the current community dynamics of the site, potentially leading to decreased numbers of a different species through competition. It may also mark formerly recreational areas as "off-limits" temporarily or permanently, to ensure full restoration of this lupine population.

→ Interactions: Whether or not the species achieves medium density will depend on the interactions (i.e. competition) the lupines have with the site's currently existing plants.

→ Potential for Success: The success of reaching this goal will largely depend on the site's physical characteristics, climate, and biotic community composition. If an optimal project site is selected, the chances of achieving success will be high.

* Establish a stable *Lupinus formosus* population that can host local butterflies or provide new habitat for nearby Mission Blue butterflies.

→ Interactions: As with the associated large-scale goal above, the beneficial interaction between Mission Blue butterflies and the host plant lupines will be a major factor.

→ Potential for Success: If the chosen site is historical Mission Blue butterfly habitat, located on coastal grassland or scrub, and/or located in the San Francisco Bay Area, the chances of success in establishing a stable community of host plant lupines and Mission Blue butterflies will be higher (Golden Gate Parks Conservancy n.d.; National Park Service 2011). If the site does not have these characteristics, success will depend on the site's habitat suitability for the butterfly.

B. Restoration Plan

Methodologies

Seed Collection: Lupine seeds should be collected from various sites throughout the Central Valley, most commonly valley and foothill prairie areas with sandy soils, since these areas have been found to contain greater populations of *Lupinus formosus* in recent years (Shapiro 2002). This will ensure that the new germinating lupines will be adapted to the region.

Seed Preparation: To prepare the seeds for optimum germination, it is recommended to soak and/or scratch the seed coats overnight so that seed coat penetration will be better facilitated after planting (Badgett n.d.). As it is suggested to plant seeds in late fall and winter due to the colder temperatures, seed preparation can also include chilling (in a refrigerator) for a week prior to planting (Natural Resources Conservation Service 2013; Badgett n.d.).

Site Choice (if applicable): If there is the opportunity to actively select a restoration location within the Central Valley, the following site characteristics should be favored to ensure the plants' greatest chances of survival and reproduction: open grassland, an elevation level of no greater than 3000 meters (9850 feet), soil pH of about 5.3-7, USDA Hardiness Zone between 6a and 10b, limited salinity and CaCO₃, and soil with dry, rocky, clay, and/or sandy properties (Theodore Payne Foundation 2010; Calflora.org n.d.; The Watershed Nursery n.d.; Dave's Garden n.d.; Cushman 1993). It is acceptable if the site shows signs of "recent disturbance" or contains heavy soils, as *Lupinus formosus* has been found to tolerate these conditions (Cushman 1993; Theodore Payne Foundation 2010). Major factors to avoid are excessive water levels and areas with frequent floods; this is due to the plant's drought-tolerant characteristics, and its increased risk of contracting fungal diseases in cool, wet areas (Theodore Payne Foundation 2010; The Connecticut Agricultural Station 2007; Golubev et al. 2006). Other preferred conditions include 13 to 53 inches of precipitation per year, an annual average temperature of 64°F, and a balance of 4-8 wet season months and 1-6 dry season months (Calflora.org n.d.).

Site Preparation: The site should be evaluated for presence of invasive woody tree species, such as blue gum, Monterey cypress, and Monterey pine, and if such species are creating considerable shade over the site (or will likely create shade in a few years), then such trees should be removed from the property (if physically feasible) (National Park Service 2011). These trees can "shade out" lupines planted below, compromising the lupines' growth (Cushman 1993). As the site will likely be located within a field or grassland, perennial and "aggressive" annual weeds will need to be removed as much as possible (Natural Resources Conservation Service 2012). This will decrease the competition for the native seedlings (*Lupinus formosus*). Finally, as a final preparatory step, a controlled fire disturbance regime should be applied to the site. Studies have shown that different *Lupinus* species increase their population density following a natural fire event, since germination is stimulated by heat and other chemicals released during fire (Goergen et al. 2009). Additionally, certain *Lupinus* species have shown the ability to increase soil inorganic nitrogen and nitrogen mineralization after a fire event (Goergen et al. 2009). Thus initiating the lupine restoration with a thorough burning of the site will

likely enhance the establishment and growth of *Lupinus formosus* on the site. The burning should mimic a natural wildfire as closely as possible, so a single burn event is suggested. The intensity should resemble that of the area's local wildfires.

Seed Planting: Seeds should be sowed across the site, and spaced appropriately to allow for a medium density of lupines upon reaching mature size. The plants should be allowed a minimum soil depth of 39 cm, and should be placed in areas receiving full or part-sun (Calflora.org n.d.; The Watershed Nursery n.d.). Native ground cover plants can simultaneously be planted, as these individuals will keep the lupine roots cool when both plants grow larger, and can benefit from the lupine's increased soil nitrogen production (Badgett n.d.).

Watering and Fertilizer Use (if applicable): After planting, a light watering can be applied, depending on the site's climatic conditions. If using fertilizers is considered beneficial in this restoration event, and the fertilizer will not severely alter the functioning of the site's nutrient cycles, then a high-nitrogen and/or high-phosphorus fertilizer is suggested to increase foliage growth and to increase lupine blooms, respectively (Badgett n.d.).

Temporal and Spatial Scale

Temporal: The seeds should be planted in 'autumn' or late fall so that the winter's colder temperatures can essentially "freeze" the seeds before spring (Badgett n.d.; Natural Resources Conservation Service 2013). The restoration event will span one year long, including a 1-4 day planting period and seasonal monitoring. Monitoring will continue for multiple subsequent years.

Spatial: The restoration event will occur on a specific parcel within the Central Valley, with a size ranging from a typical suburban "backyard" to a couple of acres, depending on the area's needs and resources.

Potential Problems

When attempting to prepare the site before planting the lupines, lack of physical equipment or applicable expertise may make removal of the non-native woody tree species very difficult.

In addition, nearby livestock farms must make sure that their animals (especially pregnant individuals) do not become loose and begin grazing on the lupine plants, since digesting them can be toxic, leading to fetal malformation, heart problems, other congenital contractures, and even death (Bunch et al. 1992). Local livestock raisers should be warned of this impending risk, although this may provoke extreme opposition to the restoration event in local farmers.

Throughout the course of the restoration event's first year and subsequent 'monitoring' years, there is the potential for the *Lupinus formosus* plants to become infected with fungal diseases, viral diseases, or damaging insect populations.

Dealing with these threats may require fungicides, pesticides, or other resources that may be difficult or costly to obtain in the area.

Risks and Uncertainties

Restoring this lupine plant to areas which have not hosted *Lupinus formosus* for many years have the potential to experience a strong biotic community composition shift when this species is introduced. There is a chance that another native plant will experience a decline in numbers, since the community dynamics have been altered, depending on the site's conditions.

Using a controlled fire to prepare the site poses the risk of lost control and unintentional spreading to nearby urban areas, causing considerable physical and economic damage and endangering human health. This can also cause extreme crop and economic damage on agricultural lands, and can seriously damage natural or 'wildlife' protected areas, through altering habitat and endangering vulnerable organisms.

C. Monitoring Plan

Monitoring Techniques (Pre-Restoration)

Before any restoration efforts begin, the site should be checked to make sure that there is a minimum amount of invasive species present, as these will likely have a negative effect on the native lupines' reestablishment success. Additionally, the frequency and type of any disturbances that may occur on the site (especially floods, since this species appears to have a low water preference) should be recorded and taken into account before restoration efforts.

→ **Threshold of Action:** If indeed the site seems to experience frequent or intense disturbances (especially floods), and the site was selectively chosen, it is suggested to select a different site. If the site was not selectively chosen and restoration must occur on this particular site, then additional efforts will be needed to help the lupines survive a disturbance event. Physical formations such as water runways, berms, or other features can be built into the site.

Monitoring Techniques (Post-Restoration)

After planting the lupine seeds in the fall, the site should be monitored about once a month until the late spring months or early summer (June), since this is the beginning of its blooming season (Dave's Garden n.d.; S&S Seeds n.d.). Once these months arrive, monitoring should be increased to every two weeks to monitor the total number of blooming individuals.

→ **Threshold of Action:** If the site experiences complete failure of *Lupinus formosus* reestablishment, then efforts should be made in the following year to plant young *Lupinus formosus* transplants in their first or second year, either in the winter or early spring so that they are rooted before the major blooming/reproducing season arrives. The transplants may prove a more effective second option due to the species' perennial qualities: the plant allocates more energy to growing roots and leaves systems in its first year, since it will have time to allocate more energy into reproduction in subsequent years (Pitelka 1977). Therefore, bringing the plants in after this initial growth stage will increase overall allocation of reproductive efforts in the plants, and increase chances of stable population establishment.

→ **Threshold of Action:** If the site experiences partial reestablishment, the soil conditions and community composition in the empty patches should be evaluated and compared with those in the lupine-occupied patches, to identify any local heterogeneity. If the empty patches' conditions can be altered through fertilizers, weeding, or other methods, the patches should be treated to match the 'successful' patches, and lupine seeds or transplants should be planted in the next year.

→ **Threshold of Action:** If during this first year or during the site's 'monitoring' years, the site experiences extensive lupine population declines due to diseases, the appropriate treatment method should be applied. For fungal diseases, fungicide may

be applied or the diseased part of the plant should be removed; for viral diseases, infected individuals must be removed; for insect problems, horticultural oil, insecticidal soap, or products like Malathion can be applied (The Connecticut Agricultural Experiment Station 2007).

One year after the restoration event (and after the first blooming season), the soil should be tested to see if the lupines do indeed have the ability to increase soil nutrient content (research question mentioned below). In the first and second years, the site should continually be monitored multiple times a year, including continual removal of invasive weeds, and protection of the lupines from herbicide sprayings (Natural Resources Conservation Service 2012). Yet the necessary frequency of monitoring events per year is unknown. Three years after the restoration event and controlled fire regime, the *Lupinus formosus* population size should be checked to see if the greatest numbers have been reached by this time. Previous studies have shown this, and observing this by the third year likely means restoration success (Goergen et al. 2009).

→Threshold of Action: If after these three years, the population does not exhibit maximum population numbers, the community composition, soil conditions, and other abiotic factors should be checked to see if a major change has occurred since the original restoration event, and to see what may be the causal factor. If and when the factor is found, it should be changed to reflect the previous conditions that had allowed lupine population growth. If the population's change is drastic (almost the whole population has perished), a re-seeding or re-transplanting event in the next year may be necessary. After these three years, annual site monitoring may be decreased to biennial monitoring, depending on available monitoring staff and resources.

Unanswered Research Questions

One unanswered question is the extent to which *Lupinus formosus* is tolerant to flooding in the Central Valley. It is identified as drought-tolerant, requires low water levels, and prefers drier soils, but there is uncertainty regarding its ability to withstand flood water levels. It is also unknown which fungal and/or viral diseases are the most prevalent and most damaging for *Lupinus formosus* in California (and in the Central Valley). Therefore it is uncertain which fungal and/or viral diseases deserve the most careful monitoring efforts. Finally, there is a lack of information regarding the recommended frequency of monitoring the lupine population, in the years following the restoration year (and the first growing season). The third year, for reasons mentioned above, is important to monitor, but the needed monitoring intensities of before and after that year are unknown.

Research Questions Potentially Answered by Project

One research question that could potentially be answered is whether this species, in the Central Valley, can improve soil nutrient conditions as other *Lupinus* species can. The potential benefits include increased soil microbial biomass carbon, soil fungi, and nitrogen levels, creating higher soil fertility for community use (Goergen et al. 2009; Potthoff et al. 2009). Additionally, the project could verify if *Lupinus formosus* responds to fire regimes similarly as other *Lupinus* species. Furthermore, a question potentially answered is whether the planting of *Lupinus formosus* in certain regions of the Central Valley can actually support and establish stable Mission Blue

butterfly populations, despite this species' endangered status and low local population numbers.

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CA meadow barley (*Hordeum brachyantherum*)

Clancy McConnell

Part 1: Project Background and Justification



Large tuft (left) and small tuft

Distribution: California Meadow Barley is found throughout California and in some areas of Oregon and Nevada (CalFlora, USDA). This subspecies prefers wetlands, pastures, and streambanks, and it can tolerate both intermittent flooding and drought (Jepson Herbarium, USDA).

Physical Characteristics: A tufted grass, meadow barley grows to 40cm in wet soils, though mature plants can be shorter (USDA). The plant has slender stems and hairy leaves (Jepson Herbarium). Inflorescences consist of many lateral radiating spikelets and are green and/or dark purple when in full bloom (Jepson Herbarium). It can be discerned from other meadow barley subspecies by its style of spikelets, which are less numerous and more radiating than those of other subspecies.

Phenology: Meadow Barley is a perennial species with a blooming period from May through July (CalFlora). It will turn golden brown in late summer and remain so, even with watering, until the next spring (CalFlora).

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USDA: https://plants.usda.gov/factsheet/pdf/fs_hobr2.pdf

Background

California Meadow Barley is a perennial grass native to California and some parts of Oregon. Since it establishes and grows quickly in restoration, stabilizes soil, and provides forage and cover, it can facilitate the establishment of other perennial grass species (Darris, 2004). The conservation status of Meadow Barley has not yet been determined, though it can be assumed that its remaining populations are in decline due to invasion by non-native annual grasses and forbs. Lulow et al. state that less than less than 2% of pristine California grasslands remain due to invasion by Mediterranean-region annual grasses (2006). However, it is well understood that California Meadow Barley prefers moist, fertile meadows and maritime environments, though it can tolerate intermittent flooding, drought, and infertile, dry soils (Darris, 2004). This wide tolerance of habitat type makes the species a valuable tool in California grassland restoration.

Plant Information

Elevation:	6-2,900m
Annual Precipitation:	40-230cm
Temperature Range:	<63°F
Blooming Season:	May-July
Warm Season:	0-7 months
Soil pH:	6.0-8.2
Soil Depth:	>33cm
Soil Texture:	fine (clay), medium, coarse (CalFlora, N.D.)
Habitat Types:	Freshwater Inland Tidal Marsh Dry Meadows Riparian/Maritime Environments (Darris, 2004)

Other Habitat Information: Meadow Barley is common or sporadic in moist meadows, clearings, marshes, and along stream channels (Darris, 2004). It tolerates saline, alkaline, and saturated soils, as well as intermittent flooding, though it prefers semi-moist soils (Darris, 2004; Hordeum, 2009).

Seeding: **Density:** Seeding rates depend on packing density, site conditions, and restoration objectives, though the typical range is 8-40 lbs/acre; lower densities will allow other species to establish (Darris, 2004). A study in the Central Valley found that highly diverse stands of native grasses, including Meadow Barley, did not have higher resistance to invasion by non-native annuals; actually, grass stands with high native biomass had much stronger resistance to invasives than did those with low native biomass (Lulow, 2006). For effective establishment, this finding suggests that grass stands be planted/seeded for high density or high biomass rather than for the highest possible diversity in order to resist exotics. Seeds can be purchased at Delta Bluegrass, in Stockton, and at Hedgerow Farms, in Winters.

Timing: Seeding of perennial grasses is usually performed between late fall (late November) and late winter (late February) (Kephart and Amme, N.D.). Alternatively, plugs can be purchased from nurseries (or grown by involved agencies) and planted in spring depending on the site conditions and costs of planting. In lieu, a study by Deering and Young of UC Davis found that seed priming greatly increased germination speeds of native perennial grasses after seeding, but that this faster germination did not result in significantly higher than normal establishment in a competition setting with non-native annuals (2006). In essence, there are important benefits and costs to consider

when performing seed priming for native grass establishment.

Meadow Barley will mature and produce seeds in its first year if sown in late fall or early spring (in long growing seasons, it can produce a second seed set in the late summer), and its seeds do not persist in the soil for more than several months (Darris, 2004).

Pollination: Meadow barley is primarily self-pollinated, and is dispersed large distances via animals brushing against the plant and spreading its awns, which attach easily to fur (USDA, 2013). While there is no literature to suggest that livestock in particular may substantially increase the dispersal of this species or other perennial grasses, the awns of Meadow Barley are well-shaped for animal dispersal.

Germination: Seeds of Meadow Barley in the Central Valley germinate best in temperatures around 20°C and with a light soil covering (California, N.D.). Depending on the timing of precipitation after planting, they will germinate in 10-90 days (California, N.D.).

Competition: Meadow Barley competes with other perennial grasses and invasive annual grasses and forbs, and it usually out-competes native forbs and grasses for resources under high disturbance and nutrient presence (Lulow et al., 2006; Brown and Bugg, 2001). However, it is short-lived and thus susceptible to competitive exclusion after 5 or more years, indicating that, in the long-term, seedlings do not establish well in the presence of other, longer-lived, intact perennial grasses (USDA, 2013).

Disturbance: Meadow barley is adapted to, though not obligated to, a range of disturbances, including grazing, fire, and flooding (Darris,

2004). Populations of the species can be maintained by preventing competitive exclusion with regular mowing, intermittent grazing or fire regimes, though it has been found that, after the species' first year, it has low grazing value (Darris, 2004). In general, there is no literature on a preferable frequency of fire or flooding, though for species persistence, Kephart and Amme suggest 2-3 mowings during the growing season (January-August) of the first year and 1 mowing per year thereafter (N.D.)

Diseases:

Meadow Barley populations can be susceptible to fungal diseases, including head smut and leaf/stem rust--use fungicides for treatment (Darris, 2004). The species is also susceptible to barley yellow dwarf virus, which weakens the plant and is transmitted to wild species from crops of cultivar barley—minimize contact with barley crops (Malmstrom et al. 2005).

Establishment/Management:

Controlling Invasives: Holl et al. found that exotics can be controlled before and during the establishment of Meadow Barley with an herbicide treatment (broad spectrum is most effective, and is well-tolerated by Meadow Barley), solarization, and mulching, though herbicide treatment is the most cost effective (2014; Anderson, N.D.). In addition, most native perennial grasses take two or three years to develop into strong stands, though this will vary by site and climate conditions (Kephart and Amme, N.D.).

Soil/Climate: In restoring native grasses to roadsides in Sacramento County, researchers found that California Meadow Barley grew well in all tested topographic zones, which varied by slope, soil type, and proximity to the road (Buss et al., 1997). This finding further confirms that the species is versatile in habitat conditions, and usually does not require management to

alter soil conditions (aside from some fertilization--see below) for planting/seeding or persistence. While there is substantial literature on the versatility of CA Meadow Barley, there is no published literature on the response of the species to climate change. However, its high tolerance for drought and a variety of climates suggest that it may persist in future Central Valley grasslands (Darris, 2004; CalFlora, N.D.)

Transplanting: A UC Davis study concluded that native forbs establish much better in perennial grass stands (including Meadow Barley stands) when transplanted from nurseries (via plugs) than when seeded into the grass stands (Brown and Bugg, 2001). This indicates that Meadow Barley and other, fast-growing perennial grass species out-compete native forbs during establishment and during stand maintenance without disturbance (when the grasses have been established and forbs are being introduced or are growing from the seed bank). Management should consider this competitive exclusion when seeding/planting initially and when maintaining a diversity of grass and forb species.

Fertilizer: A UC management guide for native grasses recommends using fertilizer in the establishment phase of some fast-growing perennial grasses, including Meadow Barley, though the guide states that it is often more productive to perform a second-year fertilizer program when non-native annuals are profuse at restoration sites (Kephart and Amme, N.D.).

Disturbance: As stated previously, 2-3 mowings can be performed in the first year to establish perennial grasses, and 1-2 mowings per year thereafter can ensure prolonged stand maintenance (Kephart and Amme, N.D.). Prescribed burning is also very

effective in establishing and maintaining perennial grass stands, but is often accompanied by cultural backlash and administrative red tape (Darris, 2004, Kephart and Amme, N.D.).

Part 2: Project Goals and Management Plan

Goals

- Establish an effective population of meadow barley in the first season (1 year).
- Achieve persistence of the population into the second and third generations (2 years).
- Maintain at least 10% cover of this species in the primary planted areas (2+ years).

Goal Considerations

- All restoration projects are financially and administratively limited. In particular, these limitations are a problem for CA Meadow Barley because persistence of the population in the short term (5 years) may be difficult without adequate disturbance (Darris, 2004; Kephart and Amme, N.D.).
- Over the long term (30+ years), climate change may render this species incompatible with the area; this incompatibility will occur as percent cover drops over time due to increasing drought and extreme heat conditions (though the species can tolerate some drought, it may not tolerate decades-long drought in the Central Valley in lieu of other stressors, such as low disturbance or low gene flow) (Darris, 2004, CalFlora, N.D.).

Restoration Plan

Methodologies

First, pre-monitoring for perennial grasses such as Meadow Barley should be part of a site-wide vegetation monitoring program. Establish permanent transects and/or quadrat barriers that can be used throughout the restoration process and for years thereafter (Gayton, 2013). If possible, establish control plots for answering research questions.

As well, before introducing CA Meadow Barley, effectively control exotics for good native perennial establishment. While several options are available, Holl et al. found that, of three common invasive plant control strategies, herbicide treatment was the most cost effective, especially for large restoration sites (2014). In lieu, Hedgerow Farms states that at least one year of highly effective weed control (using broad-spectrum or broadleaf selective herbicides) should be performed

prior to planting, and that the last herbicide treatment can be performed within 2 weeks of plug planting (Hedgerow, 2011).

Local seed sources are Hedgerow Farms, in Winters, and Delta Bluegrass, in Stockton. Request local genotypes (western and upland Central Valley) to ensure that seeds and plugs are compatible with the site. Unfortunately, no literature specifies exact seeding density for perennial grasses, much less for CA Meadow Barley, though the USDA recommended range for this sub-species is 4 lbs/acre when seeded with other perennial grasses, and 8-40 lbs/acre when seeded alone (Darris, 2004; 2007). In general, seeding at higher rates will allow for rapid cover and fast evolution of the population to site conditions (Hedgerow, 2011). If one is available, use the lead agency's standard perennial grass seeding rate for this species when creating an establishment plan.

In addition to density, timing of seeding is one of the most important aspects of the establishment of grasses and forbs in restoration projects. For perennial grasses such as Meadow Barley, seed in late fall (November) or late winter (February), when there is still high likelihood for some winter precipitation (this sub-species requires an average minimum of 40cm of rainfall per year and tolerates up to 230cm of annual rainfall, though there is no literature on its ideal range of precipitation) (Kephart and Amme, D.D.; CalFlora, N.D.). Since Meadow Barley is primarily self-pollinated, no actions must be taken to promote pollination, though it is important to consider inter-population connectivity when creating planting sites in order to promote gene flow (USDA, 2013).

Using seeds is risky in that it depends on periodic winter precipitation (no exact amount specified in literature) for good germination and establishment, especially for CA Meadow Barley, the seeds of which do not survive more than one season (Darris, 2004). However, seeding tends to be far less expensive compared to plug planting in both establishment and preliminary maintenance for large sites (Kephart and Amme, N.D.)

Alternatively, transplant all or some of this species from nursery plugs, which are available from Hedgerow Farms by order. Plugs should be ordered in September and planted between December and February, when soils are still relatively moist (Anderson, N.D.). John Anderson, nursery specialist at Hedgerow Farms, specifies a planting density of 3-6 plants per square yard for high individual establishment and 9-27 plants per square yard for rapid cover and faster evolution of the species to site conditions (Anderson, N.D.). These rates apply to planting of all plugs in an area; they indicate total plant density, not density of individual species. To illustrate, medium-density perennial grass plantings are placed at 12"-18" centers, and the ideal percent cover for CA Meadow Barley in mature grassland and riparian stands is between about 10% and 30%, based on several studies on the restoration of perennial grasses in the Sacramento Valley (Anderson, N.D.; Lulow, 2006; Bugg et

al., 1997). Maintenance of the species above the 10% threshold may better ensure that it is not being outcompeted by more competitive, longer-lived species (Lulow, 2006, Bugg et al., 1997).

As well, it is important to consider density in the species' resistance to exotics. Lulow found that native grass stands of high biomass had much higher resistance to invasive forbs and grasses than did native grass stands of low biomass or high diversity (2006). This means that high density plug plantings or high seeding rates will increase the success of native grasses and decrease the chances for establishment of exotics.

Temporal/Spatial Scale

Since CA Meadow Barley tolerates a wide range of environmental and topographical conditions, it can be used in all meadow, stream channel, and grassland site settings (Darris, 2004; Buss et al, 1997). In general, consider the placement of other grass and forb species when designing site plantings, and place CA Meadow Barley with only several other perennial grass species so that high biomass is achieved (Lulow, 2006). In relation to connectivity, interaction with the outside gene pool should not be a priority since there are very few viable populations of CA Meadow Barley in the Central Valley and the species is almost entirely self-pollinated (Darris, 2004).

Management

Again, no specific data exists for the frequency of disturbance required for perennial grasses, much less for CA Meadow Barley. However, this species is known to tolerate and even thrive under grazing, fire, and flooding, all of which can prevent competitive exclusion of or by the species (Darris, 2004). In general, periodic grazing is useful for moderate disturbance and fire is useful for reducing thatch and creating patch diversity. However, since Meadow Barley provides low forage value and fire regimes are typically expensive, mowing is common in perennial grass restoration projects (Darris, 2004; 2007). For prolonged stand maintenance, perform 2-3 mowings of grass stands in the first year (after initial seed set) and 1 mowing per year for several years thereafter (mowing can replace the functions of some other disturbance regimes, and the length of time that it can be sustained will depend on financing available) (Kephart and Amme, N.D.). Again, unfortunately, there is no literature on the frequency or intensity of fire or grazing as disturbance tools, though CA Meadow Barley likely responds to these tools in ways similar to other short-lived, native perennial grasses.

To follow, during the establishment of CA Meadow Barley and other perennial grasses, fertilizer can be used for rapid growth in the first generation. However, a UC management guide states that a second-year fertilizer regime is often more productive when non-native annuals are profuse at a site (Meadow Barley tolerates both broad spectrum and broadleaf selective herbicides) (Kephart and Amme, N.D.; Hedgerow,

2011). There is little to no literature on the frequency or amount of fertilizer used in perennial grass stands, likely due to the high variation of restoration sites in environmental conditions, planting density, and exotics present. So, use industry standards for fertilizing perennial grasses such as CA Meadow Barley and, when in doubt, use less fertilizer to avoid competitive exclusion of one or several species.

Other Uncertainties

It is possible that this species will not establish well in the first season due to a lack of precipitation or prolific invasive annual grasses and forbs. In the case of low precipitation, re-seed at the same density and continue herbicide treatment for invasives. In the case of prolific invasives, perform 1-2 more years of extensive herbicide treatment and only re-seed after treatment (Anderson, N.D.).

It is also possible that the species will not remain within the acceptable range for percent cover; disturbance can resolve a scenario of competitive exclusion or weediness. In the case of the exclusion of CA Meadow Barley out of grass stands, which is common in low disturbance areas, perform more frequent/intense disturbance or reanalyze the composition of species in site grass stands (USDA, 2013). In the case of weediness of the species, such that forbs or other annual grasses decrease below their cover thresholds, use patchy mowing or grazing to reduce perennial grass cover and allow for better forb establishment (Darris, 2004).

Uncertainty about climate change is an issue for restoration around the world, though especially in California due to its relatively dry climate. While the effects of climate change on entire ecosystems are unknown, it is likely that CA Meadow Barley will not become excluded from the area; it is well-adapted to drought and a wide variety of environmental conditions (CalFlora, N.D.). However, given the rapid and continuing proliferation of invasives in the Central Valley, it is still unclear whether native perennial bunch grasses stand a chance in the future grasslands and riparian environments of California.

It is also unknown if CA Meadow Barley can be maintained at a small site in the long term (30 years) without regular, managed disturbance. If possible, managers should examine new research as it becomes available to inform future management and monitoring decisions.

Monitoring Plan

Post-monitoring for this species should be part of a site-wide plan for vegetation that begins as soon as areas are seeded or planted, and should use the same transects/plots as were used in pre-monitoring. Since grasses are seeded in fall or winter, monitoring for grasses in particular should begin around December and run until the end of the first seed set (late July); if plugs are used, monitoring can begin directly after planting in winter and should last until the first seed set (Darris, 2004). During this time period, monitor the percent cover of CA Meadow

Barley and other individual species in relation to site stratification (topography, connectivity, habitat type, etc.) (Gayton, 2013). After the first seed set, it will be important to monitor the species' germination from seed and the invasion of any exotics, while continuing monitoring for percent cover of CA Meadow Barley and other individual species, vegetation groups, or general vegetation characteristics in stratified site areas (Gayton, N.D.). In particular, monitor for percent cover and seedling recruitment after the first few disturbances, since this phase of establishment is vital (Lulow, 2006; Bugg et al, 1997).

In the short term (2-4 years), monitor for the establishment of second generation plants by percent cover, and, if desired, take special management action if the species drops below 10% cover (Bugg et al, 1997; Lulow, 2006). In the long term (10+ years), monitoring will be greatly limited by financing, and regular monitoring may not occur or may not be performed by the same agency. So, planting records and data collection for monitoring should be made and stored adequately to ensure their use by future trustee agencies.

Research Questions

- How well does CA Meadow Barley establish and persist in a full-scale Central Valley restoration project?
- How does CA Meadow Barley compete with other native perennial grass species and forbs?
- In which micro-topographical settings does CA Meadow Barley perform best and persist?
 - To test all of the above: establish several replicates and control plots for each topographical setting or stratified site type.

Further Research Needed

What degree of drought can be tolerated by the Central Valley ecotype of CA Meadow Barley? What are the optimal types and frequencies of disturbance for persistence of CA Meadow Barley (while also considering other species' disturbance requirements)?

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Blue wildrye (*Elymus glaucus*)

Naftali Moed

Part 1: Project Background and Justification

Range: *Elymus glaucus* (*E. glaucus*) can be found across the western half of North America from Alaska all the way to Mexico thriving in open areas, prairies/grasslands as well as in chaparral, woodlands and forests (https://plants.usda.gov/plantguide/pdf/pg_elgl.pdf)

Appearance: *E. glaucus* is a large perennial bunch grass growing up to five feet high if not grazed or mowed. Tufts often consist of relatively few stems. "Leaf color changes from green to blue with a white, waxy coating." (https://plants.usda.gov/plantguide/pdf/pg_elgl.pdf)

Images:



(calphotos.berkeley.edu)



(calphotos.berkeley.edu)

Characteristics:

Stem: 3–14 dm

Leaf: sheath glabrous or hairy, auricles $\pm$ 2 mm; ligule < 1 mm; blade 4–12(17) mm wide, generally flat

Inflorescence: 5–21 cm (except awns), erect or nodding, not breaking apart with age; internodes 4–8 mm; spikelets 2 per node

Spikelet: 8–16 mm, appressed to divergent; glumes 6.5–19 mm, generally short-awned; florets 2–4 lower florets concealed; lemma 8.5–14 mm, awn 0–30 mm, generally straight; anthers 1.5–3.5 mm" (http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=24107)

Distinguishing from other grasses:

- Relatively wide soft leaves unlike wheat grasses
- Both auricles and ligules present

(http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/wa pmstn9835.pdf)

Background and Justification

Elymus glaucus, commonly referred to as Blue wildrye, is a graminoid indigenous to western North America (Lambert 2003). One of the most abundant and broadly distributed species of the genus *Elymus*—which encompasses species known as wildryes and wheatgrasses—Blue wildrye can be found from Alaska to as far south as Mexico. Blue wildrye exists going west from the Pacific coast all of the way to the Great Plains, where it is somewhat less common (Johnson 1999). Widely known for its abundance in riparian portions of woodland ecosystems in cooler regions, Blue wildrye is believed to have once been common throughout California’s Central Valley grasslands prior to European settlement (D’Antonio et al. 2002). The demonstrated ability of Blue wildrye to live in relatively moist riparian areas as well as in sites with drought conditions makes it an ideal species for use in restoration projects in the Central Valley (Johnson 1999). Its ability to quickly reestablish and thrive after significant disturbance from fire or other vegetation stripping events makes it an ideal native grass to revegetate many areas (Merenlender 2001). Given the significant decrease in the amount of grasslands in the Central Valley, there is a much lower abundance of Blue wildrye presently than under historical conditions. The combination of stress from invasive annual grasses as well as habitat destruction have left approximately only one percent of the once 30,000 square miles of native grasslands in the central valley in a natural state (Young 2014). As work progresses to restore these grasslands, Blue Wildrye will serve as a key component not only of initial restoration efforts but also the long-term attempt to enhance native habitat and biodiversity.

Literature Review/Fact Sheet:

1. Botanical Characteristics

- Blue wildrye is a perennial bunch grass (Lambert 2003)
- Blue wildrye can range in height anywhere from 60 to 180 centimeters (Johnson 1999)
- Blue wildrye grows erect, often growing in small bunch with relatively few stems (Sampson 1951)
- Blue wildrye possesses 6-16 cm long, relatively thin inflorescence in the form of an erect long spike with only 2 (sometimes three) spikelets per node (Lambert 2003)
- Blue wildrye is commonly grows in proximity to alders, oaks, potentilla, yarrow, aster as well as many species of the genera *Bromus* and *Poa* (Johnson 1999)
- Blue wildrye struggles to compete with wide variety of grasses and ultimately tends to decrease in overall cover 4-5 years after a disturbance, at times disappearing completely in a given year (Johnson 1999)

- The expansive range of Blue wildrye has given rise to many locally unique variations, each suited to unique soil types, climates, elevations, amounts of water and nutrient levels (Wilson 2001)

2. Life Cycle

- Time from germination to maturity of Blue wildrye is often around two months varying slightly with growth conditions, most growth occurs during cooler season (Flessner 2009)
- Frost induces dormancy amongst majority of Blue wildrye plants (Dyre 2005)
- Blue wildrye seed remains viable for two to five years after it hardens (Lambert 2003)
- Blue wildrye germinates within 6-10 days of planting (Johnson 1999) and anywhere from 6-31 days following the first rains, depending largely upon temperature (Plummer 1943)
- Blue wildrye flowers between April and May throughout much of California (Dyer 2005)
- Blue wildrye is known for its exceptionally high seed viability (80-85%) as well as the persistence of upwards of two thirds of its seed in seed banks where it is found for upwards of three years (Johnson 1999)
- Blue wild rye produces a variable amounts of seed, with seed production in various zones varying from 350-1000 pounds per acre under monoculture, farmed conditions (Darris et al 1996)
- Blue wildrye can be grown from seed or from divisions (Flessner 2009)
- It is best to collect Blue wildrye seed within 300 miles and 1500 feet elevation to insure success and mitigate against altering gene pool of local plants (Lambert 2003)
- Blue wildrye sometimes regenerates through rhizomes or short stolons (Lambert 2003)

3. Range

- Geographic range includes regions from Alaska to Mexico north to south and the Pacific Coast to just east of the Rocky Mountains going from west to east (Johnson 1999)
- Sometimes found naturally occurring in Great Plains and infrequently in other places further east (Johnson 1999)
- Can grow from sea level up to elevations over 10,500 feet in California (Johnson 1999)

4. Habitat

- Blue wildrye persists in wooded, semi wooded, chaparral and grassland environments, in variety of ecological regions (Lambert 2003)

- Blue wildrye often grows in riparian areas, within a floodplain or beside stream edges above the level of water in the soil (Johnson 1999)
- Blue wildrye performs best in well drained soils and is not well suited to long term inundation of its roots (Darris et al. 1996)
- Blue wildrye exhibits mixed success under varying shade conditions, often preferring full sun (Darris et al. 1996)
- Blue wildrye thrives in nitrogen rich soils with moderately acidic to neutral pH 0 levels of 5.5-7.0 (Lambert 2003) (Darris et al. 1996)
- Blue wildrye can grow with vastly differing amounts of water, ranging from minimal water in drought conditions in years after first year of growth, to damp soils in riparian areas (Johnson 1999)

5. Tolerance to Disturbance/Disease

- Blue wildrye is very well adapted to large scale disturbance from fires , and is well adapted to succession in a variety of different ecosystems (Johnson 1999)
- Blue wildrye is often one of the most dominant grass species in the 3-4 years following a fire, with increased passage of time resulting in decreased abundance (Johnson 1999)
- Blue wildrye is poorly adapted to flooding, and is not able to survive inundation for extended periods of time (Darris et al. 1996)
- Established Blue wildrye can with stand limited to regular grazing, although grazing can both inhibit and decrease the speed of growth, especially in drier areas (Merenlender 2003)
- Grazing of Blue wildrye before plants reach maturity leads often to death and significantly decreases survivorship of young plants (Hufford 2008)
- Blue wildrye can withstand mowing one or two times throughout primary growing season without significant losses in growth after the plant has reached maturity (Forrest Service 1999)
- Frequent mowing, mowing more then two time during the growing season will result in decreased growth and the possibility of death (Forrest Service 1999)
- Blue wildrye can be killed/damaged by broad spectrum and grass selective herbicides, but can with stand treatments of 2,4-D or similar broadleaf selective herbicides (Flessner 2009)
- Blue wildrye is susceptible to *Fusarium circinatum*, the fungal pathogen that causes pitch canker in pines on CA Coast (Gordon 2015)
- Blue wildrye has demonstrated susceptibility to *Claviceps purpurea* (commonly referred to as ergot) as well as *Ustilaginomycetes* (commonly known as smuts) based upon

analysis of seed collections made in Oregon and Washington
(Flessner 2009)

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Part 2: Project Goals and Management Plan

Restoration Goals:

Blue wildrye is one of the species that must play an essential role in the restoration of native grasslands in the Central Valley. Given the incredibly altered state of the central valley as well as the substantially decreased abundance and diversity of grassland species, it is first and foremost critical that Blue wildrye be incorporated into existing landscaping and restoration efforts. Whether in small gardens or landscapes, swales or drainage ditches, or even large meadow or grassland restoration projects, Blue wildrye possesses the potential to succeed under a variety of conditions.

At a regional scale, the restoration of Blue wildrye would be best accomplished by restoring native grasslands and riparian areas that include somewhat moist, upland habitat (Lulow 2006). The first step in accomplishing this goal would be to assess the current status of Blue wildrye throughout the Central Valley over the next three years, noting existing patches as well as areas that pose the potential for rehabilitation of weak populations or reintroduction if there is currently no Blue wildrye. This assessment could be initially focused on moist upland and fringe riparian areas in parks, preserves and lands managed under conservation easements that cannot be converted to an agricultural use or developed. As only one percent of native grasslands in the Central Valley remains in a natural state (Young 2014), it will be critical to look beyond these ideal sites to other areas that possess suitable Blue wildrye habitat in the long term to increase abundance as well as connectivity of patches (Buss 1997). After an assessment is completed, existing stands of those areas that are most suitable for restoration should be identified, and plans for grassland restoration for individual sites should be adopted and enacted. In the interim period before large-scale restoration efforts, Blue wildrye should be incorporated into seed mixes and plug plantings for current restoration projects in moist, upland areas.

Restoration Plan:

Restoration of Blue wildrye in the Central Valley should take many forms, dependent on the ecosystem type, project budget and desired site outcomes. Destruction of substantial amounts of both grassland and riparian habitat across the Central Valley has left relatively scarce amounts of naturally occurring seed sources in many watersheds within the Central Valley. In order to enable the accomplishment of the first goal, it will be critical to develop a larger supply of Blue Wildrye seed, as well as use seed from adjacent watersheds when necessary. Seed from the same source could theoretically be used throughout the Central Valley, as seed can be sourced within 300 miles and 1500 feet of elevation (Lambert 2003). Blue wildrye is currently grown by a number of nonprofits, government agencies as well as private native plant growers including Hedgerow farms, but more seed would likely be necessary in the long term were demand to steeply increase. In large projects or projects

with limited budgets, broadcast or drilled seeding would likely prove most effective, with drill seeding proving more effective in sites where the terrain allows (Darris 1996). Seeding is most successful at shallow depths at a rate of approximately 55 seeds per square foot (Flessner 2009). Where funding allows, plug planting of Blue wildrye between the first rain and late spring for restoration would be ideal as it increases the likelihood of individual mortality, optimizes use of available seed and increases options for weed control (Anderson 2001). Planting plugs of Blue wildrye at a spacing of up to two meters has demonstrated the ability to maintain populations for upwards of over a decade (Young 2015). Regular irrigation where possible by overhead sprinklers or other means during first three months of growth has also been demonstrated to be beneficial to helping plug plantings establish. Given the high propensity of Blue wildrye to withstand disturbance, burning at three to five year intervals as well as mowing or grazing up to three times a year to prevent invasives from reseeding would ultimately prove beneficial to Blue wildrye (Johnson 1999).

A plethora of factors will define the overall scope of Blue wildrye restoration as well as the time in which restoration can be implemented. Financing aside, it would likely take multiple years to thoroughly reestablish Blue wildrye throughout much of the Central Valley. The most effective restoration efforts in the immediate future would be to incorporate Blue wildrye into already planned/existing habitat restoration projects and native gardens. Although this would occur on individual sites that were small in scale, the potential of the Blue wildrye to spread could vastly expand the abundance of the species over a broader area within the Central Valley. Blue wildrye plantings (in conjunction with other native grassland and riparian species) should ultimately be expanded to other areas ranging in size from entire meadows to road and ditch edges, where Blue wildrye has been shown to succeed (Buss et al 1997). It is important to note that Blue wildrye will likely decrease in abundance under all of these circumstances if appropriate disturbance regimes are not maintained and the number of individual Blue wildrye plants would most likely progressively decrease at any given site following more than three years without a fire or other major disturbance (Johnson 1999).

The success of restoration will hinge on obtaining enough seed, changes in climate conditions, destruction by disease and other pathogens. Although a substantial amount of seed can currently be produced by existing production entities and collection sites, a substantial increase in demand for Blue wildrye seed coupled with increased demand for other native grass species would likely require increased seed production. If more seed could not be produced, the duration of restoration would likely increase. The continuously warming climate and California drought also pose a high degree of uncertainty. If water is unavailable and the moist conditions ideal for Blue wildrye continuously decrease, there will be fewer areas with potential for restoration and existing populations might be strained to such an extent that they are destroyed by invasion (Johnson 1999). The other risk that could significantly hinder the

success of restoration would be the introduction of a pathogen not currently prevalent in Blue wildrye communities within the Central Valley. Blue wildrye is susceptible to *Fusarium circinatum*, the fungal pathogen that causes pitch canker in pines on the CA Coast (Gordon 2015). Although this pathogen has not yet manifested itself in stands of Blue wildrye throughout the Central Valley, its spread could substantially hinder restoration efforts. Blue wildrye seed has demonstrated susceptibility to *Claviceps purpurea* (commonly referred to as ergot) as well as *Ustilaginomyces* (commonly known as smuts) based upon analysis of seed collections made in Oregon and Washington (Flessner 2009). If seed production is to increase in order to meet demand, proper steps must be taken to minimize the potential spread of these diseases. In addition to these risks, many other factors such as shifts in herbivory, increased fire or a host of other factors could significantly hinder the success of restoration efforts.

Monitoring Plan:

Monitoring before and after the restoration will be essential to successfully planning and ensuring the success of restoration efforts. Prior to restoration, the extent of existing cover should be considered, as Blue wildrye is most successful under less competitive conditions when provided appropriate access to water and nitrogen (Lambert 2003). Assessment of existing stands as well as newly planted areas should occur in the transition from winter to spring as that is the time in which the most growth occurs (Lambert 2003). Plants often fully develop two months after initial broadcast or sowing of seeds so it would be best to assess survivorship at this point on a site by site basis (Flessner 2003). Should less than half of a population survive to this point from plug transplants at a given site, it would be critical to assess the site as well as others in the area to determine what factors might have contributed to this (Flessner 2003). It would be best to compare areas with low success to areas with higher rates of survivorship in after two years under similar disturbance regimes in order to ascertain what corrective actions could be taken to enhance sites with poor establishment. Over multiple years, it will be critical to take into account the expected decrease in prevalence of Blue wildrye in a given area each year after the third year following a major disturbance (Johnson 1999). It would be ideal to monitor for at least five years after a disturbance in order to determine what the baseline levels of Blue wildrye may be in areas where it will be difficult to mow, graze or conduct regular burns. Although substantial research has been done with regards to Blue wildrye genetic variation as well as the success of Blue wildrye in the wake of a major disturbance, it would be useful to better understand the baseline levels of Blue wildrye under minimal disturbance conditions. As many parks and reserves are often inclined to restrict grazing, maintenance budgets are constantly decreasing, and burn permits are often difficult to obtain, a baseline for Blue wildrye in the Central Valley without disturbance would be useful to help ascertain success of certain sites. As the vast majority of published research available about Blue wildrye propagation has been conducted outside of California in altitudes higher than the Central Valley, it would also be beneficial to better outline the most successful propagation techniques in the Central Valley. Answers to these

questions, as well as many others about natural increases in the abundance of Blue wildrye outside restored areas, could prove useful for furthering restoration efforts.

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Jason Whitney
ENH 160
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Spring 2015

***Leymus triticoides* (creeping wildrye, beardless wildrye)**

Kingdom: Plantae
Subkingdom: Tracheobionta – Vascular plants
Superdivision: Spermatophyta – Seed plants
Division: Magnoliophyta – Flowering plants
Class: Liliopsida – Monocotyledons
Subclass: Commelinidae
Order: Cyperales
Family: Poaceae/Gramineae – Grass family
Genus: *Leymus* Hochst. – wild rye
Species: *Leymus triticoides* (Buckley) Pilg. – beardless wild rye



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Background and justification

Leymus triticoides (common name: beardless wild rye, creeping wild rye) is a drought tolerant perennial, sod-forming ryegrass native to the western United States (USDA 2015). Beardless wild rye once dominated the California Central Valley prairie savannas (Aigner 2011). It is commonly used in restoration projects for soil stabilization and wildlife habitat in riparian areas (USDA 2015). Native understory species are recognized for their importance in restoration efforts due to their ability to enhance ecosystem services such as increasing foraging and refuge habitat and contribute to overall restoration success (Rayburn 2013) likely by increasing soil nutrient and moisture holding capacity (Ingham, 2015). Due to its fast growing, tall stalks, and robust rhizomes, *Leymus triticoides* is able to resist non-native grass invasion once established (Lulow 2006). Creeping wild rye forms dense stands, resists trampling, and is a good soil binder (Bishop 1996). Agricultural and urban disturbance has reduced the amount of *Leymus triticoides* from historic levels due to its poor competitiveness to invasives while a seedling (Monsen 2004).

Fact Sheet

Project Goal:

- To expand community greenspace by 16 acres and restore two tributaries in the area with native plants (Solano RCD 2013).

Growth characteristics:

- Beardless wild rye grows from 0.5 to 3.9 ft. tall (Monson 2004), and is strongly rhizomatous (USDA 2015), that build turf (Lulow 2006) and increase nutrient and moisture holding capacity (Ingham, 2015).

- Considerable ecotypic variation can occur and it is recommended that seeds are collected from a similar environment to where they will be grown (Monsen 2004).

Reproduction:

- Seeds and by lateral rhizome growth from nearby bunches (USDA 2015).
- Seeds mature between midsummer and early fall (Monsen 2004).
- 175,000 seeds/lb (Monsen 2004) and a production of 300 lbs/acre (USDA 2015).
- Hybridization can occur with salina wild rye (Monsen 2004), *Leymus condensatus*, *L. mollis* and *L. cinareus* (USDA 2015).

Distribution:

- Beardless wild rye is distributed throughout the western United States (USDA 2015).
- Elevations below 9,000 ft. (USDA 2015).
- Western Montana and south to California and western Texas (USDA 2015).

Habitat Requirements:

- Does well on sandy loams to poorly-drained soils where adequate moisture (more than 5 inches of rain per year) is present during the growing season (late spring to early fall) (USDA 2015).
- It is important to minimize weed competition with proper seedbed preparation and appropriate weed management in the year prior to seeding (USDA 2015).

Tolerances:

- Saline, wet, alkaline, dry, spring flooded (Monsen 2004)

Human Interactions:

- Historically the seed was used as meal, or pinole by Native Americans (USDA 2015).

Wildlife Interactions/Ecosystem Services:

- The woodland skipper is associated with various species in the genus *Leymus* including *triticoides* (CalFlora 2015).
- Native understory species such as creeping wild rye are important foraging patches for rodents such as the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*), birds such as the Least Bell's Vireo (*Vireo bellii pusillus*) (Rayburn 2013).
- Soil fertility is increased by the abundant root formation of beardless wild rye (USDA 2015).
- Soil stabilizer (USDA 2015).

Threats:

- Disturbance in the presence of invasives can create conditions that allow non-natives to outcompete *Leymus triticoides* (USDA 2015).
- Soil born fungal pathogen *Ophiobolus graminis* which causes leaf and seed sheath damage (USDA 2015).
- Extreme drought conditions due to climate change could inhibit successful reintroduction if precipitation is less than 5 inches per year (USDA 2015).

Propagation Requirements:

control is needed or 2 to 3-ft centers with no erosion control problem (USDA, 2015).

- Seedlings have difficulty competing (Monsen 2004, USDA 2015).
- For range and pasture seedlings drilling seeds into disked seedbed in late fall 0-1/4 inch depth, 7-10 lbs pure live seed (PLS) per acre or if seeding not possible broadcast at a rate of 15 PLS lbs/acre (USDA 2015).
- Seedling herbicide tolerance includes most broadleaf herbicides except for those containing chlorosuluron, aminopyralid can decrease seed production (USDA 2015).
- Fall planted to provide overwinter exposure to cool, moist seedbed conditions (Monsen 2004).

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<http://plants.usda.gov/core/profile?symbol=LETR5>>

Restoration Plan for Creeping Wildrye

Goals:

Ideally a feasible restoration of Creeping Wildrye in California's Central Valley would occur in discrete patches that could simulate, by way of an island metapopulation distribution structure, its once prevalent patchy structure (Aigner 2011). The patchy structure would benefit the plant

by providing habitat for seed dispersers such as birds and allowing local evolution to create zones of adaptation. Restoring Creeping Wildrye into disturbed soil is a considerable challenge as the seedlings have difficulty competing with existing plants and the seed coat is relatively impenetrable (USDA 2015). Various cultivars have been found to exist (Monsen 2004) in the Central Valley but the most successful has been the “Rio” variety (USDA 2015). Therefore I recommend that this variety be used to quickly and cost effectively restore this species and the associated ecosystem functions that it provides, namely turf building (Lulow 2006), soil stabilizing and increased soil fertility (USDA 2015), woodland skipper habitat (CalFlora 2015), and the creation of foraging patches for rodents such as the endangered riparian brush rabbit and birds such as the Least Bell’s Vireo (Rayburn 2013). The goals for the restoration of Creeping Wildrye are as follows:

1. Find appropriate areas to reintroduce Creeping Wildrye.
2. Address specific site conditions and plant as required to maximize success.

Restoration Plan:

Site Discovery and Preparation:

Creeping Wildrye is thought to have once dominated the prairies and lowland oak woodlands in the Central Valley of California (Aigner 2011). On appropriate sites that have existing non-native grasses a removal of these plants is necessary as Creeping Wildrye is a poor competitor but once established can prevent invasion (Monsen 2004). Initial site preparation can include controlled burning in fall, herbicides in fall or early spring to control invasives (RCD, 2013), or disking (USDA 2015) can prepare the soil for seeds. While seeds are cheaper and of the recommended variety (HEDGEROW FARMS, 2011), seeds have been shown to be less successful than installing plugs where rapid cover is needed (USDA 2015). For sustainable restoration efforts to be a success it is

2015). However it can tolerate saline, wet, alkaline, dry, and spring flooded stress conditions (Monsen 2004).

Creeping Wildrye could be established to prevent the soil from becoming airborne and contributing to a lack of air quality or being eroded and contributing to a lack of water quality. In addition to maintaining existing soil by preventing erosion, Creeping Wildrye also has the additional benefit of building soil (Lulow, 2006), which increases humus levels increasing nutrient and soil retention capabilities (Ingham, 2015). Along with former fields and orchard parks and even heavily trafficked areas can be ideal locations for creeping wildrye to be reintroduced as it is highly tolerant of trampling (Bishop 1996).

Restoration Effectiveness:

To maximize restoration success and to make effective choices, existing site conditions as well as future goals for the site are required. In situations where existing site conditions make restoration difficult those challenges will be addressed and mitigated. Common challenges for the reintroduction of Creeping Wildrye include existing plants (Monsen 2004, USDA 2015), extreme drought or nutrient depleted conditions (USDA 2015).

Multiple restoration options exist for areas that have existing plants such as non-natives that may outcompete Creeping Wildrye. As Creeping Wildrye is relatively slow growing it is recommended that reintroduction by plugs during mid-September to November is the most effective way at creating rapid patches (USDA 2015). Plugs should be planted on 1-ft centers if erosion control is needed or on 2-3ft centers for larger projects (USDA 2015). Plugs and seeds for some cultivars of Creeping Wildrye can be found at

<http://www.hedgerowfarms.com/grasses.html>, they have a distribution center in Winters and the plugs are produced in Lodi. The phone number is 530-662-6847. Allow 12-16 weeks for plug growth, this means that if plugs are to be ordered for planting in fall, ordering needs to occur in

For planting seeds to be successful seeds should be planted in fall to allow overwintering to break down the seed coat (USDA 2015). Seeds should be drilled into a well disked seedbed at a 0.25 inch depth at 7-10 lbs. PLS/acre or broadcast at a rate of 15 lbs. PLS/acre. Moist soil is needed for germination and blown and crimped in straw is recommended to retain soil moisture. (USDA 2015). There are 175,000 seeds/lb. (Monsen 2004). Weed control is important with seeding as the seedlings of Creeping Wildrye are not good competitors for the first year (USDA 2015). They are tolerant to some herbicides including most broad leaf herbicides (USDA 2015), however ideally spraying should occur before seedlings appear.

Nutrient availability and drought conditions may affect the success of the restoration effort. Available nitrogen and above 5 inches of rain per year improves stand establishment, increases forage yields, and increases growth rates(USDA 2015). If these conditions are not met growth will be sluggish or fail. Supplemental nitrogen could allow the plants to get established and once a solid soil community developed nutrient retention should allow more growth to occur in the future (Ingham 2015) . Soil moisture conditions are also stabilized due to a cover of Creeping Wildrye. Supplemental watering may be necessary to keep the plant alive for the first year or two if there are extreme drought conditions (USDA 2015). Creeping Wildrye stays green throughout summer.

Monitoring Plan:

To maximize effectiveness a monitoring plan should be put in place to ensure success. The monitoring plan would initially consist of annual monitoring in early spring to address the levels of invasives that may be present due to a seedbank and application of broadleaf herbicides as necessary to control them. Additional monitoring in the fall would be useful to measure survival success and if necessary plant additional seeds or identify sites to replant plugs in the following spring. Once the Creeping Wildrye has been established it is very resistant to invasion (Lulow

two. Adaptive management strategies should include the option of replanting sections that did not survive or changing to an alternative type of grass. Although Creeping Wildrye is drought tolerant mid-summer irrigation can reduce loss of plantings (USDA 2015). This plant is also very tolerant of the extreme moisture conditions of flood inundation. The structure of the plant allows it to grab the bottom of a floodplain and withstand floods as the blades can flex and flow allowing the plant to protect stream banks vulnerable to erosion (USDA 2015). This characteristic makes Creeping Wildrye ideal for the lower sections of a stream bank.

With the challenges of non-natives interfering with the seedlings and the potential for drought conditions mitigated, the restoration of Creeping Wildrye to California's Central Valley should be a success. Adaptive management strategies of monitoring site success rate can guide improvements in successive years and is essential should initial plans prove inadequate.

References

- Aigner, Paul A., et al. "RESTORING CALIFORNIA'S INLAND GRASSLANDS: DON'T FORGET THE FORBS!" *FREMONTIA* (2011): 41.
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- USDA-NRCS. 2015. The Native Grassland Model Plant Data Table. Web. 24 April 2015. <

Nodding needle grass (*Stipa cernua*)

Leyla Mousli

Part 1: Project Background and Justification

Kingdom: Plantae

Subkingdom: Tracheobionta – Vascular plants

Superdivision: Spermatophyta – Seed plants

Division: Magnoliophyta – Flowering plants

Class: Liliopsida – Monocotyledons

Subclass: Commelinidae

Order: Cyperales

Family: Poaceae/Gramineae – Grass

family

Genus: *Leymus* Hochst. – wild rye

Species *Leymus triticoides* (Buckley) Pilg. – beardless wild rye



Background and justification

Leymus triticoides (common name: beardless wild rye, creeping wild rye) is a drought tolerant perennial, sod-forming ryegrass native to the western United States (USDA 2015). Beardless wild rye once dominated the California Central Valley prairie savannas (Aigner 2011). It is commonly used in restoration projects for soil stabilization and wildlife habitat in riparian areas (USDA 2015). Native understory species are recognized for their importance in restoration efforts due to their ability to enhance ecosystem services such as increasing foraging and refuge habitat and contribute to overall restoration success (Rayburn 2013) likely by increasing soil nutrient and moisture holding capacity (Ingham, 2015). Due to its fast growing, tall stalks, and robust rhizomes, *Leymus triticoides* is able to resist non-native grass invasion once established (Lulow 2006). Creeping wild rye forms dense stands, resists trampling, and is a good soil binder (Bishop 1996). Agricultural and urban disturbance has reduced the amount of *Leymus triticoides* from historic levels due to its poor competitiveness to invasives while a seedling (Monsen 2004).

Fact Sheet

Project Goal:

- To expand community greenspace by 16 acres and restore two tributaries in the area with native plants (Solano RCD 2013).

Growth characteristics:

- Beardless wild rye grows from 0.5 to 3.9 ft. tall (Monson 2004), and is strongly rhizomatous (USDA 2015), that build turf (Lulow 2006) and increase nutrient and moisture holding capacity (Ingham, 2015).
- Fast growing after first year of being established (USDA 2015).
- Considerable ecotypic variation can occur and it is recommended that seeds are collected from a similar environment to where they will be grown (Monsen 2004).

Reproduction:

- Seeds and by lateral rhizome growth from nearby bunches (USDA 2015).
- Seeds mature between midsummer and early fall (Monsen 2004).
- 175,000 seeds/lb (Monsen 2004) and a production of 300 lbs/acre (USDA 2015).
- Hybridization can occur with salina wild rye (Monsen 2004), *Leymus condensatus*, *L. mollis* and *L. cinareus* (USDA 2015).

Distribution:

- Beardless wild rye is distributed throughout the western United States (USDA 2015).
- Elevations below 9,000 ft. (USDA 2015).
- Western Montana and south to California and western Texas (USDA 2015).

Habitat Requirements:

- Does well on sandy loams to poorly-drained soils where adequate moisture (more than 5 inches of rain per year) is present during the growing season (late spring to early fall) (USDA 2015).
- It is important to minimize weed competition with proper seedbed preparation and appropriate weed management in the year prior to seeding (USDA 2015).

Tolerances:

- Saline, wet, alkaline, dry, spring flooded (Monsen 2004)

Human Interactions:

- Historically the seed was used as meal, or pinole by Native Americans (USDA 2015).

Wildlife Interactions/Ecosystem Services:

- The woodland skipper is associated with various species in the genus *Leymus* including *triticoides* (CalFlora 2015).
- Native understory species such as creeping wild rye are important foraging patches for rodents such as the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*), birds such as the Least Bell's Vireo (*Vireo bellii pusillus*) (Rayburn 2013).

- Soil fertility is increased by the abundant root formation of beardless wild rye (USDA 2015).
- Soil stabilizer (USDA 2015).

Threats:

- Disturbance in the presence of invasives can create conditions that allow non-natives to outcompete *Leymus triticoides* (USDA 2015).
- Soil born fungal pathogen *Ophiobolus graminis* which causes leaf and seed sheath damage (USDA 2015).
- Extreme drought conditions due to climate change could inhibit successful reintroduction if precipitation is less than 5 inches per year (USDA 2015).

Propagation Requirements:

- Plugs are recommended where rapid cover is needed, in California 1-ft centers if erosion control is needed or 2 to 3-ft centers with no erosion control problem (USDA, 2015).
- Seedlings have difficulty competing (Monsen 2004, USDA 2015).
- For range and pasture seedlings drilling seeds into disked seedbed in late fall 0-1/4 inch depth, 7-10 lbs pure live seed (PLS) per acre or if seeding not possible broadcast at a rate of 15 PLS lbs/acre (USDA 2015).
- Seedling herbicide tolerance includes most broadleaf herbicides except for those containing chlorosuluron, aminopyralid can decrease seed production (USDA 2015).
- Fall planted to provide overwinter exposure to cool, moist seedbed conditions (Monsen 2004).

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- USDA, NRCS. 2015. The Plants Database National Plant Data Team, Web. 24 April 2015. < <http://plants.usda.gov/core/profile?symbol=LETR5>>

Part 2: Project Goals and Management Plan

Goals:

Ideally a feasible restoration of Creeping Wildrye in California’s Central Valley would occur in discrete patches that could simulate, by way of an island metapopulation distribution structure, its once prevalent patchy structure (Aigner 2011). The patchy structure would benefit the plant by providing habitat for seed dispersers such as birds and allowing local evolution to create zones of adaptation. Restoring Creeping Wildrye into disturbed soil is a considerable challenge as the seedlings have difficulty competing with existing plants and the seed coat is relatively impenetrable (USDA 2015). Various cultivars have been found to exist (Monsen 2004) in the Central Valley but the most successful has been the “Rio” variety (USDA 2015). Therefore I recommend that this variety be used to quickly and cost effectively restore this species and the associated ecosystem functions that it provides, namely turf building (Lulow 2006), soil stabilizing and increased soil fertility (USDA 2015), woodland skipper habitat (CalFlora 2015), and the creation of foraging patches for rodents such as the endangered riparian brush rabbit and birds such as the Least Bell’s Vireo (Rayburn 2013). The goals for the restoration of Creeping Wildrye are as follows:

1. Find appropriate areas to reintroduce Creeping Wildrye.
2. Address specific site conditions and plant as required to maximize success.

Restoration Plan:

Site Discovery and Preparation:

Creeping Wildrye is thought to have once dominated the prairies and lowland oak woodlands in the Central Valley of California (Aigner 2011). On appropriate sites that have existing non-native grasses a removal of these plants is necessary as Creeping Wildrye is a poor competitor but once established can prevent invasion (Monsen 2004). Initial site preparation can include controlled burning in fall, herbicides in fall or early spring to control invasives (RCD, 2013), or disking (USDA 2015) can prepare the soil for seeds. While seeds are cheaper and of the recommended variety (HEDGEROW FARMS, 2011), seeds have been shown to be less successful than installing plugs where rapid cover is needed (USDA 2015). For sustainable restoration efforts to be a success it is ideal to have the creeping wildrye in areas that will

have moist soil throughout the growing year (USDA 2015). However it can tolerate saline, wet, alkaline, dry, and spring flooded stress conditions (Monsen 2004).

Creeping Wildrye could be established to prevent the soil from becoming airborne and contributing to a lack of air quality or being eroded and contributing to a lack of water quality. In addition to maintaining existing soil by preventing erosion, Creeping Wildrye also has the additional benefit of building soil (Lulow, 2006), which increases humus levels increasing nutrient and soil retention capabilities (Ingham, 2015). Along with former fields and orchard parks and even heavily trafficked areas can be ideal locations for creeping wildrye to be reintroduced as it is highly tolerant of trampling (Bishop 1996).

Restoration Effectiveness:

To maximize restoration success and to make effectiveness choices, existing site conditions as well as future goals for the site are required. In situations where existing site conditions make restoration difficult those challenges will be addressed and mitigated. Common challenges for the reintroduction of Creeping Wildrye include existing plants (Monsen 2004, USDA 2015), extreme drought or nutrient depleted conditions (USDA 2015).

Multiple restoration options exist for areas that have existing plants such as non-natives that may outcompete Creeping Wildrye. As Creeping Wildrye is relatively slow growing it is recommended that reintroduction by plugs during mid-September to November is the most effective way at creating rapid patches (USDA 2015). Plugs should be planted on 1-ft centers if erosion control is needed or on 2-3ft centers for larger projects (USDA 2015). Plugs and seeds for some cultivars of Creeping Wildrye can be found at <http://www.hedgerowfarms.com/grasses.html>, they have a distribution center in Winters and the plugs are produced in Lodi. The phone number is 530-662-6847. Allow 12-16 weeks for plug growth, this means that if plugs are to be ordered for planting in fall, ordering needs to occur in late summer. Seeds of the recommended Rio variety are available.

For planting seeds to be successful seeds should be planted in fall to allow overwintering to break down the seed coat (USDA 2015). Seeds should be drilled into a well disked seedbed at a 0.25 inch depth at 7-10 lbs. PLS/acre or broadcast at a rate of 15 lbs. PLS/acre. Moist soil is needed for germination and blown and crimped in straw is recommended to retain soil moisture. (USDA 2015). There are 175,000 seeds/lb. (Monsen 2004). Weed control is important with seeding as the seedlings of Creeping Wildrye are not good competitors for the first year (USDA 2015). They are tolerant to some herbicides including most broad leaf herbicides (USDA 2015), however ideally spraying should occur before seedlings appear.

Nutrient availability and drought conditions may affect the success of the restoration effort. Available nitrogen and above 5 inches of rain per year improves stand establishment, increases forage yields, and increases growth rates (USDA 2015). If these conditions are not met growth will be sluggish or fail. Supplemental nitrogen could allow the plants to get established and once a solid soil community developed nutrient retention should allow more growth to occur in

the future (Ingham 2015) . Soil moisture conditions are also stabilized due to a cover of Creeping Wildrye. Supplemental watering may be necessary to keep the plant alive for the first year or two if there are extreme drought conditions (USDA 2015). Creeping Wildrye stays green throughout summer.

Monitoring Plan:

To maximize effectiveness a monitoring plan should be put in place to ensure success. The monitoring plan would initially consist of annual monitoring in early spring to address the levels of invasives that may be present due to a seedbank and application of broadleaf herbicides as necessary to control them. Additional monitoring in the fall would be useful to measure survival success and if necessary plant additional seeds or identify sites to replant plugs in the following spring. Once the Creeping Wildrye has been established it is very resistant to invasion (Lulow 2006), however getting to that point may require some replanting and spraying for the first year or two. Adaptive management strategies should include the option of replanting sections that did not survive or changing to an alternative type of grass. Although Creeping Wildrye is drought tolerant mid-summer irrigation can reduce loss of plantings (USDA 2015). This plant is also very tolerant of the extreme moisture conditions of flood inundation. The structure of the plant allows it to grab the bottom of a floodplain and withstand floods as the blades can flex and flow allowing the plant to protect stream bands vulnerable to erosion (USDA 2015). This characteristic makes Creeping Wildrye ideal for the lower sections of a stream bank.

With the challenges of non-natives interfering with the seedlings and the potential for drought conditions mitigated, the restoration of Creeping Wildrye to California's Central Valley should be a success. Adaptive management strategies of monitoring site success rate can guide improvements in successive years and is essential should initial plans prove inadequate.

References

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Nodding needle grass (*Stipa cernua*)

Leyla Mousli

Part 1: Project Background and Justification



© 2013 Christopher Bronny from CalPhotos



@ 2014 Annie's Annuals & Perennials from Plant Lust



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@ 2011 Smmflowers

Description

Habitat: *Stipa cernua*, most commonly known as "nodding needlegrass", is a perennial herb that is both native and endemic to California. This

bunchgrass does well in a grassland, chaparral and juniper woodland type environment, but can tolerate other environments as well. Generally, the plant thrives in lower level elevation areas with some coastal influence. It is well adapted to sandy, well drained, loamy soils, but is not limited to these specific soils. Full sun allows the plant to prosper, however, it will also grow in partial shade, and can tolerate heat and wind.

Appearance: This dicot bunchgrass can stem up to approximately 2-4 feet (60-120cm) tall.

- Stem: many ridged, densely packed stems at the base of the plant.
- Roots: fibrous root system

- Leaves: numerous, alternating distichous, narrow leaves with waxy texture. Leaf blades are fine with terminal segments covered in awns that can span up to 4 inches (10 cm) long.
- Fruit: contains achene, a type of a simple, small, dry, indehiscent, one-seeded fruit.

Discerning From Other Species:



(purple noddling needle grass)



(nodding needle grass)

Stipa pulchra, pictured on the left, can sometimes be commonly misidentified for *Stipa cernua*, however *Stipa cernua* is generally much smaller with finer leaf blades, and generally produces more flower spikes.

1. Stover, Ed, Malli Aradhya, Louise Ferguson, and Carlos Cristosto. "The Fig: Overview of an Ancient Fruit." Hortscience 42.5 (2007): 1083-087. Web.
2. Bossard, Carla C., John M. Randall, and Marc C. Hoshovsky. "Ficus Carica." Invasive Plants of California's Wildlands. Berkeley: U of California, 2000. 193-98. Print.



Background & Justification

The perennial herb *Stipa cernua*, most commonly known as "nodding needlegrass", is native and endemic to California. It is frequently used in restoration projects, critical area planting, cover crop, and wildlife habitat in California due to its tolerance to a variety of conditions (USDA). Its ability to withstand harsh conditions such as drought, and low fertility soils, hot and dry meadows, roadcuts and roadsides, (Buss) makes it an ideal plant for restoring heavily degraded areas (CNPSSD). Nodding needlegrass is typically found in juniper, foothill woodland, chaparral, coastal sage, scrub areas in elevations lower than 4,500 feet but can generally thrive in all soil types, with little to no water, & even extremely disturbed areas. It is a readily available plant that provides excellent forage for some grazing species. It is also highly valued for its erosion control due to its strong, fibrous, rooting system (USDA). A main issue in restoration projects in the California area is the spread of the invasive plant yellow star thistle (*Centaurea solstitialis*), however if dense enough, nodding needlegrass can completely inhibit this invasive weed (USDA) (Kyser). Therefore, *Stipa cernua*, is an invaluable native species that benefits the environment, its inhabitants, as well as humans.

Literature Review

Taxonomic Hierarchy:

Kingdom:	Plantae (plantae, Planta, Vegetal, plants)
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta (land plants)

1. Stover, Ed, Malli Aradhya, Louise Ferguson, and Carlos Cristosto. "The Fig: Overview of an Ancient Fruit."

Hortscience 42.5 (2007): 1083-087. Web.

2. Bossard, Carla C., John M. Randall, and Marc C. Hoshovsky. "Ficus Carica." Invasive Plants of California's

Wildlands. Berkeley: U of California, 2000. 193-98. Print.

Superdivision	Embryophyta
Division	Tracheophyta (vascular plants, tracheophytes)
Subdivision	Spermatophytina (spermatophytes, seed plants, phanérogames)
Class	Magnoliopsida
Superorder	Lilianaes (monocots, monocotyledons, monocotylédones)
Order	Poales, Poaceae (grasses, graminées)
Genus	Nassella tussockgrass
Species (Itis)	Nassella cernua

Growth characteristics:

- *Stipa cernua* can occur throughout California in a variety of different plant communities.
- Its a dicot bunchgrass can stem up to approximately 2-4 feet (60-120cm) tall.
- Can form 20- 50' clumps near seeps, however they don't often form extremely large bunches, generally are seen as locus individuals (Las Pilitas).
- This species contains ridged, densely packed stems at the base of the plant.
- Has a fibrous root system making it ideal for locations that has suffered from heavily eroded soils.
- Contains numerous, alternating distichous, narrow leaves with waxy texture. Leaf blades are fine with terminal segments covered in awns that can span up to 4 inches (10 cm) long.
- Contains achene, a type of a simple, small, dry, indehiscent, one-seeded fruit.

Propagation:

- Nodding needlegrass reproduces through the dispersion of achene
- Bloom period is typically from late February to late July. (Cal Flora).
- Seed matures in mid to late spring and collection is possible for approximately 2 to 3 weeks (USDA).
- If planted at a rate of 1 lb./acre there should be between 118,000 and 250,000 seeds/lb and therefore 4.3 seeds/square feet. (USDA).
- The sharp ends of the seeds are augured into the soil by twisting of awns.
- Seeds can also be harvested using flow-vac or combine. (USDA)

Range/Habitat:

- Nodding needlegrass is endemic to California

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- Generally found in native grasslands, meadows, woodland, coastal sage, chapparal and juniper woodlands (Watershed Nursery).
- Can be found at both high and low elevation from 8 to 1500 meters but typically does well in areas with coastal influences. (Cal Flora)
- Well adapted to areas with full sun to light shade.

Requirements:

- Precipitation: 10 to 49 inches
- Wet Season 2 to 8 months
- Temp Range $\leq 64^{\circ}\text{F}$
- December Low 32°F
- July High 98°F
- July Low 52°F
- Warm Season 3 to 10 months (Cal Flora)

Tolerances:

- Has the ability to withstand areas with drought of little to no water, but will stay greener longer if provided with some water during summer (Watershed Nursery).
- Can tolerate heavily disturbed areas
- Can tolerate moderate grazing
- Can also tolerate some other invasive species such as yellow star thistle.
- Able to survive in sandy, well-drained, loamy soils, and can also tolerate rocky soils as well.
- Tolerates and actually thrives in full sun areas with minimized shade, but can also grow in partial shade areas.
- Tolerate heat and wind (USDA)
- Frost and heat resistant. (CNPSSD)

Wildlife Interactions:

- Provides good habitat for many insect species.
- Also can provide excellent early forage for some grazing species (Fourdir)
- Seeds often eaten by birds and attracts a variety of songbirds. (Fourdir)

Plant Interactions:

- Generally in the coast nodding needlegrass occurs with annual wildflowers, buckwheats (*Eriogonum*), Golden Yarrow (*Eriophyllum*), Salt bush (*Striplex*), and Sagebrush (*Artemisia*) (Las Pilitas)
- Can also inhibit Yellow Star thistle if planted densely

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Human Interactions:

- Provides humans with an excellent plant to facilitate restoration projects
- Fibrous roots hold soil decreasing the amount of soil erosion and therefore landslides

Threats:

- Currently *Stipa cernua* is listed as a vulnerable species
- Declines in the population of this native species mainly comes from the encroachment of introduced, exotic and invasive species of grasses.

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Part 2: Project Goals and Management Plan

Nodding needlegrass provides habitats within the California Central Valley with imperative ecosystem services, therefore, it is necessary to restore this vital species to its endemic region. However, in order to fully restore this native species back to the areas in which it has been eradicated, there are certain objectives that must be identified, evaluated, and reached prior to continuing with any restoration project. Our first goal is to determine where this species historically and currently exists. This information will allow us to determine crucial information for its restoration. If we examine the current range of where nodding needlegrass exists, it will provide good information of what kind of environment is tolerable and ideal for this species. Within these areas, we will assess whether the species is either simply tolerating the environment and surviving, or flourishing. Reaching this goal will allow us to conclude the potential regions that can sustain introduced nodding needlegrass. It will also supply us with information on the ideal environment for nodding needlegrass, and its less than ideal, but acceptable, environment. Since nodding needlegrass is a perennial herb, this survey should be done various time a year to ensure that the grass is present all year round in the long term, rather than the short term. Determining the historical ranges that nodding needlegrass used to exist in would provide us with the history of conditions that were ideal for this species and how they have perhaps changed. After this goal is met, we can evaluate what specific condition, or set of conditions, caused nodding needlegrass to cease to exist in that area. Our next goal would then be to determine how the site needs to be prepared. We would need to find out how the feature/condition can be removed, modified, or its impact lessened, so that nodding needlegrass can persist and flourish in that area for the long term. Once these goals are accomplished, and any potential set backs are removed, we can then have a good basis for planting the species, and allowing it to establish. The next goal would be to plant the species in acceptable areas that were previously determined. With some moderate monitoring in the first year, the species should be allowed to establish and adapt. After the first year of establishment, there is hardly a need to monitor the hardy species. Nodding needlegrass is an excellent choice for restoration projects due to its many interactions with wildlife and the environment. It does not have any major tradeoffs due to its ability to withstand a variety of harsh condition, however, a minor tradeoff could be that this species thrives in areas with plenty of sun, therefore it would not flourish in areas with high canopy and many consecutive cloudy months. Nodding needlegrass can thrive in areas with plenty of sun, areas with drought, disturbances, and soils with low fertility. It provides excellent cover crop and wildlife habitat, along with erosion control and inhibition of certain invasives.

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Restoration Plan and Preparation for Nodding Needlegrass (*Stipa cernua*)

A strategic and specific plan is essential for the successful restoration of nodding needlegrass. Nodding needlegrass should be deposited in rather bare zones, for they flourish in areas with full sun, and little to no shade (CNGA) during the day. For these plants, flowering typically occurs around the month of April, therefore seeds will mature in mid to late spring, making seeds available for collection within three weeks after maturation time (USDA). Therefore, it would be advantageous to begin restoration attempts and seeding in late spring when seeds are peaking. It is possible to begin planting in early spring, however late dormant spring, early fall seeding is highly recommended for best emergence as well as an advantage against annual invasive weeds (USDA). Generally, nodding needlegrass is cultivated by many plant nurseries, and the seeds are easily and readily available and can be bought with a reasonable price. Purchasing in large quantities will likely be the best and most inexpensive option. Per pound, nodding needlegrass can produce approximately 118,000 and 250,000 seeds (USDA). Once collected, nodding needlegrass can be planted at approximately a rate of 1 pound per acre at the restoration site, which will yield 4.3 seeds per square foot (USDA). To propagate, seeds are typically pushed into the soil at the sharp ends of the seeds by the "twisting action of the awns" (USDA). To attain maximum yield it results, seeds are recommended to be planted at a depth of $\frac{1}{4}$ to $\frac{1}{2}$ inch into a weed-free seedbed (USDA). This method will likely be successful in generating well rooted mature plants in the long run. Another excellent method for propagating seeds could be hydroseeding, a process in which a semi-liquid mixture of seed and mulch is transported with a tank and sprayed over desired area. Though this method may be more expensive, it is argued to attain a quicker sprout and stabilize any sort of habitat, especially those on slopes (HomeGuides, 2012). Because this species does well in low fertility soils, it would likely be unnecessary to modify the soil in any way, it can even endure roadcuts and roadsides, as well as steep slopes (CNGA). However, another method of planting would be to collect and plant plugs that have been grown in a green house. This method is generally the most common way to restore grasses. Though this is considered one of the cheapest methods, it is also very labor intensive (HomeGuides, 2012). Plugs should be planted in fairly shallow holes that have been spaced about six to ten inches apart (HomeGuides, 2012). Though no actual modifications need to be done to the soil specifically, it would be beneficial to attempt to remove any invasives. In any restoration project, there are numerous uncertainties that must be taken account. For example, there would be the uncertainty of funding, there is a real possibility that there would be a lack of funding and in that case perhaps hydroseeding wouldn't be an option. Also, finding the labor would also be an uncertainty and a possible set back to the problem. Environmental variability always poses a problem in restoration attempts, for example

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perhaps the year is exceptionally dry or wet etc., which is why monitoring is a crucial part in restoration, bringing us to our next topic. Despite the fact of uncertainties which are inevitable, the restoration project is critical in the facilitation of California's central valley habitats.

Monitoring Plan for Nodding Needlegrass (*Stipa cernua*)

Once the restoration area has been seeded, monitoring is needed in order to ensure that the restoration project and goals will persist through all environmental factors. Monitoring should likely occur once the seedlings have sprouted past the top soil, which will generally occur after spring in mid fall (USDA). Due to the hardiness of nodding needlegrass, it has been determined that an intensive monitoring system is not heavily needed, however it should be readily monitored for mowing and grazing (USDA). *Stipa cernua* is a hardy plant species, however during its establishment as a seedling a moderate amount of monitoring should be done. This has been chosen for a multitude of reasons; first, nodding needlegrass generally has really slow establishment during the first year (USDA) therefore we would want to ensure that the seedlings are not lost because it would take a long recovery time, also during establishment the area should be kept free of exotic invasives which could present competition to the species. While the plant is a seedling it is extremely vulnerable to succumb to more competitive species, so any invasive should be removed and kept under control because it is possible that the invasive could out compete the seedlings. A more competitive species will quickly grow near the seedling, removing any available nutrients and water from the soil but the biggest impact is that the weed will shade the seedlings from sunlight which dramatically affects their establishment. When the nodding needlegrass is a sprout it should receive plenty of sunlight, therefore any potential competition should be kept under control during its first year. To remove invasives it is likely best to physically remove the species rather than apply herbicide which could potentially harm the seedling. However, after approximately a year once the seeding has grown and adapted to its environment, herbicide applications, mowing and closely controlled and timed grazing are good options to remove any potential competitors (USDA). Mowing, herbicide applications and limited grazing can be helpful because it would deter and remove any competitor species and open the plant canopy to allow full sunlight for the seedlings (USDA). However, these methods can become tricky for a variety of reasons. First, it would be difficult to control the grazers from attacking the nodding needlegrass seedlings. To ensure full, healthy establishment, any sproutings should be withheld from grazing for approximately three years (USDA). Second, it would also be difficult to control exact where is being mowed. Generally, as a mature adult, nodding needlegrass can withstand frequent mowing, however as a seedling, this species

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can not tolerate mowing, and should therefore be extremely careful when attempting to control any exotic plant species. It is most advantageous to control weeds prior to nodding needlegrass emergence (USDA). Overall, during sprouting time periods and establishment, any sort of disturbance should be minimized, and sunlight should be maximized. As a seedling, watering should occur but be kept at a minimum. Drip irrigation is not needed, however it can be a good alternative to physically watering. This process would be less labor intensive, yet it would only be needed for the first year of sprouting (Costello). However, once the sprout has grown, nodding needlegrass will do best with no summer water after the first year in the ground (USDA).

If the yellow appearance of the plant seems to dull, extremely minute amounts of water routine watering will keep it green all year, but it also has a high chance of killing the nodding needlegrass. Soil should be monitored for especially dry conditions. Extremely dry soil can eventually lead to crusting of the soil, which will reduce the chances of seedling emergence (Bugg). Soils should even be monitored after seedlings emerge, if soil is not moist, seedlings face the possibility of dying due to lack of water (Bugg). Though it is fairly drought tolerant, it is extremely intolerant to flooding (USDA). There has been evidence of the monitoring technique of prescribed burning has been shown to benefit the species. Historically, Native Americans would burn the nodding needlegrass in the California mountains in order to facilitate its regrowth on new shoots, which they then harvested and ate (Maunakea 2010). However, it remains to be determined how often burning was prescribed in order to facilitate the species growth. Though this question is unanswered, it would be best to assume that at a moderate frequency and low intensity burning would be beneficial for the species as a whole. During low intensity burning it has been shown that nodding needlegrass can produce more abundant seed crop the following year after a fire (USDA). However, fire must also be dealt with care due to the risk of spread. Also, fires should only be prescribed in fall or winter months typically every three or four years (Nathistoc 2005). Generally nodding needlegrass does not recover as quickly when fires occur in summer normally due to higher fire temperatures at the surface of the soil (USDA). Fires should also be used only on smaller bunches of the grass because larger plants have a build up of burns at the base of the plant, and therefore increase fire temperatures and decrease its probability of recovering. Once a mature adult, nodding needlegrass is fully established and monitoring and management can be reduced significantly, however, limits on grazing and fire intensity should still be set in place. For example, nodding needlegrass should not be allowed to be grazed upon during the flowering season of May to April in order to guarantee proper formation of the seed and to allow food storage in the crown (USDA). In conclusion, nodding needlegrass is regarded as one of the highest

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choices for restoration and revegetation project due to its ability to withstand the harshest of environments.

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Purple needle grass (*Stipa pulchra*)

Jocelyn Garcia

Part 1: Project Background and Justification

A. Background & Justification:

Restoring California native bunch grasses, especially the state grass(NRCS,2009), *Nassella Pulchra*(*Stipa*) or more commonly know as Purple needle grass. Purple needle grass is commonly used in restoration projects for hill stabilization and erosion control in grasslands (NRCS, 2009). The species is able to withstand disturbed ecosystems because of its tolerance to poor soil conditions (NRCS, 2009). Although Purple needlegrass is able to adapt to harsh soil conditions, populations have been decreasing due to; invasive, annual, european grasses, heavy grazing, and severe drought (Hufford, 2012). However, this species has been successfully established after weed control(NRCS,2009). There have been many studies of the effects of grazing and fire intensity on purple needle grass, which have turned out to have a range of results. The studies have focused on grazing because purple needlegrass provides food for wildlife and can be a valuable source of food for livestock because of its high value in protein and high palatability(NRCS,2009),however, results show that removing the livestock does not increase *N. pulchra* populations(Hufford,2012). Others studies have focused on fire effects on *N. pulchra* because of the observed benefits to the species in post-fire conditions and preadaptations to fire.

B. Literature review

Habitat/ Distribution

- > *N. pulchra* can be found in grasslands, oak and pine woodlands, mixed evergreen forests, chaparral, and coastal scrub. (Steinberg, 2002).
- > Currently, *N. pulchra* can be found in the Central Valley and the foothills of the Cascades and Sierras (NRCS, 2009).
- > It is estimated that *N. pulchra* was a climax species in California's valley and coastal grasslands and foothills prior to European invasion (NRCS, 2009).
- > *N. pulchra* thrives in Mediterranean climate with mildly wet winters and hot summers with little water available. Due to water scarcity in the summer and cold temperatures in the winter, *N. pulchra* seeds go into dormancy(Steinberg, 2002).

Growth/Germination/Seed bank/Seasonality

- > Depending on water availability, most of the growth of *N. pulchra* occurs from March to May/June. Growth increases again in September or October with an increase in precipitation but generally stops growth in December because of freezing temperatures (Steinberg,2002).

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> *N. pulchra* flowers begin to develop in May and seed dispersal begins in July, as oppose to Unlike nonnative annual grasses which begin to develop flowers 1 month earlier (Steinberg, 2002).

> Purple needlegrass has a monoecious breeding system, pollinated through wind, and produces large quantities of seeds (Steinberg, 2002). The seeds have a twisting awn and a sharp point, which helps increase self-burial, however, the seed bank is low compared to non-native annual grasses (Steinberg, 2002).

> Germination is greatly reduced in the presence of annual non-natives, fire on the other hand, may increase germination and emergence after the first postfire growing season (Steinberg, 2002).

> Seedling success rates are impacted by the climate, competition from annuals, intensity and frequency of grazing and fire(Steinberg, 2002).

> *N. pulchra* is regenerated through fragmentation and tillering, this is an adaptation that allows the species to recover from high intensity but short duration by grazing and fire (Steinberg, 2002).

Environmental Tolerances and Preferences

≥ *N. pulchra* is well adapted to serpentine soils, clays, and dry soils (NRCS, 2009).

> Conditions that this species is able to withstand include; full sun but not over shaded by nonnative annual species, extreme heat, drought conditions, and depending on the location, some ecotypes have partial flood tolerance (NRCS, 2009).

Mutualist/Competitors

> *N. pulchra* biggest competitors are European Annual grasses, generally *N. pulchra* does not compete well against annual grasses or broadleaf weeds in the first year because of slow establishment (NRCS,2009).

> Purple needlegrass has been widely replaced in grasslands, oak and pine woodlands, mixed evergreen forests, chaparral, and coastal scrub by rye (*Lolium perenne* ssp. *multiflorum*), wild oat (*Avena fatua*), slender oat (*A. barbata*), ripgut brome (*Bromus diandrus*), soft chess (*B. hordeaceus*), mouse barley (*Hordeum murinum*), and rattail fescue (*Vulpia myuros*). (NRCS, 2009)

- Species Tolerance to Moisture/Temperature

> *N. pulchra* annual precipitation ranges from 11 to 85 a year with wet seasons that also have a wide range; 3 to 8 months(Calflora, 2015).

> During the months of December and January, seedlings are susceptible to damping because of the cold wet weather. However, fungal issues can be prevented by pre-treating the seed with fungicide (NRCS, 2009).

> *N. pulchra* temperature range is as low as 32 ° F in December and as high as 96 ° F in July, warm period will typically 3-10 months (Calflora, 2015).

How does your topic respond to:

≥ *N. pulchra* rarely found in cultivated lands or lands that were formerly cultivated, these sites are typically dominated by native and nonnative annuals (Steinberg, 2002).

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- >Purple needlegrass is well adapted to light grazing, fire, and drought conditions (Steinberg, 2002).
- > N. pulchra has seeds with a sharp tip which can be painful after they become dry, because of this livestock tend to avoid purple needlegrass especially in the later season(NRCS, 2009). This could potentially explain its abundance compared to other species with high palatability (NRCS, 2009).
- > Grazing effects on N. pulchra vary depending on the life stage; new seedlings should not be grazed in the first couple of years after planting for a successful establishment, should not be grazed during flowering so formation of seeds and food storage in the crown to take place (NRCS, 2009).
- > Grazing can also have positive effects on N. pulchra because it gets rid of competition and opens up land for establishment (NRCS, 2009).
- > Fire suppression is believed to aid in the decline of N. pulchra because purple needle grass is fire tolerant and actually benefits from prescribed burns (NRCS, 2009).
- > Effects on N. pulchra by fire depend on the season in which it is occurring. For example, after spring or fall fires N. pulchra will resprout. In the summer however, the species typically does not recover as well because of the higher burning temperatures at the soil surface (NRCS, 2009).
- > After a fire, because of the increased soil surface, light availability, and nutrient release, purple needlegrass increases in cover, density, more abundant seed crop, seedling establishment(Steinberg, 2002).
- > After a severe fire, basal area and foliage height decrease after the first year, however, it is followed by an increase due to fragmentation in the following years(Steinberg, 2002).
- > Overall, fire effects on the species depend on fuel loading, landscape position, and fire seasonality.
- ≥ Controlling competing annuals prior to the emergence of N. pulchra can be done through mowing, herbicide and light grazing (NRCS, 2009).
- What restoration/management options have been effective or ineffective?
- > For best establishment results N. pulchra seed should be planted in a weed-free seedbed a quarter to half an inch in depth (NRCS, 2009).
- > It is recommended to use about 9.5 pounds of pure live seed per acre, about 25 seeds per square feet (NRCS, 2009).
- > To prevent the settling of smaller seed during seed mixtures, it is recommended to use rice hulls or another dilutant, however, seed mixtures typically reduces establishment (NRCS, 2009).
- >Removing topsoil prior to seeding has proven to be a good strategy to reintroduce N. pulchra into degraded sites, through this method little to no native seed bank is left on the site, makes more nutrients available, and reduces the cover of other vegetation (Buisson, 2008).

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> Be warned that the assumption that all nonnative annual grasslands were dominated by bunchgrasses has led many restoration projects to fail (Steinberg, 2002).

>Do these change site to-site or project-to-project?

> Restoration and management practices do change from site to site depending on the differing variables. For example, *N. pulchra* when moved from a low productivity site to a high productivity restoration site does not result in a high survival rate, plantings survived at higher rates in low productivity sites versus high productivity (Lombardo, 2007).

What are key gaps in our knowledge that limit effective restoration planning?

Although most studies have found that fire and grazing, for the most part, tend to have positive effects on *N. pulchra*, many of the results from the studies do not correlate with one another or have highly variable or insignificant results. One crucial piece of information that could help increase success rates of establishment of *N. pulchra* in restoration projects is the native range before the colonization of the European annual grasses.

Part 2: Project Goals and Management Plan

A. Goals:

Restoring Purple needlegrass back into foothills and grasslands can be beneficial in the oncoming years in restoration work because of its tolerances to drought conditions, fire, along with other disturbances, which are expected to increase in frequency and intensity due to climate change. The goals of this project are connected to one another and accomplishing of one will help accomplish another.

> The first goal in restoring Purple needle grass is to restore it back into its known native range. This may be difficult because there is little information about Purple needlegrass native range, but making this a goal can aid with getting closer to knowing more information.

> The second goal is to control invasive nonnative species in the *N. pulchra* native range.

>The third goal is to introduce *N. pulchra* into sites that need erosion control, drought resistance or mound stabilization.

B. Restoration plan:

Timeline of Project

June 2015=Site survey will be conducted

July 2015-October 2017= removal of weeds and seed bank will occur in prospective sites

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November 2017= Plants will be transplanted, right before germinating rain.
December 2017=Seeds will distributed after the first germinating rain.
January 2018-January 2020=weed control and close monitoring of site will be needed to ensure that invasives stay out of the the sites.

Site Survey

A survey of the sites that are being considered for the location of the restoration project is a crucial component of any restoration project. For this project the focus will be on upland and grassland sites. Things to take note of when on site is topography, native vegetation present, invasive vegetation present, soil samples, seed bank composition, soil composition, slope, local climate, rainfall, probability and duration of flood (Stromberg, 2007). Since there is little information about the native range of *N. pulchra* before the European annual grass invasion, more recent records of the range will suffice.

Site Preparation

Depending on the site, site preparation will vary depending on whether *N. pulchra* will have to be introduced on an upland area or grassland area. The first step is to make sure the area is free of invasive weeds and their seeds. This can be done by using any of the following techniques or combinations of these; burning, disking, mowing, mulching, selective or broad-spectrum herbicides (Stromberg, 2007). This is a crucial step in the restoration process because at least two years prior to introducing *N. pulchra* the site should be free of invasives and their seeds. The establishment phase of *N. pulchra* is the most important and delicate part of the project (Stromberg, 2007), heavy weed control will be necessary. To reduce soil compaction and maximize seed germination disking, imprinting, or ripping along contour lines will be used (Stromberg, 2007).

Seed/ Plant Selection

This restoration project will have sites that require seed and plant introduction. Larger sites and sites where the soil is bare, seed is a better choice for introduction because it is cheaper for larger sites and easier to establish if the bare soil is weed free (Stromberg, 2007). Choosing seeds from a local source is important to keep the genetic integrity of the species but also minimizes the chances for invasives to slip in. For sites requiring seed introduction, source-identified seeds are important to obtain for the success of the project to ensure that the seed source is collected from local populations (Larson, 2001). Turning to nonlocal seed sources may ultimately result in a failed reintroduction (Larson, 2001). When transplanting it is important to know the source of the plants, because *N. pulchra* populations may be ecotypes of a small local environment (Stromberg, 2007).

Seeding Method

The planting of seeds will occur in the late fall or early winter because studies show that restorations are more successful after the first rain (Stromberg, 2007). What tends to happen if the seeds are planted before the first rain; many are ate by seed predators or they dry out (Stromberg, 2007). If the seeds are planted in the spring,

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the project will most likely be unsuccessful because *N. pulchra* requires a long period of warm wet soils for a successful establishment and germination (Stromberg, 2007). Seeds can be distributed by hand or an ATV-seed spreaders, depending on the site size and topography (Stromberg, 2007). The site can then be covered with a topsoil and the lightly compacted using ring rollers (Stromberg, 2007). Depending on the site's size, 12-25 pounds of seeds per acre can be used depending on the desired area (Stromberg, 2007).

Transplanting Method.

For the best results when transplanting *N. pulchra* is to get individuals that are larger than the other competition, if found on site (Stromberg, 2007). Large plants have a higher chance of survival when transplanted to new locations because they are better at competing with the annuals than smaller individuals do (Stromberg, 2007). Depending on the site's size, plugs for smaller sites or tractor operated seed drills will be used.

Possible risks

Some risks that may be encountered throughout the establishment phase of the project make cause the entire thing to fail. A major risk is invasive species being reintroduced into the site. The invasives will mostly likely outcompete *N. pulchra* for light availability, soil surface, nutrient availability and water availability. Another risk that can be encountered is that the source of the seed or plants are not adapted to the sites disturbances and drought conditions. This risk can be reduce if research about seed source if thorough.

C. Monitoring plan:

Making sure that invasives stay out of the sites will be a determining factor of whether *N. pulchra* will be able to succeed in the new sites for the purposes of hill stabilization and erosion control. The first step that will be taken after the successful establishment of *N. pulchra* in the chosen sites will be to record the species found in the site. It is important to know the site's plant communities in order to understand the system's processes and services. Vegetation can be monitored over time by measuring plant density, cover, biomass, and height (Stromberg, 2007). Aerial photography can be useful to compare to reference sites (Stromberg, 2007). Conducting prescribed burns to rid the sites of invasives will be used but not until the first couple of years to allow the plant to establish successfully. The frequency of the prescribed burns will depend on the need and status of the site. Scheduled monitorings will happen once a month for three years and once every six months after that for the next 5 years after that will be needed. A full site survey will be conducted including examination of the vegetation, soil, hydrology, etc.

The ultimate objective for this restoration project like any other is that one day the restored sites will no longer need to be managed, this however, is almost never the case and is extremely difficult to accomplish.

What if's

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Scenario planning can be useful when planning for possible outcomes of the project. Most important scenario to plan for is, What if the entire population of plants transplanted fails. If this occurs a possible solution could be to first find out what was the reason for the failure. If it was due to invasives, it all depends on the severity of the invasion. If the invasion is scattered all over the site, the entire area will have to be tilled and turned over. If it is found in smaller patches, removing the outer newer weeds can help stop the spreading (Stromberg, 2007). Making sure the seed bank is gone and no remaining root segments of the invasives is crucial. The same would apply to a failed seed population if the same problem was occurring.

Possible Future Research

Finding more data that can get us closer to knowing *N. pulchra* native range can help increase the percent of successful restoration projects and research. Conducting further studies that examine the effects of grazing at different intensities to yield more concrete and definitive results can help managers understand the role of grazing in restoration projects and when and where not to use them. Overall, Purple needlegrass can have a promising future if the right restorative measures are taken and research is continued to be conducted.

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By : Kristina M. Hufford and Susan J. Mazer

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Volume 20, Issue 6, pages 688–695, November 2012

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By: Knapp, EE; Rice, KJ

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By: Andrew Dyer

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By: Morghan, KJR; Rice, KJ

Restoration Ecology, Volume 13, Issue 3, pages 524–528, September 2005

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15. Research Note: Alignment of Elongated *Nassella pulchra* Plants with Hill-Slope Contour

By: Jeffrey S. Fehmi, Michele Hammond & James W. Bartolome

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18. California Grassland Restoration

By: MARK R. STROMBERG, CARLA M. D'ANTONIO, TRUMAN P. YOUNG,
JEANNE WIRKA, AND PAUL R. KEPHART

Grassland Restoration Volume 21; 254-280

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Fig (*Ficus carica*)
Emma Greene

Part 1: Project Background and Justification

Can possibly cause dermatitis (skin rash); DO NOT TOUCH BROKEN PLANT



@2005 Luigi Rignanese (CalPhoto)



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HABITAT

Forms dense thickets in “riparian forests, streamside habitats, levees, and canal banks in and around California’s Central Valley, surrounding foothills, the south coast, and the Channel Islands.”²

Excludes other plants from these areas²

APPEARANCE

1. Stover, Ed, Malli Aradhya, Louise Ferguson, and Carlos Cristosto. "The Fig: Overview of an Ancient Fruit."

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Tree height from 3-10 meters (~ 9-32 feet).¹
"Tend to be greater in width than in height."¹

Trunk: "Trunk and branches are covered with smooth, light grey, flaky bark."²
Can have either a singular trunk or, if injured, multiple trunks that sprout from the tree's roots.¹

Leaves: "Rough to the touch, bright green, with three to five lobes ... two to 8 inches wide, two to ten inches long, with a two to four inch long petiole (stem)."²
Deciduous: drop their leaves in mid to late autumn and sprout leaves again in early spring.²

Fruit: 2-4 inches long and wide; can be dark purple-black, pale greenish-yellow, or white with a purple tint.²
Ones found in CA's central valley found in canyons and riparian often drop few greenish yellow fruits.²
'Fruits' are actually an inflorescence called a synconium. These are filled with flowers that you can only see when synconium is opened. Has a "small, scale-covered opening (ostiole) at its distal end."²

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COMMON EDIBLE FIG (*FICUS CARICA*)

A. BACKGROUND AND JUSTIFICATION

The common edible fig (*Ficus carica*) is a subcanopy tree that is native to Southern Arabia. However, this tree is used in commercial cultivation and has consequently spread throughout most of the world, including California's Central Valley. Originally introduced to California in 1769 for this purpose, it has invaded natural areas at an exponential rate over the past twenty years (Holmes et al. 2014). It has invaded riparian forests, streamside habitats, levees, and canal banks in areas of the Central Valley, nearby foothills, southern coast, and Channel Islands (Hickman 1993). This tree is able to invade areas that have low light and are dominated by native plants and poses a threat to native habitats because of its ability to form dense stands and therefore crowd out native trees and shrubs (Holmes et al. 2014). Because of this, CalIPC has listed this tree as "a moderate threat with severe invasiveness potential and moderate distribution and impact levels" (Holmes et al. 2014). Currently, the major stands of this species in the wild can be found in Dye Creek Preserve, Woodson Bridge State Park, Cosumnes River Preserve, Caswell State Park, and on Santa Cruz Island (Randall 2000). The complete eradication of *Ficus carica* in California has been recommended due to the impact the species on the native riparian forests, which have been reduced to 6% of their original area (Holmes et al. 2014) and therefore have been classified as an "endangered habitat" (Gaines 1980).

B. LITERATURE REVIEW

Environmental Tolerances/Preferences

- This species can invade habitats that have low light levels, low disturbance, and moist conditions. At risk habitats that are preferred by *F. carica* are floodplains that are moist well into the spring (Homes et al. 2014). No information about what types of disturbance are not tolerated, on what level of soil saturation is considered "moist", what level of light is considered "low", or what "well into spring" means.
- Most of the cultivation of figs occurs from 36°N to 38°N in California (Homes et al. 2014).

Reproduction and Dispersal

Reproduction/Pollination

- Fig trees have both female and hermaphroditic (both male and female anatomy) varieties of tree. There are caprifig trees (hermaphroditic fruits) and fig trees (female fruits). However, caprifigs are considered to be generally male, since the female flowers in these almost never get pollinated due to fig wasp ovule parasitism (Holmes et al. 2014).

- Reproduction in *F. carica* relies on the wasp *Blastophaga psenes*, which was introduced to California in 1899 specifically for the fig industry (Holmes et al. 2014). Female wasps lay eggs in both caprifigs and figs. The only larvae that survive are ones laid in the caprifigs. Males mate with the female larvae in the fruit before they hatch. When the females hatch, they squeeze out of the end of the fig, taking pollen with them. These pregnant females laden with pollen then enter either a caprifig or a fig and pollinate the flowers while depositing eggs. Only figs can be pollinated this way because the caprifig flowers are killed in the process of egg laying (Randall 2000).
- Figs have three crops: one that ripens around June, one that ripens in August and stays ripe for 3-4 weeks, and one that ripens in November or December, most fruits of which are killed by frost. Most trees start to enter dormancy at this time for the coming winter. On the trees that do produce fruit at this time, any fruits that do not ripen before the frost hits often do not develop with the next coming spring. In warmer areas of California, the first crop may happen in May, which suggests that as temperatures rise with climate change, the first fig crop will gradually occur earlier (Storey 1977).
- Caprifigs also have three crops to correspond with the timing of fig crops in winter, spring, and summer.

Dispersal Methods

- Vegetative spread – These trees spread through vegetative means, which means that any limb or branch that reaches the ground can take root. Also, they can spread by “suckering”, which means that the roots from one plant can send up a shoot elsewhere that can turn into a whole new plant (Holmes et al. 2014).
- Drupelets spread – Drupelets (seeds) can only germinate if they have been removed from the fleshy synconium (fruit-like body) that they are housed in. This can be accomplished by being chemically removed through the digestive tract of a vertebrate who eats the fig, or through manual means such as heavy rainfall (Randall 2000).

Dispersal Scale

- Short distance dispersal - Accomplished through both vegetative spread and from the dropping of seeds near the reproducing tree. This type of dispersal allows this species to dominate sites that it already occurs in by forming dense stands, and allows for a constant rate of linear expansion at source population sites (Holmes et al. 2014).
- Long distance dispersal - Facilitated by vertebrates such as birds and deer (Randall 2000), who eat the pollinated figs and disperse their seeds (Holmes et al. 2014). It is also accomplished by broken limbs of trees floating down rivers and taking root where they settle (Randall 2000). This method of dispersal causes recruitment of satellite populations at about 20 to 200 meters away from reproductively mature fig groves, which allows for colonization of new sites (Holmes et al. 2014).

- The rates of intermediate and long distance dispersal have been shown to be increasing exponentially. It is hypothesized that this exponential growth is due to infill. This means that invasion is mostly happening in between satellite populations to the point where two satellites end up becoming one, rather than spread through establishment of many different far away satellite populations (Holmes et al. 2014)
- The expansion rate of this species (0.13) is similar to the expansion rate of other aggressive invasive species (Holmes et al. 2014).

Germination Requirements

- The temperature range needed for germination is from 10°C to 30°C.
- Constant humidity is needed for germination and early growth, which means that the drupelet needs to be covered by earth at all times to avoid dehydration.
- Germination does not occur when the drupelets are left within the synconium. They must be removed from the fruit by either digestion and excretion by vertebrates (foxes, hedgehogs, ferrets, and various birds) or by heavy rains. If the rains fail to remove the drupelets from the synconium, the fig is exposed to attacks from fungi and bacteria, which prevent germination.
- Germination is rapid when humidity and temperature are at optimal conditions because the embryo is already developed and it has reserves to help it start growing without much delay.
- In the Mediterranean, germination occurs when the autumn rains begin. If the temperatures in winter do not drop below 10 degrees Celsius, the seeds germinate and grow. However, in areas where the winter temperatures drop below 10 degrees, the seeds stay dormant in the soil until the temperatures warm up in spring (Lisci and Pacini 1994).
- DiTomaso et al. (2013) states that the time until sexual maturity/fruit bearing is 2-3 years from seed and 1 year from vegetative growth. However, it has been suggested that this is true only for orchard trees or trees in high light environments. Figs have an extended juvenile stage in low-light environments: up to 15 years before sexual maturity (Homes et al. 2014).

Pests and Diseases

- Nematodes of genus *Meloidognye* are the prime pests of figs. However, no other substantial pests of *Ficus carica* are widespread or consistent. This has led fig growers to not require the spraying of pesticides on commercial fig trees.
- *Alternaria* and *Fusarium* fungi cause internal fruit rot and is the primary concern in California's edible fig industry. Endosepsis, known as pink or brown rot, causes 30 to 50 percent loss of fig crop. This is spread from caprifigs to figs by means of female fig wasps and has led fig growers to stop using pollinator-dependent varieties of the tree (Stover 2007).

Negative Impacts

- Figs form dense monocultures that decrease native plant biodiversity in riparian woodlands of the central valley.
- The canopy layer of forests is the only layer that is not effected by fig trees (Holmes 2008).
- Light competition – Fig trees have wide, multi-leveled leaves which make them very effective competitors for light. Other understory species are outcompeted in this respect (Sedna 2003).
- Leaf litter cycling – Fig tree leaves decompose very quickly, so in areas dominated by fig trees, there are usually large patches of bare ground for most of the year. In contrast, native plant dominated areas have a large proportion of leaf litter and very little bare ground (Holmes 2008). This has the potential to alter nutrient cycling, the uptake of carbon by the soil, and soil biota (Ehrenfeld 2003) although these effects have yet to be demonstrated in fig stands (Holmes 2008).
- Allelopathic effects – Allelopathic compounds (chemicals that impede the growth of other species around the source plant) leached by fig leaf litter have been found to suppress the seedling root and shoot growth of other native plants. It is not clear as to what specific allelopathic mechanism by which fig plants reduce the biomass of native plants (Holmes 2008).

Potential Management Actions

Physical Control

- Can be manually pulled easily when young due to shallow roots.
- Mid-sized specimens: can be removed with small or medium sized weed wrench.
- Manual removal is not completely effective due to the species' vegetative growth. One plant can simply be the sprout of a network of sprouts or trees that can grow back if one sprout is pulled.
- Theoretically, repeated and frequent cuttings of resprouts can exhaust the energy reserves of these sprouts so that they can no longer resprout, but this yet to be demonstrated. (Randall 2000)
- Grazing and burning are not efficient due to vegetative growth (DiTomaso et al. 2013)

Biocontrol

- No safe biocontrol has been approved by the USDA (Randall 2000).

Chemical Control

- Cut and herbicide: cut trees six to eighteen inches from the ground and treat the stumps with a 100% solution of an amine formulation of triclopyr. This method has been successful but had to be repeated at yearly intervals to eliminate resprouts. It is possible that performing this at shorter time intervals could have yielded less resprouts.
- Hack and squirt: A tree is wounded and a 100% solution of an amine formulation of triclopyr is applied to the wounds. This method has been

attempted at Cosumnes River Preserve but it is too early to tell if it is effective. It has not been shown to be effective at Dye Creek Reserve.

- Basal bark application: An eight to twelve inch band of herbicide is applied around an uncut tree trunks that do not exceed two to three inches in diameter. This method has been shown to be effective for killing *F. carica* stands, but in dense stands the amount of herbicide that would need to be applied exceeds the maximum amount allowed per hectare by three to five times. It has therefore only been suggested for small invaded areas.
- Herbicides used in these methods tend to stick to the tree trunks and are washed into the soil with winter rains, possibly causing off-target effects on other species (Holmes 2008).
- The herbicides glyphosate and imazapyr may be as effective as triclopyr on fig trees but they have yet to be tested (Randall 2000).

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Part 2: Project Goals and Management Plan

A. GOALS

The main goal that has been previously suggested for the restoration plan of *Ficus carica* in the Central Valley has been complete eradication of all individuals (Holmes et al. 2014). However, due to the possible limitation of resources such as money and man-power, complete eradication may not be possible for the near future. Because of this, the control of the spread of already established stands of trees should be the first goal for the short-term, and complete eradication of the tree from the Central Valley should be the secondary but ultimate long-term goal. Here the sub goals for both control and eradication are listed.

CONTROL OF FURTHER EXPANSION

- Because most of the spread of this species is due to infill from satellite populations 20-200 meters from the edge of a stand, areas outside of this region do not need to be acted upon very heavily. The area from the edge of a stand to this 20-200 meter boundary should be controlled the most in order to prevent infill and keep stands patchy and manageable (Holmes et al. 2014).
- The area downstream of an established *F. carica* stand is prone to vegetative colonization by broken branches being carried downstream

by a body of water (Randall 2000). Control of vegetative spread via breakage, focusing on stream and river banks downstream of established stands should then be a sub goal.

- Along these same lines, another sub goal should be to reduce vegetative spread on land, that is, control of the core network of clonal trees and saplings. This includes the removal of any new saplings that emerge.
- The control of the reproductive spread of fig trees is an important sub goal. This involves the reduction of the number of fruits that reach the ground and germinate.

ERADICATION

- The one key goal of eradication is to completely remove or kill each clonal grouping of trees, or in other words, remove all saplings and trees that are branching off of the same clone. These trees can resprout from fallen limbs, roots, and stumps, so elimination requires complete of all plant matter, and this can be done through physical or chemical means (Holmes et al. 2008). However, this will likely prove difficult, as the nature of this tree is to form very dense stands that are therefore hard to completely eradicate (Holmes et al. 2008).
- Eradication, in order to be permanent, must also be paired with prevention so the cycle does not repeat itself. This involves monitoring of the agricultural and ornamental aspects of fig trees in California. Information on how to go about this cannot be found in the literature, however.

Currently, the major stands of *F. carica* occur in riparian areas of Dye Creek Preserve, Woodson Bridge State Park, Cosumnes River Preserve, Caswell State Park, and on Santa Cruz Island, so these areas need to be the focus of both control and eradication efforts (Randall 2000). However, due to the nature of this tree, any occurrence outside of these areas should be swiftly controlled and eradicated, as the process of removal becomes more difficult as time goes on. This species has been spreading exponentially within the past 20 years, and has a short time period until it reaches reproductive maturity, so action must be quickly taken before it spreads to the point where eradication is no longer possible (Holmes et al. 2014). Fig trees are also resistant to many different types of control methods, which may prove to be a problem for effective control and eradication (DiTomaso et al. 2013).

B. RESTORATION PLAN

AREAS OF FOCUS

Priority in the control of *Ficus carica* in the Central Valley should be given to the preserves and areas listed above and their surrounding areas, although attention should also be paid to any other small satellite populations that emerge anywhere outside of these areas. From a community perspective, riparian areas whose soils are moist year-round are the most at-risk habitats (Randall 2000). Within riparian areas, seasonal sloughs have been shown to have the largest amount of cover by fig trees, followed by terraces and finally

the banks of waterways (Holmes et al. 2014). Because of this spatial pattern, efforts in restoration should be focused on these seasonal slough habitats. Holmes et al. (2014) warns, however, that increased propagule pressure may cause increased prevalence of fig trees in the other less-than-ideal areas, so terraces and banks are still of moderate importance from a monitoring standpoint. Another factor that has been shown to influence where figs establish is the presence of altered hydrology such as dams, which increase summer stream flow and therefore maintain soil moisture during the summer in areas that would have otherwise had low soil moisture (Holmes et al. 2014). Since fig seeds require constant moisture to germinate, anywhere where stream and river hydrology have been altered should implement a control plan to reduce water presence during the summer (Lisci et al. 1994).

Satellite populations that are formed by intermediate and long distance spread pose the greatest threat because they spread out more rapidly and end up covering more area than a source population that just expands from its perimeter (Radosevich 2007). Because of this, satellite populations should be the focus of eradication efforts. The diagnosis of a satellite population lies in the distance between the edge of a reproductive stand and the nearest individual in question: anywhere from 20 to 200 meters is considered far enough for long distance spread and classification of a satellite. Any shorter of a distance and the tree is considered to have originated through short distance vegetative or reproductive spread and is less of a threat due to the linear rate of expansion (Holmes et al. 2014). Being surrounded by native plants is also an indicator of being a satellite population (Holmes et al. 2014).

Within established populations or stands, figs form dense monocultures and therefore block out a lot of light (Randall 2000). Although fig recruits can grow well in this environment, it has been shown that it takes adults longer to reach reproductive maturity in these conditions: an average of 15 years compared to the four years found in agricultural fig orchards where full sun is present (Holmes et al. 2014). These shaded populations of figs that experience an extended juvenile period pose less of a threat than figs on the outskirts of stands that receive more light and therefore reach reproductive maturity earlier (Holmes et al. 2014). The fact that early-stage satellite populations are more likely to be sparse in nature, and therefore reach sexual maturity earlier, is another reason why satellite areas should receive the heaviest management. There is a tradeoff here, however, as dense, shady stands provide more of a threat to native plants by virtue of the leaching of harmful chemicals by the figs (allelochemicals), alteration of nutrient cycling, and shading of the ground (Holmes 2008). A decision must be made for a particular site whether reducing the spread of figs or rebuilding native plant communities is more important.

METHODS OF CONTROL

Now that it has been established where efforts should be focused, the methods of control can be introduced. Control consists of reducing both vegetative spread that occurs through waterways and on land by means of “suckering” and reproductive spread through seeds (Holmes et al. 2014). Suckering occurs when a new shoot grows from the crown or roots of a tree

(Lloyd et al. 2014). The means for controlling vegetative spread downstream cannot be found in the literature, but monitoring of stream sides for fig debris, especially after storms, could possibly be a viable means of controlling this kind of spread. How easy or effective this method is, however, is not known. Control of vegetative spread through suckering, however, has been more extensively documented. The only two viable methods of controlling these fig populations are physical and chemical control with herbicides (DiTomaso et al. 2013). Physical control has varying success. Small seedlings can be manually pulled or hoed due to their shallow roots (Randall 2000). Medium-sized trees can be removed with a weed wrench, but care must be taken to remove all of the root matter because resprouting can occur from leftover roots (DiTomaso et al. 2013). Theoretically, repeated cuttings of the trunks of large trees will eventually drain the stump of resources, but this method has not been shown to be very effective (DiTomaso et al. 2013). However, this is the only physical means of removal for stands that are already well established and old in age. Physical means of tree removal should be attempted before chemical means, due to the possible consequences discussed below.

Chemical control can be done in one of four ways. The first is “hack and squirt” or “stem injection treatment”, where the tree is wounded and herbicide injected into the wound (Holmes 2008). The second method is “cut and herbicide” or “basal cut stump”, where the tree is cut six to eighteen inches above the ground and injected with herbicide (Holmes 2008). Thirdly, there is “basal bark application”, where an eight to twelve inch band of herbicide is applied around an uncut tree trunks that do not exceed two to three inches in diameter (Holmes 2008). Finally there is “spot foliar treatment” that is applied to resprouts where the soil is sprayed with herbicide (Miller 2003). Upon reviewing the literature, one cannot find any significant support suggesting that one of these methods is superior to the others.

Below is a table that lists how to use the herbicides Triclopyr, Imazapyr, and Glyphosate in these four methods of control with data from DiTomaso et al. (2013). If there are any doubts as to the application of these herbicides, DiTomaso et al. recommends following the product’s label.

Method of Control	Triclopyr Application	Imazapyr Application	Glyphosate Application
Stem Injection Treatment	100% <i>Garlon 3A</i> (amine formulation)	100% concentration of <i>Arsenal of Habitat</i>	100% concentration
Basal Cut Stump	25%-100% concentration of either <i>Garlon 3A</i> or <i>Garlon 4 Ultra</i>	20%-100% of any formulation	20% to 100% volume-to-volume in water
Basal Bark	10% to 25%	13%-25%	None noted

Application	concentration of <i>Garlon 4 Ultra</i> mixed with crop oil concentrate or basal oil	<i>Chopper</i> mixed with crop oil	
Spot Foliar Treatment	None noted	None noted	10% volume-to-volume in water

All of these herbicide treatments have been shown to be more effective at the end of the growing season before leaves start to fall. In the case of stem injection treatments, if the herbicide is applied at any point before this, the tree will ooze sap and the herbicide will be flushed out of the wound and effectiveness will be reduced greatly (DiTomaso et al. 2013).

Triclopyr is specifically targeted for broadleaf species (DiTomaso et al. 2013) and has been shown to be very effective for control of *F. carica* stands (Holmes 2008). In dense stands, however, the amount of herbicide that would need to be applied exceeds the maximum amount allowed per hectare by three to five times (Holmes 2008). Over-application can lead to residual herbicide levels in the soil, which can then cause groundwater contamination and off-target effects (Holmes 2008). What classifies a “dense” stand is not established, however, so it is unclear as to when to use this herbicide and when not to from a mathematical standpoint. The safest and most advisable route to follow would be to not exceed the recommended amount of herbicide per area of land and only applying herbicides to individual trees or small groves (Homes 2008).

Imazapyr and Glyphosate are both nonselective, which means they are used widely and have a broad spectrum of what weeds they affect (DiTomaso et al. 2013). This means that they could have some unwanted effects on other non-target species, so Triclopyr should be preferentially used. If Triclopyr cannot be used, Glyphosate should be preferentially used over Imazapyr because Glyphosate does not leave soil residue, whereas Imazapyr has long residual activity (DiTomaso et al. 2013).

Holmes (2008) stated that herbicides used in these aforementioned methods tend to stick to the tree trunks and are washed into the soil with winter rains, which can cause off-target effects on other species and must be taken into consideration. However, although these herbicides remain in the soil when used at these high levels, they were shown to not have a very large effect on the ability for natives to grow on these soils after the figs were eradicated (Holmes 2008). If replanting native species is a priority and chances do not want to be taken, application of herbicide should be done once the rains have subsided for the dry season. Also, these herbicide methods may be best to use in non-satellite, monodominant stands that do not have many native species in the area because of possible effects to these natives.

Sexual reproduction through the dropping of fig fruits is a large part of the way figs spread (Lisci et al. 1994), and seeds often have a high germination

rate ranging from 86% to 93%, so they have the capacity to spread efficiently through these means (Holmes et al. 2014). Despite this fact, there was no method of control for seed dispersal suggested in the literature. Picking up ripe fruits during the three fruit drops (see previous literature review) would decrease the number of seeds that make it to the soil to germinate, and although there is nothing in the literature concerning this method of control, common sense dictates that if seeds are removed from the habitat, fewer trees will sprout in the future. Although there is no information available on the subject, research on whether focusing control on either the caprifig or fig tree is more preferential due to their difference in reproductive capacities may prove to be insightful.

C. MONITORING PLAN

There was very limited information in the literature on how monitoring of post-restoration should be performed. However, it was stated that the nature of *F. carica's* extended juvenile period means that monitoring of areas where control has been applied does not need to be very frequent: every 5 years is enough of an interval to take care of any resprouts before they become reproductive (Holmes et al. 2014). If any new fig trees have sprouted, they will be small and should therefore be removed through manual pulling or hoeing (DiTomaso et al. 2013). When this monitoring should stop was not discussed.

One thing to be aware of is encroachment of figs onto drier terraces and upland areas when propagule pressure becomes high (Holmes et al. 2014). Any areas where seeds have access to constant moisture for a period long enough to germinate is at risk (Lisci et al. 1994). Monitoring of these areas was not suggested in the literature, but due to the threats that newly emergent satellite populations pose, any fig seedlings found in these areas should be promptly pulled, hoed, or wrenched, and larger trees should be removed through herbicide means, as suggested earlier.

If herbicide is used in control and eradication of this species, questions as to the extent of herbicide levels that remain in the soil afterwards can be addressed. Tests of herbicide levels in the soil should be performed starting at 175 days so as to reduce unnecessary effort, since Holmes (2008) demonstrated that at this point there were still remains of herbicide in the soil. The intervals of testing after this cannot be advised as there is no evidence to support a particular interval in the literature. If various different herbicides are used in different but similarly ecologically structured locations, the effectiveness of these herbicides can be compared, and the same can be done for different methods of herbicide application. Little research has been done to compare these factors, so any data that can be documented on the subject will greatly help any future restoration projects.

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Chinese tallow tree (*Sapium seiferum*)

Mia Bianchi

Part 1: Project Background and Justification

Habitat: Natively found in Japan and China. Tolerates saline environments, many soil conditions, and periodic flooding and are often found in “bottomlands, old growth fields, coastal prairies and riparian areas” Invasive in the United States because of fast root growth (SE-EPPC <https://dnr.state.il.us/Stewardship/CD/eppc/SASE.html>).



Figure 1: Tallow Tree at Full Height. Source: <http://www.eih.uh.edu/>



Figure 2: Tallow tree color during cold vs. warm seasons. Source: CalPhoto

Appearance:

Flowers - Tassel shaped and spiked that can grow as much as 8 inches in length; “Each flower cluster along the spike contains basal nectar glands.” No actual petals are present; tassel shaped spikes are sepals (Tassles shown in Figure 2 Above) (USDA Plant Guide https://plants.usda.gov/plantguide/pdf/pg_trse6.pdf)

Leaves - Alternate and contain a wide, smooth margin shaped blade that appears rhombic in shape. Leaves “turn orange to scarlett and fall as the cold season approaches” (Colors shown in Figure 2 Above) (USDA Plant Guide https://plants.usda.gov/plantguide/pdf/pg_trse6.pdf)

Seeds - “Three lobed capsules appear from August to January and release 3 white, wax- coated seeds” (NC State University <http://www.ncsu.edu/goingnative/howto/mapping/invexse/chineset.html>)

Trunk - Divided into multiple trunks and many times twisted. Pale grey in color with multiple furrows (USDA Plant Guide https://plants.usda.gov/plantguide/pdf/pg_trse6.pdf)

Chinese tallow tree (*Triadica sebifera*)

Kingdom: Plantae

Phylum: Magnoliophyta

Class: Magnoliopsida

Subclass: Rosidae

Order: Euphorbiales

Family: Euphorbiaceae

Genus: *Triadica*

Species: *sebifera*

Background and Justification:

Triadica sebifera, or the Chinese tallow from China and Japan and that is a nonnative in (Urbatsch). The Chinese tallow tree is a rapid-g sprout both via roots and basally. It completely and outcompetes all natives around it due to its types and to resist pests (Meyer, 2011).. Tallow trees are incredibly adaptive and have many physiological advantages that make it easy to outcompete native tree species (Meyer 2011).



The tallow tree was originally introduced to South Carolina in the 1700's, but was more widely spread to the Mexico coast region and California in the 1900's because its seeds contain a vegetable oil that was needed for the soap making industries at the time (Meyer 2011). Although there is extensive understanding of the disastrous effects of this nonnative species in the southeastern United States, Chinese tallow trees are continuously being planted in California's Central Valley (Bower et al. 2009). The tallow tree species is known to grow in riparian and wetland areas located nearby the American, Sacramento, and San Joaquin Rivers. Today, Chinese tallow trees are no longer legally sold due to their invasive nature, however, the tree species continues to flourish and is becoming more widespread due to seeds being dispersed by water and birds.

Chinese tallow trees have been denoted as an alert species in California because of their status as a noxious weed. Tannins, a plant chemical compound, are produced by the roots of this tree which alters soil chemistry and degrades the entire ecosystem by eliminating native plants ability to establish in the surrounding soils. Tallow trees are also problematic due to the toxicity of their leaves and fruit to both cattle and humans. Cattle have been known to consume their berries when tallow trees invade pasture land. Multiple instances have been reported regarding farms in

the Central Valley producing milk and beef that caused illness in people consuming the products due to poisonous berries the cows consumed (Bogler et al. 2000).

Due to the Chinese tallow trees heavy destruction of riparian and wetland areas in the Central Valley and its status as a noxious weed, restoration ecologists find it imperative to systematically remove this species in its nonnative ranges (Meyer 2011).

Project Goal:

- To remove the highly invasive Chinese tallow tree from California's Central Valley riparian forests and wetlands in order to promote the reintroduction of native plants that are outcompeted by the tallow tree.

Growth Characteristics:

- Chinese tallow tree typically grows to a height between 24 and 35 feet, but has been reported to grow as tall as 64 feet (Meyer 2011).
- It behaves as a woody invader that grows very rapidly and starts producing viable seeds when it is 3 years old (Bogler et al. 2000).
- Tallow trees are deciduous. During the fall, their leaves turn red, yellow and orange before they drop (Bogler et al. 2000).
- The trees grow in dense stands due to older trees dropping thousands of seeds each year, allowing for new trees to sprout in the area (Bruce et al. 1995).

Habitat:

- Tallow trees have the ability to inhabit a wide variety of habitat types; including bottomland hardwood forests, riparian zones, alluvial forests, wetlands, old fields, coastal prairies and grasslands (Bogler et al. 2000).
- Although they can tolerate living in a large variety of conditions, their ideal habitat would consist of alluvial forests containing an abundance of leaf molds as well as clay-peat soils (Bogler et al. 2000).
- California's riparian habitats are most vulnerable for invasion by tallow trees because they contain areas where birds and water deposit seeds in ideal conditions downstream of natural wildlife populations (Bower et al. 2009)

Tolerances:

- Chinese tallow trees are tolerant to flooding and high levels of salinity. (nwrc.usgs.gov).
- They have evolved with short fire-return periods of time. Areas with frequent fires reduces recruitment of tallow trees (Bogler et al. 2000).
- Tallow trees can establish growth in fully shaded canopies and thrive in an area with direct sunlight. Therefore, they are both shade and sun tolerant (Bogler et al. 2000).
- Tallow trees prefer soil types that are mesic to hydric, but can grow successfully in a variety of other soil types (SE-EPPC).
- They tolerate and even thrive from soil disturbances via ground-foraging animals because soil disturbances remove native plants and allow the tallow trees to encroach (Siemann et al. 2009).

- The tallow tree seeds benefit from climate change indirectly because climate change-destroyed habitat remnants attract birds to the areas (Burkett et al. 2005).
- They are tolerant to all levels of soil drainage and water tables. Water typically sends seeds downstream to germinate (Bogler et al. 2000).
- Seedlings aren't as drought tolerant, which is why they are not as often found in upland territories (Bower et al. 2009).

Range:

- These trees are native to China and Japan, but have been successfully introduced to the United States, Puerto Rico, Costa Rica, Taiwan, India, Martinique, Sudan, and southern France (Bogler et al. 2000).
- They have most recently been discovered in riparian and wetland habitats of California's Central Valley (SE-EPPC).

Reproduction:

- Tallow trees can begin producing seeds when they are as young as three years old and each tree produces up to 100,000 seeds each year until the end of their reproductive life at the age of 60 years old (Meyer 2011).
- Tallow trees produce a seed bank that reaches its germination prime at the age of 2 years (Meyer 2011).
- There are two different forms of Chinese tallow tree's seed type with one where the male seed clusters develop before the female seed clusters and vice versa. Since both forms can cross-pollinate, this contributes to tallow tree diversity (Bogler et al. 2000).
- Tree stumps are able to resprout with their roots capable of developing shoots (Bogler et al. 2000).
- Bird species consume tallow tree seeds and deposit them into broad habitat areas which promote germination (Meyer 2011).
- Winter birds readily consume tallow seeds because they are an excellent source of fatty oils due to the waxy coating over the seeds, further promoting birds as a necessary seed disperser for the Chinese tallow tree (Lewis and Cunningham 2013).

Part 2: Project Goals and Management Plan

Restoration Goals:

The systematic removal of the Chinese tallow tree as a nonnative invasive tree of the Central Valley is crucial in restoring the integrity of the native flora within this area (Bower et al. 2009). The following describes the short term goals as well as the long term goals for successfully removing Chinese tallow trees within the Central Valley:

- The first short term management goal for the removal of the trees is to conduct a thorough aerial survey of the land at least 2 months before seeds are dropped in the fall in order to identify every Chinese tallow tree within the site of removal to ensure the success of removing all trees in the location and to determine patch sizes for later removal (McCormick 2005).

- The following step would be to start cutting back the trees manually by plowing and frequent mowing of the fields in which the tallow trees reside (McCormick 2005).

The second set of goals depicts a long term solution for the successful removal of the Chinese tallow trees from the Central Valley. This shall be conducted after the short term goals of keeping the tallow tree population in check are reached. The following describes these goals:

- Apply the suitable herbicide method based on the previously determined patch and tree sizes. Small patches require foliar and basal spray while large areas of trees and branches need large scale supplication via aerial spraying until coated (MacDonald et al. 2008).
- Remove all remaining branches and remove all roots manually to ensure that no more roots will grow (McCormick 2005).
- Carefully evaluate which native plants will survive best in the areas where tallow trees have been removed via herbicides and determine when to plant natives after chemical application (MacDonald et al. 2008).

It is important to note that there are many uncertainties regarding how native plants will react to the application of herbicides (MacDonald et al. 2008). To achieve the goal of successfully planting native plants in place of tallow trees, monitoring the area weekly for post- tree removal will be vital in ensuring the permanent success of the restoration to native vegetation (MacDonald et al. 2008). As noted in the short term goals, management practices should commence at least 2 months before the fall seed drop period in October (MacDonald et al. 2008).

Management Practices:

Task 1: Collection of Seeds/ Removing Seedlings

Directly after the initially conducting a pre-monitoring evaluation (See monitoring section for details), check the ground of the Chinese tallow trees for any premature seeds or seedlings in which have sprouted for their immediate removal. Seedlings shall be removed mechanically by being pulled by hand (MacDonald et al. 2008). There may need to be several weeks of close monitoring to ensure that all saplings have been removed from the site (MacDonald et al. 2008). Apply a systematic burning of the fields nearby to ensure that any seeds that may have blown into the field will not germinate (McDonald et al. 2008). Although this step will occur before the typical seed dropping period that begins in October, this step can reduce the likelihood of germination for any seeds that have dropped prematurely. Since this is an intensive management practice, use caution by monitoring the land after the burn since fire can potentially promote the generation of new sprouts and can increase the biomass of root shoots in mature trees (Urbatsch). There is no current site prepping alternative to prescribed burns except for intensively mechanical pulling of saplings and removal of seeds and constant removal of saplings by mechanical pulling. It is important to note that this alternate likely will not fully eradicate the ground of seeds and saplings because of the rapid growth and spread of the species (Urbatsch).

Task 2: Cutting back the Larger Trees

Starting immediately after the previous step in mid-September, mature tallow trees that are approximately 40 feet in height shall be cut down mechanically via the

use of chainsaws (MacDonald et al. 2008). This mechanical removal will not fully extract the trees, but will eliminate much of the branches and bulk before any application of chemicals or uprooting the trunks (MacDonald et al. 2008). These trees shall be cut down to the ground as close as physically possible and should be cut level in order to successfully apply basal spray to the stumps (MacDonald, 2008). Carefully read step 4 for instructions regarding the removal of mature trees because the following step of basal chemical treatment must be completely within no more than 30 minutes after the stump cut (MacDonald et al. 2008).

Task 3: Removal of Trees

Different Chinese tallow tree removal techniques shall be applied depending on the size of the stand as well as the age and heights of the trees (McCormick, 2005). The size and stand density of the trees should have been previously determined from initial evaluation step. The largest trees have already been cut back and noted. The following describes the methodology to use for tree removal depending on the trees' characteristics:

a). Small Chinese Tallow Trees (Trunk less than 6 inches in diameter):

On the Chinese tallow trees that are less than 8 feet tall and densely packed in their stand, use a 5% triclopr liquid spray that is applied as a foliar treatment. This shall be applied during late September directly before the fall months have started in order to avoid seeds from being produced and dropped (MacDonald et al. 2008). Along with foliar treatment, use a basal bark treatment that consists of either Garlon 3A or Pathfinder II 5% triclopr – ester solution mixed with an oil diluent for trees that have a trunk diameter of less than 6 inches (MacDonald et al. 2008). Tallow saplings should be pulled from the ground by hand as long as they are found in low densities of less than 50 individuals per acre (MacDonald et al. 2008).

b). Large Chinese Tallow Trees (Trunk greater than 6 inches in diameter):

Mature Chinese tallow trees that have a tree diameter of over 6 inches shall have its stumps cut and within 30 minutes of being cut should be applied with either Garlon 3A or Pathfinder II brand 15-20% triclopr- ester solution mixed with an oil diluent (McCormick 2005). The outer surface of the stump should be coated with the chemical solution until the trunk is visibly wet (MacDonald et al. 2008). For dense stands of trees, aerial application of the 15-20% triclopr- ester solutions shall be utilized for a larger scale spatial application (MacDonald et al. 2008). The same 30 minute maximum interval should be applied to the trees sprayed aerially (McCormick 2005).

Note: No biological control will be used in the plan because Chinese tallow trees are resistant to all pests (Meyer 2011).

Task 4: Treatment of Site

After the application of chemical sprays, the site formerly containing the Chinese tallow trees should be covered with a thin layer of wood chips from the biomass of woody California native trees such as the wax myrtle or the box elder (McCormick 2005). Directly after this application, multiple hot prescribed burns shall be administered in order to clear the area of any saplings that may have sprouted post chemical spraying (McCormick 2005).

Task 5: Restoring Native Vegetation after Chinese Tallow Tree Removal

Once the site has been stabilized without any growth of saplings for 2 continuous weeks, the addition of native trees approximately the same size as the Chinese tallow tree should be planted in their place (McCormick 2005). As outlined in the uncertainties section below, there is no indication of which exact California native species will be best to plant after the removal of Chinese tallow trees.

Uncertainties/ Risks:

There are many unknowns regarding the successful removal of the Chinese tallow tree without impacting the native species of plants surrounding the area (Bower et al. 2009). There is no indication of what the risks of applying either the 5 or 20 percent triclopr- ester solutions would to the surrounding native plants. Use all herbicide sprays with caution as more studies need to be conducted in order to understand the effects.

Another important note is that although the Chinese tallow tree's management has been extensively studied in the Southeastern part of the United States where the tree was originally introduced; there is still a large gap in knowledge about correct management in the Central Valley of California (Bower et al. 2009). There is no certain documentation regarding what California native trees would be best to plant after the successful removal of the Chinese tallow trees on the premises (Bower et al. 2009). Tallow trees are allelopathic plants, meaning that they produce long lasting growth suppressing chemicals through their roots and litter fall which changes that would makes soil conditions uninhabitable for many native plant species (Macdonald et al. 2008). Because of these technicalities that have not been studied extensively, it vital to evaluate native planting potential on a per site basis based on native vegetation that currently grows or has historically grown there and on their reactions to chemically altered soils (MacDonald et al. 2008).

Monitoring Plan:

As a pre-monitoring plan, initially survey the land during the month of August and within the areas of interest in order to identify the presence of Chinese tallow trees. The monitoring plan shall commence during August in order to complete all steps including removal of the tallow trees before the trees drop their seeds in the fall (MacDonald et al. 2008). Collecting aerial remote sensing data used to map out exact locations of the spatial distribution of the trees is the best approach as opposed to on the ground field observations. Take note of the number of trees, their size and age, the density of the stand, and the surrounding environments (MacDonald et al. 2008). These factors will determine which management technique is best suited for the given plants. The following sections pertaining to tree removal will detail how to determine which methodology should be used based on these factors (MacDonald et al. 2008). Initial evaluation should occur during the month of August to early September so that later tree removal using foliar chemical application can occur before the trees drop their seeds in the fall months (MacDonald et al. 2008).

For the post-restoration monitoring plan, conduct weekly monitoring of the land in which the Chinese tallow trees have been removed in order to see whether new seedlings have sprouted from any seeds that went uncollected or if trunks that may not have received enough chemical treatments sprouted any new seedlings

(Urbatsch). It is important to adhere to a high frequency of monitoring days due to the tallow trees rapid ability to spread and grow, (MacDonald et al. 2008). Multiple threshold parameters need to be set in order to successfully monitor the site. If saplings are found on the site in low density, it is necessary to manually pull these saplings and take note of problem areas to pay attention to during the following monitoring day. If a large density of saplings is found in patches, it would be advisable to spray the 5% triclopyr- ester with oil diluent to the samplings before mechanically pulling them up (McCormick 2005). If there are no new signs of growth of saplings or re-sprouts from trunks of unremoved trees, then no additional steps shall be taken other than continued weekly monitoring. There has been no research stating the duration of time needed for post monitoring so take careful precaution not to cut monitoring time short (Bower et al. 2009).

Some potential research questions to answer would pertain to the fact that there is so little information present regarding the successful removal of the Chinese tallow tree in California (Bower et al. 2009). The vast majority of the information contained in this document is derived from successful monitoring efforts pertaining to Chinese tallow trees located in Florida (Bower et al. 2009). The information regarding chemical treatment and mechanical pulling applies to all Chinese tallow trees. However, it would be of importance to know the answer to the following questions in order to determine strategies post-removal: a) Which California native plants would be best for planting after the removal of the Chinese tallow trees? b) How long should one wait before planting the California native plants after the application of chemicals to the site? Further research that answers these questions will provide better guidance in successfully restoring native flora after the removal of Chinese tallow trees.

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Medusahead (*Elymus caput-medusae*)

Elizabeth Wilson

Part 1: Project Background and Justification

Common names: Medusahead, medusa's head, medusahead rye, medusahead grass

Habitat: "Medusahead (*Taeniatherum caput-medusae*) is native to the Mediterranean region." "Medusahead maintain its dominance on sites where native vegetation has been eliminated or severely reduced by overgrazing, cultivation, or frequent fires." (<http://www.fs.fed.us/database/feis/plants/graminoid/taecap/all.html>)

Photos:



Craig Thornsen, California Dept. of Food & Nelson
Agriculture, Botany Laboratory

Julie Kierstead

Appearance:

"Medusahead is a nonnative, cool-season annual grass

Height: Plant height ranges from 8 to 20 inches (20-50 cm), depending on the site.

Leaves/flowers: Plants produce tillers, but very few leaves. Medusahead has a distinctive flowerhead.

Life form: Therophyte" -

(<http://www.fs.fed.us/database/feis/plants/graminoid/taecap/all.html>)

Typical sites/habitat:

"Medusahead inhabits disturbed sites, grassland, openings in chaparral, oak woodlands, and rangelands. It tends to grow best on clay soils where deep soil moisture is available late in the growing season. However medusahead can also be a problem on sandy soil in many areas of California." -

(<http://www.countyofplumas.com/DocumentCenter/Home/View/1582>)

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Liliopsida
Subclass: Lilianae
Order: Cyperales
Family: Poaceae
Genus: *Taeniatherum* Nevski
Species: *Taeniatherum caput-medusae* (L.) Nevski

Background and Justification:

Medusahead or *Taeniatherum caput-medusae* is a non-native species that can be found all throughout the California central valley. Although it is native to Europe and is most commonly found in Spain, Portugal, southern France, Algeria, and Morocco, the similar Mediterranean climate (cold, moist winters and hot, dry summers) of California has allowed this invasive species to flourish and propagate to the detriment of other native grasses and vegetation (Higgins and Torell, 1960). Because medusahead is a particularly vigorous winter annual grass it is capable of out competing several less dominant native grasses that would populate grasslands in California. It has grown to exceedingly high population densities in areas that are degraded by overgrazing, agricultural cultivation or by high frequency of fires. Medusahead has rapidly grown due to high migration rates and has dominated fields, roadsides, and disturbed sagebrush slopes in British Columbia, Washington, Idaho, Oregon, and California (USFS, 2015). This species of invasive has been particularly difficult to eradicate throughout this region because of its vigorous competitive characteristics as well as the fact that foraging wildlife do not tend to utilize it as a food source. Studies conducted by the Bureau of Land Management have found that nearly 14 million acres are infested with medusa head or its similar counterpart cheatgrass, and 62.1 million acres are degraded enough to be at risk for invasion in the US (USFS, 2015). However it has been shown that the best approach for preventing this species from invading grasslands is to cultivate a stand of robust native perennial grasses. Medusahead is most commonly found in habitats already without much vegetation structure in place due to disturbance regimes or human interaction, therefore the best defense for this species is to ensure these regions are cultivated with an abundance of perennial grasses (Higgins and Torell, 1960).

Literature Review: Fact SheetProject Goal:

- To eradicate and prevent the further appearance of the invasive species medusahead as well as to promote a high density of native perennial grasses to eliminate any future possibility of invasion and to ensure sustainability of the vegetation structure.

Species Characteristics and Appearance:

- Stem: The stem is tall, slender and is round in cross-section. Stems can be between 0.5 and 2 feet tall at maturity. (Stannard et al., 2010)
- Leaves: Leaves are between 4 and 12 inches long and are mostly less than 0.12 inches in width. The leaves are narrow and are rolled within the stalk and are not generally hairy. The leaves and shoot are a shiny yellow-greenish color. (Medusahead Identification and Management, 2009)
- Flower: Medusahead has a seed-head spike as a flower and is about 0.5 to 2 inches long generally. The awns coming off of the seed-head are stiff and straight or twisted, are barbed and are approximately 3 inches long. (Stannard et al., 2010)
- Roots: As medusahead is a grass, its roots are fairly shallow and are made up of a complex system of fibrous roots below the soil. (Medusahead Identification and Management, 2009)

Seed Germination and Growth Patterns:

- Medusahead is an annual grass meaning that the whole life cycle from germination to growth and production of new seeds and eventual death of the plant occurs within one year
- This particular species of grass is a winter annual meaning that it germinates in the fall and grows during the fall, winter, and early spring, then will produce seeds in the spring and die in the late spring (Young, 1992).
- It can achieve high root growth at lower temperatures during the winter which makes it more capable of outcompeting those perennial grasses that may take longer to form stable root systems or are not able to grow during the winter months due to a harsher climate.
- Medusahead tends to grow at such a rapid rate as to create a highly dense thatch layer that is difficult for other species of grasses to penetrate, thus medusahead suppresses other vegetation growth (Dudney, 2011).

Site Characteristics Allowing for Invasion:

- Plant communities with high soil clay content allow for medusahead invasion as there tends to be a higher accumulation of moisture near the surface due to a lower water infiltration rate in clay soil, which is beneficial for its shallow roots (Nafus and Davies, 2014).
- Medusahead is particularly prevalent in regions where precipitation comes in the cooler season while the hot season is relatively dry, this is similar to the conditions of its native range in the Mediterranean region of Europe.
- Sites with plant communities that have been disturbed recently are also highly likely to be invaded by medusahead as there is an increased level of organic litter and nutrient content that is favorable for medusahead growth (Kyser et al., 2008).

Range:

- Medusahead appears in regions that have relatively mild to cold winters but are quite hot and arid in the summer. This invasive grass is generally found in areas that experience precipitation in the fall, winter and into spring months but have dry summers (Stannard et al., 2010).
- In a northwestern Californian site where medusahead presents, about 60% of the vegetation is grassland or woodland/grass type (Kyser et al., 2008).
- This grass will also appear in other mediterranean climate regions such as the southwestern section of Oregon.
- Medusahead is most likely more dominate in fine-textured soils in mountainous regions, as it can exploit and utilize all moisture in the soil over other less vigorous grasses (Cherr, 2009).
- Medusahead is highly common in the central valley of California as well as all areas of the Pacific northwest as these areas provide for all of it's specific needs.
- It is however less common for medusahead to extend to the more arid areas of the Great Basin that it's counterpart invasive cheatgrass can invade (Cherr, 2009).

Wildlife Interactions:

- Medusahead is not an important species of grass in wildlife foraging habits as it is not palatable because of it's high silica content (Nafus and Davies, 2014).
- It reduces grazing overall by wildlife because it is indigestible and therefore is not naturally kept in check by grazing species. This is another reason why medusahead can rapidly grow without disturbance due to grazing.
- It's seeds are also unpalatable to upland game birds, although these same large birds are consumers of cheatgrass seeds (USFS, 2015).
- It has been seen that when various wildlife species are restricted to medusahead as the main component of their diet, there is dramatic weight loss and malnutrition (USFS, 2015).

Plant Interactions:

- As medusahead is most prevalent in areas that have lost a large portion of vegetation already, it furthers the plant species loss to eventually overtake an entire habitat range (Davies, 2010).
- This annual grass grows to a thick thatch ground cover that essentially blocks all other plants from occupying the area.
- Medusahead is also a highly efficient water consumer and therefore utilizes most of the soil moisture that would otherwise be available to other plant species (Davies, 2010).
- Medusahead can essentially dominate all other plants around it by outcompeting for soil nutrients, water and space to grow.
- Perennial grasses native to California have the most direct interaction with medusahead as these grasses occupy the same general niche and require the same habitat characteristics for survival (Kyser et al., 2012).

Impact on Agricultural Lands and Livestock:

- Medusahead is considered a threat to the agricultural industry because of how well it can suppress vegetation, this is a major concern because agriculture is dependent on being able to cultivate desirable crops or vegetation that may be outcompeted by medusahead.

- It is also mostly unpalatable to livestock so it is not useful for grazing, although there has been studies on California agricultural lands showing that domestic sheep will consume medusahead in the early stages of development prior to flowering (DiTomaso et al., 2009).
- While medusahead is generally accepted to be of little nutritional value to grazing livestock, it has been noted that if there is no alternative the livestock will utilize this as a source of food (DiTomaso et al., 2009).
- As the plant develops into the later stages of its life cycle it develops long barbed awns that can injure and harm the eyes, nose and mouth of animals grazing in the area (Young, 1992).

Response to Disturbance Regimes:

- Because medusahead is an annual grass it is particularly well adapted to the most common disturbance in California, which is fire (Brooks et al., 2004).
- In fact it can actually fuel fire as it is a fairly dry grass that creates high concentration of organic litter that can easily ignite.
- Frequent fire in one region can increase the density and dominance of medusahead. Fire clears away all vegetation, then because medusahead is an annual grass and grows very rapidly, it can quickly take root and overgrow the other less vigorous vegetation (Brooks et al., 2004).
- The medusahead will continue the frequent fire cycles by increasing the dry fuel load to promote fire in regions that would not be so affected without the presence of this invasive (Kyser et al., 2008).

Management Approaches:

- Mechanical removal of medusahead can be achieved through spring plowing after the species has germinated, which has seen a 95% reduction in growth with optimal management practices (Higgins and Torell, 1960).
- This type of prevention method may also be achieved through hand weeding by removing the full specimen, ensuring that all root systems have been removed as well. However this is only most effective in moist soil during the spring and as it is fairly labor intensive may not be the most practical approach.
- Cultivation of other crop on top of a weeded area may also help to ensure that the medusa head seeds are driven so far into the soil that they may not emerge, however this also may not be practical based on the steepness of the terrain in the management region (Kyser et al., 2012).
- Grazing as a management strategy is seen as a vegetative manipulation measure. Allowing cattle or other animals to graze on medusahead dominated areas will reduce the density as well as benefit the grazing species (DiTomaso et al., 2009). This does not necessarily ensure that the roots are removed, but as medusahead is an annual species grazing may reduce the propagation of new seedlings for the next season.
- Controlled burns can dramatically reduce the stand for the next season, by up to 95% if the burn is conducted at a time before the seed-head has released its seeds (DiTomaso et al., 2001). However in many regions where medusahead is common fire is not a feasible option as they are often near human populated areas.
- Reseeding or revegetating with natives may reduce the dominance that medusahead has on a particular region. However the reseeded must be done

with very sturdy and highly competitive species of native vegetation as medusahead must be out competed to see any reduction in its abundance (Davies, 2010). Some examples of perennial grasses that may fair well against medusahead are bottlebrush squirreltail, blue-bunch wheatgrass and intermediate wheatgrass (USFS, 2015).

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Part 2: Project Goals and Management Plan

Goals

The overall goal of restoration project is to eradicate and prevent the further appearance of medusahead, as well as to promote a high density of native perennial grasses to eliminate future invasion and to ensure sustainability of the vegetation structure. A common starting point for any study or project involving habitat and vegetation structure and that is to determine the extent of the Medusahead infestation and to assess where these populations are most dense and robust (Cherr, 2009). This first goal must be done over a broad spatial scale, and may entail surveying the full spread of the site being studied to determine an accurate percent coverage of the invasive.

The next major goal of this project will be to prevent the spread of Medusahead to unaffected areas. This can be broken down into limiting seed dispersal where this is possible and eradicating existing Medusahead infestations before they are allowed to spread further (Medusahead Identification and Management, 2009). The seed dispersal management will need to be looked at from a specific temporal scale based on the life cycle of medusahead. The timing of seed dispersal reduction is crucial because if this can be limited before the medusahead seeds can disperse and take root in the soil, there is a greater chance of limiting their establishment. This will also need to be regulated intensely as seeds can spread even further through contact with livestock and harvesting machinery (Dudney, 2011). In order to achieve the eradication portion of this goal, the removal will need to take place over a very broad spatial scale and would ideally consist of all areas infested with medusahead. Removal efforts will need to be undertaken several times within a season depending on the method of removal and will need to consist of a vigorous effort to clear the site of the invasive species.

The final goal of this project will be to reduce the availability of vulnerable and open space for Medusahead to inhabit and establish. This can be done with several different methods, and ideally would include a combination of many techniques to restore the proposed site. This will be done by revegetating the area with native species as well as by clearing any medusahead litter that may hinder these natives from successfully establishing here (Young, 1992). As most of these native species are perennials the temporal scale for plantings will be especially significant here, as well as the space over which this revegetation should take place. However if revegetation of native species is successful it should reduce the ability of medusa head to colonize any further within the restored site (USFS, 2015).

These goals are fairly idealistic and are meant as a best case scenario for what we hope to achieve through implementing our restoration and monitoring plans. Although we do not expect all of these goals to be fulfilled in a flawless manner, it is reasonable to expect that there will be some positive changes to the site after restoration. However this is contingent on the fact that the restoration plan is carried out properly and each plan is feasible for the resources we will have at our disposal.

A. Restoration Plan

Determine the extent of the Medusahead infestation

The first step in the restoration plan will be to determine the range and distribution of medusahead within the region. This will need to be done by assessing the density and abundance of the medusahead population, as well as quantifying the percent coverage of medusahead head versus the percent coverage

of native perennial grasses on the site. Finding new medusahead infestations is imperative because eradicating a new and smaller population is much more likely to be successful than trying to manage it after it has spread over a larger range (Nafus and Davies, 2014). In order to gain a full understanding of the area the medusahead covers, the use of GIS mapping and areal views may prove necessary, however surveying over the entire area may be limited due to funding and other resource availability. Therefore to obtain as accurate an idea as possible of where new medusahead populations have begun to propagate looking near more mature established sites that are known to have medusahead already on them is a good place to start (Johnson and Davies, 2012). With an accurate picture of what the current state of the infestation is at the project site, the restoration plan will have the best possible background information as a starting point.

Prevent the spread of Medusahead to unaffected areas

In order to prevent Medusahead from invading outside of its current range at our restoration site, this project will mainly need to focus on eradication of the invasive in order to limit its vigorous colonization capabilities. Because Medusahead is a particularly robust winter annual grass, it has the ability to outcompete many native perennial grasses throughout Californian grass and woodlands (Higgins, 1960). This restoration plan will attempt to limit medusahead's range by implementing many different techniques to remove this invasive from the site in the hopes that this will allow native grasses to propagate.

- Use of Controlled Burns with permits

Medusahead is a particularly difficult invasive species to deal with because of its tendency to prepare the area it has colonized for germination by accumulating a thick layer of thatch that stops any other species from establishing over the medusahead seedlings (Brooks et al., 2004). Therefore the first step in effectively reducing the density of Medusahead to a particular area would be to reduce the coverage of this ground litter. One of the most efficient ways to achieve this would be by obtaining a controlled burning permit to burn off that layer of thatch that covers the soil prior to germination (Johnson and Davies, 2012). This should be done sometime in the late summer before the medusahead will have dispersed its seeds for that season. By burning off the medusahead thatch there will not only be more ground space to allow for native species growth, but there will also be a greater soil area exposed so that herbicide treatments to the soil may be more effective to continue the invasive eradication process (Johnson and Davies, 2012). Burning should be applied to reduce ground cover so that herbicide may reach the soil, as well as to improve the area so that future desirable species may propagate and to minimize suitable conditions for medusahead growth (Nafus and Davies, 2014). However using burning as the sole control method will not prove effective, it will simply clear the site of competing vegetation and create more available seedbed for medusahead to invade in the following season, therefore this must be coupled with other eradication efforts (Kyser et al., 2008).

- Herbicide treatments with permits

Once the site has been prepared through the use of controlled burning in late summer to early fall, the best course of action then is to apply herbicide with the proper permits to the area where the fire has occurred. The burn should have affected the coverage of vegetation litter that would be a physical barrier to the herbicide getting in direct contact with the soil (DiTomaso et al., 2001). It is necessary to apply the herbicide in the fall after the burn has concluded, but also early enough so that the medusahead will not have begun its seed germination for

the new season (Kyser et al., 2012). In order to ensure that the herbicide application is effective this should take place immediately after the burn sometime in early October. Many chemical herbicides have been tested and have seen results in reducing the percent coverage of medusahead for the following season. Some of these options include foliar active herbicides like glyphosate (Roundup™) (Stannard et al., 2010). This type of herbicide needs to be sprayed over the full expanse of the vegetative part of the plants in the population to produce results. Another option is to use soil active herbicides such as atrazine (AAtrex™) and metribuzin (Sencor™) (Stannard et al., 2010). These compounds need to be in contact with the soil to be effective, but they can infiltrate into the soil they will be the best option for medusahead control. A problem with using these herbicides as a control method is that the timing of the treatment needs to be very precise and the area over which the treatment is applied must reach all individuals within the population (Kyser et al., 2012). Also using herbicides may have adverse effects for the other native and desirable plant species that exist within the treated range.

- Physical eradication to eliminate juvenile and mature medusahead

Often times totally controlling the germination of new medusahead is not a feasible goal either due to the fact that the site infestation is too large to manage all seed dispersal or because herbicide use is not a viable option (Higgins, 1960). In these cases another method to control medusahead is to physically remove the invasive either through tilling or by using man power to pull all individuals out. Mechanical removal is effective for small infestations and can be managed with volunteers, however it is not practical for large areas with dense medusahead coverage, as the work will be too overwhelming and will require a huge time commitment and resources that may not be available.

- Tilling soil where medusahead is vigorous and the geographic terrain permits
Medusahead does seem to be somewhat susceptible to tilling. This is mainly due to the fact that the act of tilling the soil will break up the thatch and fuel accumulation that medusahead creates. In order for this process to be effective however the tilling must cut the roots of the medusahead and this must be done before the plants flower so that seed production will not occur (Stannard et al., 2010). However as medusahead is very robust many tillage operations may be necessary to see this method be effective. Tilling may be best utilized as a supplementary method to other eradication options and will prove to be necessary when clearing ground cover to allow for herbicide treatments to get in contact with the soil (Cherr, 2009). This method will require proper equipment which may be unavailable or be rather costly to the project. In addition, depending on the location of the site of the medusahead population being managed the geographic structure may not be conducive to using the tilling machinery safely and effectively.

- Utilizing grazing species of animals to reduce medusahead vegetation

The use and effectiveness of grazing to control medusahead is somewhat debated by scientists in this field. A study through the UC Cooperative Extension asserts that high-density, short term grazing of medusahead infested areas can produce a reduction in percent coverage by 95% as well as to promote the biodiversity of native grasses (Controlling medusahead with intensive grazing, 2015). This would only be effective if the live stock is forced to compete heavily and thus would become less selective when grazing. Forcing this competition among animals is required when controlling medusahead because this invasive is particularly low in nutrient value and has low palatability making it less likely to be grazed when food supply is in abundance (Lusk et al. 1961). However a study

conducted in Oregon suggests that if grazing is not managed properly, there may be a dramatic affect on the native perennial grass abundance which could increase the spread of exotic grass (Nafus and Davies, 2014). It has also been shown that when grazing is allowed to occur concurrently with herbicide treatments there may be an increase in medusahead density and the success of native perennial grass growth will be reduced (DiTomaso et al., 2009). Therefore grazing needs to be properly managed and without the use of herbicides during the same time period. *Reduce the availability of vulnerable and open space for Medusahead to inhabit*

- Reseeding and revegetation of desirable perennial grasses and forbs

In order to see a functional control of the medusahead population, planting desirable perennial grasses is necessary to prevent the recolonization of the invasive. The best course of action would be to first use prescribed burns and tilling to reduce thatch and ground coverage that restricts native growth and access to the soil for herbicide treatments (Davies, 2010). Then to apply the herbicide immediately after the physical removal of the medusa head litter sometime in the fall to ensure this is done before seed germination. Ideally there would then be a full season where the site is allowed to fallow and will be unaltered before the eventual reseedling of native perennial grasses in the site (Young, 1992). Deciding which species of perennials to plant can be difficult as many of them will not compete with the existing medusahead that is expected to still inhabit the site. Bluebunch wheatgrass does not grow fast enough to rival the rapid growth of medusahead, and crested wheatgrass performs poorly on clay soils where medusahead is mainly found (Stannard et al., 2010). However bottlebrush squirreltail grass has proven to have the ability to replace medusahead, and crested wheatgrass may fair well in soil types with less clay (Nafus and Davies, 2014).

B. Monitoring Plan

Before the implementation of any part of the Restoration Plan the site should be surveyed so that the current medusahead and native grass populations are measured to determine the current functional state of the site. This monitoring should occur over the course of one year prior to restoration to ensure that all stages of the medusahead annual life cycle are accounted for in the data (USFS, 2015). Monitoring should first occur in the summer before germination has begun to have a baseline survey to compare other data collections against. Then again in the fall right after the germination process has begun to observe seed dispersal mechanisms and range. Finally another monitoring event should occur in the spring to evaluate the increase in medusahead ground cover after the seedlings have had time to grow (Medusahead Identification and Management, 2009).

Following any eradication efforts the site should be monitored and should show how each treatment and eradication method interacts with the medusa head population as well as with the native species in the area. The same monitoring method as prescribed above should be followed, but now when the monitoring occurs in the spring there should be an assessment of how the medusahead density and abundance has changed from the pre-management survey. In addition to this analysis will need to be taken at a later date, within a few seasons of growth to evaluate the success of the eradication and revegetation methods for suppressing the abundance of Medusahead populations within the site.

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Teasel

Caprifoliaceae Family

Dipsacus fullonum

Other Common Names: Teazel, Teazle, Fuller's Teasel, Wild Teasel, Venuscup Teasel

Habitat: This plant flourishes in open spaces where full sun is available. Soil conditions are most suitable when moist, but Teasel tolerates both wet and dry conditions well. Fields and pastures, creek sides, roadsides and gardens that are not well managed provide ideal habitat conditions for Teasel. This plant originally came from Europe and North Africa in the late 1700's, and since has dispersed across the entire United States. It is most commonly spread when plants that have formed seeds are mowed down.

Appearance: Teasel grows as a basal rosette for its first year, perhaps longer, depending on resources. In this stage, leaves are wrinkled and have a lighter colored midvein, scalloped margins, and are often hairy or spiny in older plants. The plants sends up a tall stalk with flowering heads, after which the basal leaves will usually die. Stems are generally 2'-7' tall. Small light purple-white flowers grow in band shaped patterns on an egg-shaped cone-like head. These heads are about 4" tall and occur alone at the tips of each stem. Sharply upturned bracts are left behind after flowers have fallen away to form a protective layer on the head. Teasel typically blooms from June until October, depending on climactic conditions and water availability.

Similar Species: There are 3 species of tall herbaceous *Dipsacus* that are most common in North America; Cultivated Teasel (*Dipsacus sativus*) and Cutleaf Teasel (*Dipsacus laciniatus*). Cultivated Teasel can be identified by its white flowers. Cultivated Teasels flower bract tips are shorter, stiffer, and have more pronounced curve backward than the other two species'. Up to 15 species of *Dipsacus* are currently known in all.



Common Teasel

Class: *Magnoliopsida*

Order: *Dipsacales*

Family: *Dipsacaceae*

Genus: *Dipsacus*

Species: *fullonium* L.

Synonym: *Dipsacus sylvestris* Hudson

Other Common Names: teasel, teazel, teazle, wild teasel, Indian teasel

Project Goal:

The goal of this portion of the project is to identify and outline the characteristics of the invasive weed species, teasel, so it may be identified in the field. Teasel is a highly competitive plant with a history of overtaking agricultural fields and grazing land, as well as pushing out native grasses. It is especially threatening to plants with special species status due to its competitive nature. Teasel is known to overtake floral species that certain insects rely on. This species also poses a threat to wetland and riparian habitat integrity and biodiversity. Identifying this plant is the first step toward proper management and ultimately eradication.

Information Sources: <Cheeseman, 1998>, <Crooks & Soule, 1996>, <Donaldson & Rafferty, 2002>, <Rector et. al., 2006>, <Shaw, 2015>



Habitat Preferences:

Teasel is found in over 40 states and Canada.

This plant is native to Europe, temperate Asia, and North Africa.

Teasel flourishes in open spaces where full sun is available, but also fares well in part shade.

Riparian areas, grasslands, meadows, grazing ranges, and forest thickets all provide supportive habitat conditions for teasel. Fields and pastures, creek sides, roadsides and gardens that are not well managed provide ideal habitat conditions for teasel.

Soil conditions are most suitable when moist, but teasel tolerates both wet and dry conditions well. Common teasel generally grows better in areas that receive moisture in the summer.

Most teasel species grow in fertile, loamy soil types; lower quality soils inhibit overall plant size. Sandy soils will produce stands of teasel with adequate moisture. Clay soil types are also tolerate, even if they have poor drainage or have a pattern of flooding.

Climate preferences are not thoroughly documented, however teasel is known to not handle below freezing temperatures in winter or temperatures below 50 degrees in summer months.

In California, teasel is found at elevations below 5,600 feet.

Habitat Preference Information Sources: <Baker, 1974>, <Crooks & Soule, 1996>, <Daubenmire, 1970>, <Donaldson & Rafferty, 2002>, <Gremaud & Smith, 2002>, <Hickman, 1993>, <Munz & Keck, 1973>, <Werner, 1975>

Growth Characteristics & Physical Description:

Teasel is a biennial plant, which means that it's biological life cycle spans two years.

During its first year, teasel forms its roots. A large taproot can grow to more than 2 feet deep and 2 inches in diameter at the base.

Leaves form as a basal rosette at ground level. These leaves have scalloped margins, are often furrowed, and have a lighter colored midvein. These basal leaves die in the flowering stage.

The second year teasel will form an upright woody and prickly stem, with supporting branches near the top, and terminates in a flowering cone. Stems can grow to be 6-10 feet tall when given the ideal conditions. The stem also forms leaves that appear similar to the basal leaves, but they are smaller and usually in an opposite arrangement.

The egg-shaped cone, which also does not appear until the second year, produces horizontal rows of densely arranged, small flowers that bloom just a few rows at a time, originating from the middle bands.

Flowers can occur in a range of colors from purple, lavender, fuchsia, pink or white. These flowers only bloom for a single day, before dying.

Sharp bracts grow just below the flowering head. These bracts are usually sharply upturned, and remain as a protective layer on the cone after the flowers have fallen away.

Achenes, teasel's fruit, have a hairy exterior and are generally 0.25-0.50 inches long.

Growth & Physical Description Information Sources: <Great Plains Flora Assn., 1986>, <Hickman, 1993>, <Munz & Keck, 1973>

Historic Relevance:

It has been seen in North America since the late 1700s and since has dispersed across the entire United States.

This plant is believed to have originated from Europe, temperate Asia, and North Africa, and cultivated locally as an ornamental plant, or because of its role in the textile industry. The dried flower heads were used primarily in wool processing to brush, clean, and tease the wool fibers. Teasel is also used in floral arrangements.

Historic Relevance Information Sources: <Donaldson & Rafferty, 2002>, <Great Plains Flora Assn., 1986>, <Munz & Keck, 1973>

Reproduction & Seed Dispersal:

Teasel typically blooms in California April through August. In other parts of North America, flowering can occur any time from April until October, depending on climactic conditions and water availability.

Each cone produces 250-1500 flowers and seeds.

Hybrids can occur between common teasel and Cut-leaved teasel species. Their frequency of occurrence had not yet been reported.

It is commonly spread when plants that have already formed seeds are mowed down by tractors and mowers. Since seed germinate in spring or fall, this can often occur along freeways and hi-ways during

median and ditch maintenance. The most likely method of spreading these seeds is via roadways and waterways.

Water facilitates the widest spread of seeds. Teasel seeds have been known to withstand 3 or more weeks floating in water.

Seeds are not adapted for wind dispersal, due to their size, shape and weight.

Germination rates among the various species of teasel are high when buried in soil, however, seed age (over 5 years in a seed bank), long-term exposure to water, and fungi exposure all reduce likelihood of successful germination.

Well established grass, dense shrub cover, or thick layers of organic litter also limit seed germination and growth. Slow-growing, late-successional species have shown the ability to overtake teasel stands.

Reproduction & Seed Dispersal Information Sources: <Bentivegna & Smeda, 2011>, <Crooks & Soule, 1996>, <Munz & Keck, 1973>, <Werner, 1976>

Similar Species:

It has only been recently understood that Fuller's teasel and common teasel are, in fact, different species. Their names (*Dipsacus fullonium* L. and *Dipsacus sylvestrus* Hudson) are often still used interchangeably.

Three species of herbaceous *Dipsacus* are most common in North America;

Common or Wild Teasel (*Dipsacus sylvestrus* Hudson)

Cultivated Fuller's Teasel (*Dipsacus fullonium*) Cultivated Fuller's Teasel's flower bract tips are shorter, stiffer, and have more pronounced curve backward than the other two species'.

Cut-leaf Teasel (*Dipsacus laciniatus*); Cut-leaved teasel can be identified by its white flowers, as well as its pinnately divided leaves.

Up to 28 species of *Dipsacus* species names are currently accepted, with 54 synonym names.

Similar Species Information Sources: <Bare, 1979>, <Gremaud & Smith, 2002>, <The Plant List, 2013>

Wildlife Interactions:

Multiple species of small mammals and birds that consume teasel seeds for food:

- Mice
- Northern bobwhites
- California quail
- Ring-necked pheasants
- White-winged crossbills
- Goldfinches
- Blackbirds

Wildlife Interaction Information Sources: <Caswell and Werner, 1978>, <Crispens, 1960>, <Knight, 1979>, <Mittelbach & Gross, 1984>, <Putnam, 1955>, <Werner, 1976>

Methods for Management:

Locating teasel communities early on is key in controlling this invasive species. Methods for control include:

Wetland restoration or maintenance can help prevent the advancement of teasel.

Biological control, in terms of livestock, have provided promising results for teasel management. Both grazing and trampling can decrease stands of teasel in pasture areas.

Digging up the plant while it is still small. By removing the entire plant, including the taproot, and before it produces seeds, small stands of teasel can be removed in a fairly short amount of time.

Herbicide use is also effective for killing the basal rosettes. This process also should be completed prior to the flowering stage and seed production when plants are dormant. Local noxious weed offices should be contacted for information as to which chemicals are safe to use in the area that needs to be covered.

Mechanical control, through the use of a plough, can provide successful elimination, especially for larger fields or pastures. It is important to avoid mechanical methods if teasel's flowers have already emerged, to avoid further spread of seeds. If the area is large and ploughing is still preferred, the plants should be

cut low with a sickle, sharp shovel head, or machete, and the flowering heads should be collected by hand to prevent the spread of seeds.

Mowing has shown to be far less effective than the methods listed above because as the plants are damaged by the mower, they will be able to regenerate if enough of their stem and leaves are left intact, or if their seeds are left behind.

Controlled burns may also thin dense stands of teasel, but should be considered one portion of an integrated management practice. Following up with ploughing will raise the chance of successful eradication.

Always remember, whichever control method you use, be sure to inspect and clean off your machinery and tools prior to leaving the area in order to restrict teasel from spreading.

Methods for Management Information Sources: <Bentivegna & Smeda, 2011>, <Caswell and Werner, 1978>, <Cheeseman, 1998>, <DiTomaso, 2013>, <Gremaud & Smith, 2002>, <King County Noxious Weeds, 2015>

Common Teasel (*Dipsacus sylvestrus* Huds.): A Guide for Successful Management

Goals:

Effectively decreasing the occurrence of the invasive plant, teasel, is a necessary part of facilitating restoration efforts. Teasel's highly competitive nature has allowed it to overtake agricultural fields and grazing land in most of the continental United States. It poses a serious threat to plants with special species status, as well as to the integrity and biodiversity of upland, wetland, and riparian areas, (Cheeseman, 1998) (Caswell, 1978) (Hickman, 1993). Goals relate to preventing teasel from establishing, as well as eliminating existing plants and preventing their spread. These management methods pertain to California's Central Valley land typologies and conditions and can vary depending on specific site circumstances. The following guides the effort in decreasing teasel occurrences within upland and riparian land types:

Prevention:

Through responsible management practices, prevention of teasel invasion is possible. Since teasel is such a versatile invader and is able to withstand a fairly broad range of conditions, it is somewhat difficult to predict precisely where invasions will occur. What is known are teasel's habitat preferences, which can help inform proper site maintenance or restoration. Riparian areas, grasslands, grazing ranges, and forest thickets, with both full sun and part shade, all provide supportive habitat conditions for this plant. Fields and pastures, creek sides, roadsides and gardens that have been disturbed or are not well managed can become ideal habitats for teasel growth, (Donaldson, 2002) (Munz, 1973). Multiple counties within the California Central Valley have reported teasel occurrences, so threat of invasion should be taken seriously, (University of Georgia- Center for Invasive Species and Ecosystem Health).

Elimination & Control:

Early detection is crucial, not only when individual plants are small, but also before teasel stands are established. Because teasel is a biennial herb, only its basal rosette forms the first year, (Caswell, 1978), (Crooks & Soule, 1996). The following year during spring, the stems and flowering cones form as it prepared for its reproduction stage. It is important that if teasel is located, it is removed prior to seed production. The reason for this is that teasel reproduces through seeding alone, and a single plant can produce, if given the right environment, over 30,000 seeds, (Institute, 2015). Plants that have already

produced seeds generally die, however careful collection and containment of the seed cones should be conducted, (Donaldson, 2002) (Gremaud, 2002) (Werner, 1975)

Advantages & Disadvantages:

Multiple species of insects, small mammals and birds consume different parts of the teasel plant as a food source. Mice, northern bobwhites, California quail, ring-necked pheasants, white-winged crossbills, goldfinches, and blackbirds consume teasel seeds, (Caswell, 1978) (Crispens, 1960) (Knight, Seasonal Food Habits of four game bird species in Okanogan County, Washington) (Mittelbach, 1984) (Putnam, 1955) (Werner, 1975). Though none of the named species rely on teasel as their primary food source, it should be a consideration during any restoration or management strategies, as other food sources should be made available.

Insects, such as the rose aphid, *Macrosiphum rosae*, also feed on *Dipsacus*, (Alford, 2012). The rose aphid is a non-native species on the west coast, including California's Central Valley, so abolishing teasel benefits the fight against these particular invasive insects, (Flint, 2014) .

Teasel has been known to trap insects and other small invertebrates when water pools at the base of its leaves. Examples of insects and invertebrates that have been found within these water-filled leaf cups include, but are not limited to:

- slugs
- caterpillars
- Earwigs
- flies
- beetles
- aphids
- spiders

Though the plant may assist in stamping out some bothersome creatures, and provide food for others, these factors are fairly insignificant when addressing the greater goals of site restoration. (Darwin, 1877) (Werner, 1975) (Mittelbach, 1984)

Methods for Prevention:

If *Dipsacus* is allowed to establish itself, it becomes much more difficult to control. The construction of our highway systems has been one of the largest contributors to the advancement of teasel, (Bentivegna) (Donaldson, 2002). Careful care should be taken on all sites where the ground has been disturbed, especially when irrigation or flooding is present. If teasel has been observed within the local surroundings, outside the jurisdiction, action should be taken to identify and contact the land owners to see if measures have already been taken to control the plant.

Well established grass, dense shrub cover, or thick layers of organic litter can limit seed germination and growth, (Roberts, 1986). Slow-growing, late-successional species of trees have also shown the ability to overtake teasel stands, (Donaldson, 2002) (Roberts, 1986) (Werner, 1975). Restoring late-successional trees, should be included as part of the restoration plan when the site permits.

There are not many natural predators for teasel, but the animals mentioned in the previous section can help eliminate seeds from the area, (Knight, Seasonal Food Habits of four game bird species in Okanogan County, Washington). Many of the known predators are considered to be invasive species themselves, so introducing them onto a site may produce other undesirable results, such as the eradication of plants that are desired on the site, (Mittelbach, 1984).

Soil conditions are most suitable when moist, but teasel tolerates both wet and dry conditions well. Most teasel species grow in fertile, loamy soils. While lower quality soils inhibit overall plant size, sandy, clay or saline soil types can still produce stands of teasel, so long as adequate moisture is available, (Donaldson, 2002)(Roberts, 1986) (Werner, 1975). Monitoring areas that receive moisture during high-growth periods is covered in the monitoring plan portion of this document.

Methods for Elimination & Control:

Since full removal may be most difficult with established stands of plants, effort should be placed on minimizing expansion of populations. This is done through identification of pre-established stands of teasel and subsequently their removal. (Donaldson, 2002) (Gremaud, 2002) (Roberts, 1986)

Plants can be removed individually by hand or with a shovel, as with many other common large weeds. Small stands of teasel can be removed in a fairly short amount of time using this method. The area directly surrounding the basal rosette should be loosened with a shovel or other hand tool. Even though

vegetative reproduction does not generally occur with *Dipsacus*, the plant should be completely removed, including the deep taproot, and contained for proper disposal. (Institute, 2015)

Herbicides are used when hand removal is not practical, and are effective for killing teasel during various stages of its growth. This process also should be completed prior to the flowering and seed production stages when possible. Application is generally conducted during the growing season when the plants can take up the chemicals in greater quantities, (Institute, 2015). Glyphosate is distributed through the company Monsanto, and marketed under the Round-Up label. It is applied directly to the vegetative material via hand sprayer in accordance with the manufacturer's recommendations. Since Glyphosate is non-selective, it can kill any other plant material it comes in contact with. Take care to apply this chemical evenly and, if possible, when local non-target plants are dormant or not present. For this reason, it is not commonly used for covering large natural areas, in spring and summer months, as it can damage native species, (Institute, 2015) (Cheeseman, 1998). Local noxious weed offices should be contacted for information as to which chemicals are safe to use in the area that needs to be covered, (Shaw, n.d.). (Werner, 1975)

Mechanical control, through the use of a plough, can help with successful elimination, especially for larger fields or pastures. It is important to avoid mechanical methods if teasel's flowers have already emerged, to avoid possible spreading the seeds, (Glass, 1991). Germination occurs April through August, however this time frame is somewhat flexible depending on climactic conditions and water availability. Seed longevity is relatively short, however they should not be left behind in the soil. If the area is large, mechanical control may still be preferred, but any ploughing must be conducted before the plants first spring, prior to flower formation. In cases where this is not possible, plants should first be cut low with a sickle, sharp shovel head, or machete, and the heads should be collected. Teasel has been known to reestablish unexpectedly at times when premature flowering heads have been left behind to seed, (Cheeseman, 1998) (Gremaud, 2002).

Controlled burns may also thin dense stands of teasel, but should be considered one portion of an integrated management practice, (Gremaud, 2002) (Institute, 2015). Teasel does not burn very hot or fast, so fire can spread to dryer surrounding plants if it is not closely controlled, (Donaldson, 2002). Given the current drought situation in California's Central Valley, fires are not advised in dryer seasons due to the risk of wildfire. Permits are often required to conduct controlled burns, and permission is granted through the local CAL FIRE department or by contacting the Board of Forestry and Fire Protection. It is also important to check with the California Environmental Protection Agency's Air

Resources Board for concerns regarding smoke that may cause air pollution. Permit requirements and burn bans, including effective dates within the State Responsibility Area, as well tips for wildfire prevention tips are provided on the CAL FIRE website: http://www.fire.ca.gov/fire_protection/fire_protection_burnpermits.php. In cases where controlled burns are conducted, following up with ploughing the soil will raise the chance of successful eradication. (Glass, 1991)

Mowing has shown to be one of the least effective methods because as the plants are damaged, they will be able to regenerate if a large enough portion of their stem and leaves are left intact, or if their seeds are left behind, (Glass, 1991). If mowing is preferred, the chance of success can be increased if the mower blade is first set as low to the ground as possible. It is essential that future checks of the area are done to locate any surviving plants or new sprouts. (Cheeseman, 1998)

Biological control, in terms of livestock, have provided mixed results for teasel management, (Daubenmire, 1970) (Institute, 2015). Both grazing and trampling have been shown to decrease stands of teasel in pasture areas, but not substantially. Though teasel is not categorized as a toxic plant, additional research is needed before it is safe to say whether or not livestock health could be negatively impacted by exposure to large quantities of the plant, or through long term exposure. (Rector, 2006) (Gremaud, 2002)

Always remember, whichever control method is used, inspect and check and wipe down your machinery and tools prior to leaving the area in order to restrict transferring seeds off-site. Even if plants in the area appear to be dead, decontamination of equipment should still be completed.

Methods for Monitoring:

Regularly recurrent monitoring should be conducted in areas prone to *Dipsacus* invasion. Areas that receive year round moisture, either naturally or through irrigation, and areas that have experienced recent construction, within the past year or two, should be monitored especially closely, (Baker, 1974).

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Fennel (*Foeniculum vulgare*)

Sequoia Williams

Part 1: Project Background and Justification



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Appearance:

Fennel is an “erect perennial herb, four to ten feet tall, with finely dissected, almost feathery leaves and characterized by a strong anise [licorice] scent originating from stems and leaves” ...

“Roots: mature plants have a thick, deep taproot from which erect, solid glaucous-green stems arise.

Stems: 10-20 stems originate from a basal cluster in late winter, then die back the following September-November. Inflorescence: compound umbel with 15-40 spreading-ascending rays...”

(Cal-IPC : [http://www.cal-](http://www.cal-ipc.org/ip/management/ipcw/pages/detailreport.cfm@)

[ipc.org/ip/management/ipcw/pages/detailreport.cfm@](http://www.cal-ipc.org/ip/management/ipcw/pages/detailreport.cfm@usernumber=51&surveynumber=182.php)
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Habitat:

Fennel is often found invading disturbed areas and more open habitats. It tends to thrive in sandy soils rather than clay soils and prefers acidic conditions (Cal-IPC). According to Cal-IPC, it is especially found in “weedy sites adjacent to fresh or brackish water, and pastures, abandoned lots, and roadsides”.

Similar Plants:

WILD CELERY (<i>Apium graveolens</i>) Rob and Fiona Richardson (http://keyserver.lucidcentral.org/weeds/data/080c0106-040c-4508-8300-0b0a06060e01/media/Html/Apium_graveolens.htm)	
WILD CARROT (<i>Daucus carota</i>) Trevor James (http://keyserver.lucidcentral.org/weeds/data/080c0106-040c-4508-8300-0b0a06060e01/media/Html/Daucus_carota.htm)	
POISON HEMLOCK (<i>Conium maculatum</i>) Trevor James (Image 1 and 2) Sheldon Navie (Image 3) (http://keyserver.lucidcentral.org/weeds/data/080c0106-040c-4508-8300-0b0a06060e01/media/Html/Conium_maculatum.htm)	

Background and Justification

Fennel (*Foeniculum vulgare*) originally comes from southern Europe and the Mediterranean. It is still not known when fennel was introduced to California, however it is estimated that it first arrived about 150 years ago (Thurston County 2011, Bell 2008). Fennel has many medicinal and culinary uses and can escape cultivation in California, although it is still uncertain if culinary varieties of fennel are invasive (BLM). Fennel is present throughout the state of California, especially along the coast in southern and central California, where many regions are experiencing the spreading of the invasive species (CalWeedMapper). According to a report generated by the Cal-IPC which allows for local experts to input data on invasives statewide, fennel infests 47% of the current suitable range for the species (the suitable range being about 28% of the state of California) (Invasive Species Management Opportunities 2015). By 2050, it is expected that the total suitable range of fennel in California will not significantly change, making control of the plant a

more feasible goal (Invasive Species Management Opportunities 2015). The control of fennel throughout the state and across the world is important for various reasons (Washington State 2006). Once fennel had been established it is difficult to control due to its persistent seed bank which allows it to outcompete natives. Additionally, the expansion and control of the dense population of fennel on Santa Cruz Island has been analyzed extensively (Regional Species Map Report 2015, Brenton and Klinger 1994). The endemic California fox is only provided seasonal cover on Santa Cruz Island since native chaparral is being replaced with fennel which dies back in the winter (Washington 2006, Cal-IPC Plant Assessment Form 2015). Fennel can also alter fire regimes by creating conditions that lead to fewer but more intense fires (Cal-IPC Plant Assessment Form 2015).

Literature Review

Plant Description:

- Perennial herb characterized by its strong anise scent (Cal-IPC-Invasive Plants)
- Can get quite tall (4 to 10 feet tall), has dissected leaves and flowers are a yellow compound umbel (Cal-IPC-Invasive Plants)
- Triangular ovate leaf blades (Washington State 2006).
- Mature plants develop a taproot (Washington State 2006).

Distribution in California:

- Found in Sacramento, Salinas, San Joaquin valleys and foothills (Cal-IPC-Invasive Plants)
- Found in hillside pastures along the coast from Mendocino all the way to San Diego (Cal-IPC-Invasive Plants)
- Especially prominent in the central and southern coastal regions of California (Bean et al, 1988).
 - o Dense populations on Santa Cruz Island, Palos Verdes Peninsula and in Camp Pendleton (Regional Species Map Report 2015).
- Not found in the Great Basin or desert regions in California (Cal-IPC Plant Assessment Form 2015).

Environmental Conditions:

- Tolerates between 11 and 83 inches of precipitation per year (Calflora).
- December low temperature = 34°F. July high temp = 96°F. July low temp = 50°F (Calflora).
- Tolerates a wet season between 4 and 10 months long (Calflora).
- Tolerates a warm season between 3 and 11 months long (Calflora).
- Grows better in sandy dry soil better than in fertile loam soil or clay soil (Bean et al., 1988, Cal-IPC-Invasive Plants).
- Prefers acidic soils, but can be found in soils with pH between about 4.4 and 8.9 (Bean et al., 1988, Washington State 2006, Calflora).
 - o Soil must be a minimum depth of 13 cm (Calflora).
 - o Can tolerate strongly saline soils (Calflora).

- Grows well in disturbed areas like roadsides, as well as in grasslands, scrub-shrub, savannas, freshwater wetlands and streams (Washington State 2006)
 - Not very successful at invading chaparral, grazed areas, or undisturbed/natural areas (Bean et al., 1988, Cal-IPC Plant Assessment Form 2015).

Reproduction:

- Fennel plants flower for the first time when they are between 18 months and two years old (Cal-IPC Plant Assessment Form 2015).
 - Fennel can be controlled more easily in its first years before it reproduces and when it can still be grazed.
- Can reproduce with seed and through root crown (Washington State 2006).
 - Root division allows for invasion- dispersed through water and cultivation equipment (Bean et al., 1988).
- Persistent seed bank (Washington State 2006).
 - Seeds remain viable in soil for three or more years (Weed Report, Cal-IPC Plant Assessment Form 2015).
 - One fennel plant can produce tens of thousands of seeds its first year and even more the next year (hundreds of thousands) (Washington State 2006, Cal-IPC Plant Assessment Form 2015).
 - Seeds are produced in the summer and fall and then the flowering stems die back in winter (Cal-IPC Plant Assessment Form 2015).
- Seed dispersal
 - Dispersed by birds, rodents, water, clothing, dirt transported in boots, tires (Bean et al., 1988).
 - Water dispersal of seeds is important for fennel distribution near watercourses (Bean et al., 1988).
 - Water and animals likely do not disperse the seeds very long distances (Cal-IPC Plant Assessment Form 2015).

Germination:

- Seeds can germinate at almost any time for the year- depends on accumulation of growth degree days (Bean et al., 1988).
- Germination of fennel seeds occurs after 14 days at 18C (Bean et al., 1988).

Interactions with Other Plants:

- Non-native annual grasses typically replace fennel after it is removed if natives are not planted (Ogden 2005, Liu 2009).
- Excludes most other vegetation once established (Bean et al., 1988, Cal-IPC Plant Assessment Form 2015).
- Invasion of fennel into grassland communities leads to the exclusion of grassland species but an increase of seeds from native fleshy fruited species due to an increase in vertical complexity (Cal-IPC Plant Assessment Form 2015).

Interactions with Animals:

- Feral pigs eat the roots (Weed Report 2013).
- Feral animals disturb areas which leads to the spread of fennel (Cal-IPC Plant Assessment Form 2015).
- Birds and rodents eat the seeds and disperse them (Weed Report 2013).
- Full grown plants not typically not eaten by grazers due to the strong anise odor (Cal-IPC Plant Assessment Form 2015).
- Fennel seedlings/small plants can be controlled by grazers (Cal-IPC Plant Assessment Form 2015).
- Dead fennel stems provide perches for frugivorous birds which increases their diversity (Cal-IPC Plant Assessment Form 2015).
- The Anise Swallowtail butterfly breeds on fennel plants (Calflora).

Control:

- Herbicide can be used for control; must be an active process (Bell et al. 2008).
 - o Garlon4/triclopyr can be an effective herbicide (Brenton et al. 1994, Bell et al. 2008).
 - o Glyphosate can reduce cover by 75-80% (Cal-IPC-Invasive Plants).
 - o 2,4-D is also an effective herbicide (Bean et al. 1988).
 - o Burning after herbicide application can essentially eradicate fennel (Washington State 2006).
 - Burning alone, doesn't appear to control fennel (Washington State 2006).
 - o Apply in late spring (in S. CA) when biomass is greatest but before the plant flowers (Washington State 2006, Bean et al. 1988).
 - o Thoroughly wet the plants, especially the root crown (Bean et al. 1988).
- Spot spraying has been found to be less effective and requires more herbicide than broadcast spraying (Bell et al. 2008).
- Mechanical control would lead to the reestablishment of fennel since taproots can regenerate (Brenton et al. 1994, Washington State 2006).
 - o Repeated harvesting could deplete underground reserves if harvested in short enough intervals (Washington State 2006).
 - o Make sure plant doesn't have seed when removing mechanically; could lead to dispersal (Washington State 2006, Cal-IPC-Invasive Plants).
- Introduced herbivores can control the growth- like on Santa Cruz Island (Washington State 2006).
 - o Livestock aren't a good method for dense or old stands since they can also spread the plant easily (Washington State 2006, Cal-IPC-Invasive Plants).

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Part 2: Project Goals and Management Plan

A. Goals

The control of the fennel, *Foeniculum vulgare*, is crucial to the success of restoration projects in California. Although fennel invades much of the state, especially areas near the coast in central and southern California, in this report control of fennel in the Central Valley will be highlighted (Bean et al, 1988). As with all non-native management plans, goals include 1) Understanding what environmental factors allowed fennel to establish 2) Understanding the current effects fennel has its plant community and 3) Understanding what impacts the removal of fennel will have on the plant community (Brenton and Klinger 1994). An infestation of fennel must be evaluated to determine its reproductive tendencies and to better plan a timeline for its eradication. For large, spreading areas of infestation, simply containing the species so it doesn't spread anymore is a good goal. Smaller scale fennel stands can effectively hope to be eradicated completely in a shorter time frame. Determining what species will replace fennel once it is removed will insure that a community is not simply transitioning from one invaded state to another. Although invasions of fennel decrease overall biodiversity of an area, the removal of fennel could decrease the diversity of frugivorous birds which perch on the dead stems (Cal-IPC Plant Assessment Form 2005). The removal of fennel also removes important Anise Swallowtail butterfly breeding grounds (Calflora).

B. Restoration plan

Assessing the Population: The removal of fennel has many differing approaches, which vary depending on many factors. It is important to first establish whether the current population is 'aggressive' or 'non-aggressive' as described by Jennifer Ogden in her dissertation “Integrating Ecology and Conservation in an Invasive Species Context: A Case Study Using *Foeniculum vulgare*” (Ogden 2004). 'Aggressive' fennel populations are those that typically already completely dominate a landscape, or are spreading. 'Non-aggressive' fennel populations do not overtake a plant community. The populations may be established, but they are not spreading (Ogden 2004). Populations can be determined to be aggressive or non-aggressive by assessing the invasion attributes of the fennel population in question. Aggressive plants have

significantly larger seeds and germinate earlier (Ogden 2004). For reference, seeds from Cosumnes (non-aggressive population) had an average mass of about 1.20 grams while seeds from Fairfield (aggressive population) had an average mass of about 4.15 grams (Ogden 2004). However, environmental shifts can lead to a shift in invasion strength, making a once non-aggressive population aggressive. Once the type of fennel invasion has been properly identified, further steps can be taken.

Disturbance Regime: In herbaceous plant communities that are dominated by fennel, Mediterranean annual grasses and exotic forbs, burning has been used to remove the standing dead fennel (Ogden 2004). This is effective because fennel stems die off and then resprout from their root crown after the first rain in the winter. This is a good technique for insuring that there is better herbicide contact with the plant although it does not actually kill the root crown (Ogden 2004, Washington Stat 2006). Burning should be completed in the fall, followed by the application of herbicide the next two springs (Weed Report 2013).

Burning can also help deplete the soil seed bank by stimulating germination, a key component of effective control of an invasive species (Weed Report 2013).

Herbicide Use: It is recommended that concentrated herbicides be diluted by the person controlling an infestation of fennel since ready to use and pre-mixed herbicides often do not contain enough active ingredient (Thurston County 2011). It is best to apply Triclopyr, Glyphosate, or 2, 4-D in late spring around May or June (regardless of whether spot treatment or broadcast spraying is being used) since this is when many other species have already gone to seed but when fennel is still actively growing (Ogden 2004). Since Triclopyr and 2,4-D are a systemic herbicide, they will be translocated throughout the growing plant and will effectively kill it. 2, 4-D can damage other broadleaf plants and is not as effective as Triclopyr (the standard herbicide used for fennel control) (Weed Report 2013). If there is concern about fennel or other plants in the area evolving herbicide resistance, herbicides can be used in combination, such as using Triclopyr with Glyphosate at 1lb a. e./acre each or by alternating what herbicide is used from year to year (Weed Report 2013). If used separately, Glyphosate should be used at a rate of 2.8 lb a.e./acre, Triclopyr should be used at a rate of 1 to 2 lb a. e./acre and 2, 4-D should be used at a concentration of 0.25 to 0.5% v/v using spot treatment due to it impacts on other broadleaves (Weed Report 2013). However, if no desired broadleaf natives exist in the site and there are only other broadleaf invasives, then a broadcast treatment of 2,4-D might actually be beneficial since it can control other non-native vegetation in the area (Weed Report 2013, Bell et al. 2008). Additionally, if there are only a few fennel plants that seem to be non-aggressive, spot spraying can be used (Bean 1988). Otherwise, in general for more efficient results, broadcast spraying is recommended (Bell et al. 2008). Broadcast spraying is quicker than spot spraying (Bell et al. 2008). Additionally, although glyphosate is non-selective, *Nassella pulchra* isn't harmed by the herbicide when applied to control fennel (Bell et al. 2008). This is important when considering what species can quickly establish after fennel removal.

Scale: In small and young infestations, mechanical control is a viable technique for removing fennel (Bean 1988). It is easiest to hand-pull small seedlings because once a plant is mature, its large taproot makes it difficult to remove (Thurston County 2011). The plants must be removed in short intervals so that the underground reserves are depleted (Brenton et al. 1994, Washington State 2006, Weed Report 2013). Cutting fennel can only control the plant if it is done multiple times in one growing season and then sequentially for at least 3 more growing seasons (Thurston County 2011). If an infestation is relatively young, uniformly aged, and hasn't contributed to the soil seed bank yet, grazing is a good option. Fennel often doesn't flower until it is eighteen to twenty-four months old, so grazing can be a good control tactic (Cal-IPC Plant Assessment Form 2005). However, if fennel is allowed to mature and produce large stands, grazers often won't eat it due to its strong anise odor (Cal-IPC Plant Assessment Form 2005).

Risks and Uncertainties: Untreated areas of fennel have been known to decline naturally without management (Ogden 2004). Therefore, it is important to always compare a treated site with a baseline site in order to determine the significant decline of a population. Ogden also found that although the control of fennel on SCI was successful and that the invasive species was replaced with natives in the pilot studies, invasive grasses eventually replaced the fennel in the field study (Ogden 2004). Although pilot projects are often used to determine the feasibility of a project, there is always the possibility that the results will not extend to a larger scale. Additionally, often times restoration projects are only monitored for short periods of time, especially when an agency has limited time and money. However, if a site is not monitored for an extended amount of time, managers might think that they have successfully controlled fennel and restored natives, when this isn't actually the case (Eviner 2015).

Evaluation of a site's history must be used to determine the state of native plants in the soil seed bank. If a site has not had a significant amount of natives on it for more than five years, managers must realize that they must invest in native seed and plants and be very proactive about getting the seed out as soon as the fennel has been removed (Ogden 2004, Liu 2009). If it is known that there is a large proportion of nonnatives in the seed bank, removal of the topsoil and subsequent planting of natives such as *Nassella pulchra*, can limit competition from other invasives (Liu 2009, Bean 1988). The removal of fennel itself should be viewed as a disturbance which might allow for other ruderal non-natives to move in.

Risks of using livestock for grazing include that they can bring in additional fennel seeds, which could lead to genetic swamping, they can bring in other non-native seeds other than fennel and/or they can spread the resident fennel from the site if any of the plants have flowered (Washington State 2006, Cal-IPC – Invasive Plants).

Management of a system that is prone to fennel invasions must avoid further disruption of the soil, as this will promote the future establishment of fennel (Bean 1988).

C. Monitoring plan

Before a fennel-infested site is restored, it should be monitored for at least one year to determine the aggressiveness of the stand, as described in previous sections (Ogden 2004).

It is important to monitor a site that has been treated for fennel removal to ensure that the plant is not reestablishing. If a fennel stand is burned in the fall and then sprayed in the late spring, it should be checked after at most 4 months (Bell et al. 2008). It then should be evaluated when the winter rains come to see how many root crowns are resprouting. Additionally, the depletion of the fennel seed bank should be carefully monitored. Seeds can persist for 3 years or more, so follow up burns can be completed to further deplete the seed bank (Cal-IPC Assessment Form 2005). After 3-5 years, monitoring of a previously infested site can be less frequent, if it looks like fennel has remained controlled, since the seed bank should be adequately depleted (Cal-IPC Assessment Form 2005).

Land owners and other relevant individuals should pay close attention for any new invasions of fennel. If a non-aggressive population is found then they must make sure conditions do not arise making it aggressive (Ogden 2004). Typically, since fennel is a ruderal species, disturbance is a key environmental factor that can lead to a non-aggressive population becoming aggressive (Weed Report 2013). If a person is trying to eradicate an aggressive population, it is best to focus on reducing the spread of the patches while taking a year or so to formulate a method of removal.

When completing restoration projects which center on the removal of fennel populations, nearby plots of similar infestations should be used as controls. Comparing the restored site to the control plot after burning and two years of herbicide application will help determine the efficiency of fennel control.

Finally, many more questions need to be answered to better understand the role fennel plays in Californian ecosystems. It would be useful to determine more native species that can coexist with fennel populations so that when fennel is removed there is already a native species present to keep fennel out. Finding a genetic basis to what makes fennel aggressive versus non-aggressive would also help in evaluating a fennel population. The control of fennel should also be looked at in a larger time scale, to see how frequently sites are removed of fennel to simply be invaded by annual Mediterranean non-natives.

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Perennial pepperweed (*Lepidium latifolium*)

Lauren Broder

Part 1: Project Background and Justification

Basal rosette leaves
http://www.ipm.ucdavis.edu/PMG/PES_TNOTES/dn74121.html



Appearance:

“Stem: 2-4 feet tall, mature plants have several semi-woody stems

Roots: long, minimally branched, enlarged at the soil surface forming a semi-woody crown



Leaves: smooth and green to gray-green in color, rosette leaves are ovate to oblong with smooth to slightly toothed margins on long stalks, they are about 4-11 inches long and 1-3 inches wide, stem leaves are at the base of the plant, are shaped like a lance with smooth to toothed margins, and

become smaller toward the top of the stem

Woody crown and roots
<http://www.ipm.ucdavis.edu/PMG/PESTNOTES/dn74121.html>

Flowers: small and white flowers that form dense clusters in panicles at the tip of each stem, often confused with hoary cress, but hoary cress stems are less than 3 ft tall and have leaves that clasp the stem and lack an obvious stalk



Habitat: introduced from southeastern Europe and Asia, can establish in a wide variety of environments, a common problem in flood plains, irrigation

Perennial Pepperweed	Hoary Cress
	

structures, pastures, wetlands, riparian areas, roadsides, and residential sites”

Clusters of white flowers
<http://www.nps.gov/plants/ALIEn/fact/img/lela1a.jpg>

Stem leaves
<http://www.nwcb.wa.gov/admin%5CWweedImages%5Cperennialpepperweed6.jpg>

Part 1: Project Background and Justification

A. Background & Justification

Although perennial pepperweed (*Lepidium latifolium*) was originally found in the United States in the 1930s, it became widespread during the 1980s. This species is an invasive from Eastern Europe and Asia that managed to become established and a huge issue in much of the U.S. In the intermountain west, it establishes and colonizes riparian areas extremely fast (Miller et al. 1986). But the species is also well adapted for all kinds of other habitats. It is suitable for wetlands that have freshwater, brackish, salt, or alkaline water. Because of its tolerance of many different habitats, it easily spread quickly throughout California and has become an aggressive species (Miller et al. 1986). Because perennial pepperweed is so destructive, it often out competes other native species for habitat and resources. It is difficult to manage because although many methods are effective at eliminating above ground biomass, there is a huge issue with regrowth from the root system (even if it has been disked) (Young et al. 1997). In order to manage this species properly it is essential to obtain all the details about its growth, regrowth, habitat, and interactions with different management techniques to prevent regrowth.

B. Fact Sheet

a. Germination

- i. Each plant produces tens of thousands highly germinable seeds (Robbins et al. 1951).
- ii. Seeds germinate readily when there is a wide fluctuation of temperatures (Miller et al. 1986).
- iii. The seeds are more likely to germinate at the soil surface; those far below will not experience temperature fluctuations needed for germination (Miller et al. 1986).

b. Seed Bank Dynamics

- i. There is not a dormancy system in this species so buried seeds are probably not a source of reinfestation, but further research must be done to definitively conclude this (Miller et al. 1986).
- ii. Little is known about the seeds and seedbanks of perennial pepperweed (Young 1999).

c. Environmental Tolerances/Preferences

- i. It is able to adapt to many different environments, such as conifer forests, saline/alkaline deltas and sinks, and stringer meadows characteristic of the sagebrush zone (Young 1995). (Young 1995).
- ii. Not usually found in coastal rain forests or lower elevation deserts, high mountain meadows or coniferous forests (Young 1995).

d. Phenology

- i. The above ground portion of the plants die annually, but the woody stems can remain for years (Young et al. 1998).
 - ii. The seeds do not dehisce from the pods at maturity. They tend to fall at random times during the winter and some even remain in the pods until the spring (Young et al. 1998).
 - iii. More research is needed in the area of seedlings and their establishment because they are not commonly found in the field, but they may be a key step in the plant's establishment (Young 1999).
- e. Key Interactions (mutualists, competitors, pathogens, etc.)**
 - i. The presence of perennial pepperweed greatly increases the concentration of C, N, P, Ca, Mg, and S in the soil (Blank and Young 2002).
 - ii. The accumulation of plant litter from each year when the above ground plants die may contribute to wildfires (Andrew and Ustin 2006).
- f. Ecosystem Requirements**
 - i. It is insect pollinated so there must be insects in the ecosystem (DiTomaso and Healy 2003).
 - ii. Perennial pepperweed can grow in fresh, brackish, and saltwater wetlands, in/near agricultural fields, in waste places, and on stony terrain (Howald 2000).
 - iii. The species is most successful with a narrow range of soil water saturation and grows poorly with higher saturation, but can live in either situation (Blank et al. 2002).
- g. Spatial Scale (home range, dispersal, etc.)**
 - i. Perennial pepperweed seeds can spread via long-distance water dispersal (Andrew and Ustin 2006).
 - ii. It can also be spread via the wind, agricultural products, vehicles and machinery, waterfowl, or other animals; but the species does not have a special adaptation for widespread dispersal (Howald 2000).
 - iii. It occurs as dense, almost monotypic communities (Young 1995).
 - iv. It is most common to see perennial pepperweed spread by creeping roots and by regeneration from roots or root fragments (Young 2004).
 - v. Roots can be transported long distances by water and successfully establish a new colony if they break off on banks (Young et al. 1997).
- h. Temporal Scale**
 - i. A single plant that has established can grow into a population several meters across in 2 seasons and become infested in the area within 5 (Blank 2002).
 - ii. Little is known about the life stages and the timing of them for perennial pepperweed (Renz 2002).
- i. How Does Perennial Pepperweed Respond to Management?**
 - i. Use of mowing and chlorsulfuron (0.052 kg ai/ha) or glyphosate (3.33 kg ae/ha) reduced the biomass of dense pepperweed by more than 90% (Renz 2002).

- ii. Disking or burning does not prevent or reduce the rate that perennial pepperweed spreads (Renz 2002).
- iii. If the root system is disked it will likely sprout more roots and shoots profusely (Young et al. 1998).
- iv. One year after plants were treated, chlorsulfuron (0.104 kg ai/ha) was found to reduce biomass of very dense plants more than 74% (Renz 2002).
- v. Application of glyphosate or 2,4-D, although effective at reducing the aerial part of the plants, is not a good management strategy because the roots sprout new roots and shoots regardless (Young et al. 1998).
- vi. Removal of the above ground plant parts by cutting/mowing, grazing, or herbicide treatment is not effective on its own because of the regrowth from roots or root fragments (Young et al. 1997).
- j. How does Perennial Pepperweed Respond to Climate Change?**
 - i. Perennial pepperweed may become infected with the white rust in wet years, which may largely inhibit seed production (Young et al. 1997).
 - ii. In dry years, the plant will produce many flowers but minimal seeding and maturity also occurs (Young et al. 1997).

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Part 2: Project Goals and Management Plan

Goals:

Goal 1-Vegetation Analysis: A vegetation analysis must be conducted to determine whether there are mature perennial pepperweed communities, whether there are areas with seedlings, and how large/densely populated those areas are. Knowing this will help determine which management strategies to use when managing the plants. Different areas may require different methods depending on plant maturity, but treatment of all the area with perennial pepperweed will be a crucial part of ensuring the plants are unable to re-establish.

Goal 2-Eradiction: To eradicate perennial pepperweed, a combination of management techniques will need to be implemented. These include a combination of herbicide treatments, the promotion of native perennial grass establishment after the stands of perennial pepperweed are eliminated, and controlled grazing or mowing.

Goal 3-Continued Suppression: If the plants fail to grow back, it will be considered a complete success. Repeated use of management techniques may be required to reach this goal. The need for this repetition will be determined through the monitoring of the populations after treatment.

Restoration Plan:

Eradication plan

The key to eradicating perennial pepperweed is early detection and action (Schultz 2011). Because perennial pepperweed has root systems that produce many buds, large energy reserves that allow for regrowth, and low leaf area for herbicide uptake, management of mature stands of the species is very difficult. This means the best strategy for eradication is to target young plants without extensive root systems (Schultz 2007).

The most successful option is to allow for controlled grazing (by domestic goats or sheep) (Baker 1997) or mowing in the spring and then treat the plants with herbicides once regrowth begins (United States National Park Service). Different herbicides may be used on perennial pepperweed. Treatment with the herbicide Cimarron® Max is recommended to be during early budding to very early flowering of the seedlings (Schultz 2007). However, herbicide treatment of mature plants only results in aboveground killing and the roots and crowns continue to sprout if nothing else is done (Schultz 2011). For plants in full bloom up until desiccation, Plateau® is recommended and Escort® is recommended for plants at the early bud stage. Schultz 2007 article found that using a boom twenty four inches off the ground was an effective way to distribute these herbicides because the canopies of the plants were pulled over and the herbicide was then able to reach the leaves (where it would be absorbed by the plant and distributed). This may have increased herbicide uptake by the plant and increased mortality. In addition, using a combination of herbicides may be beneficial because it can extend the effective treatment period (Schultz 2007).

Perennial pepperweed stands have a seedbank that may exceed one million seeds. This happens because each plant has the capability of producing tens of thousands of seeds. For proper management of the plant, the seedbank needs to also be controlled. More research must be done to determine how long the seeds can stay dormant, but it is likely that they are shortlived. Once the manager treats the mature stands of perennial pepperweed and the ground where the seeds are being stored is exposed, it provides an optimal opportunity to treat the seedbank with herbicide. It has been found that this method of management will eliminate the sprouting plants that would originate from the seedbank. In order to be successful, the ground must be treated annually for as many years as possible. But, the best way to reduce the seedbank is to prevent the weeds from seeding (Schultz 2012). This would be done using the herbicide methods previously discussed. Tilling, mowing, and grazing alone are not viable techniques for management of perennial pepperweed because these methods may spread the seeds or allow for sprouting from roots (Schultz 2012).

After the weeds are treated, immediate establishment of native perennial grasses can provide enough competition with the perennial pepperweed to potentially exclude it (Schultz 2007).

Monitoring plan

Frequent monitoring is essential for proper management of perennial pepperweed. It must be done in early spring and late summer, whenever it is possible (at least for several years). Perennial pepperweed is often one of the first plants to bud in early spring and one of the last plants to survive late in the season. In addition, it may be helpful to look for senesced stems during the fall and winter (Renz 2000).

The roots of perennial pepperweed have energy reserves that allow them to sprout and produce an entirely new plant if the roots are cut into small pieces. Because of this, it will be important to watch for new sprouting plants and treat them with herbicide between the early budding and very early flowering stage to kill the new plants and prevent them from seeding (Schultz 2007). In addition, because the plants can produce more than 10,000 seeds per plant and those can stay dormant for a short time and germinate at a later date, monitoring for those new plants will be important. If they do sprout from seeds to create new plants, herbicide will be a useful tool to kill them while they are still young. Until complete eradication is achieved, the plants should be treated annually to prevent re-establishment (Schultz 2007).

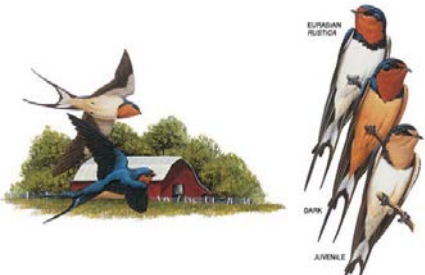
The presence of any new plant after treatment will be enough reason for re-treatment. The plants produce such a large amount of seeds and their root systems grow so quickly that if not managed immediately, the perennial pepperweed could spread and re-establish very quickly (Schultz 2007).

References:

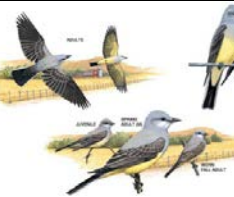
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Migratory songbirds (e.g. Warblers, Thrushes, Sparrows)
Dennise Alatorre

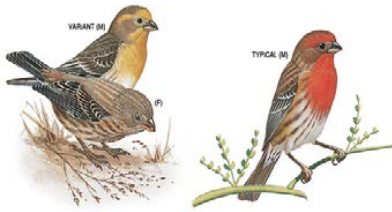
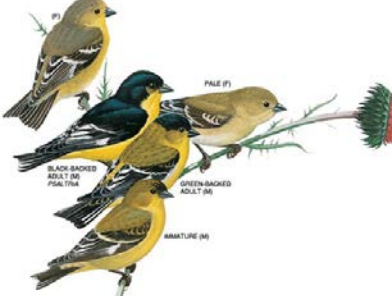
Part 1: Project Background and Justification

Swallow Family	Size (in)	Habitat	Range	Song	Notes
Violet-Green Swallow 	5	Woodland edge, farm, parks	Feb-Apr: valleys and coast Sept-Oct: valley and coast	Chip	Usu. small flocks
Cliff Swallow 	6	Fields, farm	Mar-Aug: all CA	Harsh creaking	
Barn Swallow 	7	Fields, farms	Apr-Sept: coast or Central Valley Resident : all CA	Long twitter	Box
Northern Rough-Winged Swallow	5.5	Rivers,	Feb-Aug:	Raspy brit	Usu.

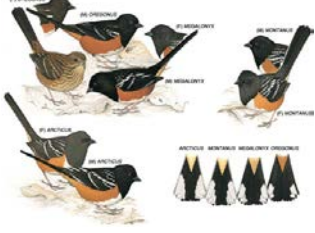
			fields	all CA		solitary pairs

Tyrant Flycatcher Family	Size (in)	Habitat	Range	Song	Notes
Ash-throated Flycatcher 	8	Open woodland, brush, mts	Apr-Sept: all CA but N. Coast Oct-Mar: along Colorado River	Soft pur-wee, pwit Harsher ka-brick	box
Olive-sided Flycatcher 	7.5	Summer: coniferous forests Migration: broadleaf woodlands, parks	Apr-May: S. CA Aug-Sept: all CA but desert Winter: tropics	Whistled bic...three-beers	Perches on highest tree twigs
Pacific-slope Flycatcher 	5.5	Coniferous forests	Mar-May: W. slope of Sierras Sept-Oct: all CA	High seet-sick-seet	
	8.5	Grassland, riparian	Mar-Sept: most CA, but central and N. coast	Shrill kit; kit-kit-kiddledit	
Western Kingbird Western Wood-Pewee 	6.5	Pine and broadleaf riparian, valleys	Apr-Sept: most CA	Peee-err	

Wood Warbler Family	Size (in)	Habitat	Range	Song	Notes
Black-throated Gray Warbler 	5	Chaparral, dry coniferous	Resident: all CA May-Sept: Pacific slope, N. CA, Sierras	Buzzy weze-weze-weze-weeet	Prefers open areas
Hermit Warbler 	5	Coniferous forest (fir, hemlock)	Resident: all CA May-Sept: N. CA mts	3 high-2 low syllables	Feeds high in trees Mixed flocks
Common yellow-throat 	5	Riparian, shrub, marsh	May-Sept: N. CA, valley Resident: all CA	Witchity-Witchity-Witchity-witch	Forages low Nests open marsh
Orange-crowned Warbler 	5	Broadleaf woodlands, brushy fields, parks	Resident: all CA May-Sept: N. and C. coast, Sierras	High trill, tapers off	Forages low
Wilson's Warbler 	4.75	Woodland edges, low shrubs, alders	Resident: all CA Apr-Sept: N to SF, coast ranges	Rapid chi chi chi chi jet jet	

Finch Family	Size (in)	Habitat	Range	Song	Notes
American Goldfinch  BREEDING ADULT (M) BREEDING ADULT (F) WINTER ADULT (M) WINTER ADULT (F) JUVENILE	5	Fields, farm, forest edge	Resident: Pacific slope, Central Valley, Sierras Oct-May: E. SE. desert	Fluctuating twittering	Feeder
House Finch  VARIANT (M) TYPICAL (M)	5.5	Cities, residential	Resident: all CA, but high elevation mts	Musical, ends with jeer	Box and Feeder
Lesser Goldfinch  PALE (F) BLACK-BACKED ADULT (M) PALE (M) GREEN-BACKED ADULT (M) ADULT (M)	4.5	Woodland edges, gardens	Resident: most CA, but desert	Repeated phrases, mimics others	Feeder
Lawrence's Goldfinch	4.5	Oak and pine woodland, chaparral	Resident: SW CA, E Coast Ranges, W Sierra	Rising and falling twitter, adds call notes of others	Flocks in

						W i n t e r

Sparrow Family	Size (in)	Habitat	Range	Song	Notes
California Towhee 	9	Chaparral	Resident: coast, foothills	Fast chip	Feeder
Spotted Towhee 	8	Forest understory	Resident: all CA but SE desert Nov-May: Imperial and Colorado Valley	Buzzy cheweeeee	Feeder
Fox Sparrow 	7	Forest understory	Apr-Oct: mt ranges Sept-Apr: Central Valley, Sierra foothill	Clear whistles	Feeder
Song Sparrow 	6.25	Shrub, marsh	Resident: all CA	Zeet zeet zeee diddle diddle dee	Feeder
Lark Sparrow 	6	Grassland, desert, farm	Resident: C and S coast, Central Valley Apr-Sept: NE CA Oct-Apr: SE CA	Broken buzzes and trills	

Golden-crowned Sparrow 	7	Forest understory, parks	Sept-Apr: N. and C. CA	Slurred ohh-dear-mee	Feeder

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Images

All sketches were from National Geographic
National Geographic:

<http://animals.nationalgeographic.com/animals/birding/bird-photos/>

All photographs were from Audubon Field Guide

National Audubon Society. 2015. Guide to North American Birds.
<http://www.audubon.org/field-guide/bird/>

Migratory Songbirds

Introduction

Songbirds are in the taxonomic order called Passeriformes, which comprise over half of the world's birds. A suborder, called Passeri, encompasses all of the approximate 4,000 species of songbirds, including sparrows, warblers, larks, and jays (Alden, 1998; Edwards, 2003). Some songbirds of concern in California are the Tricolored Blackbird, Yellow Warbler, Yellow-billed Cuckoo, Bushtit, among others (Audubon, 2015). The Central Valley of California is a critical area for migratory songbirds since it forms part of the Pacific Flyaway (Audubon, 2015). Various waterfowl, shorebirds, and landbirds use the Pacific Flyaway as a migration pathway from Alaska to South America. Migratory songbirds use the Pacific Flyaway in their spring migration, lasting 7 - 9 weeks (MacMynowski, 2007), to California where they breed in riparian and wetland habitats before returning south in the fall (Audubon, 2015). Riparian areas of the Central Valley of California were once plentiful enough to support many species of mammals, birds, and invertebrates due to the diverse vegetation structure and hydrology. Now, about 98% of the riparian habitats in the Central Valley have been lost to flood control, urbanization, and agricultural expansion (Gardali, 2011; RHJV, 2004). As a result, California's migratory bird populations have declined due to this anthropogenic-caused degradation. Current drought conditions and future predications of climate change will continue to exacerbate the issue (RHJV, 2004).

Life History

A. Morphology

- a. Despite their diversity, Passeriformes share distinguishing features such as their foot, which has three toes pointing forwards and one backwards; distinctive sperm morphology; and distinct forewing and hind limb musculature (Edwards, 2003).
- b. Winter plumages are dull compared to the bright breeding plumages, used to attract mates and establish territories. Males may have brighter colors than females of the same species, yet flycatchers, swallows, shrikes, vireos, chickadees, jays, wrens, thrashers, and meadowlarks share similar plumages between sexes (Smith, 1993).

B. Reproduction

- a. Most songbirds are monogamous throughout a single breeding season, but choose different mates each season. Clutch sizes vary from three to six eggs.
- b. Both sexes care for the young, sometimes with the help from individuals of the first brood—as seen in jays, swallows, and bluebirds (Smith, 1993).

C. Mortality

- a. There is only about a 25% chance a young bird will survive their first year due to diseases such as avian tuberculosis, avian pox,

and salmonellosis; predation by skunks, feral cats and dogs, and raccoons; and harsh weather conditions (Smith, 1993).

Interactions

A. Other Songbirds

- a. Practically all tyrant flycatchers are solitary, yet some species do form loose flocks during migration. Wrens, thrushes, and some wood warblers are also solitary species (Sibley, 2003).
- b. Social songbirds include jays, crows, chickadees, and nuthatches. Wood warblers, chickadees, some vireos, sparrows, finches, and meadowlarks usually form mixed flocks—with chickadees often comprising the central composition of the flock (Sibley, 2003).

B. Predators

- a. Garter snakes are common predators of young songbirds. Crows, Brown-headed Cowbirds (a brood parasite), and rodents prey on nests as well (Latif, 2012). Feral cats and dogs and raccoons may be an issue in more urbanized areas (Smith, 1993).

C. Prey

- a. Adult songbirds have a varied diet across species. However, young songbirds all rely on insects as a food source (Alden, 1998), which is high in protein (Smith, 1993). Tyrant flycatchers and swallows depend almost exclusively on insects—a common food source for most songbirds (Sibley, 2003).
- b. Other common sources of food include berries, seeds, and fruits. Some jays and crows specialize on oak and pinyon seeds. Small vertebrates, like mice, are a source of food for shrikes. This group of birds also stores food on thorns for later consumption, thus requiring a mixed stand of vegetation. Chickadees, nuthatches, and bushtit often use bird feeders (Sibley, 2003).

Habitat

A. Vegetation Structure

- a. A mixed stand of vegetation is need across the landscape to provide songbirds with the most productive habitat (Gardali, 2011). Larks, Wagtails, and Mimids mainly walk and run on the ground floor, requiring both open space mixed with shrubs to escape predation. American Pipit, Lapland Longspur, Horned and Sky Larks, Savannah Sparrow, and Snow Bunting are some of the few Passeri species that use open areas such as golf courses and pastures. Open ground is also foraging site for sparrows and towhees, while others glean insects from leaves (Sibley, 2003).

B. Nest

- a. Many use sticks, grass, and small branches to build nests with an open top. Songbirds often construct their nests in tree forks, shrubs, or tall grasses (Alden, 1998), yet they vary greatly among species. Wrentit species usually nest in dense cover. Starlings compete with woodpeckers and bluebirds for open cavities, as do most wrens and the Ash-Throat Flycatcher (Sibley, 2003).

- b. The spatial scale needed to sustain songbirds varies among species. For example, Wood-Pewee and Ash-throated Flycatchers depend on large trees for nesting, requiring a larger habitat landscape. Whereas, species like Bewick's Wren, Spotted Towhee, and Black-headed Grosbeak use shrubs for nesting, requiring a smaller spatial scale (Gardali, 2011).
- C. Hydrology
 - a. Riparian habitats are the intermediate areas between the aquatic and terrestrial ecosystems. Therefore, water presence, whether ephemeral or permanent, is an important factor in supporting the vegetation migratory passerines rely on. For the Tree Swallow, Song Sparrow, Yellow Warbler, and others, ecological water partitions are vital in order to sustain their riparian habitats (RHJV, 2004)

Disturbance

- A. Altered Hydrology
 - a. Over 100 years, California has undergone massive water projects, creating dams and levees for flood control measures. The alteration of natural hydrologic patterns and the lowering of groundwater table have degraded songbird habitats, such as the dense riparian areas the endangered Least Bell's Vireo is dependent upon (RHJV, 2004).
- B. Climate Change
 - a. More extreme weather patterns will destroy nests or kill young. Many species are migrating at earlier times of the year, which can be create a phenological mismatch unless insects emerge and other food sources are available at that time (MacMynowski, 2007).

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Part 2: Project Goals and Management Plan

A.Goals

For passerines, having abundant riparian habitat is crucial for migratory stopovers and breeding grounds. Classifying a single requirement of this broad group of birds is difficult, yet some recommendations are widely applicable. The main restoration goals for migratory songbirds in the Central Valley include (a) providing a diverse mix of native vegetation, that includes clumped mature trees and brush cover; (b) creating riparian habitat adjacent to remnant riparian sites and far from agricultural or densely human-populated areas; (c) reducing predation pressure—especially from Brown-headed cowbirds; and (d) limiting detrimental disturbances, such as chemical use, mowing, grazing, and prescribed fire.

- a. Migratory songbirds require heterogeneous vegetation structures to promote passerine diversity, maximize potential nesting sites, and reduce predation pressures (CalPIF, 2008; RHJV, 2004). Heterogeneity in this case refers to a spatial diversity (patchiness of large trees and open space), a functional diversity (mixture of grasses, shrubs, and trees), and a species diversity (not a monoculture).
- b. An optimal habitat will not only have the right vegetation structure but also be placed in the proper context of the landscape, which can influence bird persistence and abundance (Gardali, 2006). For example, riparian habitats near manicured parks, urban areas, agriculture can increase predation rates and chemical exposure. Instead, riparian sites should be restored near remnant sites (Gardali, 2006).
- c. High predation rates of eggs and nestlings can severely harm small and vulnerable population of songbirds. Nesting success is one of the most critical factors in determining population growth. Controlling cowbirds—especially during the peak nesting period (April 1 to June 30 for most songbirds)—and providing brush cover can help maintain a 20% nesting success rate needed for passerine persistence (RHJV, 2004).
- d. Chemical use, grazing, and burning are common restoration practices that can harm passerines. If these and other disturbances cannot be eliminated, at least restricting them to the nonbreeding season (September to February) will increase nesting success and survivorship (CalPIF, 2008).

B. Restoration Plan

Create a Heterogeneous Vegetation Structure

1. Diversify the canopy structure

Since passerines are such a diverse group of species, it is difficult to determine a single criterion for vegetation cover. Although nonnative vegetation can provide some adequate nesting habitat, planting native vegetation is preferred to establish a pristine cover that is more adapted to the local conditions. The effect of vegetation diversity depends on the species present at the site, so no one recommendation suffices. However some generalities about species response to different vegetation is known.

For example, a greater spacing of vegetation layers correlate with an increase in arboreal forage insectivores, such as the Yellow-Rumped Warbler. On the other hand, restored sites with high vegetation cover benefit ground-foraging granivores, such as the Lincoln Sparrow (Gardali, 2006) Spotted Towhees, Ash-throated Flycatchers, and House Wrens benefit from greater heights and tree diameter at breast height. Wren-tits and Song Sparrow prefer greater canopy heterogeneity, yet this can be detrimental to other species, such as the Bullock's oriole. Other species, such as the Red-winged Blackbirds, prefer open spaces and low canopy heights—characteristics common in open marshy areas (Seavy, 2009).

2. Maintain clumped, mature trees for nesting

The maintenance of large trees is necessary for cavity nesters and orioles (RHJV, 2004). Dead trees and woody debris should be left standing for passerines to excavate nests from (CalPIF, 2008). Otherwise, 10 to 15 years would be needed for mature trees to establish from replanting efforts (Gardali, 2011). If the site only has a few native, mature trees it may be more beneficial to leave the invasive trees present at the site until the native trees have established. If the site is being restored from an old orchard, it can benefit songbirds to keep clumps of some mature trees with snags and cavities. However, it is crucial to avoid trees with invasive root stocks, such as figs. When considering spacing, a cluster of trees is preferred to mimic the natural patches of high nutrient deposition that arise after floods (RHJV, 2004).

3. Maintain high diversity

A higher diversity of vegetation at all structural levels can increase bird diversity. Having more than 7 species of native shrubs and trees increases bird diversity greatly, but a minimum requirement of 2 species is needed (RHJV, 2004). In newly restored habitat, understory is especially important in creating more potential nesting sites, thus reducing predation and increasing nesting success. Fruiting plants, such as the California grape, blackberry, and blue elderberry can also increase food supply for some passerines (CalPIF, 2008). An increase in tree species diversity can increase bird abundance by an average factor of 1.2 (Gardali, 2011)

4. Promote good establishment of vegetation through maintenance

For the first two years of restoration, mowing may be required to promote revegetation of tree species in the grasslands adjacent to the riparian habitat (CalPIF, 2008). If low water availability is reducing seed dispersal and natural revegetation, one should consider cultivating trees. Furthermore, in order to establish a heterogeneous cover, a second planting of native herbs and understory is necessary (RHJV, 2004). The abundance of passerines is expected

to increase with the age of the restoration site (Gardali, 2011). The yearly rate of increase can be as low as 15% to as high as 50% for the Ash-throated Flycatcher and Bewick's Wren, respectively (Gardali, 2011).

Promote Landscape Connectivity

1. Provide adequate patch sizes

Since different species of songbirds have different needs, when making decisions about restoration size, one should focus on the species with the greatest requirements (RHJV, 2004). For example, the Western Meadowlark may have an average territory size of 3 to 7 hectares, composed of riparian and adjacent upland habitat (Allen, 2000). However, the Western Yellow-billed Cuckoo has an average territory size of 20 to 25 hectares, with a 10 ha minimum. Therefore, a 10 ha minimum should be established. Each species will have a slightly different threshold requirement, yet, to provide an estimate, a pair of Western Yellow-billed Cuckoos' optimal habitat would be 75 ha long and 600 meters wide (RHJV, 2004).

2. Connect riparian sites to intact, adjacent habitat

Connectivity among riparian habitats can improve songbird persistence by increasing the interaction of otherwise isolated populations. To establish a riparian corridor with optimal habitat, a minimum width of 100 meters is needed (CalPIF, 2008). However, a 3 to 10 meter width of vegetation can also suffice to link populations. Therefore, restoring habitat near remnant riparian sites can increase passerine abundance and persistence. Restoring riparian sites adjacent to intact upland areas also provide additional foraging area, benefiting the Western Yellow-billed Cuckoo, Common Yellowthroat, and the Least Bell's Vireo (RHJV, 2004).

Reduce Predation Rate of Eggs and Nestlings

Predators of songbirds consist of cats, skunks, crows, ravens, and cowbirds. Garter snakes mainly predate on nestlings while corvids predate on both eggs and nestlings (Latif, 2012). Keeping cats inside, not feeding stray cats, and restricting their access to bird feeders can help reduce predation (CalPIF, 2008). The Brown-headed cowbird predares on eggs but also harms songbirds through brood parasitism (Latif, 2012). Nearby agricultural land can increase predation by cowbirds, whom will travel more than 12 km from their foraging site to their host site. If cowbird predation is having extremely detrimental effects on small populations, one can consider trapping cowbirds. However, this is a short-term solution that may be costly (RHJV, 2004).

Predation rates may depend on the site's surrounding area, such that manicured parks, rural and urban areas, dairies, and intensive agricultural land can increase predation. Creating soft-edges may be beneficial in reducing this predation pressure. This is achieved by adding transitional vegetation around the riparian habitat (RHJV, 2004). Large brush piles constructed of branches, limbs, and logs and that exceed 3 feet in height should be placed next to existing ground cover, such as blackberry bush, to provide concealment from predators (CalPIF, 2008).

Reduce Disturbance During Breeding Season

1. Wisely time mowing for revegetation

Do not mow the grassland adjacent to the riparian habitat during the breeding season (April 1- June 30). If mowing is unavoidable, mow early in the year (February) and at a high frequency to discourage ground nesters from establishing there before the breeding season starts. Do not mow native saplings and shrubs, including poison oak, because birds rely on various plant species for different functions (CalPIF, 2008).

2. Moderate grazing and burning

If grazing and burning are being considered as management practices in grasslands near riparian habitat, passerines may be affected by higher predation rates. Brown-headed cowbirds are more twice as frequent in grazed and burned areas due to increased foraging habitat (Danley, 2004). Trampling by the grazing animals can also reduce nesting success and can be detrimental for several passerines, including the willow flycatchers and yellow warblers (RHJV, 2004). With fencing of nests and moderate rotation grazing, these management practices may be implemented for two summers without greatly reducing species diversity (Danley, 2004).

3. Limit chemical use

If possible, managers of the restoration site should speak with the adjacent farmers to work in tandem. Organochlorine pesticide and herbicide use should be avoided during the breeding season of birds. A more beneficial practice would be an integrated pest management or organic crop production. This would increase foraging habitat for passerines. However, if pesticides must be applied, it is important to apply after the breeding season to avoid nest failure (RHJV, 2004).

C. Monitoring Plan

From site surveys, pre-restoration records of vegetation and species composition would be known. From restoring the site, it would be critical to note how the migratory songbird population changes with an improvement in vegetation, disturbance and predation. For example, how effective are cowbird trappings in increasing nesting success to 20% ? Does an increase in vegetation richness promote novel songbirds to the site?

Predation Rates

Predation rates of nestlings and eggs should also be monitored to determine its effect on population stability. Video cameras can be beneficial in recording the different species of predators. However, camera shy species may not be accounted for, making it an inaccurate account of predation rates (Latif, 2012). Therefore, videography should be coupled with field observations to better account for these disparities. Both should be performed during the peak nesting season—April 1 to June 30 (Latif, 2012).

To reduce cowbird predation rates, it could be beneficial to utilize traps with a funnel-topped, which have a higher capture rate than flat-topped traps. The recommended slot width is 3.2 cm, so to minimize the capture rate of non-target species while still allowing female cowbird captures (McLeod, 2014). An

effective placement of the traps would be in an open area adjacent to the nesting sites of host (USBR, 2004).

The traps should be placed out 2 weeks before the first migratory songbirds lay their eggs until 2 weeks past the end of the egg stage of the hosts. However, these traps do need to be monitored every day to place food and water or to release non-target species that were captured. If funds are scarce, it can be beneficial to reduce trappings to only the first 2 or 4 weeks of the peak nesting season of the hosts, since most cowbirds are captured early in the season (USBR, 2004).

If non-target species capture rates are higher than cowbird captures to an extent that it is more harmful to the hosts, then trapping should be discontinued and habitat improvement may be a better option to increase host population size. Furthermore, trappings vary yearly, so a continual monitoring of its effect on nest should be recorded (at least 2 years prior to trappings and 3 to 5 years after trappings cease) (USBR, 2004).

Nesting Success and Population Counts

The number of surviving offspring of a community is an important indicator for population growth and persistence. If possible, an account of eggs and nestlings should be recorded to determine if a population trend is due to low fecundity or low survivorship of young. A proxy for annual productivity can come from a fledging count or noting the abundance of adults with distinct breeding color. However, not all species display such a morphological distinction (RHJV, 2004)

A nesting success rate of 20% is an average threshold for songbird persistence. As another threshold, a 10 pair minimum per site will increase the stability of a population, yet sustaining 25 pairs per site will decrease a species vulnerability to stochastic events (RHJV, 2004). If populations continually fall below these thresholds, site managers should seek other options such as captive breeding.

Using a statewide bird count every five or ten years would be beneficial to determine how the specific site compares in a larger-scale. If a restoration site is facing population declines, it may be due to an external factor of a state-wide declining trend (RHJV, 2004).

Uncertainties

It is critical to note that this restoration plan is a generality and will differ with each restoration site's unique features and characteristics. A more comprehensive research of data is needed to tailor this information to the site in question. For sensitive species known to occur at the site, more detail information should be sought from the US Fish and Wildlife Service of the California Department of Fish and Wildlife.

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Raptors (e.g. Hawks, Harriers, Kites, Owls)

Kyrillos Agaiby

Part 1: Project Background and Justification

Background and Justification

Raptors represent an ecologically significant aspect of the ecosystems in California. Like many predators, raptors serve as an indicator of ecosystem health; they facilitate community structure, inhabit wide ranges of land, and control trophic cascades. Wintering raptors migrate to the Central Valley annually during the months of December to late February because of its mild climate and thousands of miles of open land (Pandolfino et al., 2011, Smith, 2011). Approximately 25 raptor species exist in California, with 15 found in the Central Valley, and 14 of those found in the Sacramento rice lands at a density of 4.3 specimens per square kilometer (Pandolfino et al., 2011). The high concentration of raptors in rice fields is due to the high density of prey found in these areas. Raptors effectively control rodent pests and thus are significant in maintaining balance in the trophic cascade. Historically, many raptor species have declined with global events such as the use of DDT, but have risen again since the 1970's. However, today many raptor species are again in decline due to improper agriculture processes, industrial processes, and climate change (Sauer et al., 2009)

Literature Review

Raptor Characteristics- Feeding, habitat, behavior

- “Raptor” in Latin means to seize or to grasp. Raptors are carnivores and sometimes detritivores/scavengers. They have acute vision and hearing, and use their sharp talons to capture their prey. (Source: Davit 2009)
- Their diet consists of small mammals (rodents, rabbits, etc.), reptiles (snakes, lizards, frogs), and large insects. (Source: University of Missouri Raptor Rehabilitation Project) and (Davit, 2009)
- In general, territory does not range annually or by gender. However, during breeding season, territory and travel distance is smaller than during non-breeding season. (Source: Marzluff et. Al 1997)
 - For large raptors such as the Golden Eagle and Bald Eagle:
 - During breeding season, home range varies between 190-8000 hectares
 - During non-breeding season, home range varies from 1370 to 170,000 hectares.
 - For medium sized falcons such as the Swainson's Hawk, the Red-Tailed Hawk, and the American Kestrel:
 - Home range varies between 336 and 8,700 hectares (USFW).

- Nesting varies among species; however, they generally lay eggs in sand or gravel, use cavities in trees, or use nests created by other birds. (Source: US Department of the Interior: Bureau of Land Management)
- Female Raptors are larger than males—this is theorized to be because they spend more time on the nest and can defend from larger predators.
- Raptors require wide-range land to live. Territory generally corresponds with prey abundance. In California;
 - Prairie Falcon, Ferruginous, and Rough-legged Hawk have been positively associated with grasslands.
 - Bald Eagle and Northern Harrier are positively associated with wetlands and rice fields
 - Wetlands provide reliable sources of prey.
 - White tailed kites have been positively associated with wetlands
 - American Kestrel, Northern Harrier, and White tailed Kite are positively associated with alfalfa.
 - “The relatively low and open structure of alfalfa, combined with the fact that it is harvested multiple times per year in this area, may make prey accessible to raptors”
 - All Species are *negatively* associated with urbanized landscapes, orchards, and agriculture fields.

Source: (Pandolfino et. Al 2011)

- Raptor mortality is very high in early stages of life—1/4 of them do not survive their first winter, and only ½ of the remaining birds survive to adulthood. This high mortality rate can be explained by the idea that raptors are “type 2 species,” meaning that they experience medium levels of mortality throughout their entire lifecycle. In addition, harsh conditions high competition, and inability for parents to adequately protect their chicks are another factor that leads to this high mortality (Davit, 2009). The rice fields, grasslands, and wetlands found in the Central Valley provide consistent sources of food, helping raptors survive to reproduce. (Source: Davit 2009)
- Raptor reproduction is highly dependent on energy availability. On average, however, most raptors reproduce slowly, with an average incubation time of 25-60 days, and an average nesting period of 2 months (depending on size—small raptors spend less time in the nest) (USBLM 2015)

Raptor Species in California

- Fully Protected Raptors: Bald Eagle, Golden Eagle, White-tailed Kite, California Condor, Peregrine Falcon
- State Threatened and Endangered Raptors: California Condor, Bald Eagle, Swainson’s Hawk, Elf Owl, Great Grey Owl
- Species of Special Concern: Northern Goshawk, Northern Harrier, Spotted Owl, Burrowing Owl, Short Eared Owl, Long Eared Owl
- Other Species: Northern Spotted Owl, Cooper's Hawk, Sharp-shinned Hawk, Ferruginous Hawk, Osprey, Harris' Hawk, Merlin, Prairie Falcon, Red-tailed

hawk, Red-shouldered hawk, American Kestrel, Broad-winged hawk, Rough-legged hawk, Great-horned owl, Barn owl, Screech owl, Turkey Vulture

Source: US Department Fish and Wildlife:

www.dfg.ca.gov/wildlife/nongame/raptors/

- o Definitions of “Concern.” A species is considered concerned if:
 - o *are extirpated from the state totally or in their primary seasonal or breeding role and were never listed as state threatened or endangered.*
 - o *are listed as federally, but not state, threatened or endangered.*
 - o *meet the state definition of threatened or endangered but have not formally been listed.*
 - o *are experiencing, or formerly experienced, serious (noncyclical) population declines or range retractions (not reversed) that, if continued or resumed, could qualify them for state threatened or endangered status.*
 - o *have naturally small populations exhibiting high susceptibility to risk from any factor(s) that if realized could lead to declines that would qualify them for state threatened or endangered status.*

Source: (Shuford et. Al, 2008)

Abiotic effects on distribution

- Climate Change: Raptors are sensitive to climate—and with the unavoidable climate change and current drought in California; the best way to protect raptors is through restoration policies that adapt to the changing abiotic conditions of the habitat.
 - o Oak woodlands may increase as a result of climate change. However, studies have shown a strong negative correlation between raptors and oak woodlands
 - An exception to this is the Red-Shouldered Hawk, which uses borders between forests and grasslands as its main nesting/ hunting grounds.

Source: (Gardali et. al)

- o In California, 72% of threatened bird species are vulnerable to climate change.
 - They are highly dependent on weather patterns for migration and breeding timing
 - Additionally, loss of water results in degraded prey habitat, resulting in a decrease of available food for raptors.

Anthropogenic factors affecting species distribution/abundance

- Grazing: All raptor species are either indifferent towards grazing, or preferred ungrazed as opposed to grazed grasslands. This has implications on future abundance of raptors, because current expansion will increase the amount of grazed land. (Source: Pandolfino et. Al 2011)

- **Pest Control:** Farmers inadvertently kill off raptors by using pesticides to solve pest problems. Rodents that are poisoned are either slowed or killed, making them easier for birds to hunt them. When they eat these poisoned animals, they may become weakened, paralyzed, or are killed. Barn Owls are especially susceptible to this because they inhabit areas closest to farms where this method may be practiced. Therefore, to make restoration plans, we must work with farmers to develop sustainable management techniques that are safe for raptors.

(Source: Bio-Integral Resource Center—Quarles et. Al 2013)

- **Development:** Land cover in the Central Valley has been urbanized and transformed into agricultural land. Most of the historic wetlands found in the valley (where raptors are found) are no longer there.
 - o Additionally, the remaining wetlands are a “complex mosaic” of habitats. Fragmented habitats negatively affect raptors because their total habitat spaces is reduced and travelling between wetlands will be more difficult due to the fewer number of places it can occupy. This has implications on the importance of corridors that connect wetlands and allow for raptors to travel.
- California has lost 90% of its major wetlands. The remaining habitat is highly scattered.

Potential Restoration Strategies:

- o Designate protected lands—keep them ungrazed, unurbanized, etc.
- o Create corridors that allow raptors to travel between wetland habitats
- o Develop pest control strategies that do not involve poison (Raptors themselves are good at pest control)
- o Enhance survivability of young raptors by focusing restoration efforts on (indirectly) providing food for maturing raptors, especially during winter months.
- o Create more habitat by restoring wetlands in the central valley

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Part 2: Project Goals and Management Plan

A. Goals

The diversity of raptor species in the California Central Valley correlates with the quality and diversity of the ecosystems. Specifically, most raptors habitat selection is dictated by their foraging behavior and thus, the habitat selection of their prey (Cody, 1985). Birds of prey are very mobile predators with acute vision and hearing, sharp talons, and fast flying capability, making small rodents and reptiles prime targets for them. There are various factors types of habitats in the California Central Valley; however, raptors are most commonly associated with wide, open areas such as grasslands, wetlands, marshes, and rice fields. Urban areas and most agricultural lands are not favorable for raptors as they are controlled and do not contain the food supply, nesting sites, and foraging opportunity that they require (Pandolfino et. al 2011). With an increasingly large human population in California, the need for urban space and agricultural land will increase significantly and thus, complete restoration of raptor habitat is not completely possible (Pandolfino et. al, 2011). Rather, the goal of this plan is to provide high quality grassland and wetland habitats that support an abundance of prey species. In order to maintain a balance

between the needs of humans in future generations, raptors, and all other wildlife, efforts will be allocated towards reducing degradation of existing habitats (from invasive species, desertification, agriculture runoff), managing grazing, and strategically planning future agricultural land. In addition to helping the raptor populations stabilize, these management strategies will improve the overall health and biodiversity of the various ecosystems in the Central Valley.

It is important to note that there are various species of raptors that all differ in their habitat preferences. However, there are general preferences that are characteristic of most, if not all raptor species. Discrepancies between species will be addressed in more detail in the following sections.

B. Restoration Plan

a. Reducing degradation of existing habitats

Presence of raptors in the Central Valley varies annually and by rainfall and climate. In a study conducted by Pandolfino et al, presence of wetland-dependent raptors such as White-tailed Kites, Northern Harriers, and Bald Eagles increased in high rainfall years and decreased in low rainfall years. This is most likely due to the increased quality and size of wetlands during these rainy years (Smith, 2011). Because it is impossible to control the climate, there is no direct way to facilitate the presence of wetlands. A common issue with wetland and grassland health is their susceptibility to invasion by tall, fast growing shrubs that dominate the short grasses found naturally. This makes spotting prey difficult for the raptors and causes them to disperse into surrounding areas (Cody, 1985). Therefore, in order to promote the establishment of wetland and grassland dependent raptors, it is important to reestablish native grasses and remove invasive ones. To do this in the California Central Valley, we can induce succession by starting controlled fires to manage the distribution of plant species. However, this method will only be effective in long-term restoration, as it will take a few years following the fire for native species to reestablish (Stromberg et. al, 2007).

An alternate and less costly method for managing habitat is improving the quality of rice fields. In the Central Valley Winter Raptor Survey, density of raptors in wetland habitat was 4.3 birds/km², while in rice fields it was 2.6 birds/km² (Dept. of Fish and Game). This has implications of the importance of rice fields to raptors in the Central Valley. Although rice fields are a slightly less favorable habitat for raptors, they are significantly less costly to create and manage. They also provide direct service that may stimulate the economy of the California (Smith, 2011).

Additionally, it is predicted that generalist raptors that do not currently depend on rice fields for foraging (such as the Northern Harrier and the Red-Tailed Hawk) will adopt the tendency to nest there over time (Smith, 2011). Improving the quality of existing habitats is most likely the most economic and effective method for restoring the raptor population in the future. To do this, I advise implementing buffer zones , and create new rice fields in existing wetland areas. Increasing the amount of rice field habitat for rodents will subsequently increase the presence of raptors at a lower cost than fully restoring wetlands.

b. Managing grazing and erosion

Land cover in the central valley has changed significantly from urban development, agriculture, and grazing. Grazing is a method of feeding herbivores plants in a large

open field; in the case of California, cattle do most of the grazing. Grazing is unique because if properly managed, it can be beneficial to the health and presence of raptors.

Presence in grazed vs. ungrazed areas varied highly by species. Ferruginous Hawks, Rough legged Hawks, and Prairie Falcons all were found in grazed areas, while Northern Harriers and White Tailed Kites were more common in ungrazed areas (Pandolfino et. al). The goal for this restoration plan is to maximize habitat quality by eliminating overgrazing and subsequently, soil erosion. Because there is variation between species in preference of grazing, it is impossible to choose one over another. However, focusing on overgrazing is the most effective strategy because it benefits all raptor species, since none thrive in eroded, desertified habitats (Cody). To improve grazing practices, we will coordinate with cattle ranch owners to explain proper grazing practices. We will do this by calculating appropriate cattle densities based on size of the land, quality of soil, and abundance of grasses. Additionally, we will set guidelines to the ranchers regarding reduction of grazing during drought conditions. Finally, we will determine appropriate distributions of cattle as to prevent localized overgrazing (DEFRA, 2011). Following these methods will improve the availability of properly managed habitat for raptor prey, and thus increasing the probability of raptors establishing in the Central Valley.

c. Strategically planning future agricultural land

It is unrealistic to favor raptor habitat over the agricultural needs of the growing California human population. Most studies show that raptors do not establish in row-crop agricultural land, orchards, and vineyards (Pandolfino et al). Decline in raptor presence can be due to the destruction of over 100,000 hectares of grassland by humans in the past 30 years (Pandolfino 2006). However, strategically designating agricultural land may maximize the presence of raptors while also accommodating for the agricultural needs of the state. Current agricultural land is plotted in large patches that extend for hundreds of miles. Land use is shifting towards harsh, industrial-like crop fields. Our restoration plan will involve coordinating with land use developers to create more passive, evenly distributed, local crop fields. Creating wider spaces between crop fields and allowing for natural vegetation to grow. This vegetation will improve the presence of prey species for raptors, while also creating buffer zones that will prevent soil runoff from infiltrating water systems. In addition, constructing perches and nesting boxes in these “hybrid” agricultural/wetland zones will help facilitate the establishment of raptors who breed during their time in the Central Valley.

C. Monitoring Plan

When determining which restoration goals to implement and when, it is important to monitor raptor distributions, specific prey consumption, density, and nesting behavior. When implementing each method; for example, grazing control, raptors should be observed for several months before and after the new practices are implemented. By doing this, we will be able to observe various species reactions to the new habitat and can determine the effects (both positive and negative) on various raptor species.

When using fire as a method of instilling succession, it is vital to observe the primary stages of the new habitat in order to ensure that the correct species are

sprouting. Fire-controlled habitats should be observed for 3-6 months, or until the native annual grasses have established themselves. In addition, the habitat should continually be observed to compare the presence of different raptor species before and after succession.

Physically observing raptors is done simply by observations. Previous studies have used monthly monitoring periods over a 180km distance to determine raptor distributions (Pandolfino et. al). To determine the effectiveness of these implemented management strategies, we will conduct similar surveys along the central valley and compare the findings to the Central Valley Winter Raptor Survey,

Table 1 Numbers and Densities of Diurnal Raptors Observed during a Study of Habitat Associations in the Central Valley of California, Winter 2007–2010.

Species	Observations	%	Birds/block (×100; mean ± standard error)		
			2007–2008	2008–2009	2009–2010
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	7950	51%	29 ± 1	27 ± 1	34 ± 1
American Kestrel (<i>Falco sparverius</i>)	3622	23%	13 ± 1	13 ± 1	16 ± 1
Northern Harrier (<i>Circus cyaneus</i>)	1396	9.0%	4.9 ± 0.3	4.0 ± 0.3	7.0 ± 0.4
Ferruginous Hawk (<i>Buteo regalis</i>)	630	4.1%	2.4 ± 0.2	2.2 ± 0.2	2.1 ± 0.2
White-tailed Kite (<i>Elanus leucurus</i>)	468	3.0%	1.8 ± 0.2	1.5 ± 0.2	1.8 ± 0.2
Red-shouldered Hawk ^a (<i>Buteo lineatus</i>)	444	2.9%	—	—	—
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	276	1.8%	1.0 ± 0.2	0.9 ± 0.1	1.0 ± 0.1
Prairie Falcon (<i>Falco mexicanus</i>)	232	1.5%	0.7 ± 0.1	0.9 ± 0.1	0.7 ± 0.1
Accipiter spp. ^a	144	0.9%	—	—	—
Rough-legged Hawk (<i>Buteo lagopus</i>)	143	0.9%	0.8 ± 0.1	0.5 ± 0.1	0.06 ± 0.03
Golden Eagle ^b (<i>Aquila chrysaetos</i>)	95	0.6%	—	—	—
Merlin ^b (<i>Falco columbarius</i>)	80	0.5%	—	—	—
Peregrine Falcon ^b (<i>Falco peregrinus</i>)	33	0.2%	—	—	—
Osprey ^b (<i>Pandion haliaetus</i>)	33	0.2%	—	—	—

^aExcluded from analyses because of strong association with woodlands, making consistent detection difficult.

^bExcluded from analyses because of low numbers.

as shown below.

Source: California Winter Raptor Survey, Pandolfino 2011.

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Waterfowl in small (and seasonal) wetlands (e.g. ducks, geese)

Minette Plaza

Part 1: Project Background and Justification

Below is a listing of the various species of waterfowl (Order Anseriformes, Family Anatidae) that occur in California based on relevant habitat types that could occur at our restoration site. Species are listed by both their common names and scientific names. Some species may be listed more than once if they occur in more than one habitat type. All information was obtained from the UC Davis WFC 111 Lab Manual created by John Eadie and colleagues.

Freshwater Marsh Species

Dendrocygninae (Whistling Ducks)

Fulvous Whistling-Duck *Dendrocygna bicolor*

Anserini (Geese)

Ross's Goose

Chen rossii

Snow Goose

Chen caerulescens

Canada Goose

Branta canadensis

Cackling Goose *Branta hutchinsii*

Cygnini (Swans)

Tundra Swan

Cygnus columbianus

Anatini (Dabbling Ducks)

Wood Duck

Aix sponsa

Mallard

Anas platyrhynchos

Gadwall

Anas strepera

Northern Pintail

Anas acuta

American Wigeon

Anas americana

Northern Shoveler

Anas clypeata

Cinnamon Teal

Anas cyanoptera

Blue-winged Teal

Anas discors
Green-winged Teal
Anas crecca

Aythya (Diving Ducks)

Ring-necked Duck
Aythya collaris
Redhead
Aythya americana

Oxyurini (Stiff-tailed Ducks)

Ruddy Duck
Oxyura jamaicensis

Agricultural Field Species

Anserini (Geese)

Greater White-fronted Goose *Anser albifrons*
Ross's Goose
Chen rossii
Snow Goose
Chen caerulescens
Canada Goose
Branta Canadensis
Cackling Goose
Branta hutchinsii

Cygnini (Swans)

Tundra Swan
Cygnus columbianus

Anatini (Dabbling Ducks)

Mallard
Anas platyrhynchos
Gadwall
Anas strepera
Northern Pintail
Anas acuta
American Wigeon
Anas americana
Northern Shoveler
Anas clypeata
Blue-winged Teal
Anas discors
Green-winged Teal
Anas crecca

Mudflat Species

Anserini (Geese)

Brant

Branta bernicla

Pond Species

Cygnini (Swans)

Tundra Swan

Cygnus columbianus

Anatini (Dabbling Ducks)

Mallard

Anas platyrhynchos

Gadwall

Anas strepera

American Wigeon

Anas americana

Northern Shoveler

Anas clypeata

Blue-winged Teal

Anas discors

Green-winged Teal

Anas crecca

Mergini (Sea Ducks)

Bufflehead

Bucephala albeola

Hooded Merganser

Lophodytes cucullatus

Riparian Woodland Species

Anatini (Dabbling Ducks)

Wood Duck *Aix sponsa*

Part 1: Project Background and Justification

A. Background and Justification

Waterfowl are considered by many to be extremely charismatic species worthy of protecting. Whether it is hunters or birdwatchers, waterfowl continually attract the attention of many people.

Waterfowl conservation has been prominent in California for a long time, and presumably will continue to be in the foreseeable future.

The wetlands in the Central Valley of California have experienced a 94% loss from historic numbers (Euliss 1991). The primary reason for such high losses has been draining wetlands for irrigation of agriculture (Euliss 1991). In the past, when wetland habitats were still abundant, waterfowl dominated the landscape (Euliss 1991). However, in present times waterfowl in the Central Valley are mostly constrained to habitats constructed by duck clubs, wildlife refuges, flooded agricultural fields, and evaporation ponds (Euliss 1991).

There are several threats and concerns for waterfowl, including: water quality, disease, and competition with fish. In the San Joaquin Valley water quality is generally considered satisfactory. However, there may be some problems with salinity due to decreased flows during drought times (Gilmer 1982). The Central Valley of California has a long and extensive history of agriculture, consequently, the use of pesticides and other potential contaminants is rampant. This may be a concern for waterfowl (Gilmer 1982). High selenium has been connected to embryonic mortality and deformity (Euliss 1991). High levels of CaCO_3 has also been shown to cause deterioration of the feathers of some species (Euliss 1991). Lead poisoning has led to three to ten percent of all waterfowl mortality observed during sampling by the U.S. Fish and Wildlife Service and the California Department of Fish and Wildlife (Gilmer 1982). Botulism outbreaks have led to the death of over two hundred and fifty thousand waterfowl in some years. (Gilmer 1982) Avian cholera outbreaks have led to the death of over seventy thousand waterfowl over a year's winter. (Gilmer 1982) Non native fish change aquatic community structure, nutrient profiles, and modify food webs in a way that is often detrimental to waterfowl. (Bouffard 1997) Non native and native fish compete with waterfowl for invertebrate food sources. (Bouffard 1997)

With such high habitat losses, current low habitat quality, and many threats facing waterfowl, it is imperative to improve and maintain the remaining habitat in California. In addition, the Central Valley of California is considered an important overwintering ground for many waterfowl species (Fleskes 2007). Overwintering and migration stopover sites are critical to maintain for the well

being of a species and if this habitat is degraded it can lead to huge losses. Currently, there are no endangered or threatened waterfowl species in California (Eadie 2014). However, there are some species with special considerations that should be taken into account for their conservation (Eadie 2014).

B. Literature Review

Habitat Type and Seasonality for Waterfowl Occurring in California

Common Name	Latin Name	Habitat Type(s)*	Seasons in CA	Other notes
Fulvous Whistling-Duck	<i>Dendrocygna bicolor</i>	FM	year round	CA species of Special Concern
Snow Goose	<i>Chen caerulescens</i>	FM, AG	winter	
Ross's Goose	<i>Chen rossii</i>	FM, AG	winter	
Brant	<i>Branta bernicla</i>	M	winter	vulnerable to starvation
Cackling Goose	<i>Branta hutchinsii</i>	FM, R, AG	winter	
Canada Goose	<i>Branta canadensis</i>	FM, R, AG	winter	
Tundra Swan	<i>Cygnus columbianus</i>	FM, P, R, AG	winter	declines in vegetation in historic wintering grounds
Wood Duck	<i>Aix sponsa</i>	FM, RW	year round	cavity nester
Gadwall	<i>Anas strepera</i>	L, P, FM, BM, AG	year round	
American Wigeon	<i>Anas americana</i>	FM, R, P, AG	winter	
Mallard	<i>Anas platyrhynchos</i>	FM, P, AG	year round	
Blue-winged Teal	<i>Anas discors</i>	FM, P, AG	winter	

Cinnamon Teal	<i>Anas cyanoptera</i>	FM	year round	
Northern Shoveler	<i>Anas clypeata</i>	FM, P, AG	year round	
Northern Pintail	<i>Anas acuta</i>	FM, AG	year round	
Green-winged Teal	<i>Anas crecca</i>	FM, P, AG	winter	
Redhead	<i>Aythya americana</i>	FM	year round	intra and inter specific egg parasitism common
Ring-necked Duck	<i>Aythya collaris</i>	FM	winter	
Bufflehead	<i>Bucephala albeola</i>	P	winter	cavity nester
Hooded Merganser	<i>Lophodytes cucullatus</i>	P	winter	
Greater White-fronted Goose	<i>Anser albifrons</i>	AG	winter	

***Habitat type abbreviations:** FM = freshwater marsh, AG = agricultural fields, , M = mudflat, P = pond, R = riparian woodland

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Part 2: Project Goals and Management Plan

Waterfowl in Small Wetlands

A. Key Goals & Feasibility

i. Key Goals

- Manage for a wide array of small wetland waterfowl species including (Eadie 2014):
 - o Gesse (Anserini)
 - Greater White-fronted Goose (*Anser albifrons*)
 - Ross's Goose (*Chen rossii*)
 - Snow Goose (*Chen caerulescens*)
 - Canada Goose (*Branta Canadensis*)
 - Cackling Goose (*Branta hutchinsii*)
 - Brant (*Branta bernicla*)
 - o Swans (Cygini)
 - Tundra Swan (*Cygnus columbianus*)
 - o Ducks
 - Dabbling Ducks (Anatini)
 - Mallard (*Anas platyrhynchos*)
 - Gadwall (*Anas strepera*)
 - Northern Pintail (*Anas acuta*)
 - American Wigeon (*Anas americana*)
 - Northern Shoveler (*Anas clypeata*)
 - Cinnamon Teal (*Anas cyanoptera*)
 - Blue-winged Teal (*Anas discors*)
 - Green-winged Teal (*Anas crecca*)
 - Wood Duck (*Aix sponsa*)
 - Sea Ducks (Mergini)
 - Bufflehead (*Bucephala albeola*)
 - Hooded Merganser (*Lophodytes cucullatus*)
 - Whistling Ducks (Dendrocygninae)
 - Fulvous Whistling Duck (*Dendrocygna bicolor*)
 - Diving Ducks (Aythyini)
 - Ring-necked Duck (*Aythya collaris*)
 - Redhead (*Aythya americana*)
- Improve habitat, focusing on a multitude of aspects including:
 - o Water quality (Gilmer 1982)
 - o Water depth (Isola 2000)

- o Food resources (Gilmer 1982)
- o Cover resources (Gilmer 1982)
- Alleviate and/or reduce possible threats to waterfowl success including:
 - o Diseases (Gilmer 1982)
 - Botulism
 - Avian Cholera
 - o Fish (Bouffard 1997)
 - Non-natives
 - Natives

ii. Feasibility

- Potential
 - o It may prove to be difficult to manage for such a wide array of waterfowl species with a relatively small area to work with. However, several approaches can be employed to enhance the area for the most species possible. This will be discussed further in the specifics of the restoration plan.
 - o It may be increasingly difficult to ensure that the water depth needs of waterfowl can be consistently managed for with the mounting drought problem in California. In addition, climate change will only exacerbate water issues in the state over time. (Gilmer 1982)
 - o Agricultural practices introduce high levels of contaminants into the water systems of the Central Valley of California. In the future, pesticide application and the demand for agricultural products will probably only increase further.
- Tradeoffs, feedbacks, interactions and thresholds
 - o There seems to be a tradeoff in depth of the water and which species are supported. Some species require deeper water while others require more shallow water. (Isola 2000)
 - o Increasing the number and density of waterfowl also increases the probability of spreading avian diseases. (Gilmer 1982)
 - o Decreasing fish populations reduces competition with some waterfowl species, but for other species fish may be a necessary food source. (Bouffard 1997)
 - o Fish compete with waterfowl, but many fish species in the Central Valley are also imperiled. There may be a tradeoff between fish conservation and waterfowl conservation. (Bouffard 1997)

B. Restoration Plan

i. Management Actions

- Habitat
 - o Water quality
 - Need to monitor salinity, selenium, CaCO_3 , and lead levels.

- It is difficult to define what levels of pesticides, selenium, salinity, CaCO_3 and lead are acceptable for all species of waterfowl.
- If salinity or other contaminants become a problem at the site, neighboring freshwater habitats can be created to help decrease waterfowl exposure (Euliss 1991). If this is not a possibility, water depths of greater than two meters can be temporarily put into place to keep waterfowl from using the habitat if it will only be detrimental to their health (Euliss 1991).
- o Water depth
 - Different species of waterfowl require different water depths.
 - Teals require shallow waters, around 13 cm.
 - Pintails require mid-level waters, around 10-20 cm.
 - Gadwalls require deep waters, greater than 20 cm.
 - Foraging species require a large range of depths.
 - In January, increase shallow water habitat by conducting partial drawdowns or slow drawdowns of water (less than two weeks). This will benefit wintering waterfowl populations that require shallow water habitats by increasing the abundance of shallow water. It may also assist winter germinating plants. (Isola 2000)
 - Shallow water is defined as 10-15 cm. (Isola 2000)
 - In late winter deep water habitat is already abundant across the landscape, so it is not as necessary to promote it. Shallow habitats are much rarer during this time and are needed for many species to thrive. (Isola 2000)
 - Shallow inlets expand production of submersed and emerged vegetation. (Rumble 1983)
 - o Submersed vegetation of 0-61 cm is ideal.
 - o Some ideal vegetation include:
Potamogeton and *Myriophyllum*.
 - In winter and spring, average depths of 15-20 cm should be maintained if the site has variable bottom topography. (Isola 2000)
 - This would deliver a spectrum of water depths, allowing many species with different depth preferences to coexist at once. (Isola 2000)
 - Water depth Problems, Risks and Uncertainties
 - With the drought problem and climate change continuing to worsen, it may prove to be a difficult task maintaining adequate water needs. (Gilmer 1982)

- It is unclear as to whether the site has a variable bottom topography or not. If it doesn't, it may be harder to achieve a spectrum of water depths.
- o Food resources
 - Protein rich invertebrates are especially necessary during reproduction and feather molting periods, around September and March (Euliss 1991).
 - Some examples of ideal invertebrates include: midge larvae, waterboatmen, copepods, rotifers, and brine fly larvae.
 - Plant seeds seem to be of greater importance during the winter months. Low availability of seeds during this time can significantly decrease the usage of the habitat by waterfowl. (Euliss 1991)
 - Most species of waterfowl are present during the winter months, so this is an extremely important time for management.
 - Some examples of plant seeds that are ideal include: alkali weed seeds, clover fern sporocarps, fescue caryopses, and widgeongrass nutlets. (Euliss 1999)
 - Food Resources Problems, Risks and Uncertainties
 - It is not obvious what density of invertebrates and grains are suitable to sustain an acceptable amount of waterfowl.
- o Cover resources
 - Leave grain stubble in fields after peak nesting period to provide nesting cover. (Rumble 1983)
 - Wheat stubble 10-15 cm in height from previous fall has shown to be effective. Flooding the stubble increases invertebrate reproduction. (Rumble 1983)
 - Plowing should not occur until mid July. (Rumble 1983)
 - Provide shallow inlets of 0-61 cm for immersed vegetation to thrive. (Rumble 1983)
 - Trees lining the shoreline lead to decreased broods, so planting along the shoreline should be avoided. (Rumble 1983)
- Threats
 - o Diseases
 - Botulism and avian cholera
 - These devastating diseases can be reduced by diminishing overcrowding of waterfowl. (Gilmer 1982)
 - o It is not apparent at which density of waterfowl overcrowding becomes an

issue in terms of facilitating disease spread.

- Any carcasses found with the diseases should be incinerated. Water should be immediately diluted if the disease(s) show up at the site. (Friend 1989)

o Fish

▪ Non-natives

- Introduction of non natives is not advised. (Bouffard 1997)
- Non natives should be removed if present at the site.

▪ Natives

- Stocking of native fishes is also not advised unless completely necessary to increase prey for fish eating species. (Bouffard 1997)
- Planktivorous natives that compete with waterfowl for invertebrate food items should be removed from the site. The worst offenders are largemouth bass, rainbow trout and perch. (Bouffard 1997)

- o Planktivorous fish can be reduced by stocking the waters with piscivorous fish, whose diet does not overlap with waterfowl.

▪ Fish Problem, Risks and Uncertainties

- Since many native fish species are endangered or threatened, it may be necessary to keep them in the landscape even though they may potentially compete with waterfowl for food resources.
- If non native fish are present at the site, it may be extremely difficult and costly to remove them.

C. Monitoring Plan

i. Monitoring Techniques

• Habitat

o Water quality

- Before beginning the restoration project the following need to be examined:
 - Pesticide levels (Gilmer 1982)
 - Salinity levels (Gilmer 1982)
 - Selenium levels (Euliss 1991)
 - CaCO₃ levels (Euliss 1991)
 - Lead levels (Gilmer 1982)
- Throughout the duration of the project (if funding is available) it is advised that these parameters continue to be monitored.

o Water depth

- Before beginning the restoration project the bottom of the water bodies should be surveyed to see if they have a

- variable bottom topography (Isola 2000). If they do not, perhaps an artificial one should be created.
 - Amounts of shallow water habitat and deep water habitat should be recorded and monitored throughout the duration of the project to ensure that appropriate amounts of each are maintained. (Isola 2000)
 - Amounts of shallow water habitat should increase during the winter months, and if they do not, water should be diverted from the project site to create it. (Isola 2000)
- o Food resources
 - During the molting and breeding seasons invertebrate populations should be sampled to ensure that density is high enough to support the high protein needs of waterfowl during this time. (Euliss 1991)
 - During the winter months, grain producing plants should be sampled to ensure that there are enough grains being produced to support potential waterfowl populations. (Euliss 1991)
- o Cover resources
 - The number of shallow inlets with immersed and submerged vegetation should be recorded and maintained throughout the duration of the project. This is especially important during the breeding season. (Rumble 1983)
- Threats
 - o Diseases
 - Every year during peak crowding, typically in winter months, the restoration site should be evaluated to see if avian cholera or botulism are spreading. This can be done by examining the cause of mortality of a sample of waterfowl. If deaths exceed ten percent, there is a problem. (Gilmer 1982)
 - If it is determined that there is a problem, it should be examined as to what the root of the problem is.
 - If it is overcrowding, measures should be taken to reduce overcrowding (Gilmer 1982). This could potentially be done by allowing hunting.
 - If it is water quality, measures should be taken to increase water quality. This could be achieved by increasing water depth (Euliss 1991).
 - o Fish
 - Before beginning the restoration project, the species and density of fish in the restoration site should be cataloged.
 - The density of fish should be maintained at a low enough level so that there is not sufficient competition with waterfowl for food resources. (Bouffard 1997)

- The amount of competition can also be inferred from the invertebrate sampling. As long as invertebrate numbers stay high enough for waterfowl, competition with fish should not be seen as a problem. (Bouffard 1997)

ii. Research Questions

1. Questions Needed to Improve the Plan

- Habitat
 - o Water quality
 - What levels of selenium, salinity, CaCO_3 and salinity are acceptable for such a wide variety of waterfowl species? Which species are the most sensitive and which are the most hardy?
 - o Water depth
 - Does the site have a variable bottom topography?
 - o Food resources
 - What density of grains and invertebrates are considered enough to support a certain number of waterfowl? Does this change during different seasons?
 - o Cover resources
 - How much cover is needed to maintain a viable community of waterfowl of many species? Do different species require or prefer different kinds of cover?
- Threats
 - o Diseases
 - At what density does overcrowding of waterfowl facilitate spread of avian cholera and botulism? What other factors might help spread the disease?

2. Potential Questions to be Answered by the Restoration Project

- How might climate change and the drought effect water quality in the Central Valley of California?
 - o Measure how the water quality changes over time.
 - o Measure salinity, pesticide levels, CaCO_3 and selenium levels over time.
 - o This would just be a correlational study, it wouldn't show a cause and effect relationship.

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Potential for use of bird boxes (e.g. bluebirds, owls, etc.)

Evanne Harrison

Part 1: Project Background and Justification

Background and Justification

North America is home to thousands of bird species that have a great variety of habitat requirements. Approximately eighty-five species found across the United States are cavity nesters, half of which will use artificial nest boxes (Berger, 2008). With increasing rates of habitat degradation for urban development and agricultural expansion, many natural cavity sites have been lost. The removal of old trees and thinning of forested areas seriously reduces the number of suitable cavities, especially for secondary cavity-nesters who rely on pre-existing holes to create nests (Berthier et al, 2012). In intact sites management of existing old growth flora can be effective for conservation of these species. However, many sites require supplementation of artificial cavities until natural resources can be restored, and may be necessary as a long term management strategy in sites where forests cannot be fully recovered (Berthier et al, 2012). In the California Central Valley at least eighteen bird species are known to effectively use nest boxes (Sterling, 2010). Three of these species are classified as California Species of Special Concern and multiple are considered rare or have been declining in the area over the past fifteen years (Sterling, 2010). Providing nest sites for these species could encourage repopulation and help aid in reducing risk to those species of particular concern. Additionally, providing artificial cavity sites can be an opportunity to conduct both comparative and experimental studies on previously inaccessible species (Lambrechts, 2012).

Literature Review

Types of bird boxes

House Wren

- House Wrens are very receptive to nest boxes and will willingly use them when provided in suitable habitat (Berger, 2008).
- House Wrens are highly associated with woodland habitat and preferentially choose nest sites within 100 feet of open woody vegetation (Johnson, 1998).
- Box requirements: 4" x 4" or 4" x 6" base, 8" high; hole: 1-1/8", centered 6" above the floor; color: earth tone; placement: 5-10' high on post or hanging in a tree (Berger, 2008).

Wood Duck

- Wood Ducks are obligate secondary cavity nesters and typically nest in the cavities formed in trees after losing a branch (Hepp, 1995).
- Wood Ducks are typically found in riparian habitat along streams and rivers but can also occur in wetlands and forest area as much as 1.2 miles from water (Hepp, 1995).
- Wood Ducks exhibit site fidelity and will return to the same nesting site each year and will often occupy the same nest box if it is available (USDA, 1999).
- Density of nest boxes in an area can effect the occurrence of 'dump nesting' and brood parasitism and there fore spacing should be considered. In dense vegetation boxes can be as close as thirty feet apart, while for open habitat with high visibility boxes should be placed approximately 150 feet apart (Semel, 1995).
- Boxes with high predation risk should be supplemented with cone shaped predator shields to deter potential nest predation (USDA, 2004)
- Box requirements: 10" x 10" x 24" high; hole: 4" wide x 3" high (elliptical), centered 20" above the floor; color: earth tone; placement: on a post 3-5' feet above open water or on a tree 12-40' high near water; nesting material: 3-4" of wood shavings on the floor of the house



Images from USFWS. gov

Bluebirds (Western Bluebird and Mountain Bluebird)

- Both the Western and Mountain Bluebird will use artificial nest boxes when provided (Berger, 2008) and may use boxes designed for other birds such as the Violet-green Swallow (NestWatch 2011).
- Both bluebird species collect materials such as grass and twigs to build insulated cup nests within nest boxes (Guinan, 2000).
- When choosing a box, birds select sites facing northwest (variable depending on latitude), and sites with lower vegetation height (Navara, 2011).
- Box requirements: 5-1/2" x 5-1/2" x 10" high; hole: 1-1/2", centered 6" above the floor; color: earth tone; placement: 5-10' on post facing open field (preferring east, north, south, and then west facing directions) (Berger, 2008).



Images from USDA.gov

Woodpeckers (Downy Woodpecker, Acorn Woodpecker and Northern Flicker)

- Downy and Acorn Woodpecker box requirement: 4" x 4" x 10" high; hole: 1-1/4", centered 6-8" above the floor; placement: 8-20' high on tree trunk; nesting material: 4" of wood shavings on floor (Berger, 2008).
- Northern Flickers prefer habitat with sparsely scattered trees for better visibility (Berger, 2008).
- Northern Flicker boxes should be mounted so that they are angled forward slightly so chicks can more easily climb out (NestWatch, 2011).
- Northern Flicker box requirement: 7" x 7" x 18" high; hole: 2-1/2", centered 14" above the floor; color: natural; placement: 8-20' high on tree trunk; nesting material: 4" of wood shavings on floor (Berger, 2008).

Chickadees (Mountain Chickadee, Chestnut-backed Chickadee, and Oak Titmouse)

- All Chickadees and related species will use artificial nest boxes and most prefer semi-wooded habitat such as small stands of trees with the exception of Mountain Chickadees which prefer coniferous forest (NestWatch, 2011).
- Box requirements: 4" x 4" or 5" x 5" base x 8" high; hole: 1-1/4", centered 6" above the floor; color: earth tone; placement: 4-8' high in small tree thicket (Berger, 2008).

Swallows (Purple Martin, Barn Swallow, Tree Swallow, Violet-green Swallow)

- Most Swallow species nest between May and August with the Purple Martin nesting as early as mid-April (NestWatch, 2011).
- Box requirement: multiple apartments 6" x 6" x 6" each; 2-1/2" hole, 2-1/4" above floor; color: white; placement: 15-20' high (Berger, 2008).
- Purple Martins are colony-nesters and prefer boxes with multiple compartments or many cavities made from gourdes hung close together (NestWatch, 2011). They also prefer open habitat near or over water (Berger, 2008). The dimension for this species are as follows: floor should measure at least 6"x6," but 7" x 12" offers better protection. Compartment height can be from 5" to 7" high, entrance holes with diameter 2-1/8" placed 1" above the floor (Purplemartin.org)

- Barn Swallows prefer boxes mounted on buildings under awnings and must have a source of mud close by (NestWatch, 2011).
- Tree Swallow and Violet-green Swallow box requirements: These species have the same dimensional requirement as bluebirds but prefer boxes placed in a location near water (Berger, 2008). Fledglings also benefit from a fledgling ladder (series of cuts or fabric pieces leading to the entrance hole for leaving the box (NestWatch, 2011).



Images from USFWS.gov

Owls (Barn Owl, Western Screech Owl)

- Barn Owls and Western Screech Owls will use most boxes that they can fit in for nesting and are not selective about box placement, so will use boxes placed on poles, in trees or even inside barn walls (Lambrechts, 2011).
- Boxes should be in place by January in time for the late March-Early June Screech Owl nesting season, but remain year round for roosting and to accommodate the longer Barn Owl nesting period (NestWatch, 2011).
- Barn Owls can often be found using Wood Duck nest boxes as they are a good size and can commonly found in overlapping habitat (USDA, 2004).
- Box requirements: 26" x 21" top, 24" x 18" front with a 7" x 10" cutout entrance, 18" x 18" x 15" front sloping sides; inside wall to provide separate compartment; placement: 20-40' high in tree; colored dark green, brown, or black; filled with shavings or woodchips (California Raptor Center, 1992).



Burrowing Owl

- Burrowing Owls require nesting sites with at least two-three burrows spaced at least fifteen feet apart. Burrow sites should be grouped into

clusters that are spread 300 feet apart to minimize territorial effects (USDA, 2004).

- Burrows should be designed with two entrances to provide quick means of escape and reentry to avoid predation (USDA, 2004).
- Burrow dimensions: Plastic irrigation valve box, 48 cm long x 35 cm high (15" x 21" inside dimensions), Removable lid, Ca. 2m of 10cm (4") diameter perforated flexible plastic pipe, 20 x 20 x 15 cm (or 6" square) hollow concrete block, 0.5 m (2') perch post, plunger constructed of 10 foot long (½ in.) diameter PVC schedule 40 pipe, with large sponge attached to ends by duct tape. (USDA, 2004). (Specific burrow system plans can be found on the 'Nest Structures' NRCS Conservation Practice Sheet No. 734, March 2013).



Image from USDA.gov

American Kestrel

- American Kestrel box dimensions should resemble that of a Wood Duck box, but must contain ventilation holes as they are placed in more open areas (USDA 1993).
- Boxes may be placed on road signs or posts along highways in open areas of high visibility (NestWatch, 2011).
- Providing perches such as artificial tree snags can increase Kestrel area use (USDA, 1993).

Potential management issues

- European Starling use of nest boxes can interfere with native species use and can result in local population declines (NestWatch, 2011). This becomes an issue in managed habitat with increased "edge" where invasive species are more prevalent.
- Population densities can reach unnatural levels if box placement is not adequately mapped out. High population densities can lead to population decreases or reduced survival due to increased brood parasitism, territoriality, and reduction of resources (Twedt, 2001).
- Nest boxes are often used to supplement sites where natural cavities have been removed. Often this results in an overlap between restoration sites and urban development and often entails degraded habitat. Predation risk by feral cats and foxes on fledglings using nest boxes are higher in urban forests that do not have adequate cover (Jackson, 2013) and management of park lands can result in reduced forest density and thus prevent adequate cover.

- There are many potential issues such as the risk from controlled burns, the effect of checking and monitoring nest boxes of survival, and the implications of restored vs. reconciled, vs. natural habitat on fitness that are not explicitly discussed in the scientific literature but should be considered

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Part 2: Project Goals and Management Plan

In order to provide a diverse and historically representative community of cavity nesting birds at this site, a supplementation of artificial nest boxes, in place of natural cavities, is necessary to encourage the breeding and nesting of desired native species. Nest boxes should be erected and managed so as to satisfy the specific needs of each target species and

Goals

Goal	Time Scale	Description
Survey to determine existing species	Short	Determine which species are present at the site and local surrounding area. If possible obtain estimates on population size and density.
Establish complex and heterogeneous habitats to sustain a greater diversity of species	Short and long	Restoration site should have sustainable and diverse communities than can support the various bird species long term. Areas should have different flora composition and tree densities to support the most species (Purcell, 2008)
Establish nesting populations of special concern species and sustain at desired levels (Altman, 2012)	Long	Provide nest boxes for species of special concern in the Central Valley; including the Burrowing Owl and the Purple Martin, and the locally rare Mountain and Chestnut-backed Chickadees. Nesting density should be gauged based on long-term sustainable population goals or need for population increase (Sterling, nd).
Encourage a diverse community structure of native cavity nesting birds	Long	If site is unable to support populations of special concern species, instead provide nest boxes for species of least concern, such as wood ducks, kestrels, and woodpeckers to encourage site diversity

Reduce occurrence of invasive species	Short and long	Remove invasive nest parasites, such as European starlings, and predators, such as feral cats. Also, prevent re-invasion through maintaining a strong presence of native species
Manage site habitat for long term recovery of natural cavities	Long	Encourage growth and continued preservation of woodlands so that natural cavities can form. Manage populations of native fossorial rodents to increase year-round availability of natural burrows for burrowing owls.

Loss and reduced presence of cavity nesting bird species in the California central valley is mainly due to the loss of habitat through agriculture and development. To encourage re-colonization of these species, restoration actions must ensure that habitat is close enough to historic conditions to support the species long term. Year round management will be required as the use of artificial nest boxes is not a self-sustaining management strategy. In the long term, management may be reduced if natural cavities become more prevalent in the region.

Canopy/Sub-Canopy	Shrub/Midstory	Ground/Shrub

Management Plan

1. Identify appropriate habitats

To avoid use of nest boxes by invasive and non-native species it is necessary to place boxes in the appropriate habitat for the target species (Purcel, 2008). Acceptable habitat should follow the basic guidelines described in Part I. Surveys should be conducted prior to nest box erection to determine which species the site can support and what further restoration should be attempted. The primary habitat structure used by a variety of cavity nesting birds is outlined below as a general guideline for the determination of suitable sites. More specific requirements such as species tree preference and tree densities should also be considered when selecting appropriate sites.

Acorn Woodpecker		
Black-capped Chickadee		
		Burrowing Owl
Downey Woodpecker		
	House Wren	
Oak Titmouse		
		Western Bluebird
Wood Duck		
	Purple Martin	

(Altman,
2012)

2. Erect boxes for target species

To restore the site to close-to-normal conditions, nest boxes targeting locally rare and special concern species should be constructed. In the California Central Valley there are two species that are considered to be of special concern, burrowing owls and Purple Martins, and two species that have shifted out of their historical ranges due to disturbance, the Chestnut-backed and Mountain Chickadee (Sterling, nd). To restore these species to a sustainable population density the following should be considered

a. Purple Martin

Purple Martin nest boxes should be set up in large open spaces with low tree density so that there are no trees within 40 feet of the box (purplemartin.org). Box dimension should follow the specifications laid out in Part 1. Boxes should be set up for high density to have better chances of attracting birds to the site. A combination of hanging gourdes and houses will also help to increase attractiveness of the site (purplemartin.org). Timing of box availability is also important. Boxes should be open by March 15th to attract sub adult martins that do not yet have site fidelity for breeding ground choice (purplemartin.org). Boxes should not be opened before this time in order to reduce risk of nesting by non-native species.

b. Burrowing Owl

Burrowing owl artificial burrows should be set up in dry open areas with short, mowed grasses and little to no tree cover (Western, 2006). Burrow sites can occur along edges of restoration site in vacant lots or near agriculture in ruderal habitats as long as disturbance is prevented during the nesting season (Western, 2006). Burrow sites should also be maintained through mowing or grazing to keep grass short. Additionally, long-term strategies should include management of fossorial mammal species such as gophers and ground squirrels. These species produce natural burrows that can be used by the owls and are an important natural habitat facilitator for burrowing owls to maintain a year round presence (Sheffield, 1997). Artificial burrows should be set up at a medium- high density to encourage nesting by more individuals. In the future if

population is less vulnerable, reduction in density could be considered, especially if more natural burrows are available.

c. Chickadees

Chestnut-backed chickadees prefer a partial to full canopy cover or either riparian or oak woodland (Altman, 2012). Nest boxes should be placed at medium density intervals to encourage repopulation of chickadees in the area. Long-term management should focus on the recovery of old growth forest with naturally occurring cavities (from branch rot) so that nest box supplementation can be reduced (Altman 2012). Mountain chickadees are likely not suitable for this site as they require large stands of coniferous forest for nesting.

3. Erect boxes for popular species

An alternate management method is to provide boxes to the abundant, least concern species that recreational users of the site will enjoy seeing. This method can either be used in place of section two or as an additional supplement to increase diversity at the sight. By providing nest boxes for charismatic species such as Wood Ducks, American Kestrels and Woodpeckers complexity of the community is increased and the community as a whole is made more diverse (Purcell, 2008). This is an important management method for ensuring there is public support for the project as it is both a restoration and recreational area. As a restoration area this site provides the community service of being a natural reserve (NAWMP, 2012). Having natural areas is important for cultural reasons such as aesthetics, education, and providing scientific and spiritual areas. Restoration sites can also reduce what has become known as “nature deficit disorder” by providing an educational area for adults and children alike to interact with nature (NAWMP, 2012). For management using this focus, the goal is to attract species that are still abundant in surrounding areas by providing additional habitat. This is less difficult than trying to encourage reintroductions and box placement is less specific. Boxes should be placed according to habitat types notes in Part 1 and specific box dimensions should be followed. Boxes should be set up in a low density layout to avoid potential downsides of having unnaturally high breeding densities (USGS, 1999).

4. Potential Problems

- a. If managing for community composition, box density must be considered. While high density sites allow for a greater number of nesting individuals, if population densities that are too high the population can experience detrimental interactions such as Wood duck brood parasitism (NAWMP, 2012) and increased spread of disease and an un-proportional loss of individuals following a major disturbance.
- b. Management of both American Kestrels and Burrowing Owls can lead to possible direct competition for food as both have similar foraging strategies. Also there could be indirect competition from Kestrels

eating burrowing animals that provide natural nest sites for the owls (Sheffield, 1997).

- c. Purple martins may be in competition with native tree swallows and bluebirds as they use the same size and type of nest box (purplemartin.org). This can be managed for by closing the box that the other species is attempting to use, and setting up additional boxes with that species preferred dimensions elsewhere at the site (purplemartin.org)
- d. Use of boxes by non-native species is a common issue that can be reduced through careful nest box placement. Box entries can also be modified to exclude certain invasives such as the European Starling. Also non-native species can be trapped and removed from nests when found to prevent harm to the native species.

5. Uncertainty

- The specific densities that the site can support are unknown and may require referencing historical records or conducting a survey to determine the optimal population size for target species
- The effect on the community of managing a specific subset of species. Monitoring for a small subset of species could result in competition with non-cavity nesters for limited resources (Purcell, 2008)
- The effect of differing box densities on population dynamics

Monitoring Plan

Prior to implementation of the management plan, preliminary monitoring should be done to collect data on the site to ensure that box locations are optimal and that box use will be maximized (USGS, 1999). Surveys to determine what species are present at the site and information on the historical community structure will be useful in determining which goal should be emphasized.

Following erection of the nest boxes, a consistent monitoring schedule should be followed to ensure both short and long term success and effectiveness of the management plan (Sheffield 1997). For the first two years during the breeding season, typically spring-early summer, boxes should be checked every two days to determine if boxes are being utilized by the target species. If box use appears to be successful, further monitoring reduced to weekly checks during the target species' breeding season should be maintained (purplemartin.org). These checks should be used to determine if boxes are attracting the desired species, whether excess predation is occurring, and to detect invasive species. Early detection and resolution of problems is key to ensuring success. Monitoring once a known nesting population exists should be carried out as follows (USFWS, 1999)

- January-February: Preseason check

- o Boxes removed from storage or unblocked. Boxes should be cleaned
- Mid-April- early June : Midseason Check
 - o Regular, weekly checks to monitor activity
- July-August: End of seasons check
 - o Boxes should be cleaned and either stored or closed off until spring.

If a problem does arise, such as an invasive species nesting in a box, short-term actions should be taken to remove the immediate risk. In the case of invasive species, eggs or nesting individuals should be removed from the box. Long-term actions to reduce future risk should also be implemented. This could include strategies such as erecting predator guards, increasing nest box height (within species box dimension qualifications), or changing box location.

Regular monitoring and collection of data on each box's use can also be used to for multiple research purposes. Information on presence/ absence can provide valuable information about the relative ranges of locally rare or locally extirpated species and whether of not they have recolonized an area. Also, monitoring and recoding data in the format shown below can help researches calculate population density and reproductive success. This information can then be used by researches to determine if the population is increasing or declining, in addition to providing insight into population dynamics. For some species, data can be sent to programs such as the California Waterfowl Association Wood Duck Project.

Year _____	Monitor _____														
Box Number _____															
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: left; padding: 2px;">First Brood</th> <th style="width: 50%; text-align: left; padding: 2px;">Second Brood</th> </tr> </thead> <tbody> <tr><td style="padding: 2px;">Species</td><td style="padding: 2px;">_____</td></tr> <tr><td style="padding: 2px;">Eggs Laid</td><td style="padding: 2px;">_____</td></tr> <tr><td style="padding: 2px;">Young Hatched</td><td style="padding: 2px;">_____</td></tr> <tr><td style="padding: 2px;">Young Fledged</td><td style="padding: 2px;">_____</td></tr> <tr><td style="padding: 2px;">Hatch Date</td><td style="padding: 2px;">_____</td></tr> <tr><td style="padding: 2px;">Cause of Nest Failure</td><td style="padding: 2px;">_____</td></tr> </tbody> </table>	First Brood	Second Brood	Species	_____	Eggs Laid	_____	Young Hatched	_____	Young Fledged	_____	Hatch Date	_____	Cause of Nest Failure	_____
First Brood	Second Brood														
Species	_____														
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Young Hatched	_____														
Young Fledged	_____														
Hatch Date	_____														
Cause of Nest Failure	_____														
Notes/Observations:															
Date _____															

(USGS, 1999)

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Native bees

Joong Sim

Part 1: Project Background and Justification

Apidae:

Habitat: Highly varied; digger bees nest in soil, carpenter bees in soft wood, bumblebees and honey bees in large cavities or hives, and cuckoo bees which parasitize other broods' nests.

Characteristics: Most have large, chunky bodies, though some genera have small and slender bodies.



Habropoda miserabilis



Apis mellifera



Anthophora urbana

Colletidae:

Habitat: Nest in underground burrows or in cavities. Lines nest with membranous

secretions produced by the female.

Characteristics: *Colletes* have distinct triangular faces and fuzzy bodies, often striped. *Hylaeus* have yellow face marking and are smaller and relatively hairless.



Hylaeus punctatus



Colletes fulgidus longiplumosus

Andrenidae:

Habitat: Soil nesting

Characteristics: most small- to medium-sized with slender bodies. Most common genus in California is *Andrena*



Andrena subtilis



Andrena subtilis entering underground burrow

Halictidae:

Habitat: mostly ground nesting, some in wood. Many species are eusocial.

Sphecodes, among other genera, are parasites of other bees

Characteristics: Usually dark colored, often metallic. Fairly nondescript appearance-wise. Males often have yellow facial markings. Attracted to perspiration.



Lasioglossum sp.



Halictus farinosus



Sphecodes sp.

Megachilidae:

Habitat: Nest in preformed cavities and construct brood chambers using a variety of materials

Characteristics: Bees of the genera assigned to “guilds” based on materials used to construct nest. Unlike in other bees, most females transport pollen on the underside of their abdomen.



Coelioxys rufitarsis



Megachile fidelis

(images from <http://www.helpabee.org/common-bee-groups-of-ca.html>)

Background and justification

Bees are some of the most important species in any ecosystem with flowering plants, acting as pollinators for an estimated 67% of angiosperms (Axelrod, 1960). Native bees, along with other pollinators, are critical for successful restoration (Handel 1997). Aside from the ubiquitous honey bee (*Apis mellifera*), California is home to between 1,500 and 2,000 species, accounting for over half of the species found in North America (Michener 2000). Unfortunately, California has not been safe from the worldwide trend of pollinator decline. Over fifty species are listed as at risk by the Xerces Society for Invertebrate Conservation in North America, including many Californian species. Geographic ranges and population sizes have declined. The western bumble bee (*Bombus occidentalis*), for example, is no longer found in the western part of its original range, including California (Cameron et al 2011). Habitat loss is believed to be the main cause of native bee decline, and over 90% of natural habitat was lost to land conversion in the past 150 years (Schoenherr, 1992).

Literature review

Characteristics of native bees

Diversity

- 1,500 to 2,000 species in 5 families: Colletidae, Halictidae, Andrenidae, Melittidae, Megachilidae, Apidae (LeBuhn 2013, Michener 2000)

Reproduction

- Bees are holometabolous insects, starting from an egg, which hatches into larva, followed by a pupal stage, and finally maturity. Adult emerges in spring or summer for most native bees. Males tend to emerge first and mate with females as they emerge. The female then lays the egg in its nest, where it will hatch and stay in the cocoon until the following spring (LeBuhn 2013).
- Adult bees are generally active for only 2-5 weeks per year and spend most of their time in their nests (LeBuhn 2013).

- Eggs are laid on top of provisions made of nectar and pollen. Larvae will grow faster on higher quality provisions. Specialist bees require pollen and nectar from their specific plants to develop properly (LeBuhn 2013).
- Males of some species designate flowers with pheromones to mark territory. Depending on genera, a male bee will either defend a single site or set up patrol routes. Males will attempt to mate with females in their territory and to defend from other males. Some genera are more aggressive than others (LeBuhn 2013).
- Mating takes place in flight, inside a nest, on or in a flower, or on the ground (LeBuhn 2013) over 10-80 minutes.

Food Habits and Pollination

- Bees feed on nectar (adults) and/or pollen (generally only for larvae) from plants (LeBuhn 2013)
- Many bee species coevolved with their respective plants and are specialized to feed from them. These flowers are often shaped in such that only specialized bees can access their nectar (LeBuhn 2013).
- Foraging range varies by species, but generally around two miles from nesting site. Range also depends on quality and abundance of surrounding food sources. Bees in areas with an abundance of food sources will have greater ranges as they can gather enough food to make up for the extra energy expended. Minimum temperature for foraging is 13 C (55 F) while full activity requires 19 C (66F), and also varies by species (LeBuhn 2013)
- Maximum foraging distance ranges from 150 m to 600 m. Average trip duration is 6 to 28 minutes and is correlated with body length. Habitat requirements should be met within foraging range (Gathmann and Tscharntke 2002).

Nesting

- Most native bees are solitary. A single female builds a nest and lays eggs inside. Some bees build nests in clusters of dozens to hundreds (e.g. *Anthophora bomboides*) (LeBuhn 2013)
- Ground nesting bees (miners) dig a central shaft with a chamber at the end for the egg(s). The female lays the egg on a ball of pollen and nectar and seals the chamber. A single nest may have multiple lateral branches with their own terminal chambers (LeBuhn 2013).
- Cavity nesting bees use a cavity usually created by a different species. The female builds a line of brood chambers, each with its own egg and food supply. Leaf cutter bees and mason bees use pieces of leaves and mud, respectively, when constructing their nests (LeBuhn 2013).
- Carpenter bees dig into wood with their mandibles (LeBuhn 2013).
- Males generally sleep outside (LeBuhn 2013).

Threats

- Some bees attempt to take over other bees' nests by fighting the owner. Others called social parasites target social bees. They enter a nest, replace the queen, and raise their own offspring in the nest using

workers already present. Cleptoparasites, the most common type, lay their eggs in nests of other bees, sometimes destroying the host's eggs before departing. Parasitic bees generally have reduced pollen-carrying structures and strong cuticles, spines, and sting (LeBuhn 2013).

- Invertebrates including bee flies, oil beetles, mites, and spiders as well as some birds (woodpeckers, kingbirds, others) and mammals (bears, raccoons, foxes, etc.) eat bees and/or their honey (LeBuhn 2013).
- Habitat loss is the primary reason for native bee decline in California (Schoenherr 1992).
- Exposure to pesticides and proximity to crops with no rewards such as rice, wheat, and alfalfa are detrimental to bee diversity (Cane and Tepedino 2001). However, diverse bee communities can be supported by semi-natural habitats even when surrounded by agricultural or urban areas (Love 2011).
- Fire and tillage may have negative impacts on species abundance and richness, especially for ground nesting bees, but their effects are largely negligible (Winfrey et al 2009).

Part 2: Project Goals and Management Plan

Potential Restoration Actions

A. Goals

Restore habitat by increasing year-round floral diversity and provide nesting sites

Habitat destruction is the primary cause of bee population decline in California. With over 90% of land converted to human use in the past 150 years, establishing habitats for bees is the first and most important step in improving bee species diversity (Love 2011, Williams 2011). Extant research on bee response to restoration in the Sacramento Valley focuses exclusively on riparian habitats along the Sacramento River (Williams 2011) and the American and Consumnes Rivers (Love 2011). Bee species diversity and richness is dependent, at least in part, to plant diversity and floral resource richness (Love 2011, Williams 2011). Restored riparian habitats support communities with equal species diversity and richness to remnant riparian habitats, though actual species compositions are highly dissimilar between restored and remnant sites (Love 2011, Williams 2007, Williams 2011). This should not be an issue as the most important metric for pollinator success is high species richness which indicates high pollinator redundancy, the best measure of a robust pollinator community. (Williams 2011).

Regardless of the discrepancy in bee communities between restored and reference sites, plant community composition should follow that of the reference community, as they are likely better adapted to the conditions at the restoration site.

Care should be taken to preserve existing nesting sites and create new ones if necessary. Direct access to soil surface is necessary for the ground-dwelling bees that make up 70% of native bee species (Potts et al 2005). As ground-nesting bees tend to avoid nesting in rich soils, areas with poor, sandy or loamy soil should be left exposed (Xerces 2009).

Improve habitability of nearby land for native bees

Neighboring areas have a significant impact on the success of native bee populations (Love 2011). Improving these areas as bee habitats will improve success of native bees at target site. While secondary to restoration of the target site, improving neighboring lands will provide a boost to bee diversity at the restoration site.

Monitor at different successional stages and seasons

Species composition and diversity change significantly as succession at the restored site changes available habitat types, food sources, and microclimate (Williams 2011). Changes in floral diversity and floral resource abundance with the seasons also affect bee species richness and abundance (Love 2011, Williams 2011). Sample once a month for entire duration of succession (dependent on actual floral species composition). Follow statistically significant decreases in species richness between year-long periods (spring of year 1 vs spring of year 2, for example) with reassessment of floral community.

B. Restoration plan

Identify floral reference community

The species richness and abundance of a native bee community depends mostly on the diversity of flora and abundance of floral resources (Love 2011, Williams 2011). In choosing a reference site, it is critical to identify floral communities with high species richness, and focus especially on identifying which native plants are most attractive to native bees. Actual bee species composition is secondary. Restored sites and their reference remnant sites have no correlation in their bee communities even with identical floral species composition (Love 2011, Williams 2011). As such, trying to identify a bee reference community for restoration is impractical and unnecessary in most cases.

Establish native plant community with high species richness and floral rewards

The most important factor in establishing and maintaining a diverse bee community is a diverse array of flora, especially those that offer high floral rewards (Love 2011, Williams 2011). *Salix* species, *Rosa californica*, and *Lupinus* species have been identified to be highly attractive to native bees and should be planted if it suits the restoration goals of the site (Williams 2011). Due to high connectivity of bee populations, manual introduction of bees should be unnecessary. Restored sites without manual introduction of bees have been found to have equal species richness and diversity as remnant sites (Williams 2011). Furthermore, practical difficulties in collecting enough individuals and/or eggs of a species to establish a stable population make manual introduction cost-ineffective in the vast majority of cases. The success of native bee communities as nontarget species in restored areas indicates diverse communities will establish once the proper plant community is restored, and restoration should focus on creating a plant community suited to the goals for that site. Nonnative plants have also been identified as important food sources for native bees, especially in disturbed habitats (Love 2011). Therefore, care should be taken when removing these plants. Removing too many too quickly can result in a sudden drop in floral resources leading to loss of bee diversity. This is especially the case in seasons with a decrease in floral resources. Bee diversity fluctuates as floral resource abundance increases and decreases throughout the year (Williams 2011). Removal of nonnatives should be performed, if possible, during the part of the year with highest bee diversity to minimize reduction in food sources. Pesticide use should be kept to a minimum, if used at all, due to adverse effects on bee diversity and abundance (Cane and Tepedino 2001).

Improve habitability of neighboring lands by reducing pesticide drift and providing refugia

Neighboring lands, especially land used for agriculture, influences success at the restoration site. High pesticide usage has been linked to lower bee diversity and abundance, as have crops such as rice and wheat that offer few floral rewards (Cane and Tepedino 2001). Realistically, few farmers can be expected to switch crops or dramatically reduce pesticide usage for nearby native bee restoration programs without economic incentive, which is unlikely to be feasible for most programs. A more practical approach would be encouraging landowners to plant a diverse array of native plants at marginal or unused areas to act as islands of high bee diversity, creating populations that can breed with

those at the restoration site and increase genetic robustness (Holzschuh et al 2006). Convincing farmers of the economic benefits of a diverse pollinator community with high redundancy is likely to be key to this endeavor. Similarly, homeowners can be encouraged to plant native plants in their lawns to improve food supply for native bees (Love 2011).

C. Monitoring

Bee diversity and abundance changes throughout the year as the seasons affect floral diversity and resources (Love 2011, Williams 2011). Bee species composition and richness also changes as the vegetation proceeds through its stages of succession (Williams 2011). As such, monitoring should be performed throughout the year until the restoration site reaches its final stable succession state. Monitoring once a month until succession is complete and once every two months for two years afterwards to ensure bee communities are stable should be a good baseline. Pan trapping in designated plots to find species richness and composition and net trapping from flowers to find species richness and floral associations should be used (Williams 2011). Statistically significant (to 90% confidence) decreases in species richness over a period of six months or longer should prompt a reassessment of target site, especially for floral diversity. Other possible causes such as pathogens or increased pesticide usage in nearby areas should be looked into as well.

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Western pond turtle (*Emys/Clemmys marmorata*)

Will Glaeser

Part 1: Project Background and Justification

Habitat: Anywhere there is easily accessible, slow moving water. The Western Pond Turtle will use open water that occurs intermittently or permanently. They are also found on surrounding ground or basking on rock islands. "Nesting typically occurs within 200m of aquatic habitat in areas with compact soil, sparse vegetation, and good solar exposure." (www.fs.fed.us)

Identification: "The dorsal color is usually dark brown or dull olive, with or without darker reticulations or streaking. The plastron is yellowish, sometimes with dark blotches in the centers of the scutes. The shell is 11–21 cm (4.5 to 8.25 in) in length. The dorsal shell (carapace) is low and broad, usually widest behind the middle, and in adults is smooth, lacking a keel or serrations. Adult Western Pond Turtles are sexually dimorphic; that is, males have a light or pale yellow throat." (Rhodin 2010, p. 000.139)



(Images from www.arkive.org)

Key Indicator Photos: Left to right: Tracks in sand, scat, eggs in nest.



(www.naturetracking.com)
(<http://calphotos.berkeley.edu>)

(www.bear-tracker.com)

Distinction from Red-eared Sliders: "... look at the marginal scutes 8-12 (...the scutes above the tail, or back scutes). Sliders have bifid or slightly forked scutes, where Western Pond Turtles do not; theirs are all smooth and do not split (except for traumatic injuries, but it's usually only one or a few, not all scutes). The forking in the tail gives red-eared sliders the appearance that the tail is serrated or split in appearance. While looking for the presence and size of inguinal

and axillary scutes is the best way to differentiate between the 2 once you have them in hand, a good way to do it from a distance is to look at the back scutes of the turtles." (www.californiaherps.com)

Western Pond Turtle (*Actinemys marmorata*)

Background and Justification

The Western Pond Turtle (*Actinemys marmorata*) is listed as "threatened (rank: vulnerable) by the IUCN Red List of Threatened Species (Giese 2014). These turtles are rapidly becoming scarce in abundance and distribution. A survey conducted in Willamette Valley of Oregon demonstrated that current local population of these turtles is only one percent of historic numbers (Giese 2014). These animals are experiencing a declining population throughout Washington, northern Oregon, southern California, and Baja. The Western Pond Turtle now only occurs in a modest percentage of its original distribution range (Holland and Bury 1998). Conservation of the Western Pond Turtle, along with other amphibians, is particularly interesting because the implications reach into the realms of aquatic ecosystems as well as terrestrial. The turtles were once abundant in California, but habitat destruction caused by urbanization and agriculture, along with harvesting for food (particularly in the bay area) has led to dramatically reduced populations (Hays et al. 1999). Allowing this rapid decline of population could very well lead to irreversible damage to ecosystems in greater ways than might occur if a purely aquatic or terrestrial species were to undergo similar loss (Spinks and Shaffer 2005).

Literature Review

Characteristics of Western Pond Turtles

Reproduction

- These turtles follow promiscuous mating rituals. They mate May-August with eggs being laid every other year. Average age of sexual maturity is 8-14 years, but occasionally earlier. Hatching success rates are roughly 70% due to high level of predation. Incubation takes about three months. Offspring batches average 6. Most hatchlings will remain in the nest until the following spring. There is no evidence of parental care. The animals have a nature of seclusion which has resulted in an absence of knowledge surrounding the details of their mating process. (Nachman, 2008)
- Mating takes place under water (Ashton et al. 1997)
- The female turtle will wander at night to select a nesting site which usually is found on a south facing open area of sand or low vegetation. These are difficult for people to notice or find unless they have been made more obvious by a predator (Rhodin 2010)

- In California, some Western Pond Turtles will hatch in the fall (Nachman 2008)

Food Habits

- Western Pond Turtles prefer live prey to hunt and eat, but will also sometimes dine on plants. These meals are swallowed in the water, as it seems the turtles are unable to swallow unless in water (Holland 1994).
- Insect larvae, crustaceans, annelids and small vertebrate animals are the preferred sources of food for the turtles (Bury 1986)
- Western Pond Turtles have also been seen eating carcasses of small animals such as fish, birds, or mammals (Holland 1994).
- These animals do not often partake in herbivorous behavior, but females are the more likely gender to be seen consuming plant material (Bury 1986)
- Hatchlings have a yolk sac which nourishes them through the early stages of growth before moving on to consume larvae and small insects (Holland 1994)

Space Use

- Male home ranges are larger than female. Some propose this is to increase chances of mating for males. Males average 1 per hectare, while females average 1 per .3 hectares (Nachman, 2008).
- These turtles are somewhat sedentary and can afford significant overlap of home ranges between sexes and general populations (Bury 1979).
- Western Pond Turtles will move to land when they are looking to bask, nest, or 'overwinter'. They may also move to other bodies of water this way (up to 500m away) (Reese and Welsh 1997).
- Overwintering can occur under water, but movement to land is standard (Reese 1996).
- Turtles will often times return to the same spot year after year for their overwintering practice (Goodman 1996).

Habitat Preferences and Requirements

- Western Pond Turtles occupy aquatic and terrestrial space. They can be found in almost any form of water including, but not limited to, lakes, streams, ponds, creeks, irrigation ditches, and intermittent bodies of water (Nachman, 2008).
- Adults are liable to be found spending considerable time in upland habitats up to 200 meters from a body of water (Reese 1996).
- Basking sites for adults and juveniles are similar in regards to depth and total area of water, but differ in flow. Younger turtles favored basking near areas with less water flow compared to adults (Reese 1996).
- Hatchlings, more than any other age group of the Western Pond Turtle, are likely to be found in shallow and warm water lacking predators and featuring aquatic vegetation (Holland 1994)

- Terrestrial sites for overwintering (decreased activity during colder season) are required to adequately support the turtles (Reese 1996).
- Nesting will usually occur in sites with good sun exposure, low slope, and compact soil within several meters of the water (Holland 1994).

Threats

- The largest threat to these turtles is loss of habitat. Conversion of wetlands to farmland and alterations to water channels, in addition to fragmentation have had substantial impact on populations (Holland 1991).
- It has become illegal to harvest, keep, or trade these animals in California, but some breaching of these laws still exists (Bury 1986).
- Some hunters incorrectly believe these turtles prey on certain game fish, so they shoot the turtles (Holland 1991).
- Chemical spills such as diesel, gas, and oil have negative impacts on turtle populations near highways. Many physiological negative side effects occur when these chemicals are introduced to turtle habitat (Bury 1972).
- Untimely or excessive dam release may negatively alter water habitat and temperature (Goodman 1997).
- Predators, namely the Bullfrog (*Rana catesbiana*) pressure turtle populations by dining on newborns, and they create competition by occupying the same types of habitat as the Western Pond Turtle (Corkran and Thoms 1996)
- Drought can greatly affect the Western Pond Turtle. Holland states, "The 1987-1992 drought in California reduced southern and central state [Western Pond Turtle] populations by up to 85%" (Holland 1994).

Potential Management Actions

Improve Habitat

- Upland areas near water bodies should be provided and maintained to allow nesting and overwintering. These areas need grasses for nesting, trees, and shrubs for general cover. This effort is also compatible with other missions to restore native grasslands (Hays et al. 1999).
- Before introducing a turtle population, it may be necessary to intervene in the landscape to set the stage for success. This would include monitoring and treating water quality, levels, flow, vegetation, existing species, competition, feed, cover, and nesting areas.

Further Management

- In order to establish a viable population of Western pond Turtles, habitat should be provided that is secluded from areas subject to urbanization or other disturbances. The most viable land type for these goals is wetlands that contain multiple bodies of water (Hays et al. 1999).

- The growth and establishment of areas able to sustain large enough populations will require continued human involvement (Hays et al. 1999). It is not a 'set it and forget it' task.
- Predator monitoring and control will be necessary to ensure Bullfrogs are not overwhelming the turtle population (Hays et al. 1999).
- Programs to allow hatchlings to birth in protected circumstances before being freed may also be necessary (Reese and Welsh 1997).

Gaps in Knowledge

- Details of these turtles' mating rituals are unknown due to their seclusive behavior (Nachman, 2008).
- It is unknown how commonplace illegal capture, trade, and hunting of these animals currently is in California. Speculation says it was decreased significantly in the past three decades, but figures are difficult to obtain.
- Successful efforts to restore populations within home ranges that were completely diminished over time.
- The effects of accidental elimination of competition for the Western Pond Turtle - i.e. completely eradicating predators from habitats.
- Successful missions to allow these animals to exist in urban areas.
- It is unknown why some Western Pond Turtles are prompted to overwinter under water as opposed to the more common practice of moving to land during this time.

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Part 2: Project Goals and Management Plan

A. Goals

Restore and improve habitat to support a self-sustaining, viable turtle population.

Western Pond Turtles require several specific conditions of habitat such as upland areas near bodies of water for overwintering containing grasses, trees, and shrubs. Conditions need to be met on the fronts of water quality, levels, and flow, existing species, competition, and nesting areas (Hays et al. 1999). Areas of heavier protection will need to be created so that pairs can reproduce in a safe environment. These areas are especially important in urban areas or where high occurrences of predation are likely to occur. In establishing the population, it will be a priority to encourage natural recruitment of juveniles, otherwise programs of controlled birth and release will need to be implemented (Reese and Welsh 1997). Regardless of what method is used to recruit hatchlings, cover and easily accessible food will be paramount for young turtles. To accomplish this task, continued human intervention and monitoring (see below) will be invaluable to the process of ensuring juvenile safety (Hays et al. 1999)

Another consideration in establishing this population will be the natural limits of the site such as overall size. What constitutes a 'viable population' is open to interpretation and largely dependent on specific site context. The Washington State Recovery Plan, which deals with regions comparable in size to Northern California, recommends aiming for at least 5 populations of at least 200 turtles throughout the region (Hays et al. 1999). This goal aims to have the turtle downlisted to 'threatened' in the state of Washington and can be used as a model for Northern California. For the Western Pond Turtle in uncontrolled spaces, males average 1 per hectare while females average 1 per .3 hectare (Nachman, 2008). There is very limited research on how the turtles will interact if forced into higher densities. These turtles are not notoriously territorial, but they have been known to act aggressively and engage in physical combat to win and maintain basking space (Bury and Wolfheim 1973). This is important to consider because we want to maximize the amount of turtles being sustained on our site, but produce too many, and we will be creating a counterproductive situation. These considerations of spacing will influence the layout of water bodies such as potholes, straits, pools, riffles, and (primarily) wetlands which are extremely important for this species (CNDDDB 2004). These goals will be moved upon over several years. A majority of the effort will be in the first year, laying the foundation (outlined in section B) for these goals to become realized in the following years. A potential compromise to keep in mind when working towards these goals will be the total population of turtles housed on the site. We may either a) aim for lower population based on space restrictions or b) implement a "farming" plan which moves healthy, adult turtles from our site to new sites seeking Western Pond Turtle population establishment. This will require additional effort, but will avoid creating a hostile, more volatile habitat.

Create habitat corridors that are protected from threats.

Predation, drought, and human impact are the three most threatening factors, in addition to lacking reproductive activity, to consider in California while dealing with Western Pond Turtle populations (Holland 1991a). In mitigating predation, it makes sense to focus resources towards protecting nesting areas as unhatched or young turtles are the most prone attack. Females most often lay eggs in upland grassy areas such as grazed pastures up to 402 meters from water (Jennings and Hayes 1994). Because of the nature of grassland, it is difficult to provide cover from overhead predation, but it is possible with the use of nets trees with dense foliage. Additionally, it is extremely important these areas be kept at a distance (as far as site permits) from human activity. Because aquatic habitat is essential to turtle survival (Holland 1994) it is important to ensure habitat areas will maintain access to water all year, and even during droughts. An effective strategy to meet this goal is to incorporate wetland 'potholes' into the design. A wetland pothole is a relatively small area of deeply depressed topography that will hold water well beyond when the more shallow areas are dried up (EPA 1998). This is not a fail-proof strategy, but they are incredibly cost efficient and effective. These protected areas for nesting and reproduction will require experts on site to make sure they are constructed correctly, as mistakes could render them unusable. The spaces will need constant monitoring to ensure they are being used effectively and no tamperings occur.

B. Restoration Plan

The restoration plan will consist of three distinct phases: preparation, implementation, and monitoring. To begin the preparation phase, a site analysis is needed. Identify native and invasive species that have been naturalized. If they are beneficial to the Western Pond Turtle, they can stay and be implemented into the design. If they are detrimental to Pond Turtle survival, consider removing these species. Next, make note of the size of the site. How many males (1/1ha.) and females (1/.3ha.) can comfortably occupy the site? Be sure to consider how different areas of the site will be used at different times of the year, shifting the concentration of population. Both aquatic and terrestrial areas are used for overwinter, but while the turtles are more active, they must have access to water (Rathbun et al. 2002). This will influence the site design and ingress/egress points to and from water to avoid overcrowding high demand resources. Once spatial considerations have been solved, grading will take place. Keep in mind that regrading should not disturb existing vegetation or features that are to be kept in the interest of benefiting population. At this point, construction of protected breeding and rearing areas can begin. These may range from temporary installments of overhead nets and covert bedding areas while vegetation is established, to more permanent culverts, grading changes, and intentional corridors. This way, birthing can begin without necessarily having to wait for new vegetation to be established in order to provide

more natural cover. If human observation areas or walkways are desired, they should be constructed before vegetation is established to avoid destroying plants. Planting plans should incorporate varieties of native perennial aquatic species, upland grasses, marsh plants, cattail mats, and chaparral species (Baird and Girard 1852). Be sure to allow for exposed rock pedestals for basking in the sun, preferably in or next to water.

Many physiological negative side effects have been recorded to be caused by chemicals present in water used for turtle habitat (Bury 1972). Testing for neutral, safe water is essential to the success of this project. If there is unsafe water entering the site, redirection protocols will be needed and wetland treatment areas in addition to wetland habitat areas should be considered.

Some potential problems to consider are proximity to surrounding urban areas, water quality degradation from runoff, and overpopulation for smaller sites. As mentioned, there is limited documentation on the negative effects of overcrowded turtle habitats, so this is an uncertainty that should be handled with caution.

The steps in the preparation and implementation phases should be feasible to accomplish within a year provided adequate funding and community support. It is essential that basic needs, such as food, water, and shelter resources, are implemented before introducing any turtles.

C. Monitoring Plan

Monitoring and reacting will be essential for the success of the project. Before intervening, a detailed inventory shall be taken of all species present on the site, soil and water information, and ingress/egress points for humans and animals. After implementation, all of these shall continue to be monitored with special emphasis on turtle population, new species occurrences, water flow, and human disturbances. More rigorous monitoring is required earlier on once the project has been established. There should be monthly surveys of turtle population for the first year with special attention paid to adult:juvenile ratios. A healthy turtle population contains no more than 70% adults (Hays et al, 1999). If this threshold is approaching, reevaluate a) accessibility and encouragement of male and female interaction b) even dispersal of males (1 male per ~3.3 females within each hectare ((Nachman, 2008)) c) quality and accessibility of nesting areas d) ingress and egress rates of predators. Visual surveys as well as motion-activated cameras may be used to document predator activity. After the first year, if it is determined the project has thus far been successful on all fronts, it would be appropriate to lessen surveys to 4 times per year (once per season) for the following year. If again conditions are stable and favorable, yearly surveys may be adopted as per standards of fish and wildlife population surveying (IDFG 2012).

Careful monitoring of this site and project could very well contribute information to lacking research of: viability of turtle populations in proximity to urban areas, how the turtles interact when contained to a specific site, how the turtles' behavior changes when predators are no longer a constant threat, and what exactly occurs when more than 1 male is present per hectare (on smaller sites).

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Western Spadefoot Toad (*Pelobates cultripes*)

Kelsey Nelson

Part 1: Project Background and Justification

Habitat: "Prefers open areas with sandy or gravelly soils, in a variety of habitats including mixed woodlands, grasslands, coastal sage scrub, chaparral, sandy washes, lowlands, river floodplains, alluvial fans, playas, alkali flats, foothills, and mountains. Rainpools which do not contain bullfrogs, fish, or crayfish are necessary for breeding." (California Herps

<http://www.californiaherps.com/frogs/pages/s.hammondii.html#description>)

Identification:

"A small stout-bodied toad with short legs and warty skin, 1.5 – 2.5 inches long from snout to vent. The eyes are wide-set with no boss in between. Pupils are vertical. A glossy blackspade shaped like a wedge or teardrop is present on each hind foot. Parotoid glands are not present.

Color is greenish, brown, cream, or gray above, often with 4 irregular light stripes and dark blotches on the back, and reddish spots at tips of skin tubercles.

Unmarked and whitish below. Eyes are pale gold with vertical pupils. Tadpoles can grow up to 3 inches in length (7.5 cm.), but typically they transform at a smaller size. Color is olive-brown, gray, greenish black with a pale iridescent vent.

Nocturnal and almost completely terrestrial, entering

water only to breed. Spends most of its life buried underground in earth-filled burrows, and active typically between October to May, depending on rainfall. Occasionally emerges during rains at other times of the year. The burrows are probably away from the dried breeding

"Egg masses found attached to spike rush at or just below the water surface at sites with depths of 18-24 inches. Usually in abundant loose sandy substrate." (Cal Herps)



Adult



Juvenile



Tadpole



Spade (rear foot)



Eggs

pools.” (All from Cal Herps including photos)²

Kelsey Nelson

The Western Spadefoot Toad (*Spea Hammondi*)

Background and Justification

The Western Spadefoot Toad (*Spea Hammondi*) is a threatened species of toad endemic to California’s central valley and northern Mexico. Western Spadefoot Toad populations have been on the decline since the 1950s due to an 80% habitat loss caused by agriculture and development (The IUCN Red List). Specifically, the largest obstacle the Western Spadefoot Toad faces in terms of repopulation is loss of breeding grounds, such as naturally occurring pools called vernal pools, of which 90% have been lost in the Central Valley (AmphibiaWeb; California’s Vernal Pools). Western Spadefoot Toad populations are extremely sensitive to land use practices, such as farmland irrigation and intensive agriculture, which may cause early emergence due to surface vibrations. Like all amphibians, the Western Spadefoot Toad is vulnerable to pesticide use and runoff from human populated areas; consequently many of the toads’ breeding grounds are at risk (Morey 1). Western Spadefoot Toad larvae may also provide a significant food source for endangered Tiger Salamanders, when the two species coexist in the same breeding habitat, and for passing migratory birds (Fish and Wildlife Service 229). The Western Spadefoot Toad is also of particular scientific interest due to its unique ability to retain urea to prevent water loss and accelerate juvenile development if they detect decreasing water levels (AmphibiaWeb). Preserving the Western Spadefoot toad helps to maintain the central valley’s great diversity, in addition to providing a food source to other threatened and/or migrating organisms, and scientific insight into the physiological processes of temporary wetland amphibians.

Literature Review: Characteristics of Western Spadefoot Toads

Reproduction

A. Reproduction Habitat

- Temporary wetland water temperatures must remain between 48 and 86 degrees Fahrenheit (minimum water temperature for oviposition is 48 degrees Fahrenheit) for the Western Spadefoot Toad to successfully reproduce (Fish and Wildlife Service 227).
- Breeding bodies of water must be inundated for at least 30-35 days to allow for larval development (AmphibiaWeb).

² "Western Spadefoot - *Spea Hammondi*." California Herps. A Guide to the Amphibians and Reptiles of California, n.d. Web. 12 Apr. 2015.

- Note that stock tanks and artificial bodies of water may be suitable for breeding natural habitat restoration is not feasible and the above conditions are met (Butte Habitat Conservation Plan 16-6).
- There should be little to no vegetation cover around the edges of any breeding pools. Short grasses are preferable to other vegetation types. (Fish and Wildlife Service 227).

B. Reproduction Specifics

- Breeding is usually synchronous and occurs once per season, one to two days after rainfall from January to May in temporary wetland habitats (Fish and Wildlife Service 227).
- Females deposit 10 to 42 eggs in cylindrical clusters on pieces of detritus or plant stems underneath the water's surface (Fish and Wildlife Service 227). Fertilization occurs externally shortly after the female lays her eggs (California Herps).
- Eggs generally hatch between 3 and 4 days, with complete metamorphosis taking 30 to 79 days (58 days is the most common development period). Metamorphosis may be expedited if larvae perceive lowering water and oxygen levels. Tadpoles may also coat themselves in mud to avoid desiccation when water levels are low (AmphibiaWeb; Stebbins 2011).
- According to the US Fish and Wildlife Service, sexual maturity likely occurs around 2 years old in Western Spadefoot Toads (Fish and Wildlife Service 228).

Food Habits

- Adult Western Spadefoot Toads typically feed on a diverse group of insects, worms, and invertebrates. Specifically, Morey and Guinn identified, adult beetles, crickets, moths, ants, flies, and earthworms in the stomach contents of 14 toads during the course of their research in 1992 (AmphibiaWeb; Fish and Wildlife Service 228).
- Adult Western Spadefoot Toads can eat up to 11 percent of their body mass, which is enough energy to sustain a dormancy period of 8 to 9 months (Fish and Wildlife Service 226; Stebbins 2011).

Habitat Gradients Across Life Stages

- Western Spadefoot Toads are terrestrial amphibians, requiring water only to breed and avoid desiccation during extremely dry periods (Fish and Wildlife Service 228).
- Upon emerging from the pools after completing metamorphosis, juvenile Western Spadefoot Toads remain in the vicinity of the breeding ground for up to several days before dispersing usually on humid nights (AmphibiaWeb; Fish and Wildlife Service 228). According to current models, the Western Spadefoot Toad may be capable of traveling up to 1 mile from breeding habitats (Butte Habitat Conservation Plan 16-6).
- Western Spadefoot Toads are not territorial (California Herps).

- Adult Western Spadefoot Toads dig burrows with the spades on their hind feet. Toad burrows can reach 3 feet in depth or mature toads may commandeer burrows of other small mammals to use for aestivation (Halliday 87; Yolo Conservation Plan 3).
- Large migrations commonly occur twice per year, after the first rains towards the breeding habitat and after breeding away from the breeding habitat (Morey 88-89).

Upland Habitat Preferences and Requirements

- The Western Spadefoot Toad can inhabit grasslands, vernal pools, chaparral areas, pine or oak woodlands, river floodplains, stock tanks, and artificial bodies of water, alkali flats, alluvial fans and washes. However, toads living in some of these drier areas must be within one mile of suitable breeding habitat like that of temporary wetlands (AmphibiaWeb; Butte Habitat Conservation Plan 16-6; Stebbins 2011).
- Western Spadefoot Toads require a moist burrowing soil. Soil moisture tension should not exceed 10-15 atm in order to avoid desiccation. Semi-frequent rains or thick clay soil are needed to maintain a degree of soil moisture during dry months (Halliday 87-8; Fish and Wildlife Service 223).
- According to the Butte Conservation Plan, Western Spadefoot Toads prefer sandy and/or gravel-like soil with sparse vegetation and relatively short grasses (Butte Habitat Conservation Plan 16-2).
- The Western Spadefoot Toad prefers elevations of less than 900 meters (but can occur in elevations up to 1385 meters) and can tolerate soil temperature ranges between 41 and 102 degrees Fahrenheit (Butte Habitat Conservation Plan 16-1; Ruibal 1969; Stebbins 2011).

Threats and Predators

- Tiger salamanders, exotic bullfrogs, fish, garter snakes, raccoons, migratory birds, and crayfish all threaten the survivorship of Western Spadefoot Toad eggs, larvae, and juveniles when in close proximity (AmphibiaWeb; Butte Habitat Conservation Plan 16-2; Yolo Conservation Plan 4).
- In particular, mosquito fish (*Gambusia*) threaten the recruitment of Western Spadefoot Toads in vernal pools and other small, seasonal bodies of water (The IUCN Red List).
- Habitat loss and habitat fragmentation due to land conversion for agriculture and urban development are the two largest threats facing the Western Spadefoot Toad (Butte Habitat Conservation Plan 16-4).
- Western Spadefoot Toads also suffer habitat degradation from heavy motor vehicle traffic and equipment use (direct traffic effects and vibrations that may cause early emergence due to heavy road usage), overgrazing, and contaminated water run-off from industrial and urban areas (Yolo Conservation Plan 4).
- Trematodes and Chytridiomycosis may pose a possible threat to Western Spadefoot Toad populations, but the extent of the effect, if any, is unknown (AmphibiaWeb).

Potential Management Actions

Improve Habitat

- Protect existing vernal pool habitat and discourage the destruction of vernal pool habitat even when mitigation may be available as a replacement (Yolo Conservation Plan 5).
- Acquire and maintain appropriate habitat that includes seasonal aquatic and terrestrial habitat and is large enough to allow for gene flow in between populations (Morey 90; Yolo Conservation Plan 6).
- Control of exotic predators especially mosquito fish and American bullfrogs (Morey 90).
- Improve soil composition by adding sand or gravel, maintain little to no cover around aquatic breeding areas, and ensure pool inundation satisfies the minimum time period of 30 days to ensure toad success (Morey 90; Yolo Conservation Plan 6).
- Ensure suitable grassland and/or oak savanna surrounds breeding habitat in a diameter of at least 1 mile to provide appropriate burrowing habitat (Butte Habitat Conservation Plan 16-6).

Further Management

- The soil moisture tension should not exceed 10-15 atm in Western Spadefoot Toad burrowing habitat; so soil sampling to determine moisture content may be necessary during times of extreme drought in order to help toads avoid desiccation (Ruibal 1969).
- Research the possible effects of climate change on moisture limitations and the projected impacts on toad survivorship. Develop a possible strategy to manage toad habitat if drought years continue; this may include artificial aquatic breeding grounds and intense management of terrestrial habitat moisture levels (Reaser 2005; Stebbins 2011).
- Managing livestock grazing to ensure that Western Spadefoot Toad habitat does not incur heavy grazing and/or ranching (AmphibiaWeb; Morey 90).
- Begin monitoring dispersal patterns and population dynamics; if possible, to gain a better understanding of the amount of space needed to maintain a breeding population of Western Spadefoot Toads (AmphibiaWeb; California Herps; Halliday 88).

Gaps in Current Knowledge

- The diet of toad larvae
- Reproductive success rates, dispersal patterns, population dynamics and survival rates
- Factors that stimulate toad emergence
- How predation affects the population dynamics of the Western Spadefoot Toad

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A. Target Goals

Protect and prevent destruction of existing Spadefoot Toad Habitat

Western Spadefoot Toad populations are most commonly destroyed by agriculture associated uses and urban development (Butte Habitat Conservation Plan 16-4). In areas where *Spea Hammondii* populations are present, motor vehicles like tractors, ATVs, and trucks should not be operated within a mile of known population locations to avoid disrupting dispersal and/or burrowing habitat (Butte Habitat Conservation Plan 16-2). Furthermore, areas in which the toad lives or migrates through should not be permitted for agricultural use. Disruption of the soil, pesticide application, and tractor use associated with agriculture can cause toad death as well as larval death due to pesticide runoff contamination of the temporary wetlands in which the Western Spadefoot Toad breeds (Westman 2009; *Yolo Conservation Plan* 4). Specifically, pesticide levels should not exceed 0.7mg/L in areas near *Spea Hammondii* populations (Relyea 2005). In addition to the above threats, any motorized machine that can cause vibrations should be avoided within one mile of the edge of Western Spadefoot Toad habitat (Butte Habitat Conservation Plan 16-6). Equipment induced vibrations sound similar to that of rainfall, and can cause early emergence, and likely eventual death due to desiccation, in *Spea Hammondii* populations nearby (Amphibiaweb; *Yolo Conservation Plan* 4). Like all amphibians, the Western Spadefoot Toad is vulnerable to pesticide use and runoff from urban development and human populated areas; consequently many of the toads' breeding grounds are at risk due to their proximity to humans (Morey 1998). Runoff ditches stemming from urban areas should be eliminated entirely, if possible, to ensure that breeding grounds are not exposed to harsh chemicals (*Yolo Conservation Plan* 2009).

Acquire and maintain appropriate habitat

Western Spadefoot Toad populations need temporary wetland habitat, which primarily consists of vernal pools, to breed and reproduce effectively. Existing vernal pool habitat needs to be preserved and the destruction of vernal pool habitat discouraged even when mitigation may be available as a replacement (*Yolo Conservation Plan* 5). Mitigation is not an ideal reconciliation option since artificially constructed vernal pools have limited success and existing *Spea Hammondii* populations may not be close enough to utilize the mitigated area (Black 2001). However, if constructing artificial pools is necessary it is important to follow the US Fish and Wildlife Service's guidelines for slope grade and inundation period (California Fish and Wildlife Service). Western Spadefoot Toad habitat should be in an area that provides moist soil that does not exceed 10-15atm in order for it to be suitable for toad estivation (Rubial 1969). Toads utilize moist soil for burrowing, which provides protection from human disturbances, high insolation, and predatory birds. *Spea Hammondii* prefers areas with sandy soil and sparse vegetation, dense

cover should be avoided, if possible, especially near breeding habitat as it gives predators like raccoons a place to hide (Butte Habitat Conservation Plan 16-2). Appropriate habitat that would allow for gene flow in between populations would ensure populations are no more than 368 meters of one another (Morey 1998). In order for successful breeding to occur in Western Spadefoot Toad populations, temporary pools must be inundated for 30-35 days to ensure larvae have adequate time for development (AmphibiaWeb). Furthermore, breeding habitat should be surrounded by oak savanna and/or grassland for a diameter of at least one mile to ensure juveniles and adults dispersing from pools will have adequate access to suitable burrowing habitat (Butte Habitat Conservation Plan 16-6).

Control predators within toad habitat

To prevent predation and consequently Western Spadefoot Toad population decline, the presence of tiger salamanders, raccoons, exotic bullfrogs, fish (particularly *Gambusia*), garter snakes, migratory birds, and crayfish should be prevented or limited within toad breeding grounds. The most vulnerable stages of *Spea Hammondi* are during larval development and dispersal to burrowing habitat (The IUCN Red List). Extra care should be taken to prevent water-living predators, like *Gambusia*, crayfish, and tiger salamanders from cohabitating breeding grounds to improve Western Spadefoot Toad recruitment (AmphibiaWeb; Butte Habitat Conservation Plan 16-2; Yolo Conservation Plan 4). Exotic bullfrogs pose a significant competition threat to *Spea Hammondi*, but shortening pool inundation period to 30-35 days can easily control populations of exotic bullfrogs (AmphibiaWeb). An inundation period this short prevents exotic bullfrog larvae from reaching maturity, while Western Spadefoot Toad larvae are capable of developing in such a short time period (AmphibiaWeb).

B. Restoration Plan

Protect and prevent destruction of existing Spadefoot Toad Habitat

- **Restore old roads and prevent motor vehicle use**

Fencing and gates should be used around the restoration area and *Spea Hammondi* habitat to prevent motor vehicle access and unauthorized use (California Fish and Wildlife Service). If possible, roads within one mile of Western Spadefoot Toad populations should be closed and restored to appropriate habitat. Habitat type options that the Spadefoot toad can utilize include grasslands, vernal pools, chaparral areas, pine or oak woodlands, river floodplains, stock tanks, and artificial bodies of water, alkali flats, alluvial fans and washes (AmphibiaWeb; Stebbins 2011). If the Spadefoot Toad populations are unable to disperse effectively due to roads, passages under roads or other obstacles may be necessary (California Fish and Wildlife Service).

- **Prevent contaminated runoff**

Ideally, all runoff from urban and agricultural areas would be eliminated. In many cases, Western Spadefoot Toad populations are too close to human activities for this to be feasible. Another alternative that also achieves cleaner water involves

installing wetland areas to filter out sediment and other contaminants in an area upstream of *Spea Hammondii* population habitat (Eviner 2015). Otherwise it is important to ensure that pesticide contamination in water does not exceed 0.7mg/L in areas near toad meta populations (Relyea 2005). *Spea Hammondii* and other amphibians are extremely sensitive to pesticides and water quality so ensuring access to clean water is of the utmost importance (AmphibiaWeb; Halliday 2002).

Acquire and maintain appropriate habitat

- **Restore and acquire new habitat**

New habitat should be acquired near existing populations to allow for better dispersal and, more importantly, to create buffer zone between *Spea Hammondii* populations and problematic zones. Problematic zones include agricultural areas, urban areas, and areas with heavy road use (California Fish and Wildlife Service). Restoration options for new habitat and restoring existing habitat are listed above, however the ideal Spadefoot Toad habitat would include a seasonal water body and a grassland area for burrowing (Butte Habitat Conservation Plan 16-6). A habitat list with possible plant species will be included at the end of this paper. Furthermore, Western Spadefoot Toad habitat should not be grazed, or be grazed minimally, as livestock severely disrupt temporary pools and contribute to soil compaction (AmphibiaWeb; Morey 1998)

Control predators within toad habitat

- **Prevent predator access**

Aquatic predators can be diminished in *Spea Hammondii* breeding areas by managing hardpan and inundation periods in pools. When bodies of water are inundated for 30-35 days it allows the Western Spadefoot Toad larvae to complete development, but other aquatic predators like the tiger salamander, exotic bullfrogs, and crayfish are unable to establish and therefore die before predating upon Spadefoot Toad larvae (AmphibiaWeb; Stebbins 2011). *Gambusia* should not be introduced to control mosquitos, and fish and snakes are likely difficult to control in an open area, but ensuring other food sources are available may help mitigate damaging population effects (The IUCN Red List).

Monitoring

In order to ensure that the desired area is restored to meet the current Western Spadefoot Toad populations, the toad population numbers and dispersal rates should be recorded. Beginning restoration with an organism count and an idea of dispersal rates and mechanisms, and possible predators in the area will provide a background that will help determine whether restoration efforts are improving the population (Halliday 2002; US Fish and Wildlife Service). Note that organism counts should be performed after the first large rain (between January and May) when toads congregate around pools for breeding. This congregation happens once per year after a large rain (Fish and Wildlife Service 227). Sites should be monitored at least 7-8 years after restoration is complete to determine whether (Reaser 2005; Stebbins 2011) are improving (Ferren 1998). Specifically, inundation periods and their prospective invaders should be monitored yearly to ensure that Western Spadefoot

Toad populations have a higher chance than other aquatic larvae at reaching development (Black 2001). Breeding pools should have an inundation period of 30-35 days and a depth of 4-6 inches in order to favor *Spea Hammondii* over other seasonally aquatic species (Stebbins 2011). Furthermore, soil moisture tension should be monitored seasonally, especially in times of drought, and should not exceed 10-15atm (Ruibal 1969). Access roads and land use practices, like grazing, should be kept to an absolute minimum, monitoring and discouraging these activities will increase toad survival during dispersal and prevent vehicle tracks from expanding pools (AmphibiaWeb; Morey 1998).

Further research and improvement

As climate change continues to affect rain and weather patterns, the possible effects of climate change on Western Spadefoot Toad populations is unknown (US Fish and Wildlife Service). Recording seasonal weather patterns and their possible correlation with population dynamics would help others develop a possible strategy to manage *Spea Hammondii* populations if drought-induced moisture limitations continue (Reaser 2005; Stebbins 2011). Monitoring and recording Western Spadefoot Toad population dynamics may help with the understanding of the amount of space required to maintain a toad metapopulation in California's central valley (AmphibiaWeb; California Herps; Halliday 2002). Furthermore, monitoring and recording areas of *Spea Hammondii* characteristics that require further research is suggested. These areas include the diet of toad larvae, genealogy of populations, artificial and natural factors that may stimulate emergence, and the extent predators affect numbers of toads (Halliday 2002, The IUCN Red List). If a variety of habitats are within the monitored area, taking care to understand the differences in population growth rates in different habitats may be especially helpful for furthering *Spea Hammondii* research. Recording burning regimes in these areas would be ideal since little is understood about how toad populations are affected by fires (Morey 1998; US Fish and Wildlife Service). Lastly, increasing public awareness about the importance of Western Spadefoot Toad populations by public presentations and volunteer restoration work may help local government conservation efforts (Yolo Conservation Plan).

Possible species to include in restoration

- **Chaparral**

Chamise (*Adenostoma fasciculatum*), Leather oak (*Quercus durata*), White-leaved manzanita (*Arctostaphylos viscida*), Wedge-leaf ceanothus (*Ceanothus cuneatus*), Yerba santa (*Eriodictyon californicum*)

- **Grassland**

Purple Needlegrass (*Stipa Nassella*), Yarrow (*Achillea millefolium*), Blue Dicks (*Dichelostemma capitatum*), Lupine (*Lupinus*), Blue Eyed Grass (*Sisyrinchium bellum*)

- **Oak/pine woodlands**

Purple Needlegrass (*Stipa Nassella*), Blue oak (*Quercus douglasii*), Valley oak (*Quercus lobata*), Interior live oak (*Quercus wislizenii*), Foothill pine (*Pinus sabiniana*), California bay (*Umbellularia californica*), California black oak (*Quercus kelloggii*)

- **Vernal pools**

Goldfields (*Lasthenia californica*), Meadowfoam (*Limnathes douglassii*), Yellow carpet (*Blennosperma nanum*), Owl clover (*Orthocarpus erianthus*), Semaphore grass (*Pleuropogon californicus*), Toad rush (*Juncus buonius*)

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Tri-colored blackbird (*Agelaius tricolor*)

Nicolle Herr

Part 1: Project Background and Justification

Indicators: Tricolored blackbirds “song [is] a [low], harsh, [descending] *hark-a-reee!*” that is “nasal, less articulate and ringing” than the red-winged species. “Calls include [low] *chik* and *pyiu, tyiu, tzit,* and *tszeur.*”¹¹

Tricolor nests are built in freshwater marshes or in agricultural fields above water in cup shapes and their eggs are blue with brown spots (figure 3). These birds can be found foraging for insects, larvae, seed and grain.⁴

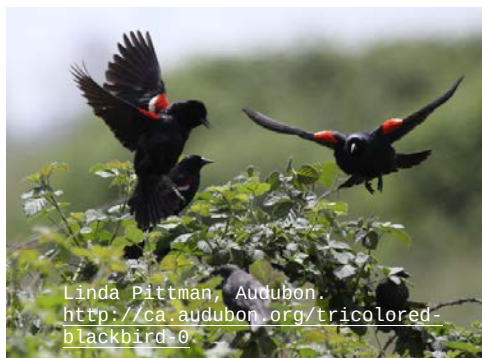


Figure 1: Male Tricolored Blackbirds



Figure 2: Female Tricolored Blackbird



Figure 3: Nest, egg, and hatchling



Figure 4: Agricultural Habitat with Red-Winged Blackbirds

Habitat: Tricolored Blackbirds are found in coastal marsh, bulrush, cattail, and agricultural habitats.¹¹

Identification: Tricolors are slightly larger than Brown-headed Cowbirds, and slightly smaller than Brewer's blackbirds, the birds they are known to flock with when it's not mating season.⁴ These other two species are also black with a brown head, and all black, respectively.¹¹ Tricolored blackbirds may range from 40-70 grams in weight and from 18-24 cm in length.⁴

The Red-Winged Blackbird is more difficult to distinguish due to the being the same size, approximately $8\frac{3}{4}$ " length, and both having a red shoulder. The shoulder is divided into portions called coverts, and in both species the lesser coverts are red. In the tricolor species the median culverts are white (figure 1) vs. the red-winged median culverts being yellow/orange (figure 4). The median culvert is the best way to tell between them, however the tricolor is also thinner and has a purple gloss look. The female tricolor is greyer overall (figure 2) and darker black underneath with longer pointed wings than the red-winged female that is brown and has a buffy or pink throat as seen in the lower left corner of figure 4.¹¹

Literature Review for the Tricolor Blackbird (*Agelaius tricolor*)

Background and Justification

Tricolored blackbirds are a highly endangered, endemic species that is beautiful and useful to agricultural pest control.³ Esthetically, observing large flocks of tricolors in flight is a majestic sight. Protecting tricolor blackbirds impacts agriculture by causing farmers to forgo harvest until fledglings can leave the nest.⁴ However tricolor blackbirds also eat a diet heavy in agricultural pests during the breeding season and this can help protect crops and increase yields.³ The population is in decline and faces extinction. Statewide populations totaling over one million have declined from hundreds of thousands to tens of thousands per region, and in many areas as low as thousands of birds. Plowing agricultural fields used as nesting sites and control of insect populations by pesticide are leading to reproductive losses, compounded by habitat loss of wetlands, putting this species at high risk for extinction.⁴

Behavioral Characteristics

- Population size is correlated to area of marshland habitat available for nesting and area of nearby grasslands for feeding, and has declined with loss of these two habitat requirements.² Large population decline has also been documented in managed wetlands.⁵
- Tricolored blackbirds will compete with and displace red wing black birds, yellow head black birds, and other marsh nesting species if they reside in overlapping habitat.⁴

- Wintering tricolors flock with red winged and Brewer's blackbirds, cowbirds, and starlings.⁴
- Tricolors are very social and the flock is very interactive, flocking and nesting at the same time to protect reproductive success.²
- A portion of the males in the nesting flocks will not breed, and leave the flock after egg laying has occurred.⁸
- Tricolors live up to 13 years.⁴

Reproductive Characteristics

- The breeding season occurs in late March to Early April in the San Joaquin Valley and May to June in the Sacramento Valley and foothills.⁴
- Mixed species flocks segregate into only tricolored blackbirds during breeding season.⁴
- Nesting begins after a few days of prospecting for nesting substrate that is strong enough to elevate the nests, has abundant insect sources nearby, and protects them from predation either by height above the ground or water, or by texture (thorns and bristles, for example).⁴
- Over 4-5 days every breeding female in tricolor flock lays 3-4 eggs in one brood per season while in high density breeding colonies.¹ Tricolor brown-spotted blue eggs⁴ hatch within 12-13 days⁷ of laying.
- Tricolor colonies may nest a second time in the season, generally in a different location, if they experience population-wide nesting failure.⁴
- Individuals may nest at the same or a new site within about 10 days of nest failure.⁸
- Males will sing in late February or Early March, breed with up to 4 females, and feed the young.⁴
- Before populations declined, up to 100,000 nests would be grouped together over only a few acres of marshland habitat allowing protection from predators.²
- Once hatched, the fledglings will be able to fly and feed themselves after approximately 24 days.⁷
- Females reach reproductive age at about 1 year, and males at 2 years.⁹

Diet Characteristics

- Hatchlings and fledglings are fed diets made up of 90% protein by weight from insects including beetles and weevils (Coleoptera), cutworms and Alfalfa loopers (Lepidoptera), snails and mollusks (Mollusca), and flies (Diptera).³
- Tricolors are also known to eat dragonflies (Odonata), caddisflies (Trichoptera), and grasshoppers (Caelifera).⁵
- Adult females consume diets containing 42- 56% protein by weight from insects and 44-59% carbohydrates by weight including oats and grains

(Avena), chickweed (Stellaria), filaree (Erodium), and pigweed (Amaranthus).³

- Adult males eat a diet heavier in forage carbohydrates at 69-72%, and only 28-31% protein by weight.³
- There was wide variation in the insects and forages eaten indicating tricolors adapt to a changing range of species availability both spatially and temporally.³

Nesting Characteristics and Requirements

- Nesting and breeding occur during peak insect populations after the end of the rain season, during late spring and early summer. This response is a temporal adaption to peak food availability in the region.²
- Agricultural practices provide food and nesting habitat during this same timeframe thus enabling tricolor use of agricultural forages for feeding and breeding.²
- Tricolored blackbirds prefer to nest in native Emergent marsh plants at least a few centimeters above water to prevent flooding the nest and deter predators.⁴
- Non-flooded habitat vegetation may include spines, bristles, or thorns to deter predators. Substrates include cattail, bulrush, thistles, blackberry, and grain silage crops.⁶
- Tricolors build their nests from a few centimeters to 3 meters above the ground or water⁹ depending on the substrate and within about a half a meter of each other⁴.
- Tricolor nests are built in cup shapes⁴ that are approximately 7.6 x 7.6 cm⁷ in height and width.
- Tricolor nests are built in three layers, a solid outer layer of woven stems and leaves, an insulation layer of material like mud or algae, and an inner layer of soft materials.⁷

Habitat Range and Requirements

- Tricolors will forage for food within 3-5 kilometers of the nesting colony.⁴
- Vegetation suitable for habitat varies and may include marsh, riparian, grassland, and agricultural grain silage.⁴
- Tricolors nest with a water source⁹ within their range (3-5 km).
- Severe storm winds can result in colony breeding failure as eggs and fledglings are thrown from nests. The wind speed that results in nest vulnerability depends on the strength of the nesting substrate.⁴
- Drought can result in decreased habitat substrate or decreased insects for forage, which can result in low reproductive success.⁴

Threats

- Land use change from wetlands to urbanized areas has been one of the greatest losses of suitable breeding habitat.⁶
- The greatest threat to tricolor populations is low numbers of insects as a source of food, decreasing the species average reproductive success. Fledglings will starve to death if the protein levels are not sufficient, grains cannot sustain them.⁵
- As nesting colonies decrease in population size, predation threats like Cattle egrets can result in loss of all the offspring from that flock during the reproductive season.⁵ Other predators may include feral cats, snakes, skunks, and other carnivorous birds and mammals.
- Blackbirds are seen as agricultural pests and removed by poisoning or being shot.⁵ Tricolors have also been killed for the market value of their feathers.⁵
- Agricultural crop cutting and tilling threaten tricolor populations by resulting in the death of the fledglings before they can fly to escape harvesting equipment.⁴
- High levels of selenium were found to lead to reproductive failure in one flock⁵, and the birds have shown mortality to other chemicals (that were deliberately applied), pollutants, pesticides, and herbicides on multiple occasions.⁴
- Grazing has been shown to lead to nest loss due to trampling.⁴ Nests located in Tule marsh where the grazers aren't walking aren't at risk of nest trampling.
- Due to the gestation time of late spring and early summer, fires that occur in the dry season may not affect the species. Uncharacteristic drought early in the season that results in early season fires could potentially wipe out nests.

Management Actions

- Loss of insects due to pesticide use can lead to lower reproductive success, thus ending pesticide use and allowing the birds to eat the insects could potentially increase reproductive success.⁵
- The mix of upland grasses, riparian blackberry, and marshland habitat at our site will likely result in higher reproductive success so long as over-predation is prevented from predators like feral cats.⁶ If an overpopulation of predators is found they can be removed from the area by animal control or another appropriate agency.
- Allowing the blackberry present to become a dominant patch in that area may promote or attract tricolor blackbird presence, especially since blackbirds, brown-headed cowbirds, and red-shouldered blackbirds nest in the reserve presently.

The two things we can do to encourage and protect this species in our site would be to encourage the blackberry population and find a way to encourage bug

populations in the grasslands. Otherwise, our reserve will be a population sink where use results in further decline of tricolor populations as a result of starvation and predation of fledglings.⁶

Releasing grasshoppers or other insects in the event tricolors are seen nesting could help supplement their protein diet however this is only possible with monitoring and may cause issue with residential neighbors.

Management Problems

- Agricultural delay in harvest to protect nests results in decreased quality of yields and therefore decreases profits of crops.
- The potential for less frequent/reliable rain and increasing temperatures could lead to more drought, less habitat, and smaller insect populations.
- The amount of decrease in habitat (over 95% of wetlands statewide) results in tricolor flocks returning to marginal breeding areas even when breeding failure has previously occurred there.⁶
- Large enough bird populations to prevent Allee effects (lowered fitness) would require more than an acre of blackberry or marshland vegetation.⁶

The greatest problem tricolors will face in our site is the lack of insects for hatchlings and fledglings. Management practices in the surrounding neighborhoods will likely keep insect populations minimized even in the open space. Connectivity to agricultural land will help provide a food source but due to flight distance will likely not make our site any more appealing to flocks of the species.

Missing Information

- Predicting insect populations in an area is a key gap.
- How many insects will each fledgling need before they leave the nest? What is the ratio of insect populations to bird populations that prevents nesting failure?
- At what intensity of grazing are nests at greater risk of being trampled?
- What is the maximum wind speed tricolor nests can endure without failure? How does this change with different nesting substrates?
What is the minimum flock size to prevent nesting failure by predation?

Part 2: Project Goals and Management Plan

Increasing Reproductive Success of Tricolored Blackbirds (*Agelaius tricolor*)

Restoration Goal

This restoration and monitoring plan is intended for use during the breeding season of tricolored blackbirds in and around nesting sites. The plan does not address wintering habits or other times of year outside of the breeding season. The goal is

to increase the number of fledglings that survive to leave the nest each year. The greatest threat to tricolor populations is low numbers of insects as a source of food, decreasing the species average reproductive success. Fledglings will starve to death if the protein levels are not sufficient, grains cannot sustain them.⁵ Other threats include death by agricultural equipment, and over-predation due to low population numbers. Protecting the tricolored blackbird demands a number of actions be taken statewide otherwise extinction is certain.⁴

Habitat Requirements and Breeding Habits

The tricolored blackbird needs large enough habitat for nesting and feeding patterns. These spatial demands include up to 3 acres of nesting substrates² (i.e. marsh, blackberry) and 3-5km of grasslands⁴ for foraging during the breeding season. Tricolored blackbirds historically nest in native Emergent marsh plants from a few centimeters to a few meters above standing water, which is high enough to deter predators yet low enough to prevent flooding the nest.⁴ Nesting substrates include cattail, bulrush, thistles, blackberry, and grain silage crops.⁶ Non-flooded habitat vegetation may include spines, bristles, or thorns to deter predators. Tricolors build their nests within approximately a half a meter of each other because close proximity gives them group protection to fend off predation.⁴

Nesting and breeding occur during peak insect populations after the end of the rain season, during late spring and early summer. This response is a temporal adaption to peak food availability in the region. Agricultural practices provide food and nesting habitat during this same timeframe thus enabling tricolor use of agricultural silage fields for feeding and breeding.² Nesting occurs in late March to Early April in the San Joaquin Valley and May to June in the Sacramento Valley and foothills.⁴

Over 4-5 days every breeding female in tricolor flock lays 3-4 eggs in one brood per season while in high density breeding colonies.¹ Before populations declined, up to 100,000 nests would be grouped together over only a few acres of marshland habitat allowing protection in numbers from predators.² If colonies breed a second time in the season they are likely to change locations in between.⁴ Once hatched, chicks will fledge and be able to feed themselves after approximately 24 days.⁷

Objectives

1. Increase insect populations:

Tricolor blackbirds have seen their protein sources decrease as a result of pesticide use and insect control.⁵ Promoting voluntary preventative use of pesticides in known or sighted nesting locations will promote insect populations, protein sources for tricolors.⁵ Allowing insect populations to be predated on by bird flocks rather than using pesticides also helps mitigate pollution. In places where insect populations cannot be increased or pesticides must be used, local agencies could supplement the tricolor flocks by releasing insects near them. Hatchlings and fledglings are fed diets containing 90% protein by weight of beetles and weevils

(Coleoptera), cutworms and Alfalfa loopers (Lepidoptera), snails and mollusks (Mollusca), and flies (Diptera).³ Tricolors are also known to eat dragonflies (Odonata), caddisflies (Trichoptera), and grasshoppers (Caelifera).⁵ There is a wide variation in the insects and forages eaten indicating tricolors adapt to a changing range of species availability.³

Community outreach and education about threats and their prevention to the tricolored species can be incorporated into websites and other community resources. For example putting bells on pets and not using pesticides on lawns in spring.⁴

2. Controlling Predation Rates:

Removing invasive predators like cattle egrets or domestic cats and mitigating excess predation from native predators like foxes and snakes will protect undersized flocks lacking their resistance to Allee effects (low fitness in low population numbers). The birds historically flock together to protect their nests from predation by perching, displaying, and harassing the predators in groups.²

3. Outreach to Agricultural Communities:

By reaching out to agricultural communities to increase awareness and support for the NRCS Environmental Quality Incentives Program, crop harvest can be deterred or delayed to protect fledglings and nests from destruction by agricultural equipment.¹⁰ Use of this program helps because over 95% of wetland habitat statewide has been lost resulting in tricolor flocks returning to marginal breeding sites even when reproductive failure has previously occurred there.⁶

4. Fire Control:

Fire is common in the Sacramento valley and fire prevention in nesting sites during dry years may be needed to conserve flocks.

Hopefully taking mitigation actions and increasing habitat through restoration will have positive impacts on reproductive success. Increasing populations above the minimum viable population numbers of the species for increased effective breeding, increased reproductive success, and decreased nest failures may help prevent extinction. Without management areas with high predation potential, low insect populations, or agricultural fields act as population sinks where use results in further decline of tricolor populations as a result of predation of fledglings, starvation, and death by silage harvest, respectively.⁶

Restoration Plan

1. Community Outreach:

Posting information on local agency websites in areas with tricolor habitat about tricolor blackbird characteristics and conservation actions for local farmers and other community members can help to enhance species survival. This information

would supplement the public with knowledge and actions that might help protect nesting flocks. Some details to include would be:

- Reducing pesticide use in neighborhoods, parks, and agricultural fields near known nesting sites, or when breeding flocks are sighted, to increase insect populations.
- Prevention of killing birds for sport, as pests, for scientific, or other purposes because of their low population numbers.⁴
- Keeping outdoor cats and free-to-roam pets indoors or fitting them with bells from March through June if flocks are seen nesting nearby.
- Educating farmers about the threat to fledgling success due to harvesting in spring when species nest in their fields and informing them about opportunities to be reimbursed for their financial loss by delaying harvest under NRCs' Environmental Quality Incentives Program (EQIP).¹⁰ Applications can be found at:

<http://www.nrcs.usda.gov/wps/portal/nrcs/main/ca/programs/>

Due to the variation in what actions can be used in different anthropomorphic situations, strict instructions are hard to determine. For example, one private landowner may be able to delay harvest and allow release of insects near the flock as a supplement but not stop pesticide use; another private landowner may stop pesticide use but refuse to delay their harvest. Delaying harvest would be a more important step to take because it protects the fledglings from death by harvesting machinery. Thus, implementation will need to be catered to the circumstances of the breeding site in question.

2. Habitat Restoration:

Restoring and enhancing *marsh vegetation* as nesting substrate where possible can help decrease predation by allowing birds to nest in larger flocks. Restored wetland areas would need to be within 5 km of a grassland source of insects and grains for food.⁴

Habitat in areas with high predation rates can be enhanced or conserved by preventing eradication of Himalayan blackberry or blackberry hybrids.⁴ Areas of *blackberry* can be used as substrate when spread across more than an acre⁴ in landscapes that fit the criteria for nesting excluding presence of wetlands. Himalayan blackberry is taller with larger thorns than native blackberry thus it provides more protection by deterring predators.⁶ Since tricolors return to previous nesting locations, maintaining and expanding blackberry stands at known nesting sites may help increase population numbers if successful reproduction can occur there.⁴

Increasing *connectivity* between potential nesting and feeding habitats, minimizing edge effects, and increasing habitat size where possible with nesting and forage vegetative will all help increase fledgling success.

3. Food Supplementation

When protein supplies are low for tricolor fledglings the adults will choose to let one or more of the fledglings starve, to ensure some of the brood survives to adulthood.⁹ Supplementing insects in sites where birds are nesting during breeding season to increase fledgling success can be done when monitoring shows fledglings in the same nest are growing at different rates or if one or more fledglings begin looking emaciated. Insects could be released in the forage sites near the nests, or, if known, in the forage sites the flock disperses to daily.

A gap in knowledge here is to determine how many insects to release, which depends on the density of the flock and the protein by mass of the insects used. Another gap is where to release insects for the highest success. This information will need to be determined by future research on the species.

4. Controlling Fire

Fire management can be done by mowing an edge buffer around large areas of land (a fire break) to disrupt connectivity of fires that do occur. The gap in vegetation slows the fire and decreases its intensity. Mow after land has dried from the last spring rain and annual grasses have come up. Using a riding mower, mow a few meters wide strip around a perimeter of a few to several acres. The width and frequency of firebreaks depend on the vegetation, if too narrow fire can jump the break.¹² I have witnessed this technique used in the California Bay Area and the fires that occurred burnt with low intensity and didn't spread.

5. Temporal and Spatial Concerns

All threat mitigation, reproductive monitoring, and other actions can occur during the months of March-June depending on the flock present, which is the extent of the breeding season. After tricolors fledge they will remain in the nest 4-14 days with their parents. Fledglings stay beyond 4 days when there are no riparian trees or shrubs to move to, as in the central valley silage belt.⁵ Enhancing riparian habitat buffers where possible may promote tricolors leaving the nest 4 days after fledging, potentially allowing farmers to harvest up to 10 days sooner than without alternative habitat nearby.

Low nesting populations may not be able to rebound without management. After comparing the species habitat requirements with your conditions you may determine your reserve will be a *population sink* as a result of nesting failure of tricolored colonies leading to decrease in species numbers. If threats are present

and unmanageable please deter the species from remaining on your reserve by flushing them out⁹ during the few days (from late March through May) colonies are seen seeking a nesting site, before they can build nests.

Monitoring Plan

Monitoring for nesting flocks in marshes and silage fields can be done twice a week starting in early March or April, and running through late May to June.⁵ Flocks that are located can be monitored twice a week for the following factors:

- Monitoring for *predators* (i.e. skunks, cats, snakes, etc.) near nesting sights during breeding season can inform management decisions to remove species for prevention of lost eggs and fledglings to excess predation. Sightings may include physical and visual indicators. For example, finding multiple broken tricolor eggs near the nest site when another species is feeding on the eggs. I recommend preventing predation completely to increase the number of fledglings per flock that reach adulthood until tricolor populations warrant delisting from the California Endangered Species Act. The minimum viable population and the threshold of predation that leads to colony nesting failure will need to be determined with further research.
- A rough *census count* of fledglings can be done because they will stay 4-14 days after they fledge, perching and being fed by their parents, before the flock leaves the site.⁵ The census collected can then be documented at the Tricolored Blackbird Portal through UC Davis at <http://tricolor.ice.ucdavis.edu/node/547> to be used in determining species population status.
- Time intervals of a half hour can be set to ensure there is enough time to track and count all individuals at each site monitored.⁵ When counting fledglings before they leave the nest, the time of day is not important. If counting for male or female adults, monitoring should occur in the morning before dispersal for feeding, or in the evening following the flocks return.
- If egg, chick, or fledgling death is detected by observation of indicators (egg shells, corpses) or by decrease in census counts, consider the potential threats at the site and mitigate for them using the management strategies aforementioned. Threats may include predation, starvation, or nest damage (from high winds, fire, etc.).

More frequent monitoring may be needed if *insect populations* are kept low by drought or pesticides:

- Monitoring nest sites during breeding season can be done as often as daily by observation and if fledglings are growing at different rates in the same nest, or if one or more fledglings begin looking emaciated, insects could be supplemented. If supplementation is needed please refer to the Restoration Plan, number 3: Food Supplementation.

Restoration and Monitoring Plan Gaps in Information

Gaps in this plan include detailed step-by-step instructions in how to carry out the restoration and monitoring plans. Different sites will have different requirements based on both the environmental and sociopolitical restrictions at individual sites. It is also hard to predict the level of public involvement and cooperation because it will vary in different communities depending on what is important to them. Thus the plan should be implemented with adjustments as needed, and choices made on what will work best at that location.

More research into the density dependence on insects is needed to provide accurate and easy ways of calculating the size of insect releases.

Monitoring can be expanded as the agency sees fit to answer research questions including but not limited to:

- Preparing or using a database (like nestwatch.org) of nesting sites that can be accessed and updated by the public to help managers keep track of nesting tricolor flocks during the spring. These databases could be used year-round for other purposes.
- Minimum viable population number for species survival may be determined by comparing the sizes of multiple failed and successful reproductive flocks over time.
- Banding birds and sampling feathers for DNA sequencing may help identify species patterns both phenotypically and genotypically.

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Swainson's hawk (*Buteo swainsoni*)

Hailey Pexton

Part 1: Project Background and Justification

Background and Justification

The Swainson's hawk (*Buteo swainsoni*) is a long-distance migratory bird whose breeding range stretches from western Canada through the western United States down to northern Mexico. The majority of the population is found in the Central Valley (Woodridge, 1998) where they were historically once found throughout its riparian communities and lowlands (Babcock, 1995), but are presently recognized as "threatened" by the California Department of Fish and Wildlife due to a decline in 90% of their breeding population first noticed 4 decades ago (Five Year Status Report, 1993). The most significant driver of loss of their nesting and foraging habitat is urban sprawl and development. This makes restoration in the Central Valley a prime focus because it is home to 80% of California's Swainson's hawk population alone and a place where agriculture



[Photo Credit: Mia McPherson]

directly affects their habitat selection and foraging behaviors. The hawks also face reductions in prey populations, pesticide poisoning, and fragmentation.

Centennial Park has the unique opportunity to offer the Swainson's hawk a habitat resemblant of a wildlife setting that's in the heart of the otherwise developed landscape of Vacaville. Because the hawk's range is correlated with available foraging habitat, nest location, and prey accessibility (Babcock, 1995), the park would act as a stepping stone so that Swainson's hawks could have more hunting opportunities and connectivity. Also, the hawks have had to adapt to the seasonality and types of agricultural crops in the Central Valley in order to survive (Estep, 2009). Providing them with sufficient tree and riparian nesting locations offers them a setting that is less subject to variability and disturbance and more natural. Thirdly, the largest Swainson's population in the state is found between Sacramento and Modesto (Woodridge, 1998), so having another qualifying substrate can offset nest locations more effectively and go a long way in terms of targeting the highest concentration at once. Loss of the Swainson's hawk in the Central Valley would mean disappearance of most of the population as a whole, making its preservation in Centennial Park a valuable pursuit.

Literature Review

Characteristics of the Swainson's Hawk

Phenology

- Incubation and early nesting occurs in Central Valley from April 12 to 29 (Estep 2008).
- Late nesting and early fledging occurs from June 9 to July 1 (Estep 2008)
- Sexually mature hawks migrate out of the Central Valley in mid-September and returning in early March (CEC and CDFW 2010).

Reproduction/Nesting

- The hawks return to the Central Valley to nest from their migration route between early March and April (England et al., 1998). They build a nest within two weeks after arrival and require about a week to do so.
- Average clutch size is 2.5 with a range of 1 to 4 eggs (England et al., 1998).
- In Central Valley in particular, the average fledging date is between July 1 and mid-August (England et al., 1998 referencing "Estep, 1989").
- Those that are migratory leave between late-August and September (England et al., 1998).
- Swainson's hawks normally nest in trees that have panoramic views and are "semi-exposed" (Woodridge, 1998). [See list in "Habitat Requirements and Preferences" section below for specific tree species].
- Many nests are in trees ranging from solitary to dense riparian forest locations (Woodridge, 1998).
- Nests are often below the canopy, towards the ends of branches, flimsy in appearance and don't last through winter (Woodridge). [See list in "Habitat Requirements and Preferences" section below for specific plant species].
- Competitors primarily include other buteos like the Redtail hawk (England et al., 1995).

Habitat Requirements and Preferences

- Woodridge (1998) states that the hawks are highly dependent on both the availability and distribution of trees that are suitable nesting sites and "in proximity to high-quality foraging habitats".
- Swainson's in the Central Valley are more likely to be found in the flat valley floor than in the margins near hilly habitat (Gifford 2012)
- Swainson's hawks in the Central Valley are highly associated with riparian forest vegetation, which at the minimum should have components of a nesting substrate such as large trees (Woodridge, 1998).

- Tree species commonly used for nesting in the Central Valley include: willows (*Salix* sp.), Fremont's cottonwood (*Populus fremonti*), valley oaks (*Quercus lobata*), sycamores (*Platanus* sp.), and walnut (*Juglans* sp.). There is occasional use of introduced species including *eucalyptus* sp., pines and redwoods (Woodridge, 1998).
- Plant species commonly used for nest-making in the Central Valley include: Russian thistle, sagebrush, tumble-mustard (*Symbriussum* sp.), and other weeds (Woodridge, 1998).
- Density is determined by tree availability and land use (Woodridge, 1998); low densities occur in abandoned, weedy fields and other types, while high densities occur in alfalfa dominant areas.

Hunting/Foraging

- Swainson's hawks are adapted for aerial foraging, of which they spend a lot of time doing, and this is associated with harvesting events in agricultural zones that exposes prey (Woodridge, 1998).
- They often sit atop perches such as fence posts or power poles (Woodridge, 1998).
- They are largely insectivores (England et al., 1998); of the non-insect prey, California voles make up 45% including deer mice, pocket gophers, etc. (Woodridge). Birds make up 32% of the menu and, the farther northeast you go, the higher the percentage that montane voles and Belding's ground squirrels make up their diet.
- Foraging value of vegetative cover types can be evaluated simply by the access that aerial predators have to rodent prey (Estep, 2009).

Tolerances

- According to Woodridge (1998), Swainson's hawks are fairly tolerant of human activities, especially that which is regular, and often nest in locations near anthropogenic noise and light pollution
- They can tolerate routine disturbances from automobile traffic cars, agricultural vehicles, and airplanes; this is especially true if it occurred during nest site selection (England 1998).

Spatial and Temporal Needs

- Range is determined by prey abundance and accessibility (based on cover and density), total available foraging habitat in home range, nest location, and vegetation types (Babcock 1995).
- They require a home range of 9,978 acres (4,038 hectares) in the Central in particular (Babcock, 1995)
- Tree patches and distribution are fairly unimportant (Woodridge, 1998)

Threats

- Disease outbreak is always a concern, especially the threat of a West Nile Virus invasion, which has a history in the Central Valley (Bradbury, 2009).
- Annual climatic variation can directly impact egg and nestling, nesting site durability, mortality rates, territorial occupation, and prey abundance (Woodridge, 1998)
- Pesticide use can lead to eggshell thinning, poisoning by consumption, and direct mortality (Woodridge, 1998). Leading kinds include organophosphate and carbamate insecticides.
- Predators include: Great Horned Owls, adult hawks, coyotes, Golden Eagles, and bobcats (Woodridge, 1998).
- Exotic invasive plant species threaten prey availability (Woodridge, 1998;
- Loss of mature riparian habitat and compatible crop types like alfalfa (Woodridge, 1998;

Management Opportunities

Habitat Surroundings

- Manage the area so that much of the vegetative cover is low or under control and therefore promotes prey visibility (Babcock, 1995; Estep, 2009). Vegetation should still be present for prey to hide, so this should be kept in mind. Clear-cutting is not an ideal option. This is an opportunity for grazing.
- Do not remove trees from the list of recommended species and plant hardwoods like Cottonwood and Oak (Woodridge, 1998). Planting them as saplings would be best to expedite the process
- Conduct surveys, monitoring, and protection measures to ensure the long-term livelihood of the Swainson's hawk (England, 1998; Estep, 2009), for at least two years. Five is ideal.

Constraints, Thresholds

- According to Woodridge (1998), setting objectives for Swainson's Hawk habitat and populations in "riparian-associated regions of California" is a challenge. "Population size, density per unit of suitable habitat, survival rates, and metapopulation structure are not well known outside of a few small intensive study areas". It is possible that conditions outside of the breeding range such as shooting and pesticide use may be in effect, masking the true breeding zone conditions.

Other Focuses

- Helping to promote the Swainson's hawk population in general can contribute to their resilience against disease simply by increasing genetic diversity over time.

- Install an informational plaque along the trail about the Swainson's hawk to spread awareness, demonstrate their importance, and encourage advocacy.

Knowledge Gaps

- Not much peer-reviewed literature speaks to isolated population subsistence in Yolo county
- There are not many reference sites or cases in the immediate area [see Phillips 2014]

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Part 2: Project Goals and Management Plan

A. GOALS

Potential nesting and foraging habitat can be restored for the Swainson's hawks of the Central Valley, but it most important to examine habitat from a large scope and take into account current plausible sites, connectivity, and temporal occupancy. Because these hawks have adapted to trees and crops that scatter the Valley's landscape (Briggs 2011; Sousa 2008), it is just as essential to protect these habitat patches as it is to create more.

Restore and Enhance Nesting Habitat

Because the Central Valley region of California is key nesting habitat for 95% of California Swainson's hawks (Anderson et al. 2007) from mid-March to September (Bradbury 2009; Gifford 2012), it is important that the core focus of restoration be on the temporal and spatial needs of the Swainson's hawks' breeding season and nesting requirements, not only to promote healthy hawk genetic biodiversity and population structures (Hull 2007), but to prevent nesting in less desirable locations (Gifford 2012). Restoration efforts should take into account territory sizes and home range (Nebraska Game and Parks Commission 2010), which vary locally and are not universally agreed upon in Swainson's hawk literature. Estep (1989) estimates a mean home range of 2760.4 ha (or 6821.1 acres) in the Central Valley. He is quoted frequently (Babcock 1995; Bradbury 2009; Hull 2007), so we will use his data to guide these objectives. The California Swainson's hawk range, in total, stretches from Red Bluff to north of Bakersfield (Estep 2008). They are tree-nesting raptors (Sousa 2008) that prefer them to be mature and isolated along roadsides or in agricultural substrates (Briggs 2011; Sousa 2008). The less available candidate trees are, the more the Swainson's hawks will have to interact and compete with other tree-nesting raptors (Sousa 2008). In addition to range and distribution, tree species should also be accounted for when choosing nesting sites to preserve or restore. A recent report shows that, between 2005 and 2006, Swainson's hawks primarily nested in Valley Oak trees with Cottonwood, Willow, and Eucalyptus trees at high frequencies as well (Anderson et al. 2007). Mean nest tree heights ranged from 53.1 to 48.6 feet and mean nest height from 43.4 to 38.9 feet. This information is useful both in regards to candidate trees for prospective nesting sites and monitoring methods. Bloom's (1980) historical and survey data also conclude a general use of Cottonwood, Oak,

Sycamore, and Willow trees depending on the region. Maintenance of existing stands of trees is important in maintaining the current population size, but planting more lone trees and nesting platforms can lead in an increase in numbers (Nebraska Game and Parks Commission 2010). In the short-term, sites that already contain the distribution, abundance, and breadth of trees described above should be monitored for presence of all nesting raptors and assessed for potentiality of Swainson's hawk nesting grounds. In the long-term, breeding pair population sizes should be assessed and compared to the values above to capture an estimation of over all population trends. From 2005 and 2006 estimations, there are 346 breeding pairs in Yolo County, 159 in Solano County, 953 in Sacramento Valley, and 595 in San Joaquin Valley to name a few locations (Anderson et al. 2007). Sites to undergo restoration should have nearby riparian and foraging habitats. The distance from such habitat types is not clearly defined, but one suggestion from CEC and DFWS (2009) suggests a 10-mile radius of the nest sites from foraging habitats. These sites should also be as far from residential areas as is feasible, as hawks have been observed to cease occupancy of nests too close (Babcock 1995; Nebraska Game and Parks Commission 2010). Additionally, there is evidence that Swainson's hawks space their nesting sites at specific distances from each other regardless of the adequacy of the substrate (Nebraska Game and Parks Commission 2010), so this should be taken into consideration when mapping and designating nesting habitat.

Restore and Enhance Foraging Habitat

As mentioned in *Part I*, Swainson's hawks in the Central Valley have greatly adapted to agricultural crops and, in some ways, are more dependent on these substrates than most others (CEC and CDFW 2009; Hull et al. 2007). Their diet breadth is wide-ranging and variable (Estep 1989; Schmutz 1987), explaining their diverse use of various crops, rangelands and open spaces. Schmutz (1987) attributes the increased reproductive success of Swainson's hawks that nest near agricultural fields to the increase in prey abundance that is found in the "artificially increased plant productivity in the presence of nearby cover". Knowing all this, efforts should ensure that multiple substrates, particularly that of agricultural crops, be preserved mosaicly across the region. This is of course a collaboration of state and regional statutes and planning with the agricultural industry. The hawks' aerial hunting technique requires visibility (Estep 2009; Schmutz 1995), meaning the height and density of vegetation should be considered when designating and/or creating foraging habitat. Many agricultural land types will suffice as long as they provide a prey base and are reliable. In Yolo County in particular, the various cover types collectively offer high value landscapes for foraging that can support large densities of nearby-nesting Swainson's hawks (Estep 2008). Orchards, corn, safflowers, and sunflowers are examples of crop types that offer little opportunities for foraging. One key preference of the Swainson's hawks in the Central Valley is irrigated hay crops (alfalfa) because they provide ground cover for prey and remain for several years at once. Additionally, in more general terms, reproductive success has been

found to be higher in pairs nesting near fields than in extensive grassland (Schmutz 1987). There are no apparent tradeoffs for designating diverse land cover for foraging habitat because of the Swainson's hawk's diverse food options, as long as the crop types in particular promote the presence of these various prey (see "Part 1" for details about prey species).

B. RESTORATION PLAN

Surveying

Before alterations to the study areas can be executed, monitoring must occur (specific techniques are enumerated in section C "Monitoring Plan"). The term for monitoring should begin at least two survey periods (see Table 1) prior to the start date [California Energy Commission (CEC) and California Department of Fish and Wildlife (CDFW) 2010] and continue for an extended period up to two years afterwards in order to ensure that Swainson's populations are using the substrates successfully, based on the plan's set standards. CES and CDFW's (2010) recommended survey periods include: "Survey Period I", which involves full days prior to the Swainson's hawks' arrival (see Table 1); "Survey Period II" that features full days during their arrival, nest-building, and when trees are somewhat bare; "Survey Period III" in which egg-laying and incubation take place; "Survey Period IV", which takes place from sunrise to noon and 4pm to sunset to observe fledglings; and "Survey Period V" that accounts for post-fledging and takes place from sunrise to noon and 4pm to sunset. These criteria should be used for the purposes of this project, but with modifications to the time periods that are suggested in the original protocol. The time periods proposed in *Table 1* are derived from the Swainson's Hawk Technical Advisory Committee (2000).

In terms of spatial thresholds for adequate observations, the Swainson's Hawk Technical Advisory Committee (2000) recommends use of the California Department of Fish and Wildlife Services' methods of conducting surveys a half mile radius from where

	Survey Dates	Survey Time	Number of Surveys	Justification
I.	January – March 20	All day	1	Nests are easier to spot with minimal vegetation cover and this allows for familiarity with site.

Table 1. Survey periods tailored to the Swainson's hawk population of the Central Valley. These dates correspond with particular life history events that occur during the hawks' breeding season.				
I.	March 20 – April 5	Sunrise to 10:00, 16:00 - sunset	1	Most Swainson's hawks return by April 1. Most trees are still bare, allowing for greater visibility of nests. Hawks are often foraging midday and otherwise in their nests.
III.	April 5 – April 20	Sunrise to 12:00, 16:30-sunset	3	Nest activities significantly increase and territorial and courtship behavioral displays occur.
IV.	April 21 – June 10	(site-specific)	(site-specific)	Tree visibility is very poor and most activities take place low in the nest out of site.
V.	June 10 – July 30	Sunrise-12:00, 16:00 - sunset	3	Hawks' young engage in activities visible to surveyors. Parents make many trips to and from the nest. Visibility of nests improves.

all surveys and restoration activities are being conducted activities and further consultation in the event that another nesting location is found within this radial zone.

This distance is believed to maximize chances of observing the hawks. Foraging sites should be surveyed by transect lines that extend 100 meters along which data is collected at 10 meter intervals (Estep 2009). For nesting sites, driving surveys are preferred when looking for present nests or potential nesting locations.

Equipment

Nesting habitat surveys should include high quality binoculars and a spotting scope [Sousa 2008; Swainson's Hawk Technical Advisory Committee (SHTAC) 2000].

Surveyors should have maps of the site, GPS units, notebooks and flagging tape (SHTAC 2000).

Determine Present Nesting Sites

To determine if existing nests are in use, we can use the CDFW standards that define a nest as “active” if it has been used at least once in the last five years (CEC and CDFW 2009). GPS waypoints should be taken at those that are abandoned. To measure effectiveness, data should be cross-referenced with previous surveys.

Driving surveys should not occur over 5 mile-per-hour speeds and observations should ideally be conducted at multiple angles for best visibility (SHAC 2000). Surveyors should maintain a distance of 50 to 200 meters from the subject trees to maximize chances of detecting a nest and young. Apart from observations, surveyors should be aware of vocalizations. Hawks will frequently communicate with one another during territorial displays, courtship and mating, notifying the existence of food or threats, and chirping of chicks or fledglings. Estep’s (2008) criteria can be used to categorize nests and their occupation status, described in Table 2. Nests can usually be sighted in the upper canopy or lateral branches of taller trees, towards the outer ends of limbs, and partly exposed to allow for a panoramic view (Woodridge 1998). They have open platforms and are usually made of sticks and other plant matter found in situ.

Table 2. General terms to categorize the status of a nest site allow for organization across datasets and easier comparisons.

Designation	Description
Active Nest	Direct observations of incubating adults indicate egg laying.
Occupied Inactive Nesting Territory	Multiple observations confirm that no egg laying has occurred by the adults occupying the nest.
Occupied Nesting Territory with Unconfirmed Nesting Status	The reproductive outcome is unconfirmed due to inaccessibility or inconclusive repeated visits
Successful Nest	The nest is active and has fledged one or more young.
Unsuccessful Nest	An active nest that did not produce fledged young or occupied territory where the pair did not lay eggs.

Create Viable Substrate

There are numerous sources that propose various home ranges for the hawks. Babcock’s (1995) study yielded a range of 723.6 - 7658.8 ha, Estep (1989) proposed 2760.4 ha, and Woodridge (1998) suggests a large range of 69 to 8,718 ha. Large ranges are essentially meaningless when superposed (Woodridge 1998), meaning ranges are site-specific based on present conditions. Home range size has been found to have a strong correlation the amount of suitable foraging habitat

available nearby (Babcock 1995; Woodridge 1989). For the purposes of this proposal, local estimations should be used based on the location and scale of this project(s). There is limited literature regarding restoration projects for Swainson's hawk nesting and foraging habitat; however parameters can be derived from the previously mentioned spatial thresholds and tree species. Trees at a restoration site should primarily include cottonwood and oaks with spacing that allows for nest density of 0.17 territories per km² (Estep 2008). Fortunately, Fremont Cottonwood trees are a fast-growing species, which would allow for a more realistic and affordable timeline relative to other tree species.

Beyond the importance of the presence of trees, Swainson's hawks are strongly associated with riparian habitat (Woodridge 1998), which, if restored for hawk habitat, would be superior to upland and urban areas. These should be located near smaller drainages or agricultural crop types ideal for the hawks in order for it to improve habitat for them. Restoration of riparian forest alone cannot benefit Swainson's hawks. Vicinity of foraging habitat is once again crucial; however, riparian habitat coupled with tall trees and neighboring foraging substrates is optimal.

Support can be gained in designating foraging and nesting habitats. As Woodridge (1998) suggested, Conservation Reserve Programs (CRPP) offered through the USDA Farm Bill can provide incentives for farmers to maintain or grow crops. Restoring landscape to riparian conditions can benefit other threatened and endangered species, which may ultimately increase support for such activities. Grasslands can be managed to have enhanced visibility for foraging, which can be done by implementing mowing and maintenance of vegetation height (Estep 2009).

Potential Problems

Riparian habitat can't simply be restored without neighboring foraging habitat (Woodridge 1998). This could be a costly endeavor if proper distance measurements aren't taken into account to predict the adequacy of the over all range. It will be important to have both these measurements as well as more accurate range predictions regarding local hawks. Secondly, gaining support for designating foraging and nesting habitat in a place in which land is very valuable (Woodridge 1998) is important both for permitting and funding. Restoration projects at this large of a scale (when calculating in the buffer zones needed around a nest site) require adequate funding and labor. Thirdly, planting trees in riparian areas or near any water source can have adverse effects to water supply and flow. Lastly, where preservation of land mainly entitles creating restrictions from the public, restoration projects require permits. It may be more beneficial to designate existing land for Swainson's hawk habitat, depending on the site location; however, Central Valley has much agricultural land cover and tree communities.

Determining Risks and Uncertainties

Anthropogenic stressors are the biggest concern (Babcock 1995; Nebraska Game and Parks Commission 2010) such as human presence, noise pollution and even physical interference. Therefore the restoration site's distance from urban centers and roadways is once again an important consideration. This is why connectivity and frequency of suitable habitats is important. Swainson's hawks are migratory and travel long distances regularly, but will not likely nest in the center of a large city like Sacramento if the nearest open space is several miles away.

C. MONITORING PLAN

Techniques (Before and After Restoration)

Monitoring of nest sites should ideally occur up to five years after activities are completed in the recommended survey periods from section B "Restoration", however this is resource permitting. This time frame comes from the CEC and CDFW (2010) guidelines regarding designating a nest as "active". To ensure that nesting has been facilitated properly, it will be important to assess the status of nesting sites. Monitoring Swainson's hawk nests can be approached using the European Bird Census Council's (EBCC) European breeding bird atlas criteria (Hagemeijer 1997, cited in Resseguie 2007). Categories include "possible breeding", "probable breeding", and "confirmed breeding". "Possible breeding" would involve the sighting of a Swainson's hawk during the breeding season within a suitable nesting habitat. Indications of "probable breeding" include: observations of a pair during the breeding season in a potential nesting habitat, courtship and display, mature hawks displaying agitation or anxious calling, nest building, visiting of a potential nesting site and at least two different days a week of territorial behavior as an indication of permanent territory. "Confirmed breeding" entails observations of recently used nests or eggshells, adults carrying food, nests containing offspring, and/or adults flying to and from or incubating in a nest that is high up. These categories serve as definitions for surveys that are conducted both prior to and following restoration or preservation activities.

To ensure uniformity and precision in assessing change over time, nesting sites should be divided into grids (Gifford et al. 2012) and surveyed systematically each time. This allows for observations of new nesting locations, which could otherwise be bypassed if only monitoring specific nests. In the event that study areas are too large or small enough to assess without transects, surveys can be conducted by nest location. To do this, each nest location should have assigned GPS coordinates (SHTAC 2000).

While initial monitoring has very specific time frames in which surveying should be executed, post-restoration monitoring is more variable. In the short term, the site should be monitored based on the recommendations found in Table 1 because they comply with Swainson's hawk life history. However, surveys should be more intensive meaning that they must occur in more time intervals per period. This is because, in the first two years, it will be important to adjust management according to success or lack thereof within the sites. After 2 years, monitoring can

occur less intensively so that one or two surveys at minimum are conducted per year to observe any potential changes in occupancy.

GPS waypoints of spatial and temporal site data should be acquired each time surveys are conducted (or according to changes observed) so that nests can be identified specifically monitored, and also so that it can be used for data compilation and analysis in software like ArcGIS.

Research Questions

It would be very beneficial to learn more about the dispersal of young Swainson's hawks (Estep 1989), about which there is minimal data. It would also benefit this project to have a breadth of data regarding the minimum spacing between nests that is required as well as concrete home range averages in order to determine if spacing of sites is adequate beforehand.

What Can Be Answered by this Restoration Project

Primarily, restoring riparian habitat will allow us to see if conditions are sufficient for Swainson's hawks and, if not, what modifications are essential to make this so. Because the literature available has limited examples of projects such as this one, occupancy data will be very important in understanding more about this species.

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California Quail (*Callipepla californica*)

Isabel Morgan

Part 1: Project Background and Justification

Habitat: “prefers chaparral, sagebrush, oak woodlands, and foothill forests in California and the greater Northwest region of the US. Can also be sighted in city parks, agricultural areas, and suburban gardens.”

(http://www.allaboutbirds.org/guide/california_quail/id)



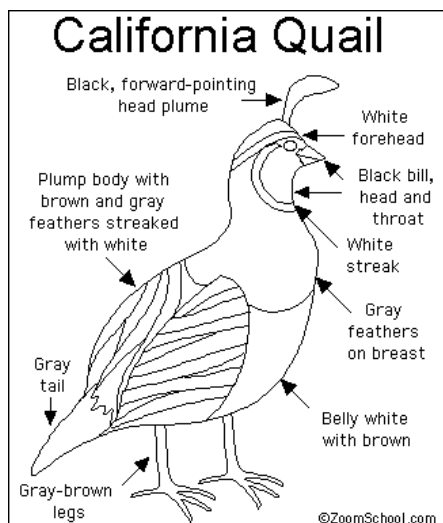
←This is a map of the United States with the range of the California Quails' habitat outlined in purple. (Photo taken from Wikipedia's California Quail page)

(http://en.wikipedia.org/wiki/California_quail)

Appearance: “California Quail are plump, short-necked game birds with a small head and bill. They fly on short, very broad wings. The tail is fairly long and square. Both sexes have a comma-shaped topknot of feathers projecting forward from the forehead, longer in males than females. Adult males are rich gray and brown, with a black face outlined with bold white stripes. Females are a plainer brown and lack the facial markings. Both sexes have a pattern of white, creamy, and chestnut scales on the belly. Young birds look like females but have a shorter topknot.”

(http://www.allaboutbirds.org/guide/california_quail/id)

Various photos of California Quail:



This photo (left) depicts the unique physical characteristics of an average California Quail. Use this photo as a reference for the following photos. (Image from Google Image)



Pictured above is a male California Quail (Google Images).



This is a photo of a mating pair of California Quails. On the left is a female and on the right is a male (photo from Google Images).

This is a photo of a male California Quail looking over his clutch of California Quail chicks. (Google Images)



This is what juvenile California Quails look like. They are not full grown and are molting their baby feathers in exchange for their adult coat and coloration (Google Images).



California Quails are often seen together in large groups. (Google Images)

Key Indicator Photos:





California Quail Scat (Google Images)

The California Quail (*Callipepla californica*) Background and Justification

The California Quail (*Callipepla californica*) is native to California and it ranges throughout low and middle elevations from northern Washington to the tip of Baja California (Ahlborn 1988). This species can be found living in a variety of habitats such as: chaparral, coastal sagebrush, foothills, riparian woodland, and the high desert. Currently the California Quail is considered of least concern according to the IUCN. It has been estimated that, overall, their populations have increased by 1.8 percent from 1966 to 2010 (“California Quail”). However, not all populations have increased. For example, the California Quail populations of San Francisco have been nearly extirpated due to rapid habitat loss and are facing local extinction (Stallcup 2007). The California Quail is an essential species to protect because by protecting and providing space, cover, and food for this species, one ends up providing a major food source and habitat for many other animals. For instance, by increasing the numbers of California Quail, various species of hawk, great horned owls, coyotes, skunks, bobcats, jays, and more have a renewed source of food (Ahlborn 1988). Additionally, by providing habitat for the quail, other animals like songbirds, brush rabbits, lizards, and more will increase in number because of the cover provided (Murphy 2014). It is also important to preserve this species because it has a large economical and emotional value to people- millions are hunted every year to the enjoyment of people and the California Quail is not only the state bird of California but it is also the official city bird of San Francisco where it has become nearly non-existent (McIlvaine 2000).

Literature Review

Characteristics of California Quail

Reproduction/Phenology

- They form mating pairs from March to early May and they nest from April until August. Their clutches are typically 14 eggs in size, which hatch after about 23 days of incubation sometime in June. The females

incubate while the males stay close; however, if conditions are favorable the female will re-nest while the male incubates the first nest of eggs (Ahlborn 1988).

- 12% of broods are reared communally and the parents of communal broods live 1.2 years longer than parents who raise broods alone. They also hatch more young during their lifetimes (McIlvaine 2000).
- Chicks are fully mature and able to reproduce at 10 months of age (McIlvaine 2000).
- California Quail have a high mortality rate of 74%. The chance of mortality is highest within their first year of life. The chances of a quail living to be 5 years old are one in several thousand (McIlvaine 2000).

Food Habits

- California Quail mainly eat legumes and other seeds (Ahlborn 1988), but have also been known to eat leaves, flowers, grain, Manzanita, poison oak berries, acorns, etc. ("California Quail")
- Sometimes they eat small invertebrates such as beetles or millipedes ("California Quail")
- Their diet is 82% seeds and the rest is a mixture of vegetation and arthropods (McIlvaine 2000).
- The California Quail forages on the ground and on low vegetation
- A study found that quail numbers may fluctuate depending on the abundance of food and whether or not cover is provided near the food source (Blakely et al. 1990).
- they never wander farther than 15-30 meters from their source of cover to feed (Ahlborn 1988).

Use of Space

- The winter home range is an average of 10.5 ha
- Quails forage in pairs over a 5-10 ha area prior to incubation, and 1.2 to 4 ha throughout incubation
- Broods of quails use a few acres of space within the first couple weeks of forming, and 4-8 ha of space by one month
- During nesting season unmated individuals wander in an indeterminate amount of space (Ahlborn 1988).

Habitat Preference and Requirements

- They prefer moist soil in late April and they have higher reproductive success rates if it rains during the previous winter (Botsford et al. 1988).
- California Quails need habitat with brushpiles because it provides cover for them (Gorenzel et al. 1991).
- There are six major cover types that California Quail prefer when living on irrigated lands and these include: agricultural lands of grass and alfalfa pastures, farm buildings and associated vegetation, field borders along ditches and roadsides, disturbed areas where parts of fields have been abandoned, riparian areas consisting of cottonwood and willow,

and floodplain shrub land dominated by sagebrush (Stinnett and Klebenow 1986).

- In the hot months the quail need a daily supply of fresh water in order to survive, however when the winter rains come this is less of a necessity (Gutierrez 1980).
- They can use mildly salty water as their water source if that is all that is available (Ahlborn 1988).
- There is a higher reproductive success rate if there is a minimum amount of fog and rain during the nesting season (Ahlborn 1988).

Threats

- Habitat loss and insufficient cover threaten California Quail in the San Francisco Bay area (McIlvaine 2000).

Competition/Predation

- The predators of California Quail are: Cooper's hawk, Sharp Shinned hawks, Great Horned Owls, various species of snake, ground squirrels, domestic cats, coyotes, skunks, bobcats, and jays (Ahlborn 1988).
- The California Quail have an allopatric relationship with the similar-looking Gambel's Quail (McIlvaine 2000) and a sympatric relationship with the Mountain Quail. They do not compete with either species even though their ranges overlap and they have similar sources of food. This is due to the fact that Gambel's Quail habitat has only a slight overlap with that of the California Quail (McIlvaine 2000) and because the Mountain Quail has a very different foraging strategy for their food that seems to inhibit any competition between the species that there otherwise might be (Gutierrez 1980).

Gaps in Knowledge

- How California Quail respond to grazing, fire, plowing, herbicides/pesticides, etc.

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Part 2: Project Goals and Management Plan

A. Goals

Restoration and Improvement to the Natural Habitat of the California Quail

The California Quail (*Callipepla californica*) requires three different elements of its natural habitat to be present and in specific

forms; these are: food, water, and cover (Emlen 1945). Their diet is 82% seeds and the rest is a mixture of vegetation and arthropods (McIlvaine 2000). The quails prefer seeds that range in size from slightly smaller than the head of a pin, such as pigweed or miner's lettuce, to about the size of a pea (Emlen 1945). Depending on the time of year, the diet of the California Quail changes. In the spring they mainly eat the seeds of newly matured annuals, whereas they feed on common clovers, lupines, and trefoils during mid-summer, and during late summer they switch to tarweed, thistles, turkey-mullein, and Spanish clover. In winter they switch from seeds to the leafy greens of annual weeds and grasses due to the lack of seeds during the winter. In order to ensure that the quail will have sufficient and appropriate food throughout the year the most common native plants of California should be planted where the quail restoration project is occurring (Emlen 1945).

California Quail also require a reliable source of freestanding water during the summer months to stay satiated. If they have enough water they will visit their source of water once per day. If the rains are delayed and the quail are without water for a few days they begin to die (Emlen 1945). Providing supplementary sources of water is an effective way to increase quail populations during the hot summer months. Digging out semi-permanent springs and seeps that last throughout the summer or ensuring existing stock troughs on the property in question stay filled for the quail are simple ways to provide water. Another option is to install "self-filling" watering devices, aka "gallinaceous guzzlers", throughout the quails' habitat. The cheapest way to make these is to clear vegetation away on a slope uphill from where the water is to be collected in a tank, coat the soil with a thin layer of road oil, and insert a below-ground concrete water tank to collect the water that drips down, which is then connected to a drinking trough on ground level (Emlen 1945).

One of the most essential aspects of the California Quail's habitat is sufficient cover. There are five types of cover that quail use: loafing cover, escape cover, feeding cover, roosting cover, and nesting cover (Blumenfeld 2004). Loafing cover is used by quail when they are napping or preening. It ideally should be close to where they feed, low in height, dense enough for them to be inconspicuous, yet open enough to allow for freedom of movement. Quail use escape cover to run to if they are surprised while they are foraging. They rarely wander more than 50 feet from cover so they can run back to it and hide if need be. It is comprised of dense, low shrubs, trees, vines, weed patches, piles of debris, and/or rock piles. Feeding cover is used by quail while they feed. It is in clearings with sparse vegetation that allow them to monitor the sky. They need feeding grounds that are extensively distributed because they do not stay in one spot for long while feeding. At night they roost in densely foliated tress or in shrubs 5 to 30 feet tall- this is known as roosting cover. A good roosting site should cover a covey inhabiting a 30

to 40 acre covey range. However, if populations are large and overlap then many sites are needed. Nesting cover consists of almost any type of cover that affords shade and concealment from predators. Their nests are on the ground. Limitations of nesting cover are farming operations and overgrazing that destroy the ground cover they need to protect their nest (Emlen 1945). By planting new vegetation around heavily browsed shrubs, near water troughs, or in pasture corners tends to result in the rapid re-growth of sufficient escape and loafing cover. Grassy nesting cover should be protected from grazing until the nesting season is over in July. Planting one-year-old Tamarisk trees would quickly provide roosting cover. It should be noted that any program to re-grow or enhance cover for quails will take patience, hard labor, and at least one year to start seeing results (Emlen 1945).

B. Restoration Plan

Restoration and Improvement to the Natural Habitat of the California Quail

- **Improve Quantity and Sources of Food**

To improve on the quantity and sources of available food to California Quail native forbs need to be planted. However, highly cultivated areas where these quail are often found are not pervasive to growing high-quality quail food. A simple fix to this problem is to set aside a few 20 to 30 foot strips of land along the borders of hedges or brush piles that will not be cultivated. Then, plant annuals in these areas and encourage them to grow by light disking or by burning feed strips before the winter rains (Emlen 1945). However, it is inadvisable to treat many strips at a time for it may have a negative effect on the following growing season. Additionally, if burning is the tactic chosen, it is important to be careful not to burn any of the cover used by the quail. Generally 1-2 feet of grasses are left un-burnt between the cover and the strips of land (Emlen 1945). Plants such as wheat, barley, millets, milo, kaffir, sudan grass, and vetches can now be planted on flat ground or gentle slopes near quail cover. All of these plants are available at feed stores. Note that quails may not eat the first crop of wheat if they are not accustomed to eating grain, barley is less desirable than wheat but is satisfactory to quail if barley has grown in the area for some time, millets are highly desirable on irrigated lands, sudan grass and vetches are considered excellent quail food, and milo and kaffir eaten at a moderate amount (Emlen 1945).

- **Improve Access to Water**

In order to ensure the California Quail have access to adequate water throughout the year certain measures must be taken. Water is of little concern during the winter months when the rains come, but during the hot and dry months the quail need free standing water. If there is no access to creeks, springs, seeps or horticulture watering then

self-filling water-collecting devices need to be built and installed like the one described above (Zornes 2009). It is also possible, and considered the simplest approach, to dig out semi-permanent springs and seeps so they can provide water year-round. This can be accomplished by boxing with redwood or concrete and fitting the spring or seep with a float valve to conserve the water (Emlen 1945). Or, existing stock troughs can be fitted with wooden board with cleats so that the quail, both the chicks and the adults, can reach the edge of the water troughs. Then a wire screen should be placed down into the water so the quail can reach it. If water is abundant, then an "L" shaped tube can be placed in the trough and pinched toward the bottom to provide a trickle of water for the quail. However, in areas where there is no access to water, rain-collecting water devices should be built. One such device, known as the "dew dropper", is made with a 50 gallon oil drum with a 3 feet long pipe fitted into its opening. The lower end of the pipe is tapped at regular intervals where ball valves are fitted into it and the pipe is capped off at the far end. The "dew dropper" is only recommended where it can be monitored and filled regularly, for if the water has high levels of minerals, the valves will become covered in precipitate from the minerals and they will stick either open or closed (Emlen 1945). A "gallinaceous guzzler" (see description above) can also be installed to grant access to water. For this device to be worth the investment, it must be placed in areas where half the minimum annual rainfall will fill the tank. A shade and protective cover should be built with 2 x 10 inch redwood planks secured over it to provide shelter and protection from large animals. It rarely needs maintenance except for an occasional cleaning (Emlen 1945).

- **Increase the Quality and Quantity of Cover**

Improving the cover of California Quail is crucial. They utilize five different types of cover that are used for specific things and have certain requirements for what they consist of and where they are located (see more detailed description above). For example, patches of loafing and escape cover must be 10 to 20 feet in diameter and cannot be more than 200 feet away from another source of escape cover. Some farmers need windbreaks along field borders like hedges of osage-orange, cypress, or tamarisk which also happen to provide adequate escape, loafing, and roosting cover for quail. As you can see, some cover improvements can be fit into farm lands with little to no interference with the day to day operations and often great benefits are seen for both quail and other species. Actually planting and growing the plants that provide cover does take considerable planning, manual labor, and time for the plants to grow to their maximum density and height (Emlen 1945).

C. Monitoring Plan

Prior to any restoration work, maps of the area under consideration for the restoration of California Quail should be studied to find current sites that are uninhabited by quail. Those sites should be closely scrutinized so as to better understand why exactly quail do not use that habitat. Once you have this information you will know what needs to be improved and what does not and the restoration work can begin. Remember, the essential elements to keep in mind of any quail habitat include: food, water, and cover. It is important to plan habitat enhancements on a watershed scale (Zornes 2009). Once the management plan has been put into action, the quail populaion(s) need to be monitored to see if the habitat enhancement worked. Therefore, ongoing population and habitat assessments should be conducted by doing walking surveys and listening for quail calls or looking for visual evidence of quails (Blumenfeld, et al. 2004). A good time to survey is during the spring when you can quantify spring call counts and brood counts (Barry, et al. 2006). Close monitoring is not necessary during years of heavy winter rainfall, but monitoring should be frequent in very arid, dry years.

Further Research and Improvement

There is still much we do not know about the California Quail. Despite extensive searches there seems to be no one who knows how much water and/or rainfall a single quail or covey needs per year. Knowing the exact amount of rainfall or freestanding water they need each year would be helpful for conservation projects. It would also be helpful to know an accurate number of the density of these quail, whether it be within a certain range or an estimate of how many there are left in the world. Due to their cautious nature they are a difficult species to census (Zornes 2009). This restoration project would reveal population densities within an area.

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Coyote (*Canis latrans*)

Lauren Mount

Part 1: Project Background and Justification

Background Information

Coyotes are an important keystone species for many areas across North America including grasslands, wetlands, and chaparral habitats (Levi, 2011). They are important for their ecosystems because they are one the most abundant predators in North American due to the decrease in the prevalence of larger carnivores such as wolves (Berger et al., 2008). Coyotes are not threatened as a species and are actually incredibly resilient to environmental changes (Meachen et al., 2012). However, coyotes play a huge role in increasing the amount of biodiversity that is within the ecosystems they live in (Levi, 2011). This is also due to the fact that they are the top predator in most of their habitats and therefore they heavily influence their ecosystem's trophic cascade (Levi, 2011). Unlike most species the abundance of coyotes increases within closer proximity of urbanized areas. Coyotes have adapted to urban environments and actually thrive within urban communities in a similar way to raccoons (Levi, 2011). Unlike raccoons however, urban dwellers sometimes feel threatened by coyotes, which leads people to have negative attitudes about them as a species (Gill, 1970). The goal of this restoration plan is to work on harmoniously overlapping human urban environments with coyote habitats without aggravating either species.

Literature Review

Coyote Habitat, Food Supply, and Behavior:

- Coyotes are found in a variety of habitats and have increased their range into many suburban areas. They can be found anywhere in North America where there are small animals, fruits, and vegetables for them to eat (Ordeñana et al. 2010).
- Carnivores like coyotes tend to live in large ranges that encompass several miles, have lower population densities, and slow population growth, which makes habitat loss a bigger threat to their survival. (Ordeñana et al. 2010).
 - Consumers that are higher up on the trophic cascade such as coyotes are often at greater risk of becoming endangered than lower consumers and plants. The loss of species such as coyotes can have direct and indirect impacts on ecosystems (Duffy, 2002).
- Coyotes can be found in almost all parts of North America. They thrive in grasslands, chaparral and wetlands (Levi, 2011).
- Coyotes in the Central Valley make their dens in a variety of places including, rock ledges, hollow logs, and slopes covered by brush (Shargo, 1988).

- It has been documented that when disturbed coyotes will often move their pups into another den (Gehrt, 2013)
- In the Central Valley, coyotes use roads, trails, open chaparral or open grassland landscapes to hunt and forage for food (Quinn, 1990).
- Coyotes need large areas that are home to many smaller birds and mammals as well as plants and berries to forage on in order to satisfy their diets (Hawthorn, 1972).
- Courtship may begin as early as 2 to 3 months before coyotes attempt to mate. Some coyotes mate with the same individual from year to year, but not necessarily for life (Bekoff, 1977).
- In the Sierra Nevada, coyotes mate from February to May (Verner and Boss, 1980).
- Coyotes are active day and night, with peak activity at sunrise or sunset (Gipson and Sealander, 1972).
 - The ecological impact of cats on natural habitat is minimized due to inter-species competition with coyotes. (Gehert et al., 2013)
- Coyotes moved towards urban developments at dusk and would often roam into urban areas at this time (Tigas et al. 2002).

Coyotes Impact as a Keystone Species:

- Coyotes act as a keystone species within their ecosystems (Levi, 2011). This is because of the loss of larger carnivores such as wolves, which controlled the population of coyotes through competition and predation. (Berger, et al. 2008).
- The increase in carnivores such as coyotes has led to an increase in the amount of predation on smaller birds of prey. (Ordeñana et al., 2010). However, another study shows that coyotes increase the abundance of songbirds and rodents in their habitats by suppressing populations of smaller carnivores such as cats and foxes. (Levi, 2011).
- Similarly another study showed that the ecological impact of cats on natural habitat is minimized due to inter-specific competition with coyotes (Gehert et al., 2013).
- Carnivores such as coyotes exert a top down control effect on their ecosystems by preying on smaller mammals and birds (Levi, 2011).

Urbanization Effects on Coyotes:

- The main threat to most species is urbanization because it causes habitat loss and habitat fragmentation (Ordeñana et al., 2010). However, coyote sightings increase with closer proximity and intensity of urbanized areas (Ordeñana et al., 2010).
- Fragmentation leaves pieces of habitat that can no longer maintain a viable population or even a single mammals home range (Beier and Noss, 1998).

- Coyotes can exploit resources from urban areas due to their adaptive behaviors and diverse diet. This is especially true within areas of concentrated garbage, food and domestic animals. Coyotes in urban areas can actually benefit and increase in population as urbanization increases. (Ordeñana et al., 2010).
- Coyotes have the ability to change their habitat range, behaviors, and ecological niche depending on how their ecosystem changes. (Meachen et al., 2012).
- Although coyotes can react positively to human development, they can also react negatively to urban development that have habitat fragments that are too small or isolated, meaning that there is not enough space for coyotes to adequately hunt without crossing into urban territories. Therefore, coyotes might frequent urban habitat but likely require access to sufficient natural areas to persist.” (Ordeñana et al., 2010).
- Roads and urban development can act as a physical and also social barrier between coyote habitats. This puts coyotes at a higher risk for being involved in a mobile collision (Ordeñana et al., 2010).
- Coyotes were less active during the day in fragmented habitat than in unfragmented habitat, which suggests that they actively avoid human activity (Tigas et al. 2002).

Possibilities for Coyote Management:

- To prevent coyote mortality via mobile collisions, corridors should be made in between habitats in urban areas. This could lessen the negative impacts of urbanization and are very important for maintaining biodiversity within habits that have been separated by urban sprawl (Ordeñana et al., 2010).
- Corridors that connect habitats underneath busy roads and developments should be implemented to connect coyotes to other habitats (Gill, 1970).
- Since, a main threat to coyotes in urban areas is complaints from urban dwellers one of the most important factors in keeping coyote populations abundant is to change people who live in cities’ attitudes on wildlife. (Gill, 1970).
- “Control activities are focused upon individual coyotes that cause specific complaints, thus a selective pressure is acting to reduce the number of those coyotes that cause problems to man, while permitting those animals which are less a nuisance to remain unmolested.” (Gill, 1970).
- . Coyotes searching for food are more commonly found in urban areas with concentrated garbage, food, or domesticated animals (Odenana et al. 2010).
- Burning small patches of vegetation makes favorable habitat for small mammals, which encourages the presence of coyotes to that area (Quinn, 1990).

Part 2: Project Goals and Management Plan

A. Key goals

-Maintain and Improve Coyote Habitat

Coyotes can be found in a multitude of habitats including sage brush, grasslands, chaparral, wetlands and deserts (Spowart et al. 1986). In California's Central Valley Coyotes are mostly found in chaparral and grassland biomes (McAdoo and Klebenow, 1979). Due to the increasing urbanization of chaparral and grassland habitats in the Central Valley coyotes have had to adapt to encroaching human populations. However, unlike most species the abundance of coyotes has been found to increase the closer they are in proximity to urban developments (Levi, 2011). Studies have found that coyotes are not threatened by human activity despite the fact that humans are developing in habitats that house coyotes (Tigas et al. 2002). In fact coyotes have been documented wandering into urban developments in search of food and new habitat without regard for human activity (Bradley and Fagre, 1988).

Coyotes are considered a keystone species for their ecosystems in the Central Valley as well as all over California (Levi, 2011). They are considered important because they are one of the most abundant predators in North America. Coyotes are currently much more prevalent than larger carnivores such as wolves (Berger et al. 2008). This is due to the resilience of the coyote species and its ability to adapt to environmental and spacial changes that occur within their habitats (Meachen et al. 2012). Carnivores such as coyotes exert a top down control effect on their ecosystems by preying on smaller mammals and birds (Levi, 2011). By keeping the populations of these animals down, coyotes help to maintain their habitats and increase the biodiversity of their ecosystems, thus preventing invading species from successfully colonizing their land (Chapin et al. 2000).

It is important that ecologists work to maintain and help improve coyote habitats so that coyote populations don't become threatened by urban development in the future. The main threat to coyote populations is habitat loss and fragmentation (Beier and Noss, 1998). Habitat loss significantly reduces coyote populations, which limits that populations available gene pool. This could lead to a bottleneck effect that would threaten that populations survival (Ordenana et al, 2010). The management and restoration of coyote habitats is necessary to limit the amount of habitat loss coyote populations experience. Similarly, developers should attempt to build urban regions with a limited amount of coyote friendly habitat on the outskirts of the development to de-incentivize coyotes from entering urban areas.

-Prevent Vehicle Mortality Caused by Limited Habitat Fragmentation

Besides habitat loss and natural causes, habitat fragmentation and vehicle collisions are the main reasons for the death of coyotes located near urban areas (Ordenana et al, 2010). Coyotes that live in habitats close to urban and suburban developments are more likely to be seen hanging around the outskirts of human inhabited areas at dawn and dusk. However, they generally won't enter urban developments until nightfall in search for food (Gipson et al. 1972). Habitat fragmentation has caused many populations of coyotes to cross into urban developments in search of food and for new areas to live (Ordenana et al, 2010).

Upon entering urban developments coyotes run the risk of being struck by a vehicle, especially since they are more likely to roam into a developed area at nighttime (Gipson et al, 1972). Since vehicle mortality is one of the leading causes of death for coyotes in the Central Valley, it is crucial that steps are taken to limit the amount of pressure coyotes feel to enter urban areas in search of food and land. In regions that have already established corridors and culverts should be made to aid coyotes in crossing into new territories. New developments that haven't been built yet should heavily consider limiting the amount of habitat fragmentation they cause, as well as adding corridors and culverts to their regions General Plan.

B. Restoration plan

-Maintain and Improve Coyote Habitat

-Limit Human Interaction with Coyote Dens

It is important that coyotes have an ample supply of areas they can use for making dens. Without enough dens coyotes will search for new habitats in other regions, thus pressuring them to enter urbanized areas. Coyotes in the Central Valley make their dens in a variety of places including, rock ledges, hollow logs, and slopes covered by brush (Shargo 1988). It has been documented that when disturbed coyotes will often move their pups into another den (Gehrt 2013). Due to their sensitivity to disturbance, human interactions with coyote dens should be limited during the months of March, April, and May when coyote pups are being born (Bekoff, 1997). In recreational areas that are home to coyotes, signs should be posted during these months that warn civilians to stay away from coyote dens. Civilians should be required to stay within 200 feet of any potential coyote dens in order to not disturb them. Restoration ecologists should check coyote habitats for potential den sites in the months of January and February to ensure there are enough dens for the coyotes. If needed, the coyotes habitats should be restored to include more potential den sites in preparation for birthing season.

-Provide Adequate Space for Hunting

In the Central Valley, coyotes use roads, trails, open chaparral or open grassland landscapes to hunt and forage for food (Quinn, 1990). Habitat loss has caused many populations of coyotes to wander into urban developments in search of food. Coyotes can exploit resources from urban regions because they have a highly adaptable behavioral patterns and a diverse diet. Coyotes searching for food are more commonly found in urban areas with concentrated garbage, food, or domesticated animals (Odenana et al. 2010). However, it is not safe for the coyotes or preferable for human populations for coyotes to roam into developed areas. Restoration projects should work to establish areas that are adequate for coyotes to hunt in so that they don't feel pressured to search for food in urban areas. Coyotes need large areas that are home to many smaller birds and mammals as well as plants and berries to forage on in order to satisfy their diets (Hawthorn, 1972). If the landscape is already developed and the habitat is already not big enough for coyotes to hunt in corridors, which will be discussed in detail later, should be established to aid coyotes in their search for food. However, it may be difficult to determine whether or not the coyotes are entering urban areas for food because they are desperate or because it is more convenient.

-Prevent Vehicle Mortality by Limiting Habitat Fragmentation

-Create Corridors To Connect Coyote Habitats

Habitat fragmentation is the main reason that coyotes wander into urban developments. When urban developments invade coyote lands they can accidentally make coyote habitats too small or too isolated from other communities that the population of coyotes can no longer all survive there (Ordenana et al, 2010). This causes coyotes to leave their habitats and enter nearby urbanized areas in search of new ones and in search of food (Tigas et al. 2002). A study found that in areas with fragmented habitats, male and female coyotes move between more than one area and in doing so they frequently cross major roads and railways (Bradley and Fagre, 1988). Since vehicle mortality is all too common among coyotes in urban areas, corridors and culverts should be made to promote connectivity between habitat fragments for coyote populations (Ordenana et al 2010) (Tigas et al. 2002). Corridors should be established by mapping out various coyote territories and finding areas that connect coyote habitats (Tigas et al. 2002). Then restoration ecologists should construct the corridors in January or February in preparation for coyote den making. Studies have found that the width of the corridor does not effect the frequency that they are used by coyotes. In the same study it was concluded that coyotes frequently used corridors of different diameters in order to cross between habitat fragments and were more likely to use the corridors the closer they lived to them. It was found that if a coyote lived too far away from a corridor they were more likely to use an urban road to cross habitats (Tigas et al. 2002).

-Manage coyote populations

Another way to limit the amount of coyotes that wander into urban areas is to actively manage their populations (Quinn, 1990). Under human management coyotes are still able to survive by adapting their behaviors (Andelt, 1985). Studies have shown that by controlling coyote populations alters their social behaviors and activities. If a coyote population goes unmanaged they will grow much larger and be more likely to enter urban areas. However, managed populations of coyotes aggregate in much smaller groups, which decreased the likelihood that they would wander into nearby urban environments (Roy and Dorrance, 1985). The one way to manage coyote populations is to create small controlled fires in areas away from urban developments. These fires destroy nearby vegetation, but they open up space that becomes occupied by small rodents, which attracts coyotes to that area. This strategy may be a little dangerous because it requires the use of an open fire. However, if done by professionals it is not likely that a larger uncontrolled fire will break out. Concurrently, other nearby areas that lack vegetation that coyotes eat should be planted to help encourage them to stay in that designated area. In areas that wish to control the population of coyotes and not just their habitat placement should designate medium sized landscapes that can't support large groups of coyotes. Coyotes in these areas will socialize and aggregate in smaller packs, which encourages them not to enter urban areas.

C. Monitoring Plan

Before the monitoring process begins, researchers should capture coyotes in the areas they are going to be monitoring and use telemetry for data collection. As done in another study, coyotes should be captured in a non violent trap and then tagged

with a collar that has GPS so that their activity can be monitored (Tigas et al. 2002). Information about the sex and age of the coyote should be documented as well.

To accurately determine where the corridors between habitats should be placed, the habitats should be monitored once a month for at least one year prior to implementing a restoration plan. The sites should be monitored for areas in the habitat that are preferred by coyotes as well as what parts of the urban environment the coyotes frequently wander into. By assessing the site prior to implementing a restoration plan, ecologists will be able to place corridors and restore areas that will help keep coyotes out of urban areas the most. This assessment will also provide researchers with information as to where to best place the corridors so that coyotes use them rather than crossing roads.

After the initial monitoring process, the restoration plan should be implemented and the coyote populations should be monitored once a month for the next three to seven years depending on how successful the reservation plan is. If after three years the coyote population is stable and they show a significant decrease in the frequency they wander into urban areas they will no longer need to be monitored except for twice a year for another three years to ensure they remain stable. The monitoring process should begin in December, a month prior to breeding season, so that their breeding and birthing behavior will be the first events monitored. In order to monitor as many coyotes as possible hidden cameras should be set up around coyote dens, coyote habitats and corridor entrances to gain more knowledge about the behavior patterns and daily activities of coyotes. Urban regions nearby to the restoration sites should be monitored as well so the amount of vehicle collisions that involve coyotes is documented. If restoration is successful the amount of vehicle mortalities and coyote sightings in urban areas will be significantly reduced, the amount of coyotes using corridors will increase, and the populations of coyotes will stay stable.

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Beaver (*Castor Canadensis*)

Rachel Fazzi

Part 1: Project Background and Justification

American Beaver (*Castor Canadensis*)

Habitat: “Beavers live near rivers, streams, ponds, small lakes, and marshes. They build lodges of sticks and mud on islands, on pond banks, or on lake shores” (nhptv.org/natureworks/beaver).

Appearance: “They have a waterproof, rich, glossy, reddish brown or blackish brown coat. The under-hairs are much finer than the outer, protective, guard-hairs. The ears are short, round, and dark brown in coloration. A beaver’s hind legs are longer than its front legs, thus making the ear end to be higher than the front end while walking”. “Beaver skulls and teeth are disproportionately large . . . the upper incisors, bright orange in color, are at least 5mm wide and 20-25mm long”. “A beaver’s tail is broad, flat and covered with large black scales”. An adult beaver will range in size from about 35 to 46 inches long and weigh between 28 and 70 pounds. (animaldiversity.org/accounts/Castor_canadensis).

Identification: Beaver presence can be identified by examining ecosystems for signs of “girdled or felled trees, limbs with bark removed” and “dams and lodges made from limbs and mud”

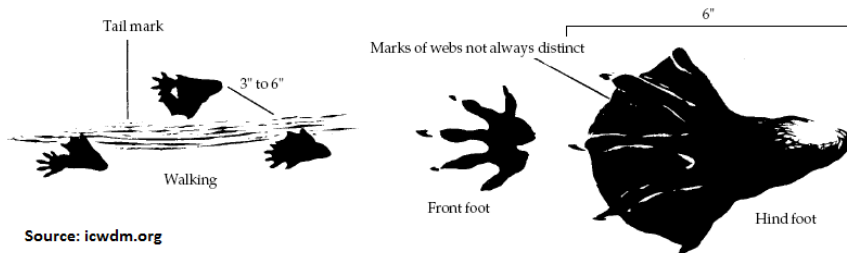
(portlandoregon.gov/BES/article/348260). “Beaver scat is commonly deposited in the water. When it is deposited on land, it is on the edge of the water. Scat appears composed of sawdust and is cylindrical. The segments are 1½ to 2½ inches long” (http://www.bear-



Source: en.wikipedia.org



Source: portlandoregon.gov



Source: icwdm.org



Source: en.wikipedia.org

tracker.com/beaver.html). Beaver tracks and tail marks can also be helpful in their identification and are depicted in the figure below.

Ecosystem Roles: Beavers are a keystone species, meaning that their “presence or absence strongly affects populations of other species in that area such that the extirpation of the keystone species in an area will result in the ultimate extirpation of many more species in that area”. “Beavers maintain wetlands that can slow the flow of floodwaters. They prevent erosion, and they raise the water table, which acts as a purifying system for the water” (animaldiversity.org/accounts/Castor_canadensis).

The American Beaver (*Castor canadensis*)

Background and Justification

The American Beaver (*Castor canadensis*) is the largest rodent in North America and is widely distributed around the entire continent (Linzey, 2013). Their numbers were once estimated to be anywhere between 60 and 400 million individuals, but populations were decimated by human hunters in the 1700 and 1800’s as a result of the fur trade (Baker and Hill, 2003). Regulation of hunting and numerous reintroduction projects eventually allowed for the successful recovery of the species (Baker and Hill, 2003). Today population trends are stable, and beavers are listed in the category of “Least Concern” on the IUCN Red List (Linzey, 2013). The importance of beavers lies in their role as a keystone species, or a species that has a vital role in maintaining ecosystem functions (Wagner, 2010). Through their extensive felling of woody tree species and the construction of large dams, beavers act as ecosystem engineers and highly alter the areas they inhabit (Linzey, 2013). Through these activities beavers naturally maintain wetland systems and provide habitats for many other species (Pollock et al., 2014). California has lost approximately 90% of its wetland area, and beavers have the potential to aid in their restoration. There is, however, some concern that in the future beavers may become a pest species if population sizes increase (Siemer et al., 2013). Careful management in central California will be required to ensure that beavers are allowed to perform their crucial ecosystem functions but also to prevent the species from becoming a nuisance.

Literature Review

Beaver Characteristics:

Food sources

- Beavers are known as “central place foragers”, meaning that they travel around to collect food and consistently return to a central location to feed (Busher, 1996).
- Beavers are an herbivorous species that may subsist on both herbaceous and woody vegetation. Herbaceous vegetation is preferred when available and woody vegetation is mainly consumed from late fall to early spring (Tesky, 1993).
- Lodges are built that serve as an area for beavers to store food for winter months when herbaceous vegetation is unavailable (Tesky, 1993).

- Deciduous tree species are preferred over coniferous; however, beavers will still feed on coniferous species if they are present (Busher, 1996).
- Some preferred food sources include quaking aspen (*Populus tremuloides*), willow (*Salix spp.*), cottonwood (*Populus fremontii*), alder (*Alnus spp.*), and red maple (*Acer rubrum*) (Tesky, 1993).
- Additionally, beavers may consume aquatic vegetation including duck-potato (*Sagittaria spp.*), duckweed (*Lemna spp.*), pondweed (*Potamogeton spp.*), and water weed (*Elodea spp.*) (Tesky, 1993).

Habitat requirements

- Beavers generally do well in a variety of habitats and have been able to quickly adapt to life in close proximity to humans (Baker and Hill, 2003).
- Beavers are semi-aquatic and reside in areas near water sources such as lakes, ponds, rivers, and streams (Linzey, 2013).
- They require riparian areas with access to woody tree species for food and building (Baker and Hill, 2003).
- Habitats that are unsuitable for beavers include lakes, reservoirs, and streams with large fluctuations in water levels over the course of the year (Tesky, 1993).
- Narrow valleys with steep slopes are unable to support the variety of vegetation that beavers require. A gradient of more than 15% will prevent beavers from inhabiting an area, and they are most frequently found where the slope is 6% or less (Tesky, 1993).

Reproduction and development

- Beavers are a monogamous species (Baker and Hill, 2003). They often form colonies of closely related family groups in which only the dominant female breeds (Tesky, 1993).
- They breed only once a year during the winter. The length of the breeding season decreases at higher latitudes and with colder climates (Baker and Hill, 2003).
- The gestation period lasts approximately 4 months, and the average litter size is between 3 and 4 kits per female per year (Tesky, 1993).
- Young develop fairly rapidly; they are born fully covered in fur, can swim by 4 days old, and begin to walk on land and aid in dam construction by 90 days old. They are weaned at around 40-45 days old and reach sexual maturity at 1.5-3 years of age (Baker and Hill, 2003).
- Wild beavers survive up to 11 years in their natural habitats (Tesky, 1993).

Space use

- Young beavers that have recently reached sexual maturity disperse from their colony in search of their own mate (Baker and Hill, 2003). They leave their homes in late winter or early spring and migrate an average distance of about 5-10 miles to a new suitable habitat (Tesky, 1993).
- The size of a beaver colony depends on the area of suitable habitat. Colonies can be very widely spaced along a riparian area or can exist at more saturated densities (Baker and Hill, 2003).

Beaver Ecology:

Threats

- Beavers do not face heavy predation due to the fact that their lodges provide them with shelter in aquatic areas away from large carnivores. Some predation of adults occurs by wolves, coyotes, and lynx in areas where they are present. Kits are preyed on by minks and otters as well as birds of prey such as hawks and owls (Tesky, 1993).
- They are highly sensitive to a bacterial disease known as tularemia (Linzey, 2013).
- Humans occasionally still hunt beavers for their pelt, but hunting is strictly regulated at the national level (Linzey, 2013).
- Development by humans nearby natural beaver habitats can potentially reduce the sustainability of these ecosystems (Tesky, 1993).

Role as a keystone species

- Beaver dams serve a number of ecosystem functions. They “slow current velocity, increase deposition and retention of sediment and organic matter in the pond, reduce turbidity downstream of the dam, increase the area of soil–water interface, elevate the water table, change the annual stream discharge rate” (Baker and Hill, 2003, pp. 297).
- Through these shifted processes, beaver dams may be able to create perennial wetlands in dryland areas (Gibson and Olden, 2014).
- By felling large woody trees, beavers naturally aid in forest succession which allows for increased diversity of plant species in beaver inhabited areas (Nummi and Kuuluvainen, 2013).
- Through the creation of wetland habitats, beavers create suitable areas for waterfowl and have been known to increase waterfowl diversity over extended periods of time (Nummi and Holopainen, 2014).
- Beaver activity also improve suitable habitat for fish species such as salmon and bass which are important to humans as a food source. A study in the Sierra Nevada Mountains found that flooded areas caused by dams contained increased invertebrate densities which indirectly improved salmon yields (Tesky, 2013).
- These wetland areas may also help to improve water quality through their ability to filter out water pollutants (Baker and Hill, 2003).

Negative impacts

- Beaver populations are currently stable, but are expected to increase due to their ability to quickly adapt toward life in areas nearby those with heavy human activity (Baker and Hill, 2003).
- Flooding caused by beaver dams can cause damage to roads and bridges (Siemer et al, 2013).
- Flooding also has the potential to kill trees downstream from the dam that would be used as timber for human construction (Tesky, 2013).

- The estimated economic costs of beaver activity to the United States is between \$75 and \$100 million each year (Tesky, 2013).

Gaps in Our Understanding

Beavers are generally a well understood species. They serve highly important ecosystem services and are a charismatic species and have thus been the subjects of countless research projects and experiments. The uncertainties with management of beaver populations lie in the future, since we are not able to accurately predict what long term growth in beaver numbers would mean for humans. There has been limited success of sterilization experiments as a method for population control (Brooks et al., 1980). Many beavers are removed or exterminated from areas where their activities may disrupt human development (Linzey, 2013). As we proceed into the future, it will be important to focus on way in which we can limit beaver population growth while still maintaining stable colonies which provide many benefits to the areas in which they occur.

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Part 2: Project Goals and Management Plan

A. Goals

Foster Beaver Habitat

The American Beaver is a semi-aquatic species and can only inhabit areas near lakes, ponds, rivers, and streams (Linzey, 2013). In order to ensure that a habitat is suitable for beavers, managers should focus on restoring riparian vegetation. A combination of deciduous tree species such as cottonwood and alder along with diverse herbaceous and aquatic vegetation will ensure that food will be available year round. Beavers are a classic example of an ecosystem engineer, an organism that significantly modifies its surrounding environment. Through the building of dams, beavers cause flooding which creates wetland habitat and slows the flow of water (Anderson, 2002). Beavers can improve the diversity of waterbird species (Nummi and Holopainen, 2014) and increase size and numbers of fish species such as salmon (Pollock et al., 2003). The creation of wetlands can also increase water filtration and improve water quality in an area (Baker and Hill, 2003). A focus on fostering beaver habitats in restoration projects will have many indirect benefits.

Control Nuisance Beaver Populations

Beaver reintroduction projects in the 1950's were one of the great early success stories of species restoration; however, now there is some concern that populations may continue to grow out of control and become a nuisance to humans (Siemer et al., 2013). Flooding as a result of beaver dams can cause damage to timber sources, roads, and agricultural lands (Tesky, 1993). Estimated economic costs of beavers in the US is \$75 to \$100 million every year (Tesky, 1993). Several techniques have been tested to control beaver populations including destruction of beaver dams, trapping, and shooting (Bhat et al., 1993). There is also some potential for the use of sterilization as a technique to slow population growth (Brooks et al., 1980). Due to the fact that beavers are a migratory species and disperse from their colonies after they are 2 years old (Anderson, 2002), control of beaver populations must occur on a large scale and requires cooperation from landowners, managers, and the public (Bhat et al., 1993).

B. Restoration Plan

Restoration projects that wish to foster beaver populations should focus in areas with preexisting bodies of water and gradual slopes. Unsuitable

habitats include large reservoirs and streams with significant fluctuations in water levels over the course of the year; beavers require relatively shallow standing water at all points in their life (Tesky, 1993). Beavers are also unable to inhabit areas with slopes with inclines greater than 15% because these narrow valleys are unable to support the variety of vegetation that beavers require (Tesky, 1993). They are most commonly found in places with slope gradients of 6% or less (Tesky, 1993). Therefore, in order to ensure that beavers can inhabit an area, sites with steep slopes should be avoided unless the slope can be reduced to create a more favorable environment.

Another key factor in fostering beaver habitat is to ensure that there is adequate food availability. Herbaceous vegetation is preferred by beavers as a source of nutrition; they are generalist feeders and will eat most grasses and leaves that are available to them (Johnson and Harris, 1999). They can also consume a wide variety of aquatic vegetation (Tesky, 1993) and prefer deciduous tree species over coniferous (Busher, 1996). In order to begin restoring riparian ecosystems a manager must first do a thorough evaluation of site conditions including factors such as hydrology, soils, and existing vegetation (Griggs, 2009). Native grasses and shrubs should be selected based on soil texture and nutrient levels and invasive vegetation should be targeted for removal. Cottonwood trees are an excellent source of both food and building materials for beavers and survive well in sandy soils (Griggs, 2009). The depth of the water table should be measured to determine where to plant certain tree species. Cottonwoods, alders, and willows require their roots to reach the water table and should therefore be planted closer to bodies of water (Griggs, 2009). Seedlings can establish well in nutrient rich soils and require little fertilization or irrigation (Griggs, 2009). Aquatic vegetation is also an important food source for beavers. Waterweed is a submerged plant that is native to California and grows best in fine sand and can be easily transplanted from cuttings (Aquatic Plants of the California State Region, 2006). Managers should strive for a rich diversity of riparian and aquatic vegetation to ensure that beavers have a supply of food at all times of the year.

Beavers generally migrate between 5 and 10 miles away from their home colony in search of a mate, though they have been known to travel up to 100 miles in rare cases (Tesky, 1993). As long as connectivity between riparian habitats is sufficient, beavers will likely establish in a suitable area without human intervention. If quick establishment of a beaver colony at a site is desired, a single mated pair can be trapped and relocated (Baker and Hill, 2003). Colony densities usually range from 0.4 to 0.8 per km but can reach up to 3 per km in very densely populated areas (Johnson and Harris, 1999). In areas with several nearby beaver colonies, dispersal will often be delayed and beavers will continue to live in large family groups with a dominant mating pair (Tesky, 1993).

If managers wish to exclude beavers from an area they can limit the abundance of riparian tree species and create steep slopes with sparse vegetation. However, this may alter the natural ecosystems and have potential negative impacts on other riparian organisms. For this reason, other methods

are suggested for control of population size. Beavers are a highly recognizable and have high public appeal so control projects need to be handled carefully. The destruction of beaver dams can temporarily remove the effects of flooding; however, beavers can easily rebuild dams which will lead to further removal of woody tree species (Bhat et al., 1993). In areas where timber damage is a main concern of flooding, trapping and relocating projects in New York have shown great success (Bhat et al., 1993). Beavers were once highly desired for their fur but hunting has substantially decreased in recent years. Incentivizing hunters to kill beavers may help decrease population sizes and densities (Bhat et al., 1993).

C. Monitoring Plan

Signs of beaver activity are easy to recognize and include felling of woody trees and the presence of dams in water bodies (Anderson, 2002). Sites should be monitored at least twice yearly to determine if beavers are present once in spring and again in the fall. Activity is high in the spring from January to March during mating season and highest levels of tree felling occurs in fall when beavers need to store food for the winter (Tesky, 1993). If beaver dams are visible and unwanted, the dam can be destroyed as a temporary solution and beavers can then be trapped and relocated to sites further away from human activity where flooding will not have damaging effects. If extremely high densities of beaver colonies (up to 3 per km) are present at a site it may be time to consider killing as a method for control so that vegetation and tree species can have time to regrow before being eaten by large number of beavers.

Further research is necessary before sterilization techniques should be employed to reduce beaver population size. In theory, if the dominant female in a colony is sterilized there should be no more young produced; however, it may be possible for another younger female to take her place (Brooks et al., 1980). Extensive sterilization of beaver females would be required to prevent population growth; it would be expensive and require cooperation from multiple parties. Sterilization may be a more popular alternative to killing for the general public, but it also would not solve the problems caused by flooding as a result of beaver activity.

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Ornate Shrew (*Sorex ornatus*)

Emily Read

Part 1: Project Background and Justification

Ornate Shrew *Sorex ornatus*



Appearance: Ornate shrews average a weight of 5.12 g. (Owen et al. 1983). They are small mammals with “a long snout, tiny bead-

like eyes, ears that are concealed, or nearly concealed, by soft fur, and five toes on each foot” (www.fws.gov). Unlike a mouse, their skull is “relatively flat and broad, and depressed interorbitally” (Owen et al. 1983). They are insectivores and mainly feed “under logs, rocks, low cover, dense vegetation, and litter” (www.wildlife.ca.gov). Active mostly at dusk and at night (CA Dept. Fish and Game) “Tracks are small, blurry marks, often showing drag mark of tail. Shrew tracks are seldom seen and are usually composed of only a few dots in dust, snow or sand.” (enature.com)



Habitat: They are found widely from California to Mexico in a wide variety of habitats but usually below 1875 m. These habitats include “woodland, chaparral, grassland, and emergent wetland” (www.wildlife.ca.gov). However, the ornate shrew prefers areas with “low,

dense vegetation for protection from the elements” (www.wildlife.ca.gov). A Mediterranean climate, with “long, dry summers, and short, rainy winters” is also preferred (BLM.gov)

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Enature.com <http://goo.gl/7uqESn>

Photos

(Top Left) www.fws.gov (Top Right) www.nps.gov (Bottom Left) www.fws.gov

Background and Justification

The ornate shrew (*Sorex ornatus*) is small mammal found throughout California (CA Dept. Fish and Game). They prefer moist, densely vegetated areas and are therefore sensitive to California’s current drought, agricultural and urban development (CA Dept. Fish and Game). The ornate shrew has been a species of concern since 1988 but was not placed on the endangered species list until 2002 (Center for Bio. Div.). Their presence is essential to keep insect populations in check and to provide food for larger carnivores in several types of ecosystems (www.gpo.gov). Their consumption of insects has an especially important impact on plant communities in their habitat. The presence of the shrew influences plant succession and pest management (gpo.gov). Currently, the ornate shrew located near the Buena Vista Lake area is of particular concern (Center for Bio. Div.). This species depends on a moist environment so the destruction of riparian and wetland areas limit suitable shrew habitat. (Center for Bio. Div.). 2,485 acres of critical habitat was designated in 2013 but the ornate shrew range spans all over California so more protection is needed (Center for Bio. Div.). Historic numbers of the ornate shrew are not known but currently the largest known population has been recorded at only twenty-five individuals (Center for Bio. Div.).

Fact Sheet

Reproduction:

- Breeding begins in February (blm.gov)
- Breeding ends in February to October (Owen et al. 1983)
- Peak of reproduction in Spring and late Summer (Owen et al. 1983)
- Active mostly at dusk and at night (CA Dept. Fish and Game)
- Gestation time about 21 days (CA Dept. Fish and Game)
- Litter size is 3-5(blm.gov)
- Typically produce 2 litters in lifetime (www.gpo.gov)
- Adults die in summer; lifespan is 12-16 months (www.gpo.gov)

Food:

- Generalists, but favor invertebrates, mostly insects that live in moist soil (blm.gov)
- Food generally found under vegetation and rocks (CA Dept. Fish and Game)
- Eat more than their body weight in insects per day (www.gpo.gov)

Habitat Preference and Requirements

- Mediterranean Climate: long, dry summers, short, rainy winters (blm.gov)
- Low, dense, herbaceous vegetation that provides food (invertebrates) and areas for nest making (Owen et al. 1983)
- Near brackish water, riparian, upland, dry chaparral, grassland (Owen et al. 1983)
- Most prevalent in riparian habitat (CA Dept. Fish and Game)
- During dry seasons shrews may hide in the burrows of other rodents (Owen et al. 1983)
- They are territorial of their nests (Owen et al. 1983)
- Needs moist soil and dense vegetation for insect habitat (gpo.gov)
- Positive correlation between moisture and ornate shrew abundance (Laakkonen et al. 2001-Fragmentation)
- Found from 39 N latitude to Baja California (Owen et al. 1983)
- Most common in “southern two-thirds of California west of the Sierra Nevada, from Mendocino and Butte cos. South to the Mexican border” (CA Dept. Fish and Game)
- Found at sea level to 2,400 m (Owen et al. 1983)

Threats/Predators

- Habitat loss/degradation of riparian and wetland habitat due to expansion of agriculture (Owen et al. 1983)
- Removal of vegetation, drying of environment and loss of habitat for invertebrates which are the shrew’s food source (www.fws.gov/sacramento)
- Habitat fragmentation near Buena Vista Lake leads to vulnerability to fire, disease and drought (www.fws.gov/sacramento)
- Opportunistic fungal parasite Pneumocystosis can cause lung infection (Laakkonen et al. 2001-Pneumocystosis)
- Have been known to die of fright but specific reasons are unknown (Owen et al. 1983)
- Many large predators do not prey on shrew due to their secretions and odors (U.S Fish and Wildlife 2011)
- Barn owls, short-eared owls, long-eared owls, great horned owls have a poor sense of smell so they are common predators of the ornate shrew (U.S. Fish and Wildlife 2011)

Interactions

- Keeps insect populations in check (gpo.gov)
- Pest manager for plant communities (gpo.gov)
- Provides food for larger predators (e.g. owls) (gpo.gov)

Response to Disturbance

- Habitat fragmentation may affect shrews less than large mammals due to their small size and range (Laakkonen et al. 2001-Fragmentation)
- After significant habitat loss, the Buena Vista Ornate shrew is only found in 4 locations along the western edge of Kern County (Center for Bio. Div.)

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Part 2: Project Goals and Management Plan

Goals, Restoration and Monitoring Plans

Goals:

- Grassy invasive plants should be replaced with herbaceous natives that provide a thick understory and regular leaf litter in upland and wetland areas. There are very few specific plant species recorded that the ornate shrew favors so vegetation characteristics are important (Owen et al. 1983).
- Plant native vegetation along any water sources to prevent flooding and to provide habitat for invertebrates, which are prey to the ornate shrew (www.gpo.gov, 2013).
- Survey and maintain local invertebrate populations: terrestrial and water insects.
- Invertebrates such as larvae, terrestrial and aquatic insects, amphipods, and slugs need to be present throughout the year in order to ensure the survival of the ornate shrew (www.gpo.gov, 2013).
- Plant cottonwoods and willows in an area near the water source to provide protective canopy for shrew against avian predators (e.g. Owls) (USFWS, 1998).
- Place restrictions on pesticide use on agricultural lands nearby to eliminate water contamination and pesticide drift via wind that may eliminate local invertebrate populations. (www.gpo.gov, 2013)

Restoration Plan:

Restoration of this species needs to focus on the overall type of environment and not specific plant species. The ornate shrew is mainly at risk due to habitat degradation from the expansion of agricultural land, so vegetative restoration needs to be the main focus (www.gpo.gov, 2013). There is no recorded specific density of vegetation required by the ornate shrew, but they do prefer ground covered with leaf litter and an overstory of willows and cottonwoods (USFWS, 1998). Moist areas with dense, herbaceous vegetation are essential for the ornate shrew to be able to reproduce and hide from predators (Owen et al. 1983). The amount of understory and low vegetation preferences of the ornate shrew are also not documented.

The Buena Vista ornate shrew in particular has experienced habitat loss due to agriculture and invasive plants (Owen et al. 1983). The restoration plan first needs to address this issue. Any abandoned agricultural lands need to be populated with native plants that will grow to be dense and/or drop their leaves frequently. Invasive grasses in the area that do not provide low, dense cover or allow for growth of trees for canopy cover will need to be removed and replaced with natives(www.gpo.gov, 2013). If possible, willows and cottonwood shall be planted near a water source to provide the overstory preferred by the shrew (www.gpo.gov, 2013). Ornate shrews do not necessarily need open water but do require moist soil that supports shrew prey, insects and larvae. (www.gpo.gov, 2013). Shrews are also able to live in upland areas but those populations tend to be small and scarce (U.S. Fish and Wildlife 2011).

Shrews are susceptible to disturbance, especially flooding and agriculture (www.gpo.gov, 2013). This means that native, ruderal plants will need to be placed along any water sources all the way from the riparian to upland areas to protect the shrews breeding habitat from flooding. Agriculture may also not occur within a radius that would allow for the reach of pesticides by wind. The Buena Vista shrew has experienced exposure to pesticides from neighboring agricultural lands that may have negative consequences on the local population (www.gpo.gov, 2013). They have been exposed to routine pesticides that are commonly sprayed on large-scale crops as well as direct exposure to herbicide treatments that have taken place on canal zones, wetlands, and riparian edges (www.gpo.gov, 2013). This results in the digestion of contaminated insects which may harm the shrew (www.gpo.gov, 2013).

Predation from most carnivores is not a major issue in population decline because of the odor ornate shrews release from their flank gland (U.S. Fish and Wildlife 2011). Therefore, no drastic mitigation involving predators is necessary (www.gpo.gov, 2013). However, sufficient cover from avian predators (owls that have a poor sense of smell) is still needed and the availability of prey is essential for the ornate shrew (www.gpo.gov, 2013). The type of small invertebrates in the restoration site needs to be identified and their habitat needs must be met in order to protect the ornate shrew. This includes maintaining the moisture and vegetation preferred by the local invertebrates.

Monitoring Plan:

Invertebrates such as larvae, terrestrial and aquatic insects, amphipods, and slugs need to be present throughout the year in order to ensure the survival of the ornate shrew (www.gpo.gov, 2013). Shrews do not store their food so there must be a constant supply of invertebrates (USFWS, 1998). Larval and aquatic insect abundance surveys need to be taken yearly in February because this is the start of the shrew's reproductive period (blm.gov, 2015). There needs to be food available to feed the female shrews for successful reproduction and infant survival to occur. These surveys should also occur in June when the reproductive cycle ends to make sure there is enough food for juveniles to survive until maturity (www.gpo.gov, 2013).

Soil moisture surveys also need to be taken bi-yearly to compare against the larval and aquatic insect abundance surveys. If both invertebrate abundance is decreasing it is most likely due to the drought in California. This hypothesis can be

backed by the soil moisture surveys. If both invertebrate abundance and soil moisture is decreasing then the local watershed will need more careful monitoring or the current vegetation community will need to be altered.

If there are water bodies in the area then they will need to be monitored monthly for contamination. These monthly estimates should coincide with agricultural pesticide spray schedules. In the case of the Buena Vista ornate shrew, pesticides from local agricultural land were contaminating local habitat and the invertebrates (www.gpo.gov, 2013). Ornate shrews may ingest pesticides via the consumption of invertebrates or by grooming their fur (www.gpo.gov, 2013). If there are agricultural lands nearby then pesticide testing will need to take place yearly to ensure that there is no contamination. This could take the form of water sampling near shrew habitat and lab testing for significant chemical exposure caused by runoff.

Population surveys of the ornate shrew also need to be taken yearly due to their rapid reproductive cycle. Ornate shrews usually do not live longer than 16 months so changes in population size may happen rapidly and can be quickly observed by yearly surveys (www.gpo.gov, 2013). Catch and release surveys should be taken in August, near the end/after their reproductive cycle to get an estimate of surviving young (www.gpo.gov, 2013). If populations continue to decline with adequate vegetation then introduction of individuals from other populations may need to be considered. Ideally, current shrew populations should be around 25 individuals which is the largest known population that has been recorded (Center for Bio. Div., 2013). The number of introduced individuals will need to be determined by the current effective population size and the health of surrounding populations.

In order for local restoration to be successful there are several questions that need to be answered:

- Are invertebrate populations stable?
- Is soil moisture decreasing with time?
- Does a decrease in soil moisture cause a decrease in invertebrate populations?
- What is the vegetation density necessary for ornate shrews to build suitable nests?
- Do invasive plant species in the area provide enough understory vegetation to ornate shrews or do they need to be replaced by natives?

It would be beneficial to have a plot with invasive plant species and compare it with a plot that has only native species. Soil moisture, invertebrate counts, and shrew counts can be prepared to see if the displacement of invasive species is really necessary or shrew survival. Plots of different vegetation densities would also be helpful to avoid over populating the area with unnecessary vegetation in the future. This may be necessary since specific vegetation density requirements for the ornate shrew have not been documented.

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Feral cats/ house cats (*Felis catus*)
Jolina Liao

Part 1: Project Background and Justification

Habitat: Anywhere with a food source (e.g., dumpster) and shelter.
(www.humanesociety.org)

Identification: Cats may appear differently due to coloring, coat length and patterns (e.g., solid, tabby, tortoise and calico). They can also live in large colonies and are capable of hiding from sight. "Domestic cats are characterized by a number of well-known characteristics. These include a flexible and compact body, keen eyesight and adaptations for visual acuity at night, retractable claws, sharp teeth and a reduction in numbers of teeth (e.g., the hind chewing teeth) reflecting adaptation as a carnivore, long vibrissae (whiskers), and a long and flexible tail important as an aid to balance. The average head and body length of adult *Felis catus* is around 46 cm, and the tail length averages around 30 cm. Adult feral cats typically weigh 3.3-4.5 kg, with males being at the larger end of the range and females at the lower end." (www.sms.si.edu) They can also be identified by hissing, yowling, and strong odors due to marking. (www.humanesociety.org)

Type: Mammal

Diet: Carnivore

Size: 28 in (71 cm)

Weight: 5 to 20 lbs (2.3 to 9 kg)

Size relative to a 6-ft (2-m) man:



Image: Feral cat eating

rabbit

Scrapes: Visible because of multiple scrapings that causes splintering and fraying. "Look for these scratches 18-24" above the base of the tree." (www.outwitcritters.com)

Tracks



Scat: "Feral cat scat is left not only as a consequence of but to mark territory as well. Scat are tubular" (www.outwitcritters.com)



Images from:

<http://www.ecology.com/wp-content/uploads/2013/08/feral-cats-2.jpg>

http://www.myhealthycat.com/images/trim_your_cats_claws.jpg

http://animaltrackersofnewengland.blogspot.com/2009_03_01_archive.html

<http://championofmyheart.com/2011/12/26/newsworthy-bug-the-hiking-camping-super-social-kitty/>

<http://animals.nationalgeographic.com/animals/mammals/domestic-cat/>

A. Background and Justification

The feral cat (*Felis Catus*) is an unowned domesticated cat which lives independently in rural or urban settings (Ogan and Jurek 1997). The ASPCA states that after 8 weeks of age, cats that are not properly socialized are "feral" (Appleby, Weary, and Sandøe 2014). Feral cats are carnivorous and are distributed worldwide, with denser populations existing in populated areas (Ogan and Jurek 1997). In regards to California, the government census shows a noticeable increase in human population in the Central Valley region from 2000 to 2010, which may correspond with the feline population (*Census 2010*). However, due to their hunting prowess, large numbers of birds and small mammals have fallen prey to these invasive predators. Therefore feral cats undergo population management as they are a serious threat to wildlife, can adapt to different environments, and are prolific breeders (Appleby, Weary, and Sandøe 2014). These management methods include trap-neuter-return (TNR) and trap-euthanize (TE), with the more popular method being TNR. These methods bring up controversial feelings within the public between feral cat supporters and conservationists. Thus, feral cats are considered pests, threats to wildlife and public health, victims of human neglect, and invasive species integrated into ecosystems (Appleby, Weary, and Sandøe 2014). Managing feral cats would reduce the impact they have on humans and wildlife, as well as benefiting their own health in terms of disease and longevity (Appleby, Weary, and Sandøe 2014).

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B. Literature Review

Reproduction

- Males get picked to mate based on their body weight (Yamani, Doi, and Ono 1996)
- A breeding female is known as a "queen" (Ogan and Jurek 1997).

- Domestic queens are sexually mature at 7-12 months (Ogan and Jurek 1997).
- Females can enter estrus 5 times per year at maximum (Ogan and Jurek 1997).
- The gestation cycle is about 63-65 days in length (Ogan and Jurek 1997).
- Feral queens produce an average 1.4 litters per year, but can have as many as 3, with the litters consisting of 2-5 kittens (Appleby, Weary, and Sandøe 2014).
- Feral kitten mortality rate is 75% at 6 months of age (Appleby, Weary, and Sandøe 2014).
- Overall kitten mortality rates are lower than fertility rates thus maintaining the feral cat population (Appleby, Weary, and Sandøe 2014).
- Cats can live 15-17 years, but feral cats often die young due to overpopulation, cars, coyotes, etc. (Ogan and Jurek 1997).
- After being neutered, feral cats don't have to put time and energy into producing and caring for offspring resulting in weight gain and their overall health improves (Appleby, Weary, and Sandøe 2014).

Food Habits

- An adult cat will eat 5-8% of its body weight in meat per day and a female with young can consume 20% of her body weight per day (Ogan and Jurek 1997).
- Feral cat diet consists of insects, small mammals, reptiles, amphibians, and birds. Ground-nesting, ground-roosting birds, and their young are susceptible to feral cats (Ogan and Jurek 1997).
- In the Australian grasslands (similar to desert grasslands), feral cats ate a diet consisting of about 80% rat. When rat abundance grew low, the cats ate birds, reptiles, and invertebrates (Yip, Rich, and Dickman 2014).
- In New Zealand, where the rats are invasive, cats were purposefully introduced to maintain these populations (Ogden and Gilbert 2009).
- Feeding cats has a costly effect on predators through the reduction of prey animals. In an Illinois study in 1968 and 1971, it was recorded that 82-95% of feral cat diet consisted of rodents. In the area, the cats were in competition for rodents with red-tailed hawks, American kestrels, and northern harriers (Ogan and Jurek 1997).

Habitat Preference and Requirements

- Feral cats are often reclusive and require cover. Old buildings, burrows, trees, shrubs, and hedges are all examples of required cover (Ogan and Jurek 1997).
- Many cats were once pets or rely on humans as a food source, so many cat colonies are found in close proximity to dense populations of humans (Ogan and Jurek 1997).

- In the event of nutritional stress, it may be observable that the feral cats would travel longer distances (Edwards, et al. 2001).
- Feral cats have a preference for riparian settings because of its diverse amounts of prey animals (Hall, et al. 2000).
- Home ranges of wandering adult cats estimate about 5.1 ha in a park setting (Meek 2003).
- Cat populations fluctuate with the seasons; maximum population in the summer and minimum populations in winter and spring (Jones and Coman 1982)

Reasons for Undesirability

- Feral cats display increased daytime activity and large home ranges in comparison to their owned counterparts; seen as undesired visual (Horn, et al. 2011).
- Feral cats create noise and smell that distinguish them as unwanted pests (Appleby, Weary, and Sandøe 2014).
- As of 2014, there was an estimated 86.4 million owned cats in the USA. 36-41% of the total cat population in the USA is unowned~70-100 million cats (Appleby, Weary, and Sandøe 2014).
- Feral cats can be hosts for diseases, such as rabies and FeIV/FIV (which is transferable to other cats). Another example includes mites, which can be easily transferred amongst members of a cat colony (Appleby, Weary, and Sandøe 2014).

Management

- Animal welfare organizations and feral cat advocates, such as The Humane Society of the United States, believe trap-neuter-release is the best method of population control (Appleby, Weary, and Sandøe 2014).
- TNR also stops mating fights and births, which are main behaviors that transmit the earlier mentioned FeIV/FIV disease (Appleby, Weary, and Sandøe 2014).
- TNR does not stabilize the population, but rather decreases the rate at which it expands. In order to decrease cat populations, a rate of 71-94% must be neutered (Appleby, Weary, and Sandøe 2014).
- Wildlife conservationists believe trap-euthanize is best in regards to the wildlife the neutered cats would continue to destroy (Appleby, Weary, and Sandøe 2014).

Further management

- Studies in Australia show the presence of an apex predator (dingoes) can help keep the mesopredator (feral cats) in check by suppressing feral cat activity and increasing competition. Australia has a semi-arid climate similar to parts of the Central Valley. Could theoretically work, but most native predators prefer rural settings and feral cats prefer urban settings. (Gordon, et al. 2015).

Gaps in Knowledge

- It is unknown if and to what extent feral cats are affecting wildlife beyond bird and rodent populations.

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Part 2: Project Goals and Management Plan

C. Goals

GOALS	LONG OR SHORT-TERM	DESCRIPTION
Reduce feral cat birth rates through control of entire local cat population in and around the project area (including surrounding homes)	Short-term	Prevent creation of progeny through a trap-neuter-release method (TNR) in order to halt the progress of feral cat populations
Increase mortality rates to zero out the cat population in the and around the project area (including surrounding homes)	Short-term	Trap-euthanize method (TE) to decrease feral cat populations which will strongly reduce the amounts of wildlife being eaten and prevent the spreading of diseases to housecats or other
Increase nutritional stress on feral cats in and around the project area (including surrounding homes)	Short-term	Prevent homeowners from feeding feral cats and increase competition for foodstuff through support of other predators, such as coyotes

D. Management Plan

These management plans focus on regions close to well-populated areas as there are denser populations of feral cats in closer proximity to civilization (Ogan and Jurek 1997).

Option 1:

One method to deal with the existing population of feral cats in the Central Valley would be to euthanize them through the TE method. In this way, they can no longer become a threat to both wildlife species and public health through the spreading of diseases, hunting, etc. (Appleby, Weary, and Sandøe 2014). This method will most likely take two years or more, as it is meant to be sectioned off and then applied because the Central Valley is so large of an area, as well as supporting a large cat population. The time taken for this method is only a light estimate based on the euthanasia of koalas by the Australian government; took a year to kill almost 700 of the slow-moving mammals ("Koalas Secretly Euthanized to Control Population in Australia"). The first step would be to advise local residents to keep their housecats indoors and to report undesirable ferals during the 2-3 weeks to capture cats in the area before moving on. Through the reports and an ID guide, feral cat colonies can be tracked down. Feral cats might be difficult to distinguish from roaming house cats since some do not wear collars or have implanted chips. It is best to conduct this method further from local residency as house cats travel much shorter distances than feral house cats. A male urban cat will travel around 2.6 hectares in comparison to an average feral, which travels an estimated 5.1 hectares (Haspel, Carol, and Calhoon 1989). Because feral cats are reclusive, it is best to set non-lethal traps to capture them and wait. The traps should be non-lethal so the cats can be assessed before humanely putting them down. The recommended trap is a cage with a spring loaded door set with bait to lure the cat in. The traps cost around thirty dollars per trap. Set around 5-10 traps in each acre based on the amount of refuges within the area (shrubs, trees, buildings, logs, etc); for example, in an open field there might be one tree and a few shrubs which would not require so many traps. The traps should be placed and hidden within the cover (trees, shrubs, etc.) in order to be successful in their capture. Check the traps daily so that traps can be redeployed immediately once cat is captured and so that the animal doesn't suffer in its confines. If a cat is present in the trap it is best to drape a sheet or blanket over the trap so the animal is calmer and less prone to injuring itself or the handlers. Once captured, the cats should be transported to a designated building for holding or veterinary clinic and observed for 1-2 weeks to see whether they can be tamed or not. If all the captured ferals were euthanized upon capture, it will likely result in a public upset and loss of public support is detrimental to the project. Any unborn kittens, newborns, and young kittens under around 8 weeks of age can be removed from the population and tamed within an animal adoption facility (Appleby, Weary, and Sandøe 2014). If the remaining feral cats cannot be tamed, then euthanasia should be applied. Several uncertainties exist with this method, for example, the cats might not fall for the traps; in which case, new types of traps would have to be implemented until one works, such as a drop trap (the cage drops onto the animal). For example, the spring loaded cage trap might not work if the cats are not under enough nutritional stress to be lured by the bait. Another uncertainty is that the feral cats might be scared off and scatter, thus rendering the sectioned areas through which to conduct the plan meaningless. Also, there is no guarantee that more feral cats

or another harmful species won't immigrate into the area once the territory becomes unoccupied.

Option 2:

The next method would be to neuter the feral cats through the TNR method. In this way, the feral cat population will not be able to create more progeny. The project will also gain moral support for not killing off a species that can be considered a "victim of human neglect" (Appleby, Weary, and Sandøe 2014). This method should be similar to the TE method, but would require less time due to public participation and support (est. 2+ years). The first step in this process is to talk to Central Valley locals about participating in the project. In this way, they won't have to pay for spay/neuter costs and they can protect the cats. This will especially resonate with homeowners who "keep" backyard cat colonies. After that, setting the traps to capture feral cats is exactly the same as the TE method, in which we will have to apply this method by sectioned areas and check the traps daily. It is also necessary to remove the younger progeny of the population and place them in animal adoption facilities to further halt the growth of the feral cat populations. The remaining cats will undergo surgery and be kept for recovery before being released. One concern about this method is that it doesn't truly prevent the hunting of wildlife or the spreading of diseases (rabies, mites, etc.), but is strongly favored by the general public. Also, it is probably not possible to capture and treat all the feral cats but if enough is done, it could be possible to reduce fertility enough that kitten mortality rate (75% at 6 months old) will overcome it and drastically reduce the population (Appleby, Weary, and Sandøe 2014). Another concern is the neutering the cats is known to increase their fitness by preventing mating fights and transfer of diseases amongst them, as well as diverting energies used for reproduction elsewhere. This is detrimental to our cause as we are trying to decrease the amount of wildlife eaten by cats.

Option 3:

Lastly, the physical removal of feral cats from the Central Valley would be a long-term goal to be carried out continuously as needed. This can be done by the same capture methods used in the previous 2 options and the transport of captured feral cats out of the Central Valley (best to be completely moved from the state). The feral cats can also be coaxed to leave by increasing their stress. In one study it was observed that feral cats would travel long distances due to nutritional stress (Edwards, et al. 2001). This can be accomplished by preventing locals from feeding the feral cats, as this encourages them to stay and form colonies (Ogan and Jurek 1997). Another way, would be to increase their competition by restoring one or more local predators, such as coyotes (Gordon, et al. 2015). This would further reduce the amounts of foodstuff they could obtain, which would give the cats more incentive to leave, but also requires the development of other management plans for the targeted predator species. This plan is the most implausible as there would be difficulties transporting the cats and finding a new place to release them because they are unwanted pests. It is also improbable that many feral cats would leave, even

under nutritional stress, due to their highly diverse diets, which includes insects, small mammals, reptiles, amphibians, and birds (Ogan and Jurek 1997).

E. Monitoring Plan

Before implementing the management plan, feral cats should be monitored for 1-2 months to observe their favored locations, abundance, and behavior to make tracking them down easier. A management plan will be immediately implemented after enough data has been gathered. If the cat population has more time, it will grow more since females go into estrus around 5 times maximum and have around 2 litters per year (Ogan and Jurek 1997). Also, the estimated number of cats will be the end goal (the number of cats that must be euthanized, neutered, or removed for the plan to be successful). Once implemented, the traps placed will have to be monitored daily for activity. Each plan will vary in the time it will take for all cats to be captured and taken care of.

Post-plan, the Central Valley area will have to be checked on twice a month to search for any feral cat activities. The checks must be frequent in order to make sure that feral cat populations stay low and actions could immediately be taken if a fluctuation is observed. The best ways to see whether feral cats are present or not is to search for signs using an ID guide or set traps for a population survey (total population will be a guess based on mathematical equations). If the neutering and physical removal of the feral cats doesn't keep the population from its steady gradual incline, we will have to rely on euthanization until more research can be done to find a new method in keeping the population down. An acceptable decline of cat population would be around 70% or more of the population per year since, assuming half of the remaining population is male, a female will have one litter of two kittens per year at minimum.

Further research and improvement

It would be useful to know if euthanizing the cats would actually be beneficial in keeping down the population within the area.

Also, it would be useful to know is that if the old population is removed, if new feral cats would move into the territory. It would be important to know the percentage of cats immigrating would be and the chances of establishing different native predators and other species before more feral cats establish in the area.

Since it has already been established that the presence of an apex predator helps to suppress feral cat activity, it is important to learn the effects of different predators on feral cat populations (Gordon, et al. 2015). With this information, we could observe the impacts they have on prey species and whether this would be applicable to the Central Valley.

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Red-eared slider (*Trachemys scripta elegans*)

Marcus Rodriguez

Part 1: Project Background and Justification

Preferred Habitat: Originally found near the Mississippi River and the Gulf of Mexico, in warm southeastern parts of the United States. However, this species was popularly adopted into the pet trade, and is now known as an invasive species and found all around the world. Red-eared sliders typically live in still, warm waters such as lakes, ponds, and swamps, as well as slow moving creeks and rivers.

Species Description: The red-eared slider is a small green turtle with irregular yellow markings. It has a green, oval-shaped carapace (topside of shell) that darkens in color as the turtle ages. Juvenile sliders are a leaf green, and become more of a forest green or greyish-green as they age.



Juvenile (left) and adult (right) red-eared sliders

The plastron (underside of shell) of a red-eared slider is a light yellow color with dark spots in the center of most scutes (plastron segments). Its main definitive characteristic is the pair of red markings it has on each side of its head, hence the name “red-eared slider”. This species of turtle possesses a moderate amount of sexual dimorphism. Females are typically larger than males, reaching sexual maturity at a carapace length of 15cm, while the carapace length of males is only about 10cm at sexual maturity.



Male (left) and Female (right) red-eared sliders

Males also typically have longer claws on their forelimbs, a more distally placed cloaca on their tails, and a more point-shaped nose.



Part I:

A. Background and Justification

The Red-eared slider (*T. scripta elegans*) is a particularly important turtle species due to its global popularity in the pet trade, and its worldwide tendency to invade various habitats (ENARA, 2009). It is believed to have gained its popularity in the pet trade due to the comic book heroes, *The Teenage Mutant Ninja Turtles*. It has since been the utmost predominate turtle pet species, as well as the most invasive turtle species around the world, outcompeting native species (BBC, 2001). The Red-eared slider is even included in the *List of the world's 100 most invasive species*, which was published by the International Union for the Conservation of Nature, more commonly referred to as The IUCN (Lowe et al., 2000). The presence of this species notably decreases the success of native turtle species such as the western pond turtle (*Emys marmorata*). It outcompetes natives with its younger age of reproductive maturity, higher rates of fecundity, greater body size, superior longevity, and better ability to exploit food sources (Parry, 2013). These turtles have also been known to transmit diseases as well as house the common dangerous genus of bacteria *Salmonella* (Isabel, 2007). The red-eared slider remains a problem in California's Central Valley, and can be seen in the dozens along many creeks, rivers, and ponds (Johnson, 2013).

B. Literature Review

Key Topic	Description	References
Distribution & Habitat	The red-eared slider is native to the south-eastern portion of North America near the Mississippi river and the Gulf of Mexico, but due to its invasive nature it is <u>found around the globe</u> in various bodies of water. It inhabits: • Ponds • Creeks • Lakes • Slow-flowing rivers • Swamps • Streams	Gibbons, 1990 Williams, 1999
Habitat Requirements	They tend to live in <u>calm water</u> where they are able to <u>bask</u>	Gibbons, 1990 Connor, 2002 Smither, 2002

	<u>on logs or rocks</u> and easily escape into water when predators or humans come near. Red-eared sliders need <u>aquatic plants</u> in their ecosystems; It is their primary food source.	Aguirre & Poss, 2002
Behavior	Nearly entirely aquatic. Only leave the water to bask in the sun in order to regulate their temperature. They are ectothermic and require external temperature regulation. Impressive swimmers. They are able to avoid predators with their superior swimming ability and awareness. When there is more than one male for every two females present, these turtles may become aggressive. They require a ratio of at least two or more females per male to avoid physical	Gibbons, 2009 Iglesias, 2007

	confrontation. Brumate at the bottom of bodies of water when temperatures drop below 10 degrees Celsius, typically from October to early March or late April.	
Reproduction	Breeding typically occurs from March to July. Females typically spend more time basking to keep their eggs warm, and will lay them on land in a moist but not completely wet soil burrow. She can lay as many as thirty eggs per clutch for up to five clutches per breeding season depending on body size and various environmental factors. Egg incubation takes approximately 59-112 days. Hatchlings have an egg tooth which assists in breaking out of the egg casing at the time of hatching. Some hatchlings remain inside the egg after hatching for a day or two to reap the full nutrients of the remaining yolk.	Gibbons, 1990 Connor, 2002 Smither, 2002 Aguirre & Poss, 2002 Iglesias, 2007

	After hatching, the egg yolk sac remains attached to the plastrons and must be absorbed, split, and fully heal before the turtle can swim, which takes about 21 days. The sex of the red-eared slider is determined by the environmental temperature at its critical stage of embryo development. Males are produced when eggs are incubated at 22-27 degrees Celsius, any warmer than that and females are produced. Red-eared sliders can survive up to 20, 30 or 40 years of age in the wild, but don't live as long when in captivity.	
Predation & Competition	Red-eared sliders out compete all other native turtle species due to their size, and their highly competitive and aggressive nature. Red-eared sliders have no natural predators as adults, but can be eaten as juveniles by a variety of animals such as	Connor, 2002 Smither, 2002 Aguirre & Poss, 2002

	raccoons, skunks, foxes, wading birds, and storks. Red-eared sliders have a diverse omnivorous diet, and prey upon various species such as insects, worms, fish, small tadpoles, and carrion while young. Adults tend to be more herbivorous.	
Impacts of Disturbances	Red-eared sliders are rather tolerant of human disturbances. They are known to slide off logs when humans come near. Hence the name "slider".	Connor, 2002 Smither, 2002 Aguirre & Poss, 2002
Impacts of Pesticides	Pesticides can affect the expected sex outcomes of red-eared sliders, as well as alter hatchling steroid physiology. These effects greatly impact the red-eared slider's fitness.	Willingham, 2011

Part 2: Project Goals and Management Plan

A. Goals - Mitigation

Due to the red-eared slider's highly invasive nature, it is important to ensure its presence is mitigated as much as possible. The only circumstances where it should be allowed to prosper are in its native areas, and areas where it has already replaced another species in the food chain and has completely filled its niche (Cadi & Joly, 2004). The number one contributing factor to red-eared slider invasion is pet release (Williams, 1999). Most people are under the impression that releasing their pet turtles into the wild is a good thing, when actually it contributing to an environmental catastrophe. Therefore it is of great importance that the general public is aware of the risks and potentially

damaging impacts that pet releases have on natural ecosystems, and is supportive of the restoration endeavors necessary to return degraded areas as close to their natural equilibriums as possible. However, prevention of additional turtles being released to an already established reproductive population is only half the battle. The only successful mitigation method for already infested areas is physical removal of adult and juvenile individuals as well as their eggs (Aguirre & Poss, 2002). This method has proved to be quite effective when both stakeholders and the community are also involved, or even just supporting the efforts. Other methods such as poison use in restricted water bodies have been effective, but with major negative side effects to both water quality and biodiversity (Smither, 2002). After a successful restoration, in which the red-eared slider populations are at a controllable level, diligent monitoring of both population sizes and growth rates are required. It is important to manage existing populations and prevent another invasion scenario, considering that there will always be some level of pet release (Williams, 1999).

B. Restoration Plan – Prevention & Removal

Prevention is always the best method of dealing with a problem, and invasive species are definitely no exception. It is much easier to prevent an invasion than to eliminate one. Pet release is one of the biggest causes of red-eared slider invasion, which can be prevented by enacting and enforcing policy as well as community education (Williams, 1999). In the United States it is illegal to buy, sell, or trade any red-eared slider eggs or turtles less than 4" in carapace length unless it is strictly for scientific experimentation (FDA, 1975). This regulation was put in place by the FDA in 1975 and was only enacted to prevent the spread of salmonella via red-eared sliders (Iglesias, 2007). Violators of this regulation must comply with the destruction of any eggs or turtles in their possession, or be fined up to \$1,001 and/or serve up to one year of imprisonment (FDA, 1975). The regulation has contributed to an overall decline in wild red-eared slider populations, but it hasn't entirely eradicated the problem on its own. Unfortunately, people still trade the turtles illegally or take advantage of the scientific experimentation loophole (Williams, 1999). Another prevention method is to educate the public about invasive species. Most people think they are doing the right thing by releasing their pet turtle into the wild instead of euthanizing it. It is important that communities understand the risks and impacts associated with releasing pets into natural ecosystems, and how damaging invasive species can be. Some ways of increasing public awareness of the red-eared slider include warning signs, community events/meetings, email lists, online notice boards, etc. Any way that scientists and nature enthusiasts can inform people of the situation is extremely helpful in preventing pet release.

The most successful method of eliminating an already-established population of red-eared sliders is to physically remove them (Connor, 2002). This is done by hunting, trapping, and harvesting individuals along with their eggs. It is a continuous effort by scientists, nature enthusiasts, stakeholders, and local communities, and must occur regularly in order to be effective (Burger,

2009). Removal needs to happen at least twice a year; Once in February, prior to the mating season, and again shortly after eggs are laid, in late July or early August. Following capture, the turtles are either euthanized and disposed of, or they are sterilized and then released back into the wild (Mesen & Arturo, 1992). In some cases red-eared sliders have even been caught with a line and hook or shot while basking, though these methods are not encouraged (Outerbridge, 2008). One type of trapping mechanism consists of floating board basking sites that have been equipped with baited cages (Scalera, 2006). These cages however may not be appropriate for use in all situations (O’Keeffe, 2009). When necessary, small bodies of water are fenced and drained in order to collect all individuals on site, however, females lay their eggs in moist burrows on land (Gibbons, 1990). In order to locate these burrows one must either track females as they lay their eggs, or search for egg burrows using sniffing dogs (Ruiz & Carlton, 2003). Overall the physical removal method is highly effective in eliminating red-eared slider populations, especially when there is support from the community and stakeholders. Although this mitigation strategy is labor intensive, it is the most feasible and effective way of eradicating a red-eared slider population without causing any significant environmental degradation.

C. Monitoring Plan – Observation

Following a successful restoration it is important to continue monitoring the area in order to ensure the ecosystem remains stable. All too often sites are remedied only to fall into an ecological trap once more due to a lack of monitoring. This situation is no different; it is necessary to monitor the site once the red-eared slider populations have been eliminated or reduced to a manageable level, otherwise they can and probably will infest the area again (Boersma et al., 2006). In the case of the red-eared slider, monitoring of both population size and growth must occur regularly in order for elimination to remain effective (Boersma et al., 2006). The monitoring sessions need to happen at least twice a year, for at least 10 years, however it is recommended that the monitoring remain ongoing if feasible. The monitoring times should occur once during mating season between late March and early July, and again shortly after eggs have hatched, sometime during late September and early October (Gibbons, 1990). It is essential that the community be involved as well to provide information on any potential sightings, whether it be through a community hearing, phone call, or online message board. An informed and involved community will be the most reliable long-term monitoring resource, even when funds have run out.

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Red Fox (*Vulpes fulva*)

Sarah Murphy

Part 1: Project Background and Justification

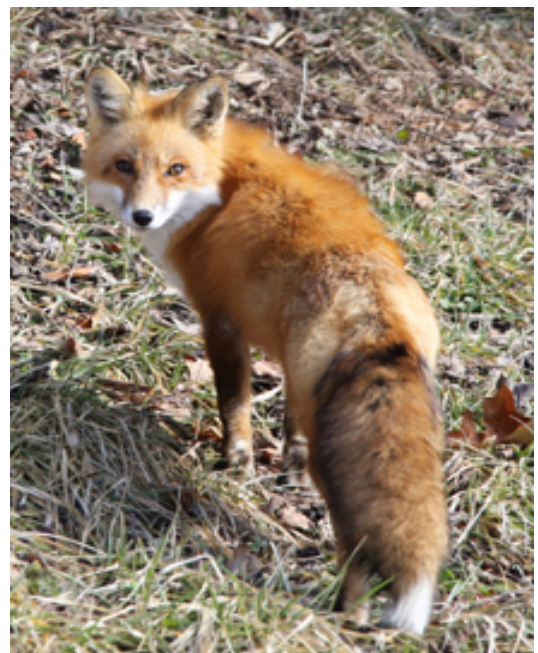
Habitat: "Can survive in a wide range of habitats. Often associated with agricultural areas. Prefers mixture of forest and open country near water. Mostly nocturnal. Hunts by smell. Uses dens for shelter during severe weather and when pups are being reared. Usually uses dens made by other animals. Seldom found far from permanent water. Thrive in bushy successional area where small mammals are most abundant. Occupies diverse habitats. In forest situations uses edge (Jones et al. 1983)" (mt.gov). They are invasive to California.

Range: "The red fox can be found in most of the United States and Canada, except for the far north in Canada and Alaska and much of the western U.S. and Hawaii. The red fox can also be found in Europe and Asia and it has been introduced to Australia" (nhptv.org).

Identification: "Red foxes have red fur across the face, back, sides and tail. The throat, chin, and belly are grayish-white. Red foxes have black feet and black tipped ears. One of the most noticeable characteristics of the red fox is the white tipped tail" (nwf.org). "Total length: 39 to 43 inches. Weight: 10 to 15 pounds" (mt.gov).

Red Fox Photo by Jim McCormic
(wildlife.ohiodnr.gov)

Distinguishing between gray fox: "Red foxes are often confused with gray foxes, which share a similar habitat and range. This can make identification difficult, because some red foxes can have large patches of gray fur and gray foxes have patches of red fur. Gray foxes are somewhat smaller and have a slightly more-rounded face and shorter snout. The surefire way to tell the difference is to look for the color at the tip of the tail. Gray foxes have black-tipped tails, while red fox tails are



white. Although they are very similar in name and appearance, the gray fox and the red fox are only distant cousins, belonging to different genera in the family Canidae" (nwf.org).

Gray Fox with black-tipped tail (sfbaywildlife.info)

Tracks: “Like the tracks of many wild canines, fox footprints tend to be oval in overall shape. They have 4 toes with a generally triangular shape. Each claw on a fox's foot generally registers directly in front of each toe. In some substrates the claws might not register clearly or be hard to see. For red foxes, the details of the toes may be obscured since their feet are very furry and their toe pads are small. A distinct chevron-shaped pad across the foot pad helps to identify this species. Red fox footprints are generally measure 1.75 to 2.5 inches long by 1.5 to 2" wide” (wildernesscollege.com).



Red Fox Tracks
front paw: 2.25 x 2.1 in.
hind paw: 2 x 1.75 in.

Tracks (purdue.edu)

Scat: “Like the scat of many canines, fox scat often has a ropey, tapered, and partly segmented shape. Fresh red fox scat often has a distinct musky scent. Fox scat typically does not have the offensive odor common to domestic dog scat. Fox scats are generally 3/8 to 5/8 inches in diameter and 3 to 6 inches long” (wildernesscollege.com).



Red Fox Scat Photo (wildernesscollege.com)

Vocalization: “It produces a wide range of sounds, and the male is at its most vocal during the mating season in January and February, when it produces a bark or chilling scream. The rhythmic whine of the cubs may also be heard in early summer when they start to emerge from the den” (sounds.bl.uk).

Background and Justification

The red fox (*Vulpes vulpes*) is an invasive predator species common throughout California, including the Central Valley. It thrives in various habitat types, including riparian, grassland, and disturbed habitats (Gosselink 2003). It is an omnivore with the ability to drastically affect prey populations and has contributed to the decline of many bird species such as the western snowy plover and California clapper rail (Merenlender et al 2008). The red fox also has the potential to compete with native species such as gray foxes and coyotes for food and habitat, as well as acting as possible vectors for disease, negatively affecting native species populations (Gosselink 2003, Bodewes et al 2013).

Literature Review

Spacial Use

- The home range of the red fox is ordinarily no greater than 5 miles in diameter, while during the time that they have kits they stay within a half mile of the den (Tesky 1995). There is no significant difference in home range size between males and females (Gosselink 2003).
- Red foxes have been known to shift their home ranges in response to coyote presence, occupying more disturbed habitat that coyotes usually avoid (Gosselink 2003).
- Dispersal distances vary, but average around 30km. Dispersal distances also generally increase with age, and are greater for male red foxes than for female red foxes (Allen 1993).

Habitat Preferences

- Red foxes use a variety of habitats including the ones within the Central Valley such as grasslands, agricultural fields, and woodlands (Gosselink 2003)
- Red foxes are successful in urban and developed areas, often being found around humans (Macdonald and Reynolds 2008).
- Red foxes prefer to use habitat edges and open spaces for hunting (Tesky 1995), and tend to avoid wooded areas, particularly when coyotes are present (Tesky 1995, Gosselink 2003).
- They prefer to be in or around cover for their den sites and can utilize abandoned dens and urban structures for this requirement (The Red Fox, Tesky 1995).

Feeding Habits

- Foxes often hunt alone, but have been documented hunting in pairs (Newsome 2005).

- Red foxes are opportunistic hunters and feed mostly on animal matter, but also some plant matter (Hockman 1983). Over a span of 9 states, the most common prey items were cottontails and mice, while they also feed on voles, other rodents and small mammals, and fruit (Korschgen 1959). Voles were their primary food source by weight in a Maryland study, which is important as the California vole is found in the Central Valley, and may prove to be a major food source for the red fox (Hockman 1983).
- Red fox diets overlap with the diets of both grey foxes and coyotes, which are native California species (Green 1981, Hockman 1983). In the same Maryland study, red foxes ate primarily animal prey, while grey foxes ate more plant than animal prey (Hockman 1983). This illustrates that there can be a difference between red fox and grey fox diets.

Reproductive Patterns

- Red foxes can either make their own dens or use abandoned dens made by other animals, such as those made by badgers or woodchucks (Tesky 1995). They also take advantage of denning sites created by human development, such as in drainage pipes (The Red Fox). They prefer loose, well-drained soils close to or under cover for their den sites, which have at least two entrances (Tesky 1995).
- Red fox breeding season is usually from December to March (Tesky 1995).
- Female red foxes are capable of breeding at 10 months old and gestation lasts 51-53 days. The average litter size is 5 pups, with each female producing one litter each year (Tesky 1995).
- Pups open their eyes at 9 days old and remain in the den for a month. They start to leave the den alone at around 10 weeks old, and really start to explore the home range around 12 weeks old (Tesky 1995).

Threats Red Foxes make to native species

- Red foxes are known to carry various diseases such as rabies, parvovirus, and hepevirus (Bodewes et al 2013). Some of these diseases may have the ability to be transferred to other mammals, with the grey fox being a particular concern due to its relatedness to the red fox.
- Their overlapping diets and habitats of red foxes and grey foxes may have negative consequences on the native species, and may even exclude the native species from the area (Merenlender et al 2008).
- Due to their varied diet, especially preying on small animals, red foxes can be threats to many native prey species. They have already contributed to the decline of many endangered water birds (Merenlender et al 2008).

Management Options

- Coyotes are known predators of red foxes, so a way of control would be to increase native coyote populations (Merenlender et al 2008).
- Lethal control via hunting is another possible option.
- Due to their habitat adaptability, it would be difficult to manipulate the habitat so red foxes would find it unfavorable. However, they have been known to prefer open spaces, especially when coyotes are present. (Gosselink 2003). Because of this, an option may be to create native woodlands, which would make the habitat less favorable for the red foxes and more favorable for coyotes.
- Through modeling, red fox populations were shown to stabilize or decline when at least half of the adults and a quarter of the juveniles have been removed from a 12000 ha area (Harding 2001) These different percentages are due to the reproductive potential of each age class, with the juveniles having greater reproductive potential.
- Fertility control can be used to help prevent population increases, though there are many factors that may affect the success of this control including current pregnancy stage and social structure (Marks 2001, Newsome 2005).

Possible Management Issues

- Translocation of red foxes is not an option due to the risk of bringing the pest problem to a different location. It is also illegal to translocate red foxes across California state lines (The Red Fox).
- While baiting has proven to be a successful and cheap way of ridding the area of foxes (Newsome 2014), poison would be a bad option for ridding the site of red foxes due to the risk of poisoning non-target animals such as the grey fox, coyotes, or domestic dogs.
- If the red fox is extricated and the grey fox population does not increase, there may be a trophic cascade effect with the small rodent populations increasing and the plant communities suffering due to increased herbivory. Though not as great as the red fox due to diet differences, grey foxes do have an impact on rodent populations through predation (Vu 2011).
- Even if red foxes are removed from an area, there is great chance that new immigrant red foxes will take their place (Harding 2001).

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Part 2: Project Goals and Management Plan

A. Goals

- 1) Promote red fox emigration from the site- if you could encourage red foxes to move away from the area on their own by doing certain restoration techniques, it would save time and money on ridding them in other, more hands-on ways.
- 2) Directly rid the restoration site of red foxes- this can be done by trapping and lethal control. Trapping and translocating is difficult because the red fox cannot be translocated out of California and permission must be granted by the California Department of Fish and Wildlife to move it to other areas within California (The Red Fox). Regulations on lethal control can be strict as well and there is always a risk of non-target consequences, especially with the native grey fox and coyote.
- 3) Keep red fox populations out of restoration site over the long term- even if complete eradication is successful, it is still likely that recolonization will occur. In this event there are a few options such as fencing, continued lethal control, and sterilization. The cost of fencing is that it will likely keep out native mammals as well as red foxes. The benefit of sterilization in this case is that it prevents other red foxes from moving into the territory. The cost is that you will still have red foxes present in the area, and therefore have the negative consequences on the other species present.

B. Restoration Plan

Restore area with increased cover and promote coyote presence

Because red foxes can survive in such a variety of habitats (Gosselink 2003), ridding them from an area is a difficult venture. They have been known to prefer open areas and disturbed, urban habitats (Macdonald and Reynolds 2008, Tesky 1995), so restoring the site to native landscape with increased cover may promote emigration from the site. An important aspect of the Central Valley is that both red foxes and coyotes coexist in the same habitats. However, it has been shown that they preferentially choose different habitats when in the presence of one another (Gosselink 2003). While living in sympatry, coyotes showed preference for high covered areas such as woodlands and wetlands,

while red foxes avoided these areas (Gosselink 2003). Because of this difference in habitat preference, restoring wetlands at the site could discourage red fox presence. There is some evidence to suggest that coyote presence drives red foxes away from an area (Gosselink 2003). Therefore, increasing native coyote presence at the site could be beneficial and promote emigration of the red foxes. In this way, restoring the site to more native woodland and wetland would not only decrease habitat preference for red foxes, but also increase habitat quality for coyotes, which would have an additional negative effect on red fox presence.

Eradicate red foxes with lethal control

Lethal control is really the only direct way of action, as it actively rids the area of red foxes. It is also the quickest way of eradication because habitat restoration takes a long time and there is a possibility that the foxes will remain in the restored environment. There are several methods of lethal control, but they all come with costs along with benefits. Trapping the red foxes and euthanizing them takes time, and the likelihood of trapping non-target animals is high. However, this method is preferable if actual sightings of red foxes are rare, and if their dens are apparent due to markings or feces. If traps are laid near every den site as well as along trails and near ideal hunting habitat (in or along the edges of open habitat) (Tesky 1995), the probability of catching the target red fox is likely higher. The issue with body-gripping traps in California is that they are illegal to use unless for the protection of endangered species (Lewis 1999). Other than that, walk-in box traps are used successfully to capture red foxes as long as regulations are followed, and then they are euthanized by lethal injection (The Red Fox). Poison is not an option for lethal control because of the risks of non-target consequences.

Prevent red fox recolonization or maintain low populations

Once red foxes are eradicated from the area, the task is to keep them out. This can be done by fencing the restored site, but it needs to be taken into account that red foxes can dig underneath fences, climb over them and even jump 6 feet high (Voelker 1986, The Red Fox). Non-electric fences should be taller than 6ft and made of metal, wood, or durable mesh with no holes or spaces that the fox could squeeze through. Electric fences could also be used because they are a great deterrent and have been proven to increase survival of nesting bird eggs (How do I keep foxes out of my garden and secure my pets? 2014). Ideally, the combination of a 6ft tall, non-electrified fence with a live electric wire running along in front of it at about 1ft off of the ground would be used during nesting season. This ensures maximum defenses against the fox while the nesting birds are most vulnerable. However, another important issue is that fences built for red foxes will likely help exclude native grey foxes and possibly coyotes. Therefore, if they were to be used, it would be most beneficial to use them only during certain times such as nesting season for birds to prevent the predation of nesting sites.

Another important step to take after eradication is monitoring the site for recolonization. If there are signs of recolonization by red foxes such as

sightings, scats, or dens, lethal control should be used before a population establishes.

If a population does re-establish and the possibility for eradication again is unlikely, sterilization is an option to keep the population from increasing. Fertility control will prevent the foxes from producing healthy, viable young (Newsome 2005) and current red fox residents will maintain territorial control of the habitat, helping to prevent immigration. However, fertility control is expensive and the medication must be directly administered to prevent non-target effects, so it is not a likely option.

C. Monitoring

After the site has been restored, it needs to be continuously monitored for as long as possible. However, because monitoring takes time and money, a monitoring plan is needed for a set period of time. If sufficient funds are available, it would be beneficial to monitor this site continuously for 2 years, allowing for the biota to settle into their restored states. In those two years, a team should go out to the site once a month to survey the area for any red fox markings such as pawprints, scat, and dens, as well as any visible and audible observations. If there are any signs of red fox activity, control should be implemented immediately before a new population is established. After the 2 years, with enough forest and wetland restoration, along with an increased coyote population, the site may be sufficiently unfavorable for red foxes and discourage them from recolonizing the area. If they are still present at the site after this time, the only main option would be to use fencing during times of prey vulnerability. Specifically, this would be around the nesting season for water birds that require use of the wetland habitat. The fence should be put up at the beginning of the nesting season and taken down at the end to prevent exclusion of native vertebrates from the area. Lastly, it would be beneficial to educate the public about invasive red foxes versus native grey foxes and how each affects the environment. This can be done through fliers, forums, or a plaque in the restored site along a walking trail. The public can be used as a tool in monitoring for red foxes, as they can contact the proper authorities if one has been sighted in the area. This is also a cost-effective way of extending the monitoring program indefinitely.

Future studies are essential to enhance our knowledge on how to better eradicate invasive red foxes. Some information we need to better understand about red foxes includes a more in-depth analysis of their interactions with grey foxes, how their eradication will affect rodent populations in the Central Valley, how exclusion of all large vertebrates (including native vertebrates) via fencing will affect the ecosystem, and most importantly, whether red foxes are causing enough damage in the Central Valley grasslands to warrant eradication and/or control with the use of government funds.

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Bullfrog (*Rana catesbeiana*)

Vanessa Seawright

Part 1: Project Background and Justification

Tadpole
Metamorphosis of American
Bullfrog
www.californiaherps.com



Adult Female American Bullfrog
www.californiaherps.com



VS.



Adult Male American Bullfrog
www.californiaherps.com



Colors and patterns may
vary.
www.californiaherps.com

Habitat: "Inhabits warm, sunny, open, permanent water - lakes, ponds, sloughs, reservoirs, marshes, slow river backwaters, irrigation canals, cattle tanks, and slow creeks. Found in grassland, farmland, prairies, woodland, chaparral, forests, foothills, and desert oases. Frequently inhabits artificial ponds and sometimes sealed swimming pools."

"Tadpoles prefer areas of warm shallow water with dense aquatic vegetation."

"American Bullfrogs are highly aquatic - rarely found far from water...In areas with freezes in winter, bullfrogs hibernate under water, buried in mud or laying on a pond bottom."

(www.californiaherps.com)

Appearance: "Adults are 3.5 - 8 inches long from snout to vent (8.9 - 20.3 cm). (Stebbins, 2003) Males grow up to 7.09 inches long (18 cm), females up to 8 inches long (20.3 cm)."

"A large frog with long legs and large webbed toes. Dorsolateral folds are not present.

A short fold extends from the eye over and past the eardrum to the forearm. The tympanum is conspicuous."

“Light green to dark olive green above, with dark spots and blotches. Sometimes light green only on the upper jaw. Cream to yellow below with grey marbling on larger individuals.”
“Tadpoles are greenish yellow with small spots, growing up to 6 in. (15.3 cm).”

(www.californiaherps.com)

Recognizable Voice Calls: “The **advertisement call** is a loud low-pitched two-part drone or bellow, popularly described as “jug-o’rum.” These calls are made during the day and at night. Bullfrogs also produce an **alarm call**, a fast squeak, which is usually made before the frog jumps into the water to escape from danger.

A sharp “bonk” **encounter call** is also made. A loud open-mouthed **screaming sound** is made when a frog is under extreme stress, such as when it is being attacked or eaten by a snake.”

(www.californiaherps.com)

Background and justification

The American bullfrog (*Lithobates catesbeianus*) is an invasive species that has invaded and massively impacted habitats throughout the entirety of California. The generalist species was introduced to California by means of both intentional and unintentional releases. The bullfrog was planted in California as a food source for human consumption and it also established itself after escaping bullfrog farms as well as via pet releases (Crayon 2009). The American bullfrog poses a threat to endemic species through its advanced adaptations- such as its mere size and ability to leap great distances- that have made it virtually impossible to be out-competed (californiaherps.com 2015). Also, the American bullfrog has introduced a destructive fungal disease called chytridomycosis that has depleted many native amphibian species populations and even caused many amphibian populations to go extinct (CDFG 2015). The American bullfrog flourishes in areas that have been subject to human modification, so this is also a contributing factor to their dominance over native Californian species (Crayon 2009). This species has been termed as an “ecosystem engineer” because not only have they decreased the populations of native amphibians, reptiles, and vertebrates, but the American bullfrog has also been proven to alter biomass, structure, and composition of algal communities (Crayon 2009). The American bullfrog has been very detrimental to California biodiversity and ecosystem services, so it is crucial to eradicate the species before it has any more negative influence.

Literature review

Characteristics of American bullfrog

Activity

-American bullfrogs are rarely found far from water. (californiaherps.com 2015)

-They are active day and night and have relatively high body temperatures. (californiaherps.com 2015)

-They are most active during late spring in areas that have overall colder temperatures. (californiaherps.com 2015)

-The American bullfrog species are opportunistic eaters. Their diet consists of anything it can swallow ranging from invertebrates, fish, reptiles, vertebrates, and even other bullfrogs. (californiaherps.com 2015)

Defense

- If disturbed or threatened, the American bullfrog propels itself and dives to the bottom of the nearby body of water. (californiaherps.com 2015)
- Because the American bullfrog is native to regions where there are far more predatory fish than in California, the species evolved mechanisms to avoid predation. Some of these adaptations are: eggs and tadpoles are unpalatable and noxious to many species of predatory fish, reptiles, and vertebrates; also, bullfrog tadpoles evolved to be inactive for a majority of the time to reduce chances of being detected by predators. (Murphy 2003)

Vocals

- The American Bullfrog has distinctive calls and sounds that mean different things.
 - Advertisement call: low pitched two-part bellow that is made during day and night.
 - Alarm call: a fast squeak that is made before the frog leaps into the water to avoid danger.
 - Screaming sound: a high pitch scream that is made when the species is under high stress such as if it is being eaten by a predator such as a snake.(californiaherps.com 2015)

Habitat preference and geographical range

- Habitat preference is a warm and sunny permanent body of water including but not limited to lakes, ponds, sloughs, reservoirs, irrigation canals, etc. (californiaherps.com 2015)
- Adult bullfrogs are more commonly found in warmer habitats that have standing bodies of water such as vegetated shoals, and they prefer still waters that have dense cover such as woody debris and emergent vegetation. (Crayon 2009)
- Most likely to be found in a habitat that has high precipitation throughout the entire year, has higher temperatures during winter season, and has been highly altered by human interference, such as artificial ponds and sealed swimming pools. (Crayon 2009)
- Ecosystem preferences include but are not limited to grasslands, farmlands, prairies, woodlands, chaparrals, forests, foothills, desert oases, etc. (californiaherps.com 2015)
- The American bullfrog is found throughout California except in extremely dry deserts and the highest elevations of the Sierra Mountains. The American bullfrog is most often seen at elevations from sea level to about 9,000 ft (californiaherps.com 2015).

Reproduction

- Reproduction is aquatic and fertilization is external. (californiaherps.com 2015)
- Males use vocalizations to advertise fitness to females and to intimidate other males. (californiaherps.com 2015)

- Mating and the subsequent egg laying occur May to late August. Reproduction begins when air temperature reaches a certain level which is generally around 70 degrees F or 21 degrees C. (californiaherps.com 2015)
- Males are sexually mature at the age of 1-2 years old and females don't reach reproductive maturity until they are 2-3 years old. (californiaherps.com 2015)
- Females can lay two clutches per year. Each clutch may contain as many as 20,000 eggs that hatch within 3 to 5 days. (californiaherps.com 2015)
- Tadpoles prefer shallow waters that are concealed by dense vegetation.
- In California specifically, the American bullfrog metamorphosis usually occurs within the second summer of the tadpole's life. (californiaherps.com 2015)

Dangers to native ecosystems

- American bullfrogs evolved in areas with predatory fish, so they are more adapted to harsher conditions and stronger competition; this gives them an advantage over endemic California frog species that do not have the size, strength, or leaping abilities to out-beat the American bullfrog. Because of this, the American bullfrog has been responsible for the decline of many native species including frogs, turtles, snakes and waterfowl. (californiaherps.com 2015)
- The American bullfrog- at any given life stage- can out-compete all other native species through both competition and predation. For example, bullfrog tadpoles eat the tadpoles of other frog species (CDFG 2015)
- American bullfrog preys on endangered amphibians including Amargosa Toad, California tiger salamander, Chiricahua leopard frog, California red-legged frog, Oregon spotted frog. (Crayon 2009).
- The American bullfrog carries and passes the chytrid fungus which is a potentially fatal skin disease in frogs. This is called chytridomycosis. (CDFG 2015)
- Chytridomycosis is presumed to be the leading cause of the global decline of native amphibians. It has been responsible for the extinction of over 100 species since the 1970s. (CDFG 2015)
- American bullfrog can be a carrier of the fungal agent without showing significant clinical disease symptoms. Amphibians that may be impacted are the Pacific Chorus frog, Northern red-legged frog, plains leopard frog, northern leopard frog, lowland leopard frog, and the entire suite of central Californian amphibians. (Crayon 2009)
- Introduction of the American bullfrog has introduced emergent amphibian diseases such as novel types of Bd and/or ranaviruses. (California Department of Fish and Wildlife 2014)
- The American bullfrog has been labeled as an "ecosystem engineer" because it alters biomass, structure, and composition of algal communities. Tadpoles have considerable impact on nutrient cycling and primary production in freshwater systems. (Crayon 2009)

Potential Management Actions

Physical Controls

- The American bullfrog can be located using flashlights which while cause them to temporarily stun. Then, the species can be killed via shooting, spears/gigs, bows and arrows, clubs, nets, etc. (Crayon 2009)

- Hand/net capture followed by killing is a labor-intensive, costly method. (Snow 2010)
- Modify the reptile-proof fence that is used to catch neonates and effectively place where American bullfrogs can be collected as they leave body of water. (Crayon 2009).
- Collect and dispose of egg masses. (Crayon 2009)
- Larvae may be killed by water borne poisons that are also used for fish. (Murphy 2003)
- Draining wetland habitats and then broadcasting toxicants is effective, but it also has severe negative effects on non-target species. (Snow 2010)
- Tadpoles destroyed via draining and chemical treatment have had limited success. (Snow 2010)
- Timing must be fully considered to avoid any of the developing portions of the bullfrog tadpoles from reaching metamorphosis. (Snow 2010)
- Some California research shows that draining ponds every two years effectively reduced bullfrog population densities and this allowed the invasive species and the native red legged frog to coexist. (Snow 2010)
- Localized spraying could be an effective way of depleting population densities, but it needs to be further tested. (Snow 2010)
- Modifying the multiple capture trap used for the invasive Australian cane toad and placing it overnight may reduce the amount of man-power necessary for restoration. (Snow 2010)

Management Controls

- Trade and introduction of amphibians should be closely monitored. Traded amphibians would be subjected to veterinary examination and IUCN quarantine guidelines. (Crayon 2009)
- Invasive Species Environmental Impact Assessment (ISEIA) gave the American bullfrog a score of 12/12 which places them on the “black list.” (Crayon 2009)
- In Europe, control of the invasive species has been based upon increasing awareness, increasing the degree of monitoring, and education the masses about the dangers and negative impacts of releasing pets into the wild. They also have strict laws in place to prevent introductions. (Crayon 2009)
- According to a 2010 study of the Trinity River in CA, human modifications to river systems have increased the presence of the American bullfrog, so restoring ecosystems to their natural state may decrease the potency of the bullfrog while simultaneously supporting native species. (californiaherps.com 2015)
- According to (California Department of Fish and Wildlife 2014) eliminating live bullfrog importation will reduce risk of the American bullfrog establishing itself in California ecosystems as well as stop the spread of non-native diseases.

Gaps in knowledge

- Efficacy of localized spraying and the multiple capture trap used for the Australian invasive cane toad.
- Effects on American bullfrog after returning ecosystem to native state.

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Part 2: Project Goals and Management Plan

A. Goals

Reduce American Bullfrog Population Size (Eradicate if possible)

The American Bullfrog is an invasive, generalist species that has infiltrated ecosystems throughout California, specifically the Central Valley. In order to restore California Central Valley habitats to their "historical" ecosystem, the best plan of action would be to eradicate the American bullfrog population- only if the species has not fully established a large, growing population. This may allow the restoration of endangered native species and disturbed natural ecosystem services. If the species has already completely invaded the region, full eradication will not be possible; if this is the case, the goal would be to reduce the population and monitor the species heavily in May- August during breeding season. In order to evaluate whether complete eradication is feasible, an assessment of the population size should be made. The American bullfrog is more active at night, so the population size should be observed when it is dark; this can be done by locating the frogs by their distinctive advertisement calls and then using flashlights to temporarily stun the individuals (californiaherps.com 2015).

The bullfrog is a generalist species that can adapt to a wide range of environments; the species can live anywhere near a standing body of water (inclusive of artificial bodies of water). It is very important and high priority to eradicate this species before altering any landscapes; doing so would prevent the bullfrog from adapting to the changing conditions because the bullfrog would undoubtedly dominate the restored habitat (californiaherps.com 2015). The species

is extremely mobile and can travel exceedingly long distances, so it is difficult to establish an exact spatial scale for the invasive species. Focusing on breeding sites would be an effective way to locate higher concentrations of species, especially offspring. Reproduction, fertilization, and transformation take place in shallow waters; tadpoles can be found in higher quantities in shallow waters with dense vegetation so these areas, especially during late May to early August, are likely to be hotspots for the species (californiaherps.com 2015). Also, in order to restore the endangered native species such as the Amargosa Toad, California tiger salamander, Chiricahua leopard frog, and California red-legged frog, the American bullfrog population must be heavily reduced to allow survival and growth of native offspring so the native populations can stabilize (Crayon 2009).

B. Restoration Plan

Physical Removal

The American Bullfrog can be extracted from Central Valley Ecosystems in several different ways including physically extracting/ killing the species by manpower, extracting the bullfrog eggs, using toxicants to kill the species, and setting multiple-capture traps. There are pros and cons to each of these methods, but a combination of several of these methods may maximize extraction success. Some methods, such as using widespread toxicants or introducing predatory species to prey on the target species are ineffective because although they decrease the invasive population (sometimes), they also decrease the native populations further worsening the condition of the habitat. Decreasing the invasive population is the goal, but not at the expense of the native species and ecosystem.

A method that is being used at various locations where the American bullfrog has invaded is manually eradicating the invasive species by shooting or using spears, gigs, bows and arrows, and nets (Crayon 2009). Manual removal should take place in the night and in late spring (around May) when the frogs are more active. Using a flashlight to temporarily stun the frogs can also improve accuracy (Crayon 2009). The negative aspect of manual removal is the large amount of energy that goes into the physical eradication of the species and the very minimal impact that this may have on the overall population of the invasive bullfrog. This may be an effective temporary fix to a much larger problem.

Another possible conservation plan that involves physical removal is collecting the egg masses of the species using a dip net. The American bullfrog has extremely high fecundity with 20,000 eggs per clutch and two clutches per year. This method of restoration will require extreme monitoring during the months of May to late August when reproduction and hatching occurs (californiaherps.com 2015). Reproduction occurs when the temperature reaches about 70 degrees F, so restoration ecologists must be extremely aware of the temperature fluctuations during this four month period (californiaherps.com 2015). High amounts of monitoring are necessary because eggs hatch within 3 to 5 days and collecting tadpoles is exceedingly more difficult than collecting eggs because tadpoles are able to swim to greater depths in order to avoid capture (californiaherps.com 2015). Once eggs are collected, they should be destroyed to avoid further expansion of the invasive species; this can happen simply by placing all eggs that were caught into a bucket and letting them dry out. Tadpoles also have a destructive effect on

ecosystems due to their extreme numbers and the amount of algae that they eat- which affects primary production and nutrient cycling- as well as the tadpoles of other endangered native species (Crayon 2009). If the eggs are not all caught in time, tadpoles can be targeted and extracted in various ways.

When targeting tadpoles, timing is extremely crucial to prevent the transitioning bullfrog tadpoles from reaching metamorphosis (Snow 2010). In California waters, the tadpoles generally reach metamorphosis during the middle of the second summer of their lives (californiaherps.com). Tadpoles are found in shallow waters and have been destroyed via draining and chemical treatment (Snow 2010). This had minimal success due to the negative effects it has had on surrounding species rather than solely affecting the target bullfrog species. A more effective procedure has been reducing densities by slightly draining the ponds about every two years. This does not fully eradicate the invasive species, but reduces the overall population size (Snow 2010). Another way to target the tadpole population is by installing a “reptile-proof fence” to catch the transforming tadpoles as they leave the pond and transition to a more terrestrial lifestyle (Crayon 2009). This multiple-capture trap would allow the species to be caught, but at the cost of allowing the tadpoles to reach an age where they will still have a dramatic effect on the surrounding ecosystem and the native species.

The overall restoration plan should go as follows: restoration ecologists should physically eradicate the species throughout the year using brute force, and monitoring should increase during the months of May-August in order to track the reproduction of the species so egg collection can be successful. If egg collection is unsuccessful, reptile proof fences should be installed in order to prevent juveniles from spreading. The reptile proof fences can be installed regardless in order to be thorough.

Management of/ Education about Illegal Trade and Release of American Bullfrog

Increasing awareness of the negative effects that the bullfrog has on surrounding ecosystems may lessen the illegal pet trade of the American bullfrog and would reduce the likelihood that pet owners release unwanted animals- specifically the American bullfrog- into the wild. Educating the nearby communities may stimulate desire for change- primarily at a local scale. This could increase the number of volunteers and could eventually create a widespread movement (Crayon 2009). Also, all of the people involved with the trade of the American bullfrog should be informed on the IUCN quarantine guidelines (Crayon 2009).

In order to prevent further spread of the invasive species, strict laws should be put in place to completely stop the intentional introductions of the bullfrog as a food source and to avoid pet owner releases of the American bullfrogs (Crayon 2009). The trade of the bullfrog should be monitored at higher intensities or banned. Current pet owners of the bullfrog should be required to make their pet amphibians undergo frequent veterinary surveillance to keep track of the captive populations and diminish pet releases within the Central Valley (Crayon 2009).

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Ring-necked pheasant (*Phasianus colchicus*)

Erin Bradley

Part 1: Project Background and Justification

The Ring-necked Pheasant is considered an upland bird, which means that its habitat tends to be more in the higher, drier lands, rather than the wetlands that are associated with what we call waterfowl (e.g., ducks and geese). Ring-necked Pheasants generally prefer valley floor grassland, variegated farmland and riparian areas, but they can also occasionally be found in wetland areas from time to time (wildlifehc.org)

A. We care about Ring-necked Pheasants for a variety of reasons. They are loved by hunters as a prime game bird that provides great sporting opportunities. Birdwatchers and nature lovers are rewarded with their beauty and bright plumage when they catch sight of one in the wild. Pheasants are not particularly destructive to other native birds with the one exception of the prairie chicken (wildlifehc.org). They are not considered a threatened species, and are listed as of “least concern” on the IUCN conservation status, (allaboutbirds.org) but it is estimated that their number have been declining in recent years due in part to a change in cropland structure across the nation (wildlifehc.org).

B. General Habitat Requirements: Ring-necked Pheasants are known for loving to dwell on the verges of farmlands- they prefer over grown, shrubby areas that give them enough shelter to take cover from severe weather and to conceal their nests, while at the same time being short enough to allow them to move about in relative ease. They are fond of abandoned farmsteads, fields that have been left fallow, and the edges of farmlands. They can be equally at home in wild grasslands or crops, as long as there is some variegation in the landscape. If all the crops of the land are mowed very short they will have no place to take cover overwinter and they will have either find new habitat or face death. They are generally able to get all the water they need from the food they eat. They also like to roost in trees at night, so prefer to have some woodlands nearby as well (wildlifehc.org).

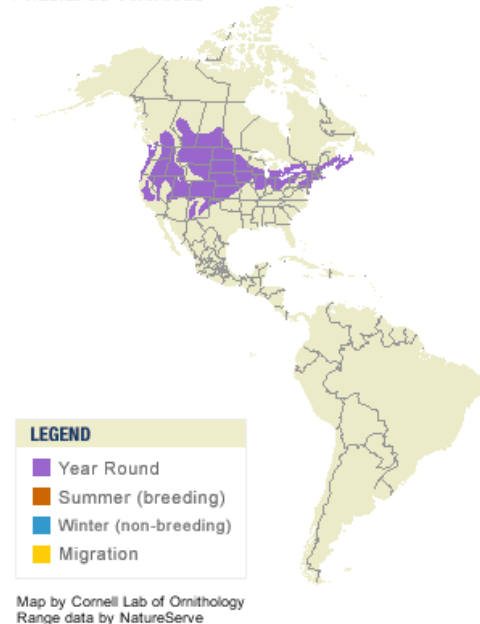
Food. Adult pheasants eat mostly leftover grains from crop lands, but also wild seeds such as legumes, ragweed, and other forbs. Over the spring and summer adult pheasants will also supplement their diet heavily with insects. They also eat wild berries and sometimes bits of snail shell to supplement the calcium in their diet. Pheasant chicks require a diet of almost entirely all insects during the first five weeks of their life. (wildlife.ech.org).

Interspersion of Habitat Types: One key feature of habitat requirement for pheasants that cannot be overstated is the need for several different habitat types available to them within fairly close proximity to each other. They need cover in which to roost at night, and taller grasses in which to nest, but the chicks when they are born need somewhat shorter grasses in order to move around and look for insects. They prefer odd fields, over grown hedgerows, briar patches and corridors of relatively undisturbed areas. This

kind of a mixture of places will maximize their habitat quality and their chances of reproductive success.

Range and Temperature Tolerance: The Ring-necked Pheasant lives in a wide area across North America, and can tolerate a wide range of temperatures.

Ring-necked Pheasant
Phasianus colchicus



Ring-necked Pheasants do not migrate. Instead they hunker down in the winter, eating what scraps of grains they find, and in very cold weather they may lie completely dormant for several days without moving. Pheasants can also live in semi-arid lands with temperatures that can reach up into the 100s as long as there is adequate food available (allaboutbirds.org).

Environmental Changes that Have affected Pheasant Survival The largest wide spread change that has significantly affected wild pheasant survival is the changing landscape of America's farmland. The change in general from small variegated farmsteads to large sweeping monocultures with little variation in the landscape has had a negative impact on pheasant survival overall as they need such a varied and diverse habitat to survive. Mowing fields and roadsides, eliminating border habitat, applying more herbicides and pesticides have all hurt pheasants, as well as moving forward the hay cutting date, as mowing too early can destroy the late nests. Hunting groups such as Pheasants Forever routinely sock certain areas with pheasants to hunt, but the combination of habitat degradation due to farmland changes, and habitat loss and fragmentation to the loss of rural agriculture land in general has had the overall greatest effect on their numbers (allaboutbirds.org).

Resources

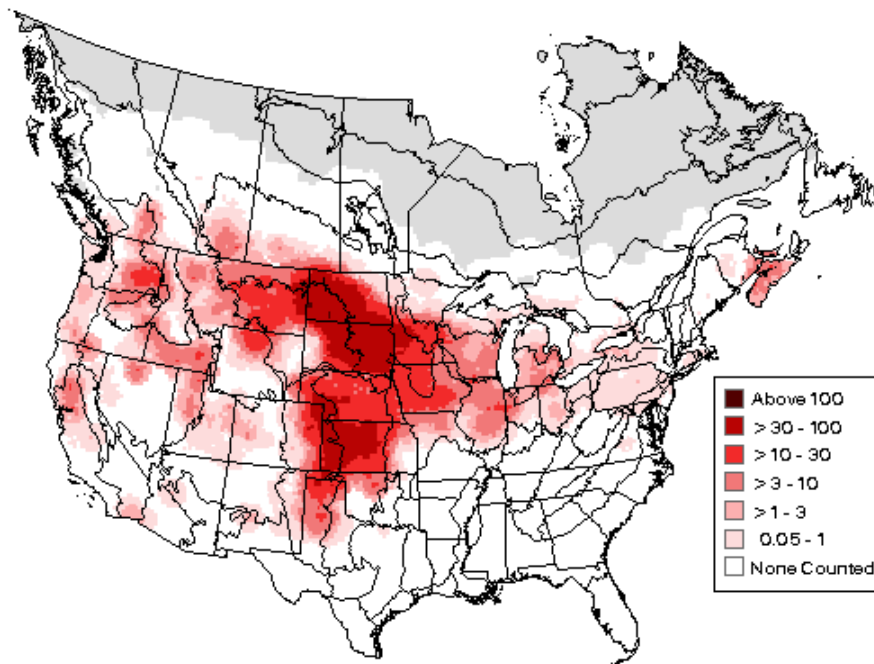
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Part 2: Project Goals and Management Plan

Goals: To increase the California BBS Ring-necked pheasant distribution by a factor of 1-2 across the present range. (see map)



(map courtesy of game-birds.com)

To increase the total range area of Ring-necked pheasants in California by 10-15%

To have these increases in density and population be self-sustaining in the long term, without the need for regular human input.

Achieving these goals will depend on The ability and willingness of farmers to leave some areas on their farms fallow and undisturbed for pheasant habitat to proliferate, as well as avoid the rising trend of large, undifferentiated monocultures in farming.

Restoration Plan

Unlike many of the other wildlife species which live in areas which are primarily wilderness, Ring-necked Pheasants live in areas which are in or near human civilization, and usually on private land. This requires working with landowners on an individual, one-on-one basis, to convince them to make their land more suitable for pheasants and then to help them achieve that. Because of this factor, a detailed and exacting description of what changes would have to be made for the pheasants would not be totally realistic as each modification would have to be agreed to by the landowner and may be changed by the landowner at any time.

The Wildlife Habitat Council suggests that farmers should be encouraged to plant the edges of their fields and fallow plots with stands of various kinds of trees and shrubs in order to provide extra cover for pheasants that may be otherwise lacking in the crop fields. Also, mowing should be done at various stages, so as to make the height of the grass at different levels, so the pheasants will never be totally without grass cover at any one time. The suggestion is for stands of trees that have the trees about 10 to 15 feet apart, and each stand of trees should be surrounded by a 15 to 20 foot herbaceous border (wildlifehc.com). Stands of trees should also be alternated by stands of tall shrubs to provide dense cover in severe winter weather.

Also of importance are “food plantings” which are stands of crops which are grown out of sync of the farmer’s main crops, which will provide food for the pheasants when the other fields are fallow. Good food crops to plant are sweet clover, buckwheat, sunflower, peas and other small grains and forbes (wildlifehc.com) About one acre of food crops should be planted for every 20-25 acres of habitat. If a farmer doesn’t want to plant food crops, he or she may also leave a few rows of the field crop up after harvest and allow the pheasant to eat that.

In an experiment done to test mortality of pheasants in relation to various landscape features (Clark & Schmitz, 1999) it was discovered that slight variations in the landscape mattered much less than the amount of predation upon the pheasants, usually by red fox or coyote. Skunk and raccoon can also raid pheasant nests and eat the eggs. However an aggressive culling of fox or coyote can result in higher levels of skunk or raccoons, which will be of little or no benefit to the pheasants (pheasantsforever.org). For these reasons, in order to maximize pheasant numbers, the suggestion is to increase the quality of the habitat, especially dense cover and roosting opportunities, in order to elude predators.

Monitoring Plan

Call counts and brood counts are considered to be the most reliable way to estimate the number of pheasants in an area, but call counts are now considered to be slightly more reliable for small patches of habitat, although brood counts are more reliable on a state wide level. (Rice, 2003). Call counts should be done either in April or May in high quality habitat about an hour before sunrise until about ten minutes after sunrise. Several days’ worth of call counts should be sufficient to get a good idea of the number of birds in an area.

Call counts should be done in an area that has low ambient noise (not by a highway for example) and not on mornings where the wind level is above 5 mph.

Brood counts should be done in August when pheasants are sitting on their nests. In drier years the brood count should be done in the beginning of August, and in the wetter years it should be done at the end of August. Years of regular rainfall should be conducted in the middle of August. Counts should be done within 15 minutes after sunrise or at dusk on mornings where there is no fog or rain (usually not problem in August). Broods should be flushed from cover so an accurate count may be taken of all pheasants; male, female and juvenile. Brood counts are often done from a slow moving vehicle in areas where cover is less dense (Rice, 2003).

Additional Resources Used

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Minimize Wildfires

Allyson Earle

Part 1: Project Background and Justification

Minimizing Wildfires

Central California has a history of large, damaging fires. Low frequency, high intensity large fires are the historic pattern. This pattern can often be associated with drought conditions and lightning storms; however, human caused ignitions have resulted in large damaging fires. Commercial timber, spotted owl habitat, archeological sites, wilderness area and other natural resources are often the protection priorities.



Central California wildfires are often characterized by heavy fuels, burning intensely in remote areas. “The Central Sierra Range consists primarily of grass and oak at the lower elevations, mixed brush at the intermediate levels and coniferous stands at the higher elevations” (Wildland Fire Suppression Tactics Reference Guide: 1996)

Wild fires are an especially dangerous threat to restored areas as they can completely destroy a successful project and the surrounding area in a manner of minutes. Precautions should be in place in order to prevent wildfires and a comprehensive plan should be put into action and actively adapted for wildfire management during dry seasons.

“Wildfire management is a series of coordinated activities undertaken by federal, state, and local authorities to resolve wildfire events when they occur”. Resolution may involve immediate and aggressive measures to quickly suppress a wildfire (e.g., personnel and large air tanker response for a wildfire moving quickly toward a populated area). However, in the case of a smaller operation they may involve immediate but less intense measures (e.g., monitoring a grassland wildfire where there is no immediate threat to humans and weather conditions are favorable for natural suppression of the fire within a short time period).

Wildfire management activities are generally categorized into four areas: preparedness, suppression, fuel reduction, and site rehabilitation.”(Bracmort and Hoover 2015).

In the case of Centennial park steps should be taken in all four of these categories with emphasis on a preparedness plan, the overall health of the site not as a means of suppression but as an ecologically healthy site, fuel reduction in the way of removing dead and potentially dangerous snags and ladder fuels. In the case of buildings that may be located near the site a *firewise approach should be considered as located in the diagram and zoning should be as follows.



<http://firewise.org/wildfire-preparedness/be-firewise/home-and-landscape/defensible-space.aspx?sso=0>

Zone 1: encircles the structure and all its attachments (wooden

decks, fences, and boardwalks) for at least 30 feet on all sides. Note: the 30-foot number comes from the very minimum distance, on flat ground, that a wood wall can be separated from the radiant heat of large flames without igniting. In this area: Create a 'fire-free' area within five feet of the home, using non-flammable landscaping materials and/or high-moisture-content annuals and perennials.

Zone 2: is 30 to 100 feet from the home, and plants in this zone should be low-growing, well irrigated and less flammable. In this area

Leave 30 feet between clusters of two to three trees, or 20 feet between individual trees. Encourage a mixture of deciduous and coniferous trees. Create 'fuel breaks', like driveways, gravel walkways and lawns.

Zone 3: is 100 to 200 feet from the home and this area should be thinned, although less space is required than in Zone 2. Remove smaller conifers that are growing between taller trees. Remove heavy accumulation of woody debris. Reduce the density of tall trees so canopies are not touching

Wildfire Management

Minimizing wildfire and its destructive effects has become an increasingly important issue, especially concerning restoration efforts in the central valley. The central valley of California has several different communities present as it stretches over many different types of topography. However, fire danger is increasingly more common in the central valley's grasslands due to the overpopulation of many exotic and highly flammable invasive plant species such as cheat grass. These invasives are highly adaptable and have been known to out compete natives and completely take over an area. This ability to compete has severely increased fuel load and density in many areas in the central valley making them prone to destructive wildfires.

Central California wildfires are often characterized by heavy fuels and burning intensely in remote areas. Logistical support problems can be a difficult challenge (Wild land Fire Suppression Tactics Reference Guide, 1996). In addition California grasslands are seeing an explosion in exotic species which create high probability of ignition and damage to the ecosystem. The restoration and long-term maintenance of ecosystems for a defined set of desired conditions including the range of variability for wild land fuel requires knowledge about fire regimes (Husari et al., 2006). There are several ways fire can be managed the most frequently used are grazing, mechanical, and prescribed burns. Grazing with goats and cattle has proven effective, as well as mechanical clearings in the way of fire breaks and thinning of trees, shrubs and undergrowth, and although the effects of prescribed burning are still highly debated it has shown promise. California is incredibly diverse and every occurrence of fire should be treated on a case by case basis and adaptive management plans should be created and implemented for individual ecosystem types in the Central Valley.

Fire Regimes

- The US has been characterized by almost a century of fire suppression, or inhibiting fires from starting and putting them out as soon as they start. This has caused the severity of fires to increase in size, spread, and temperature. (Sierra Nevada Conservancy, 2013; Collins and Stephens, 2007; Collins et al., 2011).
- The introduction of exotic species has created a buildup of non-natives that can withstand and outcompete after the intense burns that now characterize central California fire behavior (Nader 2007; Stephens 2005)
- Central valley grasslands, as well as many others throughout the western states, followed the same strategy of fire suppression. However, as knowledge has grown and with help from "LANDFIRE" mapping that shows wildfire patterns across the united states adaptive management practices such as controlled burns and grazing are now being put into effect as a means to allow small controlled burns in many of the fire adapted grasslands of central California.(Nader et al 2007, <http://www.landfire.gov/fireregime.php>)

Fire ignition/indices

- Fire ignition is influenced by many conditions the most notable are "Climate, Landscape, Land use, Human impact, Fire history, Land cover, Forest

structure, Ground coverage, Fuel characteristics, Management systems”(Kalabokidis et al. 2000).

- Fires have quantifiable characteristics that allow for scientists to mathematically predict the possibility of fire and the severity. Generally however density and height are the ideal measure of when fuel reduction is needed, such as when density reaches above “(>2,500 kg/ha)”, or where flames reach unacceptable heights following the rule of thumb that for every foot of vegetation there will be 3 foot flames. (Fuels/Fire danger OSCC, Menke, 1992).
- Fire occurrence is now most commonly caused by anthropogenic factors rather than the lightning strikes that used to characterize the central valley (Wildland Fire Suppression Tactics Reference Guide 1996)

Management

- Management should be a coordinated and interagency cooperative act starting from the local level all the way to the federal authorities, this management includes creation of fire breaks, removal of weedy species and dead vegetation accumulation, preparedness and plans of action in case of burning, and public education plans. (Thompson et al., 2015).
- All practices should be performed in cooperation with all aspects of the project so one tool does not negate another (i.e. Do not perform grazing in an area that has just been replanted, do not mow in newly restored waterfowl habitat etc.)

-Mechanical

- “In forested areas as well as grassland, installation and maintenance of fuel breaks, strategically placed fuel treatments, and defensible fuel profile zones at appropriate spatial scales should reduce wildfire area and severity”. According to the U.S. fire administration a 30 ft. fuel break is ideal for stopping the spread of flames and can greatly reduce the probability of severe expansion of the fire over the landscape.(Finney 2001, FEMA 2012).
- The removal of dead vegetation adhering to the minimum density and height requirements from above is integral to lowering the ignition index of most fires. Biomass removal however carries certain difficulties and cannot be performed in areas of high slopes, loose soil, and areas that are heavily protected from anthropogenic influences (Husari et.al 2006).

-Grazing

- Grazing is becoming a highly utilized tool in fuel management; this tool if timed correctly with seasonal growth can be used to move the system towards a more herbaceous species composition much like the grasslands of central California. Timing can be tricky however, grazing in early spring before plants seed can reduce the overall composition of the area and reduce density for the next year. In addition it may be a good idea to graze in late spring as well, before the summer dry season so as to keep flammable materials under control (Nader et al., 2007)

-Prescribed Burns

- Prescribed burns are burns that are intentionally started in order to limit the accumulation of fuels in the system. However, they represent the possibility of

becoming out of control and escaping the bounds of their prescribed area. This makes them a useful but controversial tool in fire management (Yoder and Blanter 2004).

Wildland/Urban Interface (WUI)

- The Wildland urban interface is the zone between where wildland “ends” and urban sprawl starts. This zone is of high importance as mitigation efforts are usually highest in these areas to protect homes and people(FEMA 2012)
- WUI are important in the planning of minimization of fire and have several rules and guidelines as suggested by the U.S fire administration in order to keep fire prone areas safe. These guidelines create a basic model from which to design an adaptive management plan(FEMA 2012)

Part 2: Project Goals and Management Plan

California’s central valley is highly characterized by its many fire adapted communities. These communities are generally made up of grassland areas filled with native species as well as what are considered noxious invasives. Centennial Park is a current restoration site in Vacaville, California in need of a wildfire prevention, preparedness, and monitoring plan. This site can be characterized by a riparian network of two streams and associated vegetation as well as an upland grassland area. The defining characteristic that pertains to this project however, is the direct association with the urban interface or the WUI (wild land urban interface). This interface creates challenges when creating a both an environmentally healthy fire minimization plan as well as one that protects home and people. These challenges however present a unique opportunity for a new and creative way to manage the landscape.

Management goals can be placed into two different categories based on the current conditions of the site and the ideal restored conditions. Having goals outlined for both of these conditions will allow for adaptive management as the site comes together in its final vision over time.

A) Current condition goals(Short Term goals 3-6 months)

- 1) A minimum of a 30ft perimeter between homes and the beginning of dense vegetation, this would act as a fire break between homes and the site. As of now this break is envisioned as a simple roughly cleared strip of cleared land between homes and the site. In the case of ignition, fire would be less likely to move to homes before suppressive action was taken. This 30 ft. number adheres to the fire wise plan and procedures set forth by the U.S Fire administration as a means of educating and keeping the public safe (FEMA 2012).
- 2) Instillation of fuel breaks throughout the site. Currently, with the beginnings of the instillation of the bike path these stretches of bare ground are ideal for stopping the spread of fire especially in a grassland setting where ladder fuels are not highly present. Ideally, as a precaution, several more fuel breaks should be added in the undisturbed landscape in

the far corners of the site. These should be created as axis roads that also serve a purpose that, if again a fire does start, management action can be taken immediately and with ease.

- 3) Reduction of fuels, primarily dead cover. This reduction of fuel should be a primary concern and removal should be done in any way possible such as a mechanical (i.e. mowing etc.), physical (i.e. volunteers pulling out weeds), or even done by using grazing (Nader 2007). Prescribed fires can be used, however due to the overgrown and high fuel load of the site as well as the proximity of the urban interface, there is high advisement against this method unless all precautions are taken, a fire crew is on hand, and residents in the nearby homes are made aware.
 - a. This awareness should be spread throughout the entirety of the community through the creation and distribution of flyers, pamphlets, and other similar educational tools that should be delivered by mail or door to door by a representative of the site.
- 4) Public awareness. In the central valley most fires are caused by human ignition (Wildland Fire Suppression Tactics Reference Guide 1996), therefore the public should be notified of the high fire risk in the area and what is being done to minimize it. As current conditions stand placing a plaque or sign at the major entrances to the area, explaining what the site is, how it will be restored, and the potential of fire hazards, would at this time be a suitable.

At this time, these goals will provide a relatively safe zone in which fire should not ignite or spread with severe loss to homes or integrity of the site. While these goals may not provide the most beautiful site, they are cost efficient and achievable in the short term. With more time and cooperation between all facets of the restoration project they can become both safety measures as well as aesthetically pleasing parts of the fully restored park. This next section will outline goals for the fully restored park taking into account ideal conditions and budget as well as emphasis on aesthetics, community involvement, and education.

B) Restored Condition Goals(Long Term Goals 1-2year+)

- 1) Adherence to the minimum of 30 ft between the site and houses as stated above. However, these 30 ft will be a mixture of a footpath of whatever material the designer deems suitable with a gravel buffer zone on each side, rather than the rough clearing that is expected from the above action. The gravel is to allow a smaller path based on budget and design as well as to ease the transition from “asphalt” to vegetation. In addition, in case of fire it will allow a buffer zone between the path and the outbreak which may decrease the difficulty of fighting the fire since it will not be directly next to the pathway.
- 2) Fuel breaks should continue to be implemented with the intention of using them as axis roads in case of emergency (i.e. fire, rescuing patrons in the far corners of the park). However, for ease of use and aesthetics to the area these fuel breaks should be lined with gravel. These fuel breaks now serve 3 purposes, first and foremost as fuel breaks, axis roads, and potential public pathways.

- 3) Fuel load should still be highly maintained. Dead cover should be removed as often and thoroughly as often as can be tolerated by the site. In the restored site however, there should be better seasonal flux and flow of water therefore the use of heavy herbicide and motor vehicle use is advised against in order to maintain the integrity of the site and limit the runoff of chemicals/nutrients into the system from these anthropogenic sources. These methods still can be used, but discretion is advised. Grazing is still a viable option and will be discussed in more detail in the next section.
- 4) Public awareness. Now that the site is fully restored permanent plaques should be placed in strategic places along the paths, these plaques can say a number of things about the site but should also state, the history of the fire adapted community of the upland grassland, how most fires start, and how the community can protect both their homes as well as this newly restored area. Grazing is also an opportunity for community involvement and awareness as well as dead cover removal. Having cattle graze the site in sections every couple of months, seasonally or as needed , and inviting the public, education groups, local elementary schools and other organizations to come and learn about the site, would be an opportunity to receive an invested interest from the public as well as fuel management. This educational aspect would include education about the native species at the site and importantly the reason for the grazing and how it is an effective management tool for fire management.

These goals are written under the impression of a limitless budget and ideal conditions. However, the basics are achievable and written with the intent of adaptive management of this site as it transforms over the next several years.

Restoration Plan

A restoration plan that allows for wildfire minimization is going to be a highly cooperative plan that will span uncertainties of plant behavior in a fire adapted community, ecosystem services of the vegetation, species interactions over the fuel breaks and whether these will disturb migratory or mating behaviors, and habitat availability. In addition, this plan may cause erosion into the riparian area, runoff of nutrients used for weed mitigation or fluids from motor vehicles along the axis roads into the ground water or stream system. There are many variables that need to be overcome with the best scientific evidence available, however parameters must be set of acceptable losses in order to move forward and make an impact on the site as well as keep the homes and community nearby safe.

Ideally, the first step of this plan would be to create the 30 foot buffer zone and fuel breaks if they are not already in place. The use of heavy machinery to clear this vegetation may cause residents discomfort and affect the soil in a negative way. Options of dealing with this are to file permits and make sure the community is aware that this action is happening, or to pull out vegetation by hand or with herbicides. Pulling vegetation out by hand is a long and difficult process, although it does allow for community involvement. However, if no or limited volunteers show up it would be up to the restoration team to achieve the desired effect. In addition,

herbicides would make this extraction of vegetation easier, however these herbicides may have lasting effects on the environment and research as well as an herbicide applicator license would be needed in order to move forward with this plan. These are the same issues that will be present when removing fuel load and dead vegetation throughout the park, suggested options for this plan include:

- 1) (3-6 months) Use of mechanical weed/vegetation removal where necessary, easily accessible and without damage to sensitive habitats. In addition, the use of well-known and studied herbicides in areas of high invasives, dense cover and physically dangerous or unreachable places in order to clear the way for fire breaks. This can be done in conjunction with the vegetation and topographical analysis team so the correct areas are selected and the appropriate personnel are hired.
 - a. The location of fuel breaks/axis roads may be highly debated as they will be cutting through habitat. However, these need to be easily accessible by cars (ie fire trucks) and engineered to stop fire from reaching homes. These can be planned with wildlife and vegetative experts but must be implemented into the site nonetheless.
- 2) (3-6 months) In problem areas/areas with natives/areas with sensitive soil or species a mixture of sustainable grazing, prescribed burns and mechanical removal should be used to remove species that could increase the fuel load of the area and increase fire danger. Volunteers should be asked to participate in clearing sensitive riparian areas that may be sensitive to grazing or the use of heavy equipment that could damage soils or sensitive wildlife habitat. This will allow for community involvement and awareness as well as limit the amount of invasive human activity in sensitive areas.
- 3) (6 months-1/2 yrs) After fuel breaks, axis roads, and the safety zone is set up, and dead vegetation is cleared with the help of the design manager and the restoration team, materials must be selected and trucked in to lay foundation for paths, such as the gravel axis roads.
 - a. This should be planned for seasonality; during a heavy rain is not the time to dump a truckload of gravel. In addition, if sensitive species such as waterfowl or migratory birds are mating etc. invasive construction should be put on halt until an acceptable time is reached, or a compromise is reached.
- 4) (1-2 years) Finally plaques should be installed with pertinent information in strategic places such as the entrances to the pathways that explain the fire risk and how to prevent it in the area.
 - a. These plaques should be planned as a whole and have not only fire information on it but information about the site as a whole and the amazing work that is being done there.
- 5) (1-2 yrs) Begin the planning stages of cattle grazing on the site as part of long term fuel load management, setting up when the cattle will graze, how many, will this affect plant/animal species, and how large an area at a time the cattle will be able to graze.

- a. Implementation would begin ideally after the site has come to a relatively stable state after the restoration process. This time line may be anything from 1-2 years and potentially longer. However this is a viable and effective option that should be placed into effect as soon as deemed plausible.

Monitoring Plan

Monitoring is a crucial part in the success of creating a fire safe community as well as a restored area. Heavy monitoring should be implemented at the start of the project in order to see how the wild land community is interacting with the fuel breaks and removal of vegetation. Most fire monitoring should be monitored seasonally (The National Strategy 2014). Fuel load measurements should be taken at the beginning and end of the growth season so numbers can be generated before the summer months when fire is most likely, so that action can be taken in order to mitigate the outbreak of such an event. These measurements should be taken in early spring before seeds can set and action can be taken before invasives have a chance to establish and during the late spring to measure fuel load as the summer dry season occurs so removal action can be taken before serious threshold densities are reached. This monitoring should be conducted as part of the vegetative survey adding another aspect to the coordination of many people and interests for the overall good of the site. Fuel loading in this system is a constant fear as the perennial grasses that dominate the community have a short regrowth period and are incredibly resilient to all types of removal. In addition with the current drought that the central valley is experiencing fire danger is at an all-time high. This monitoring may calm the community nearby and could be converted into a citizen science or volunteer program making the community invested in the overall wellbeing of the project and its survival into the future.

This plot of land raises several questions concerning the future; will the suite of vegetative species move towards a more natural fire adapted community without the exposure to fire, but with the introduction of these species as part of the restoration? What affect will grazing have on these communities and will it be positive or negative to the vegetation as well as the overall system. Future research such as grazing one section of the plot, burning another sections, mechanical management, and a control plot may show the effectiveness of these actions in the area. This research could later be used to create management plans all over the central valley that are both effective as well as adaptive and improve the overall management of this site.

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Increase Carbon storage on-site

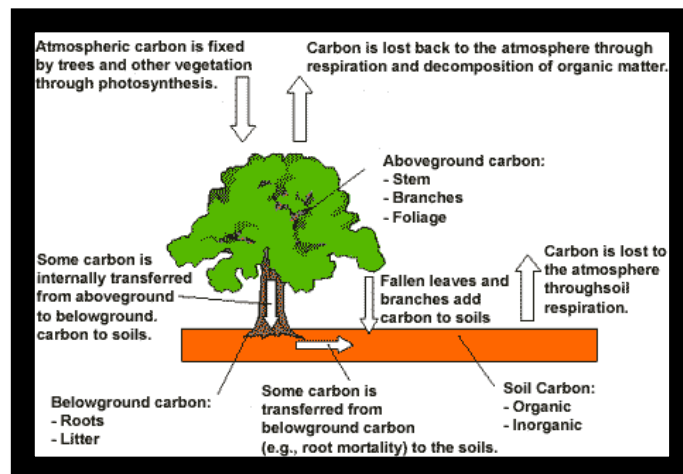
Sayla Elsbree-Kraft

Part 1: Project Background and Justification

ID Guide

According to the Society for Ecological Restoration (SER), carbon sequestration and storage is one of the top “environmental values of restoration” (SER 2015). Increasing carbon storage on-site is important for offsetting the effects of carbon accumulation in the ozone due to fossil fuel extraction, deforestation, land-use changes, and more (The Hidden Half 2015). Carbon sequestration refers to annual carbon absorption, and carbon storage refers to the total quantity of carbon dioxide in the plants and soil (Webinar 2015).

Determining the specific amount of carbon stored in any specific site can be difficult because there are so many factors that influence the calculation, such as plant life cycles and vigor (Patterson 2009). High levels of living vegetation are a good indicator of carbon storage since plants fix carbon dioxide through photosynthesis (Kocher 2002). Planting perennial trees, shrubs and native grasses will effectively increase carbon sequestration (Carbon 2015). Root exudates and buried detritus may also contribute to the total carbon storage in the soil (Course Introduction 2015). Additionally, various types of wetlands (e.g. the vernal pools located on-site) are particularly effective at storing carbon in the soil. To calculate carbon storage, it is also important to consider the rate of soil respiration. The rate of soil respiration is influenced by “temperature, moisture, nutrient content and level of oxygen in the soil” (Soil 2015).



Retrieved from: <http://teeic.indianaffairs.gov/images/photos/cycle1.gif>

Part I

Background & Justification

Loss of carbon from our ecosystems can occur in a variety of ways, whether it is due to direct mining and extraction, or a reduction in vegetative biomass and soil erosion (Conant). Restoring and protecting our carbon sinks is becoming increasingly important as the rate of carbon loss accelerates and greenhouses gases (GHGs) accumulate in the atmosphere (“Carbon Loss”). Atmospheric carbon, Nitrous Oxide and Methane levels correlate with the introduction and expansion of industrialization (as seen Figure 1 below) (Saunders), and the increased concentration of these gases in the atmosphere have resulted in global climate warming (“Greenhouse”). Soil degradation and loss of primary productivity contribute significantly to losses in carbon storage and sequestration, and alternatively indicate useful modes for mitigating the effects of GHG emissions and losses (Zhu and Reed). The conversion of wetlands and grasslands into agricultural production correlate with reduced carbon storage in the California Central Valley (Duffy, Kahara and Records); however, changing land-management practices such as reducing grazing, introducing perennial plant species, increased irrigation and nutrient application in these developed lands are propitious options for increasing levels of stable forms of carbon. Additionally, increasing the resiliency of an ecosystem through increased biodiversity and appropriate disturbance regimes can help ensure these carbon sinks remain intact in the face of unpredictable changes in climate (Conant).

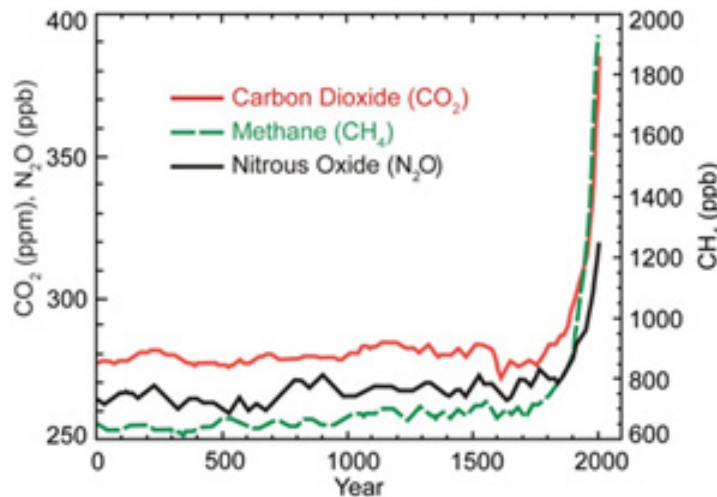


Figure 1: Exponential increases in GHGs correlate with the introduction of industrialization.
<http://www.epa.gov/climatechange/images/science/graph-increase-in-ghg.jpg>

Literature Review

Importance of Carbon Storage in Natural Systems:

- Improving land management to increase carbon storage has been shown to be effective for reducing levels of atmospheric carbon and green house gases (GHG's) (Conant 1).
- Productivity and economic returns are usually enhanced with the implementation of practices that sequester carbon (Conant 15).
- The GHG emissions from livestock raised on various forms of rangeland including grasslands, shrublands, and woodlands (accounting for half of California's land-use) can be *completely* offset through proper management ("Carbon Storage").
- Because grasslands and shrublands cover large areas of land, managing them to increase carbon storage and sequestration can have a large impact on C storage despite the fact that their C storage per unit of area is small (Zhu and Reed 10).
- Grasslands in California store a substantial amount of the world's soil organic carbon (SOC) (Zhu and Reed 10).
- Because of the unpredictability of our future due to climate change, increasing the carbon storage of an ecosystem is a useful way to prepare for these unavoidable environmental shifts (Conant 19).

Effects of Disturbances, Land-use Shifts and Climate Change on Carbon Storage:

- The frequency and severity of disturbances affect the availability of moisture, and hence carbon uptake in an ecosystem (Zhu and Reed 9).
- Wildland fires may decrease levels of C storage due to losses via combustion (Zhu and Reed 9). Increased fire frequency in Western United States poses the risk of significant decreases in carbon sequestration (Zhu and Reed 9).
- Invasive species can also change the cycling of carbon in a system and reduce on-site storage (Conant 7).
- WRP managed wetlands had reportedly lower carbon storage than perennial agricultural crops, but lower carbon storage than annual crops (Duffy, Kahara and Records).
 - The conversion of wetlands to agricultural land in the California Central Valley has contributed to a great amount of soil (and carbon) loss from the system (Duffy, Kahara and Records).
- Overgrazing has led to losses in carbon storage due to erosion of in top-soil ("Carbon Storage").

Management Strategies to Increase On-site Carbon Storage:

- Seasonal changes in an ecosystem, potential evapotranspiration, present plant communities, and the age of the ecosystem are all important considerations for management (Duffy, Kahara and Records).
- Because water availability is a highly limiting factor in the Western United States (Zhu and Reed 9), improving soil water retention will encourage the growth of vegetative biomass and increase on-site carbon storage (Conant 7).

- In areas where water availability is limiting, higher precipitation will result in increases of on-site carbon storage (Zhu and Reed 9).
- Carbon storage has the potential to be improved by reducing grazing and increasing decomposing biomass (Zhu and Reed 10).
- Grazing in grasslands may directly impact moisture gradients, resulting in decreased carbon sequestration and storage levels (Zhu and Reed 10).
- When grasses are grazed, they deposit a portion of their roots into the soil to complement the amount of above-ground vegetation. As these grasses regrow, the roots also regrow and when the grasses are grazed again the process repeats itself. Over time, these root deposits account for large amounts of C storage in rangeland soils (“Carbon Storage”).
- Supporting strong soil microbial communities can help convert carbon stored in plant detritus into stable forms of carbon that will persist (“Conservation”).
- Accounting for losses and gains in carbon found in waterways such as rivers, lakes and wetlands should be accounted for (Conant 1).
- Maintaining any wetlands at a project site is important for retaining carbon because of their high capacity for storing SOC. (Duffy, Kahara and Records)
- Cultivating native grasslands leads to soil carbon in the atmosphere due to the losses in soil organic matter, and should generally be avoided or regulated (Conant 6).
- However, reducing biomass and shifting species communities and soil properties is a relatively natural part of grassland ecosystem management that *may* increase overall biomass and carbon storage (Conant 7).
- Introducing productive species, and improving moisture and nutrient availability increases C sequestration (Conant 15).
- Management techniques such as introducing propitious grasses and legumes, fertilizing, and irrigating to increase vegetation and reverse soil degradation may increase carbon sequestration (Conant 11).
- If too much nitrogen fertilizer is applied it may be transformed via nitrification/ denitrification into N₂O, a harmful greenhouse gas (GHG). Although applying N may increase vegetative biomass and carbon sequestration, one must be careful to not put on more than necessary, especially in wet environments (Conant 12).
- Tracking C storage in a system can be difficult, but fluctuations in net primary productivity (NPP) are generally signatory of changes in the carbon balance of an ecosystem (Conant 7).
- Applying compost (manure and plant waste) on an annual grassland can greatly increase the amount of carbon sequestration in a system by increasing water holding capacity and NPP (“California Annual”).

Part 2: Project Goals and Management Plan

Goals

The overall goal is to increase carbon storage throughout the Central Valley using direct implementation of restoration measures, and indirect methods such as land-owner education and land-use protection.

Short-term Goals	Long-term Goals
Increase NPP (Fonte 2015)	Maintain high levels of NPP (Fonte 2015)
Increase SOC through direct application of and/or incorporation of OM (Silver n.d.)	Create systems that self-sustain SOC (Silver n.d.)
Incorporate plant mulch, manure and other compost to the soil (Silver n.d.)	Implement policies for improved rangeland management for soil C (Silver 2010)
Educate ranchers to improve grazing practices (Byrd 2015)	Offset GHG emissions and reduce the effects of climate change (Silver 2010)
Protect existing C pools (Byrd 2015)	

Restoration Plan

This restoration plan emphasizes management in three predominant land-use types in California's Central Valley: rangelands, croplands, and wetlands. Management of C storage in rangelands must be addressed foremost because of its expansive cover (Silver 2010) and ability to store and affix soil organic carbon (SOC) (Silver 2010). Increasing vegetative and soil C storage per ha in croplands can be improved through a variety of farming practices, and in addition to mitigating climate change may provide a variety of other ecosystem services by improving the soil tilth (Fonte 2015). Preserving wetlands must also be prioritized because they hold deep sinks of carbon storage, and can be lost due to land-use change, development and anthropogenic shifts in hydrology (Eviner "Restoration" 2015).

Rangelands:

- General Information:
 - o About 50% or 12 million ha of land in California (Silver 2010)
 - o C pools average 140 Mg C ha⁻¹ in top meter of soil (Byrd 2015)
 - o Rangelands are predicted to be cut in half by 2051 (Byrd 2015)
 - o Baseline SOC pools in the top 20cm of soil in are higher in rangelands (161.4 Tg C) than in other grasslands (99.8 Tg C) (Byrd 2015)
- Methods for increased C storage:
 - o Implementing proper grazing practices can increase NPP, result in more rapid turnover of vegetation, and encourage root exudates in the soil. Improved grazing practices have been shown to increase C sequestration by about 0.35 Mg C ha⁻¹ yr⁻¹ (Silver 2010)

- o Proper grazing can also increase C soil inputs from root sloughing. When the livestock bites off most of the above-ground biomass of the grasses, the mature root structure can no longer be supported by the new rate of photosynthetic energy conversion. In response, the roots complement the new size of the above-ground biomass by sloughing off extra material (“Carbon Storage”).
- o Increase woody vegetation in grasslands by establishing and preserving oaks (native to California savannas; see image below) to increase C storage via increased plant litter deposits, increased below- and above-ground biomass, and mitigation of soil erosion. Establishing oak seedlings will result in a greater survival rate than direct seeding (Eviner “Population” 2015) when introducing plants. Preventing the spread of *Phytophthora ramorum* (Sudden Oak Death) can be achieved through careful sanitation of pruning equipment and other strict monitoring procedures (Holmes 2015).
- o If they are limiting factors, organic amendments and irrigation may increase NPP, thereby amplifying C cycling in the system with greater amount of organic deposition, SOC and vegetative storage (Fonte 2015).
- o Educating land-owners through outreach and implemented policy can increase the use of proper grazing practices.



Image of oak savanna in Cache Creek Reserve
Photo taken by Sayla Elsbree-Kraft

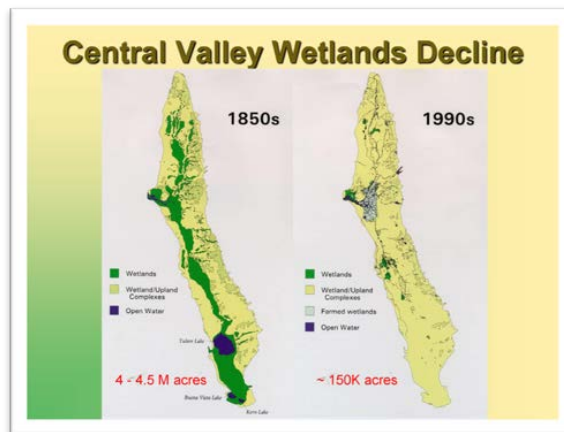
Croplands:

- General Information:
 - o In 1997, 18% and about 11.04 acres of land in California was cropland (“Measure” 2009)
 - o One square mile of California farmland is lost due primarily to conversion to urban development every day—amounting to a total of 1.4 million acres lost from 1984 to 2010 (“California” 2013).
- Methods for increased C storage:
 - o Conversion to no-till or minimum till shows positive correlations with increased soil C storage due to decreased (Fonte 2015)

- o The use of perennial crops (e.g., the development of perennial wheat crops) may increase soil C by allowing for greater rooting depths and
- o Use of hedgerows can increase SOC on farms (Smukler 2010) by reducing wind erosion of the soil (Eviner “Ecosystem” 2015).
- o Introducing and encouraging microbial populations in the soil in croplands can encourage the conversion organic matter in the soil to more stable forms of C (“Conservation”).
- o Increased use of polycultures and/or farmscaping (incorporating trees, shrubs and grasses that offer ecosystem services) increase the vegetative C storage in agriculture by allowing for greater canopy cover and root biomass due to above- and below-ground niche complementarity (Fonte 2015)
- o Use and incorporation (via tillage) of cover crops increases overall SOC by adding organic matter to various soil depths (Fonte 2015).

Wetlands:

- General Information:
 - o Re-established wetlands along the Sacramento-San Joaquin Delta have high annual C inputs of about 2 kg C m⁻² year⁻¹ (Miller 2009)
 - o The anaerobic conditions created by the water in wetlands decreases the rate of decomposition, lending to their ability to store large amounts of carbon (Collins 2013)
 - o It has been estimated that up to 87% of wetlands in California have been lost since the times of Spanish exploration due to water diversion for agriculture, land-use change, invasive species and more (“How” 2013)



This image depicts the loss of wetlands in California from the 1850's-1990's
<http://mavensnotebook.com/2015/02/19/yolo-bypass-part-2-fish-fowl-and-the-mercury-conundrum/>

- Methods for increased C storage:

- o Restoring and re-establishing wetlands is a priority for soil C storage in California's Central Valley given the significant losses of land cover. ("How" 2013).
- o Increase C storage in and inputs from *emergent vegetative growth*. Emergent vegetation contributes significantly to peat development and accounts for the majority of C inputs in wetland systems along the Sacramento-San Joaquin Delta (1.3-3.8 kg C m) (Miller 2009).
- o Reduce C output through supporting *natural hydrological regimes*.
- o Encourage greater root:shoot growth ratios. Roots plays an key role in SOC accumulation in wetlands. A 2010 study showed that tule (*Schoenoplectus acutus*) has a high root:shoot ratio (Miller 2009).
- o Where possible, anaerobic conditions in wetlands can be increased through the maintenance of permanent wetlands. This will reduce decomposition rates so the rate of decomposition does not exceed the rate of organic matter inputs (Collins 2013). For example, the Yolo Bypass Wildlife Area manages their wetlands in three ways: as permanent, seasonal and agricultural wetlands. The Yolo Bypass Wildlife Area could improve their C storage by converting their seasonal and agricultural wetlands to permanent wetlands ("Yolo" n.d.).



Image of Sayla Elsbree-Kraft observing a quadrat sample of tule (*Schoenoplectus acutus*) in the Yolo Bypass Wildlife area.
Photo taken by Rachel Davidson

Uncertainties

- Weighing Costs and Benefits:
 - o Indirect benefits of C storage include increased ecosystem services, climate change mitigation, habitat conservation, among others. While it is important to ensure the costs and ramifications are required during any restoration project, quantifying the value of these secondary outcomes of increasing C storage may be arduous or impossible.
- Outcomes vs. Correlations:

- o While there may be conditions that correlate with higher C storage (e.g., pH, temperature, soil moisture), the ways in which those conditions can be achieved are variable. The means by which these conditions are attained may cause unforeseen detrimental effects because of limited available information or factors that were not considered.
- Ephemeral Wetlands:
 - o Ephemeral wetlands such as vernal pools that are flooded only part of the year, provide oxidative states and aerobic conditions that render them less effective for storing carbon. The effectiveness these types of wetlands have for storing carbon is still being discovered (Collins 2013).

Monitoring Plan

Private owners of rangelands using good grazing practices should be steadfast about monitoring their inputs and outputs on a quarterly basis so that researchers can use the information to calculate overall C storage in rangelands. Political leaders might consider offering a grant opportunity for those ranchers that also record all management decisions that may impact their resulting carbon efficiency so that researchers may also have access to this information. Researchers can use the results to further determine which management strategies prove to be most effective. Government enforcement should visit rangeland owners annually to take soil core samples and random sampling with quadrats of above ground vegetative biomass by height and density. They may also monitor for erosion or sources for OM loss.

Croplands should be monitored for C soil levels seasonally (or between crops) by farm owners and managers, and—just as with the rangelands—should be visited by government enforcement annually to take soil core samples, and measure any topographical shifts due to wind or water erosion. Inputs and outputs of C should be averaged for a given year to determine if shifts in management are necessary to remediate any deficits in C storage.

Preserved or restored wetlands should be measured for vegetative cover during peak biomass using transects and quadrats at deep and shallow areas of the wetland (Miller 2009). It may be useful to implement *some* “destructive sampling” methods, removing plant biomass to measure total carbon content in a lab in order to estimate C storage in living vegetative (Miller 2009). Wetlands should undergo strict monitoring because of their severe conditions and the plethora of indirect benefits from wetland preservation for wildlife habitat (Collins 2013).

Because the scale of this restoration plan is very large, it is critical that there be collaboration among the restoration workers, private land-owners, state park managers, specialists, political leaders, and government enforcement sectors. The threat of climate change from increased GHG emissions creates a sense of urgency, and in addition to monitoring on-the-ground practices, monitoring overall atmospheric carbon and stored carbon on an annual basis can inform the urgency of our efforts at regional or local scales.

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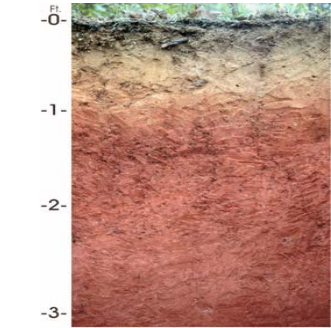
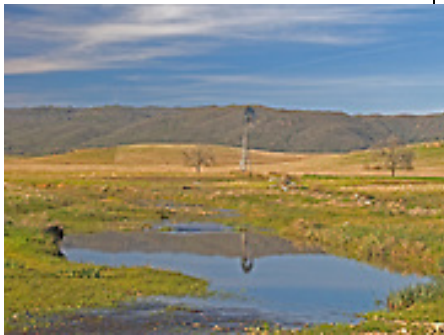
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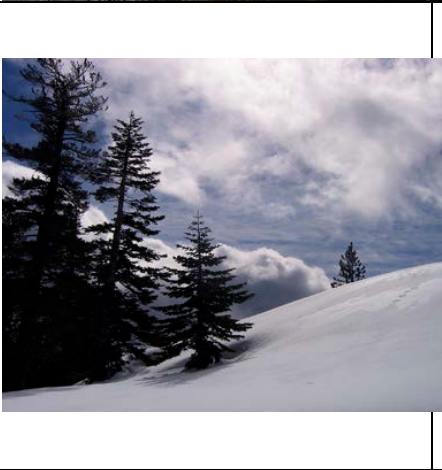
Water storage, supply, and flood control
Rebecca VanStokkum

Part 1: Project Background and Justification

Visual	Indicator	Service
Water Storage		
	Surface soil condition • Compaction • Erosion • Cracking • Microtopography • Level of soil moisture—waterlogging, drying	• Surface soil as initial receptor of precipitation or irrigation • Fate of runoff and percolation
	Soil type	• Infiltration & storage capacity • Subsurface runoff processes • Cation exchange capacity—levels of nutrient leaching
	Vernal pools and wetlands	• Environmental surface storage • Species habitat (both permanent and seasonal) • Recreation, spiritual enjoyment

		• Water filtration
	Vegetative community	• Water storage in tree species • Regulation of surface runoff • Erosion control • Species habitat
	Salinity	• Condition of the water table • Viability of vegetation and other species

	Subsidence	• Condition of the aquifer • Underground storage capacity and sediment structure
Water supply/sources		
	Precipitation	• Major source of water supply during winter months • Source of snowpack
	Surface runoff from irrigation or urban anthropogenic sources	• Use by agriculture • Use for urban landscape • Wetland water filtration of nutrients and other pollutants

	Urban storm water runoff	• Floodwater control • Regulation of flows within and between the landscape units
	Snowmelt/snowpack	• Sierra Nevada snow pack main form of water storage for the Valley • Source for the State Water Project and the Central Valley Project
Flood Control		
	Storm water drainage/recharge	• Percolation • Groundwater recharge • Flood and storm water management

	Reservoirs & canals	• Flood regulation • Anthropogenic and environmental storage and conveyance • Urban water supply—landscape and homes (approximately 20%) • Agricultural water supply (approximately 80%)

One of America’s great wildlife spectacles is found not in Yellowstone National Park or the backwoods of Alaska, but at the Sacramento National Wildlife Refuge beside Interstate 5 in California’s Central Valley. (Wilson, 2010, p. 3)

Wetlands are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season. (USGS, 2015)

Background: Why do natural water storage, supply and flood control matter?

In addition to habitat for wildlife, California’s wetlands and vernal pools provide short and long-term water storage; supply water to streams, rivers and lakes; and reduce the need for more invasive flood control measures (Martinez et al., 2014; Land, Air and Water Resources, 2010). These types of benefits are sometimes called ecosystem services (Daily et al., 2000; Costanza et al., 1997) because they are natural, quantifiable processes that provide essential elements of well-being to the people that depend on them. Globally, demand for ecosystem services is growing. At the same time, the capacity to meet this demand is being affected by human actions (MA, 2005). In the case of wetlands, the impact on water storage, supply and flood control are a vital part of the economic, social and physical well-being for residents of the Central Valley. Over the past century approximately 95% of the state’s wetlands have been drained. Because wetlands and the ecosystem services associated with them have been affected to such an extent, Californians have recently felt compelled to ensure more stringent protections both at the federal and state levels (i.e. the recently passed Sustainable Groundwater Management Act of 2014, more stringent wetland and stream regulation related to the Clean Water Act; Martinez, 2014; BenDor & Riggsbee, 2011). The fact sheet that follows explains the

basics of wetland water storage, supply and flood control for restoration sites with a focus on the benefits provided to residents of the Valley.

Provisioning Services	Food (fish, game, fruit), raw materials (timber, fuel, energy, fodder, fertilizer), genetic resources, medicinal resources, ornamental resources
Regulating Services	Gas regulation, disturbance prevention, water regulation,

Table 1. Overview of ecosystems services provided by wetlands including water storage, supply and flood control (Adler et al., 2013).

Cultural Services	Aesthetic, recreation, cultural/artistic, spiritual and historical information; science and education
Supporting Services	Climate regulation, refugia for flora and fauna, nursery function ¹⁶

Literature Review

Key components that naturally provide water storage, supply and flood control

In general, wetlands provide an important aspect of connectivity for hydrologic systems. While there is a wide array of wetland types there are some key components that come together to naturally provide storage, supply, and flood control (Kiedrzyńska et al., 2015).

- **Ecohydrology**: includes all elements of an ecosystem that would need to be managed for adequate water storage, supply and flood control (Kiedrzyńska et al., 2015). Wetlands are a highly biologically active component of any region. The pulse and rhythm of flooding dictates key aspects of ecological structure (Smardon & Fellman, 1996; Chapin et al., 2011). The surrounding landscape affects the site in question.
 - o Important factors include (USGS, 2015):
 - Topography
 - Slope
 - Groundwater flows
 - Thickness and permeability of the soil
 - Position in the watershed
 - o Factors within the site itself include:

- Water table
- Basin slope
- Soil nutrients
- Sedimentation
- o Important components of connectivity with the water table change seasonally in wetland and other riparian areas through precipitation, evapotranspiration, and water use/irrigation (USGS, 2015).
- o Storage occurs as precipitation becomes runoff or groundwater discharge that flows into wetland areas. At this point evapotranspiration or infiltration cause slow but regulated losses in storage over time. Outflows also include surface water flow and groundwater recharge (UWSP, 2015).
- **Anaerobic conditions in wetlands:** lack of oxygen in waterlogged soils creates conditions in which decomposition is lowered and organic matter builds up over time (Chapin et al., 2011).
 - o Additional organic matter causes the soil to increase in water holding capacity (Hanak et al., 2011).
 - o Soil depth can be lost quickly if anaerobic conditions are removed.
- **Vegetation:** vegetation in the catchment affects outcomes for wetland water storage. Critical conditions within a floodplain include (Chapin et al., 2011):
 - o Periodic flooding: this provides water availability, clearing the soil for new establishment and movement of sediments and the creation of new habitat.
 - o Access to groundwater: depth to groundwater and the shape of floodplain channel (in zones) affect vegetative possibilities
 - o Hydrology: the amount, speed, and timing of flows
 - o Soil fertility: high organic matter deposits (inputs from other ecosystems) affect the vegetative regime (BC Outcrop, 2015)
- **Connectivity:** floodplains sometimes function as a system of wetlands but can become hydrologically disconnected through manmade conveyance and flood control infrastructure (Poff, 2002). A key to natural connectivity is that the floodplain should remain connected from mountain sources to river mouth locations on the coast (Kiedrzyńska et al., 2015). Connectivity in the Central Valley starts with runoff from snowmelt in the Sierra Nevada Mountains and also includes groundwater discharge and precipitation. Under natural historical conditions spring snow melt and rains filled river and stream channels that led to this floodplain. Before 1900 there were an estimated 1.6-2.0 million ha of wetlands throughout the Central Valley (Duffy & Records, 2011), some of them seasonal, surrounded vernal pools and other bodies of water with distinct wet and dry periods (Galloway & Riley, 2015). The unique hydrology of the Valley tends to be driven by snowmelt at higher elevations and low elevation precipitation flow impacts, with percolation into underground aquifers taking place on the floodplain (Kiedrzyńska et al., 2015; Hanak et al., 2011; Lund et al. 2014; Duffy & Records, 2011).

There are three key strategies for promoting success of a wetland water storage, supply and flood control restoration project, including key enhancements

Strategies include both structural and non-structural approaches. Strategies one and two are non-structural, while the third strategy is structural.

1. **Increase total wetland area:** An increase in total area of wetlands will also increase the amount of water stored throughout the floodplain and regulate flashy flows associated with urban runoff.
 - Research suggests that an estimated 3-7% to 15% area of wetland is needed to maintain flood control and storage (Wright et al., 2006).
 - It is estimated that at least 5% wetland area per watershed/catchment is needed to provide adequate filtration of pollutants such as nitrate (Wright et al., 2006).
 - A modeling study by Martinez (2014) indicates that both wetland restoration and increasing wetland area, especially over 250-500 ha, increases retention of flows in the wetland and the reduction of peak output flows during flood events. Although depth was not found to influence water retention, a variety of depth to area combinations were found to be optimal depending on the restoration goals.
2. **Ensure that there are adequate buffer zones connected to bodies of water:** riparian shrub buffer zones, sometimes called ecotones, should be maintained throughout the floodplain. Buffer zones serve several purposes:
 - Riparian buffers slow runoff into water channels (Kiedrzyńska et al., 2015).
 - Research shows that tree forested wetlands on permeable soils can release as much as 100,000 gallons into aquifers (Wright et al., 2006).
 - Vegetative buffer zones can also provide filtration for pollution in soils, especially for nitrate (Rejmanková, 2005).
3. **Increase permeability in the sub-catchment:** the prevalence of impermeable surfaces affects water retention time and causes accelerated outflow (Kiedrzyńska et al., 2015). Wright et al. (2006) report a 16 times greater runoff flow from a one-acre size parking lot compared to a pristine meadow.
 - There are certain thresholds that are significant within a given catchment (Wright et al., 2006):
 - There is a significant impact on water retention at <20% permeable surfaces. This level should be the minimum goal for rural areas.
 - After this threshold there is a second significant threshold at <3% permeable surfaces. This goal should be considered for suburban and village areas.
 - Other strategies include techniques such as Low Impact Development, the Australian Water Sensitive Urban Design concept, and the Sustainable Urban Drainage Systems concept from the UK (Barbedo, 2014).
 - Design standards should be adopted in general plans and development codes at the municipal and county jurisdictions associated with the catchment (see Caltrans, 2013 for design guidelines).

Key enhancements to consider when planning a restoration project

Designed emergent wetlands (Cappiella et al., 2008 includes a variation with wooded buffer areas that help reduce mosquitos and other pests; for alternatives see Natural Channel Design, Rosgen, 1994; Leopold & Wolman, 1957):

- Emergent wetlands should use approximately 3% of the drainage area or sub-catchment.
- The site should be linear with a length to width ratio of at least 3:1 and preferably 5 or 6:1.
- There are several stages within the designed wetland:
 - *Pretreatment within the drainage area*: includes rooftop disconnection, bioretention areas and dry swales.
 - *Forebay*: the first stage within the wetland itself serves to reduce the velocity of flow and sediment load as it enter the system (4-6 feet deep).
 - *Wet pond cell*: serves to retain floodwater during peak events and is designed to retain 70% of the storage volume.
 - *Treatment area*: above the surface of the pool by extended detention. Water is then slowly released into the wetland cell by a reverse slope pipe and riser and barrel within a 12-24 hour period.
 - *Wetland cell*: water level fluctuations are limited so that a higher vegetative diversity and habitat is possible. Water surface level variation should be no more than 6 inches. For arid areas multiple cells should be created with a minimum of four.
 - *Dissipation pool*: located downstream of the wet pond cell. The cell should be 3-4 feet deep and contain approximately 10% of the total water volume.
 - *Transitional cell*: receives flow from the wetland cell and the wet pond. The cell functions as an outlet into the downstream water channel. It should be 12 inches deep with a rock cross vane separating it from the far channel.
 - *Vegetative buffer*: should consist of diverse age and structure that separates the wetland from adjoining land. This buffer is important because it increases habitat and diversity within the wetland. Possible species include:
 - Perennials: rushes, bulrushes, sedges, cattails, and willows (CNPS, 2015)

Key historical processes/components that provided storage, supply and flood services

California's historic wetland hydrology supported native plant species that used a small amount of water and were drought resistant. Specific vegetation composition occurred in assemblages that created a more regulated discharge of water stored in soils and plants. These unique assemblages allowed surface and shallow groundwater to flow in regulated pulses to wetlands, streams and rivers (CNPS, 2015).

- Perennials within wetland areas: rushes, bulrushes and tules, sedges, cattails, and willows (CNPS, 2015).
- Upland riparian vegetation: trees (e.g. Valley oak, honey mesquite), shrubs and woody vegetation (e.g. iodine bush scrub, salt bush), forbes and grasses (e.g. California poppies, salt grass, alkali grasses) (TBWP, 2015; Las Pilitas Nursery, 2015; CNPS, 2015).
- Tree species stored water over longer time periods, between dry seasons and dry years (Chapin et al., 2011).
- Both perennial wetland and upland riparian vegetation controlled erosion during normal seasonal rainfall.

Before human alteration natural water storage, supply and flood control was a dynamic natural system that included precipitation from rain and snow, capture and storage by vegetation, infiltration and storage in soils, flow into rivers, lakes and streams, collection by wetlands, and evaporation into the atmosphere (Hanak et al., 2011; Harter, 2003).

- Under historical conditions when runoff and precipitation were captured in wetlands and stored over time, more water could infiltrate the soil and eventually percolate into the aquifers below (Hanak et al., 2011; Uden, 2014).
- This groundwater eventually seeped into lowland rivers, lakes and streams and as well as bubbling up in springs (Harter, 2010).
- The slower, more regulated natural flows through wetlands and unaltered rivers allowed flooding over large areas. This flooding deposited large quantities of sediment from areas at higher elevations, keeping channels from deepening and, through deposition of sediment, increased the fertility of the floodplain (Smith, 2004; Chapin et al, 2011).
- Sediments built up over time in wetlands creating rich anaerobic conditions perfect for formation of peat and other rich soils that were converted to agriculture (Hanak et al., 2011).
- It is important to note that periodic natural flooding in a range of intensities and time scales was an important component of the disturbance regime for historical Central Valley plant and animal species, with far-reaching effects on topography, species distribution and sediment deposition within the flood plain (Hanak et al., 2011; Chapin et al., 2011; Smith, 2004).

Key disruptions caused by human activity in water storage, supply and flood control

- Nearly 90%-95% of California's wetlands have been converted to other land uses (Wilson, 2010; Robinson, 1934; Arax & Weisman, 2003).
- In the US, wetland loss accrues at a rate of 243 km² per year. Between 1986-1997 losses were due to several factors (Martinez, 2014): urban development, 30%; agriculture, 26%; silviculture, 23%; and rural development, 21%.
- The topography of wetland areas affects the fate of precipitation from higher elevations (Uden, 2014). In recent decades groundwater has been pumped for urban and agricultural uses while less water has been allowed to percolate through the soil into underground aquifers. This combination has produced groundwater overdraft (Lund et al., 2014).
- Groundwater is the source for 30% of California's water needs in a typical year and has been pumped on a large scale for more than half a century (Harter, 2003).
- As managed river and stream channels have become deeper and less porous and wetlands have been drained, less water has percolated through the soil into aquifers. Since the advent of large flood control and storage projects, sediment contaminated in part by mercury from 19th century gold mining techniques tends to collect behind dams (McFee, 1993; Starr, 2004; Bureau of Reclamation, 2013).

- Though areas of substantial subsidence exist (land sinks in comparison to historic levels because of decreasing groundwater tables) and overdraft, the Central Valley has achieved higher levels of recharge in comparison with other areas of the US because of summer irrigation and other water management techniques (Scanlon et al., 2012; Harter, 2010).

Possible Effects of Climate Change (Lund et al., 2014)

- Snowpack is one of the Central Valley's biggest sources of surface water storage. Reduced snowpack levels during winter under climate change could produce reduced flows in the Spring. This may cause water districts, counties and the state to re-operationalize dams, water conveyance systems and recharge in an effort to increase all other forms of water storage (Lund et al., 2014).
- There will be increased overall water demand from a growing population leading to pressure on supplies. This demand will include environmental, urban and agricultural uses (Lund et al., 2014).

Part 2: Project Goals and Management Plan

A. Ecohydrological Goals: As expressed by Poff (2002), a major issue for flood control in the 21st century is reconnection of floodplains with river channels and wetlands. This lack of connection in itself has become a significant driver of flood intensity, especially over recent decades. The pulse and rhythm of flooding dictates key aspects of ecological structure including the role of wetlands, a biologically active component of the ecohydrology of any region (Smardon & Fellman, 1996; Chapin et al., 2011). Loss of Central Valley wetlands—94% of total area (Duffy & Records, 2011)—for gains in economic or community development may have produced the following costs: increased frequency of flooding and flashy flows with parallel increases in property damage, insurance costs, lower overall safety for residents, and increased flood-related infrastructure costs (Wright, 2006; Dahl, 1996). On the other hand, estimates of ecosystem services provided by wetlands reach \$370,000 per acre in some studies (1992 dollars, Wright, 2006). It is the objective of this plan to restore some of the lost value of Central Valley wetlands while minimizing economic or social losses in the process.

Increase water retention through restoration and creation of wetlands.

Hydrologic connectivity supports the functionality of the natural system of water storage, supply and flood control and also effects virtually all other ecosystem services and functions including the habitat needs of birds, fish and other species (e.g. shallow wetland habitat of ducks, Isola et al., 2000; Harris, 1988; Sommer et al., 2011). The Central Valley of California has experienced severe losses of connectivity through a highly altered flow regime (Galloway & Riley, 2015). Wright et al. (2006) review several studies that suggest levels of 3-7% to 15% of wetland area per watershed to maintain flood control and storage, with an estimated 5%

reported (Eviner lecture, 5/14/15) necessary for adequate filtration of pollutants such as nitrate. **Goal:** Every five years for a decade, increase functional wetland area in the Central Valley by 3-5% with a threshold of at least 8% total area; at which point maintenance of existing sites become the priority.

Increase buffer zones around wetlands and river/stream channels. Buffer zones serve several important hydrological functions in a catchment including those related to flow regulation and water quality (Eviner lecture, 5/14/15). The ecotone associated with these zones can serve to slow runoff as it enters a channel (Kiedrzyńska et al., 2015). Additionally, Wright et al. (2006) report as much as 100,000 gallon release from forested wetlands on permeable soil into aquifers. **Goal:** Increase buffer zones by 3% of total wetland area every five years for a decade.

Increase permeability in the catchment. Impermeable surfaces within the catchment cause reduced water retention time and also accelerated outflow (Kiedrzyńska et al., 2015). According to research, exceeding certain percentage thresholds of impermeable land cover results in notable increases in flow within the catchment (Wright et al., 2006). Wright et al. (2006) also report a 16 times greater runoff flow from a one-acre size parking lot compared to a pristine meadow. **Goal:** Within a decade, reach and/or maintain the significant thresholds of permeable surfaces for rural/agricultural areas of >20% and >3.5% for suburban and village areas.

B. Restoration plan: According to current science among environmental sustainability researchers, modern anthromes fall into several categories spanning from the most to the least 'natural.' These are: wildlands, seminatural, and used (Ellis, 2013). In the plan that follows rangeland, cropland, villages and dense settlements will be addressed under the assumption that these used lands contain remnant parcels or in some cases border wild and seminatural lands (Chapin et al., 2011). All of these broad land use types contain multifunctional mosaics of parcels and patches among which the ultimate goal is to raise the level of overall productivity while also increasing hydrological function (Ellis, 2013). The region experiences both low elevation flow impacts governed by precipitation and high elevation snowmelt impacts affected by temperature, making it hydrologically unique (Kiedrzyńska et al., 2015; Hanak et al., 2011; Lund et al. 2014; Duffy & Records, 2011). These conditions along with an arid climate require adaptations to wetland design and planning.

The first step is assessment through modeling of regional hydrology using systems such as MODCEL (Barbedo, 2014) or dedicated hydrologic software programs such as Indicators of Hydrologic Alteration, Hydrologic Assessment Tool, River Analysis Package, and other statistical packages (Olden et al., 2015). These systems can be used in conjunction with a GIS to map and quantify wetland and buffer zone area (Barbedo, 2014). Hydrologic classification follows a protocol that follows six steps (Olden et al., 2015): 1) define with precision the area of study, 2) examine discharge data according to data needs including geographic distribution, 3) choose hydrologic metrics to characterize flow regimes (fit to temporal, specific and general ecological rationale, see below), 4) calculate hydrologic metrics, 5) classify the site using the chosen metrics, and 6) interpret the classification. Poff and Olden (2013) suggest several non-redundant hydrological indices that could serve as viable

metrics depending on the specific project (e.g. monitoring for specific species habitat needs); skewness in daily flows (particularly important for fish species), interannual variation in daily discharge (for the month proceeding a highlighted breeding season), duration of floods in snowmelt-driven streams, monthly/seasonal duration of high flows (especially important for riparian areas), measure of high flood pulses, rate of change in flow conditions (for native and non-native persistence or coexistence), timing or predictability of flow events, and the timing of floods (linking flood magnitude and reproductive output).

The second step is to use the tools listed above to evaluate the functions of catchments in terms of carrying capacity and regulation of processes in order to determine possible sites that, with wetland restoration, would decrease flood risk and increase water storage and supply (Kiedrzyńska et al., 2015; see Draft Opportunity Analysis, DWR, 2014). This step includes planning both buffer zone and wetland restoration based on information from the first step. Cappiella et al. (2008) outline a new generation of wetland restoration design that includes buffer zones containing trees and shrubs to slow water flow and reduce unwanted impacts such as mosquito infestations and vegetative monoculture due to water depth and flow regime variability. One possible problem is that the designs are particularly successful in areas where the water table maintains a constant water supply, unlike the arid Central Valley (average precipitation 6-15 inches per year; Galloway, 2015). In response Cappiella et al. (2008) include adaptations that include using clay lining to provide less permeability if the water balance conditions will not support planned vegetation. Tree and shrub species should be chosen carefully and planted using diversity of age, species and structure (Eniver lecture, 5/14/15). The emergent wetland design should be used if reference sites that contain forested wetlands are unavailable. Experimental sites should be chosen first to vet both designs for use in the region.

The next step is design of the wetland area itself. As part of successful, Barbedo (2014) suggests increasing permeability within sub-catchments in urban and peri-urban areas through techniques such as Low Impact Development, the Australian Water Sensitive Urban Design concept, and the Sustainable Urban Drainage Systems concept from the UK. Permeable surfaces increase regional hydrologic connectivity. Additionally policy indications for design standards using permeable paving materials in municipal and county general plans should be addressed and actions taken to promote community awareness and adoption of design standards across the catchment area (see Caltrans, 2013 for design guidelines). These structural responses are meant to support non-structural site rehabilitation and protection of natural areas in order to increase permeability of the entire catchment area over the decade timeframe of the plan (Barbedo, 2014).

An emergent wetland is the suggested base design and the wooded wetland is a modified version of it (Cappiella et al., 2008). These designs address problems associated with earlier restored sites including mosquito infestations and monocultures and, for clarity, are presented to the exclusion of other frameworks (for alternatives see Natural Channel Design, Rosgen, 1994; Leopold & Wolman, 1957). The emergent wetland design should use approximately 3% of the drainage area or sub-catchment associated with the site. The site should be linear and longer

than it is wide with a minimum length to width ratio of 3:1, with a preferred ratio of 5 or 6:1. The first component of the design is pretreatment within the contributing drainage area (rooftop disconnection, bioretention areas and dry swales). Second is a forebay that helps reduce the velocity of water and sediment load as it enters the system (4-6 feet deep). The next section is a wet pond cell that serves to retain floodwater during peak events (designed to retain 70% of the storage volume). This section includes a treatment area above the surface of the pool by extended detention. It is then slowly released into the wetland cell by a reverse slope pipe and riser and barrel (within a 12-24 hour period). The fourth section is the wetland cell in which water level fluctuations are limited so that a higher vegetative diversity and habitat is possible. Water surface level variation should be no more than 6 inches. For arid areas multiple cells should be created with a minimum of four. The fifth section is the dissipation pool located downstream of the wet pond cell. The cell should be 3-4 feet deep and contain approximately 10% of the total water volume. Next is the transitional cell that receives flow from the wetland cell and the wet pond. The cell functions as an outlet into the downstream water channel. It should be 12 inches deep with a rock cross vane separating it from the far channel. There should also be a vegetative buffer of diverse age and structure (Eviner lecture, 5/14/15) that separates the wetland from adjoining land (possible species include perennials: rushes, bulrushes, sedges, cattails, and willows; CNPS, 2015). This buffer is important because it increases habitat and diversity within the wetland.

The wooded wetland adds tree peninsulas to the emergent design. Important design elements for the wooded wetland, including some specific problem areas, are (Capiella et al., 2008): a limit on extended detention water surface elevation of 8 to 10 inches above the pool to reduce impact of water level fluctuations; avoidance of interference with wetland function by planting trees in an area 15 feet from the embankment toe; deep pools include 20-50% of the total wetland area and should be perpendicular to inflow; 2-3 tree planting peninsulas in the wetland and locate them perpendicular to the flow for optimal treatment; overplanting of tree species with fast-growing varieties to establish canopy cover quickly; avoidance of flow blockages and regular maintenance; and employment of a landscape architect. Trees and shrubs can be added here to provide filtering services and habitat but existing forest areas are preferred. For plantings consider tree species: Desert Willow (Tree Fresno, 2015) or honey mesquite. For shrubs and other woody vegetation consider iodine bush scrub and salt bush. For forbes and grasses consider using California poppies, salt grass, and alkali grasses (TBWP, 2015; Las Pilitas Nursery, 2015; CNPS, 2015). Willow, sycamore, oak, elder, poplar, alder, bulrushes and cattail (i.e. tule) are examples of historic wetland tree and shrub species to consider. As an added benefit, historically both perennial wetland and upland riparian vegetation have also controlled erosion during normal seasonal rainfall (Hanak et al., 2011; Uden, 2014).

C. Monitoring plan: Monitoring should be conducted for restored wetlands for the duration of their existence because of the possibility of changed hydrologic, biotic or environmental factors in the site (Capiella et al., 2008). Monitoring should continue the hydrologic assessment delineated above, including use of GIS to calculate at least yearly total area covered by wetlands and buffer zones (Barbedo, 2014; Olden

et al., 2015). The plan will transition to an emphasis on maintenance when total wetland area reaches >8% and when permeable cover reaches >3.5% in urban areas and >20% in rural areas (Wright et al., 2006). At this point restoration projects may be conducted but maintenance will become the priority. After 5 years of the initial 10-year plan, a major progress assessment using quantitative metrics as well as qualitative evaluation should be completed. Metrics include: skewness in daily flows, interannual variation in daily discharge, duration of floods for snowmelt, monthly/seasonal duration of high flows, measure of high flood pulses, rate of change in flow conditions, timing or predictability of flow events, and timing of floods (Olden & Poff, 2003). For the first two years this set of metrics should be used at least weekly, employing public data for catchments associated with each project. Weekly data should be compared with the original baseline from the planning phase. Bullock and Acreman (2003) suggest that wetlands play a range of roles in regional hydrology and that simplistic evaluations of these roles are contraindicated. Use of the suggested metrics will provide realistic information about the ongoing changes in hydrology actually experienced in the region and in project sites and should be used as a feedback for planning of future projects and continued management.

In this light, the first five years of the initial decade of the plan will be crucial for determining the effects of initial experimental sites, allowing for vetting of project design for future sites. This early information should provide information for planning future projects—e.g. rural upstream projects to control downstream flooding versus downstream urban projects using wooded wetlands to slow floodplain flows (Eviner lecture, 5/7/15). The initial years of the plan should also include monitoring of policy changes at municipal, county and state levels regarding adoption of design standards for permeable materials. At a minimum, design standards for permeable materials should be adopted in towns and counties with projects so that the minimum thresholds can be reached (>3.5% urban and >20% rural; Wright et al., 2006).

There are several research questions that could advance knowledge for wetland restoration in the Central Valley. First, there are few projects that have been completed in arid regions using the suggested designs (Cappiella et al., 2008). The Central Valley is unique because of its extremely modified hydrology (Duffy et al., 2011; Harter, 2010; Scanlon et al., 2012). Projects completed through this plan may provide needed information to fill these gaps in knowledge. Key factors include location of projects, success of the suggested wetland designs in this arid region and assessment of the political will to change design standards to meet ecohydrological needs (Adler et al., 2013). There have also been concerns regarding the lack of price signal and consensus regarding metrics for water associated risk and benefit (Tjossem, 2011). Wetland Investment Trusts (WIT) may provide incentives driven and stakeholder controlled solutions for these problems that could be tested through management of this plan.

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Air Pollution Control ID Guide

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Causes Of Air Pollution In Urban Areas

- *Carbon Dioxide (CO₂)*- controlled burning of trees, burning oil, fossil fuel combustion
- *Ozone (O₃)*- forms from sunlight's reaction with car fumes
- *Sulfur Dioxide (SO₂)*- burning of coal
- *Methane(CH₄)*- burning fossil fuel, gas from landfills and livestock
- *Chlorofluorocarbons(CFC)*- volatile derivative of methane and ethane, produced by old air conditioners, refrigerators

Factors That Affect Air Purification

- Mature tree size
 - More total tree biomass= more pollutant storage capabilities
- Lifespan
 - Longer lifespan= more air pollution control over lifetime
- Growth rate
 - Moderate growth rate= ability to store the most carbon
 - Slow

How Do Trees Reduce Pollutants?

- Filter out and trap harmful pollutant particles
 - Ex. Smoke, dust
- CO₂ sink
 - Plants store carbon during growth in roots and shoots, gaseous pollutants are absorbed through leaves
- Release O₂ into the atmosphere

Other important points:

- Trees do not have a positive influence in reducing carbon in atmosphere if fossil fuels are used in the maintenance of trees
- Tree decomposition releases carbon into atmosphere, and this is taken into effect when looking at how well specific species control air pollution.

Part 1: Project Background and Justification

A. Background & Justification

The distinction between natural habitats and urban areas has become less clear as urban areas expand. This is especially true of California's Central Valley, whose region has experienced a large influx of domestic and international migration over the past few decades (Johnson & Hayes 2004). As more natural landscapes become developed and inhabited by people, the Valley's parks, forests, and habitat-reserves are experiencing unprecedented levels of air pollution. Poor air quality is consequential to the people living in and utilizing an area. Air pollution both causes and exacerbates existing medical conditions such as asthma and heart problems (Kampa & Castanas 2008). Humans aren't the only ones at risk. The entire environment can be negatively affected, including animals, plant species and abiotic factors like soil and water quality (Smith 1974). Due to the Central Valley's increasing population and decreasing air quality, air pollution mitigation is an extremely relevant topic in the conservation and restoration of the remaining natural habitat that does still exist in the area.

A. Literature Review

I. Common Air Pollutants in the Central Valley

a. Ozone

i. Formation/causes

1. Created in the air when sunlight reacts with vehicle exhaust to form the reactive gas O₃ (Lipsett 1988)

ii. Effects on Humans

1. Chest tightness, cough, asthmatic attacks, decreased lung function, chronic respiratory disease, respiratory inflammation, increased airway resistance (Lipsett 1988)

iii. Effects on Environment

1. Most damaging pollutant to vegetation (Ollinger et al. 2002)
2. Reduction in plant yield and growth (Winer et al. 1992)
3. Causes decreased rate of nitrogen induced carbon-storing sinks in trees, leads to decreased rate of carbon fixation (Ollinger et al. 2002)
4. Alters carbon balances in ecosystems (Ollinger et al. 2002)

b. Carbon Monoxide

i. Formation/causes

1. Odorless and colorless gas that is formed most often from the combustion of fossil fuels in vehicles (EPA)
- ii. Effects on Humans
 1. Unhealthy levels of carbon monoxide in the atmosphere for humans are above 9 ppm. Harmful effects on humans include reducing amount of oxygen available to lungs, decreased concentration, angina attacks (Department of the Environment and Heritage 2005)
- c. Particulate Matter
 - i. Causes
 1. Made up of acids, metals, organic chemicals, soil/dust often found near roadways and industry (EPA)
 - ii. Effects on Humans
 1. PM 10 mm or less can enter the lungs and cause issues with lung and heart health, asthma, decreased organ function, heart attacks (EPA)
 - iii. Effects on Environment
 1. causes the stomatal pores on the leaves of vegetation to remain open, which allows for microbes to have greater access to the plants, and increases the chance of infection (Parmeter & Cobb, 1972).
- d. Sulfur/Nitrogen Dioxide
 - i. Formation/causes (EPA)
 1. NO_x result of fuel powered vehicles
 2. SO_x can react with other gases in air to form PM
 - ii. Effects on Humans (EPA)
 1. NO_x causes respiratory inflammation, asthma (EPA)
 2. SO_x causes bronchoconstriction, asthma (EPA)
 - iii. Effects on Environment
 1. Sulfur dioxide causes the stomatal pores on the leaves of vegetation to remain open, which allows for microbes to have greater access to the plants, and increases the chance of infection (Parmeter & Cobb, 1972).
- e. Total Ecosystem Impacts of air pollution
 - i. Overall reduced productivity in vegetative species as a result of air pollution ultimately causes an adverse effect on a community's overall productivity and biodiversity, with a decrease in total biomass and shift

in species structure as some species lose the ability to be competitive (Parmeter & Cobb, 1972).

II. Positive effects of trees on air pollution

There are four main ways in which vegetation in urban areas can positively affect air quality and reduce pollution

a. Temperature Reduction

Trees provide shade, shade causes air temperature reduction, reduced temperature reduces formation of air pollutants

- i. Many air pollutants and chemicals (incl. ozone) are formed more quickly in warmer temperatures. The use of vegetation to reduce overall air temperature in a landscape decreases the rate at which air pollutants are formed. Vegetation reduces air temperature through shading, absorbing radiation, and emitting evapotranspiration (Nowak 2000)

b. Air Pollutant Removal/Mitigation (Nowak 2000)

- i. Canopies serve as a physical barrier between the upper air on top of the canopies, and the lower air below the canopies. Tree canopies can improve the air quality of the lower air by keeping the polluted upper air from mixing with it.

c. Volatile Organic Compound (VOC) Emission

- i. 70% of U.S tree species release significant amounts of VOCs into the atmosphere, which has been shown to increase the amount of ozone present The amount of VOCs that a tree releases is dependent on species (Smith 1974).

d. Urban Energy Conservation

- i. Vegetation that is planted in a position where it will shade buildings (west), reduces the need for air conditioning and increases energy conservation as a result (epa.gov, Trees and Vegetation)

III. Constraints to air pollution mitigating vegetation (Smith 1974)

i. Reduced Growth

1. Nutrient availability to vegetation is limited in areas of high air pollution

ii. Reduced Reproduction

1. direct impact on the reproduction capabilities of species, as well as reduce the number of pollinator species present in an environment.

IV. Factors Affecting Air Pollution Mitigation

a. Location of vegetation to reduce air pollution

- i. In a study of carbon sequestration by trees in the urban area of Canberra, Australia, trees located in parks and trees located closer industry, roadways, and houses reduced air-pollutants at different rates. The closer the

trees are planted to causes of air-pollution, the larger their mitigation capabilities will be (Brack 2002)

- b. Management actions to reduce air pollution (Nowak 2000)
Reducing carbon in the atmosphere is one of the main goals in using vegetation as a means of air pollution mitigation
 - i. Choosing vegetation that requires little management is crucial in how effective and successful this ecosystem service will be. Fossil fuel powered mowers, trimmers, saws, and maintenance vehicles puts carbon back into the atmosphere.
 - ii. Choosing vegetation that does not need to be regularly burned is important because burning puts carbon back into the atmosphere
 - iii. If the maintenance of these air pollution mitigating species puts carbon back into the atmosphere, there is no net reduction in atmospheric carbon by the vegetation

V. Species Selection

- a. Importance of planting natives
 - i. Central Valley is one of the most altered landscapes in the world. This proves to be a great challenge in restoration projects, because experts can't be completely sure which vegetation is native to the area, since invasive began to take over the area in the 1700s (Wildlife.ca.gov)
 - ii. Plant natives to reduce issues of invasive species
- b. General Tree Attributes for Air Pollution Reduction
 - i. Hairy, sticky leaves to collect harmful particulate matter, large leaf area at maturity increases the tree's transpiration rates, which leads to the tree's ability to have high rates of air temperature reduction (Nowak 2000)
 - ii. Tree size: correlation between tree size and air pollution mitigation. Larger trees have the ability to absorb and store more carbon from the air, and tend to have larger leaves to trap particulate matter and provide shade (Brack 2002)
- c. California Sycamore (*Plantus racemosa*)
 - i. Closely related to *Plantus acerifolia*, which has a high impact on improving sulfur/nitrogen dioxide levels in the atmosphere (Nowak 2000)
 - ii. California native tree species, enhances native species at the site (selecTree)
 - iii. Well-suited for riparian areas, also grows well along streams and rivers (selecTree)

- iv. Tolerates extreme heat, ideal for hot and dry summers in the Central Valley, requires watering when young, but is drought tolerant in it's mature stage, which is beneficial to the drought conditions of the Central Valley (selecTree)
- d. Port-Orford Cedar (*Chamaecyparis lawsoniana*)
 - i. California native (Zobel et al. 1985)
 - ii. Important mgmt note: must actively reduce spread of root rot by using auxin treatment on cuttings (Zobel et al. 1985)
 - iii. Distributed mainly along coast, but a significant population is found in the Sacramento Valley (Zobel et al. 1985)
 - iv. High aesthetic value, major use is in ornamentals (Zobel et al. 1985)
 - v. Top rated species for improving overall air quality (Nowak 2000)
- e. Sugarberry (*Celtis laevigata*)
 - i. California native, well-suited for wetlands/riparian areas (selecTree)
 - ii. Large spread ideal for shading parking lot areas. Height=40-70 ft, spread=40-50 ft (selecTree)
 - iii. Low ozone forming potential (Nowak 2000)
 - iv. Recommended for overall air pollution removal and tolerance (Nowak 2000)
- f. Water Birch (*Betula occidentalis*)
 - i. Related to *Betula alleghaniensis*, recognized for its ability to reduce VOC emission, general air pollution, and reducing air temperature. Specifically reduces ozone and sulfur/nitrogen dioxide in atmosphere (Nowak 2000)
 - ii. California native, most often found in wetlands (Gucker 2012)
 - iii. Overall ecosystem value is for regenerating riparian areas because the tree species has the ability to stabilize stream beds (Gucker 2012)
- g. Northern California Black Walnut (*Juglans hindsii*)
 - i. Related to *Juglans nigra*, known to reduce PM, top-rated species for improving air quality, particularly the removal of sulfur/nitrogen dioxide from the atmosphere (Nowak 2000)
 - ii. California native, on the CNPS inventory of rare and endangered species (Calflora)
 - iii. Good shading ability (selecTree)
 - iv. Drought tolerant (ideal for Central Valley) (selecTree)

- v. Ideal for riparian landscape, and loam/sandy soil
(selecTree)

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Part 2: Project Goals and Management Plan

Goals

The overarching goal of this restoration project is to reduce air pollution in California's Central Valley. This restoration is important because the Central Valley is experiencing an increase in human population (6.5 million residents and counting) and urban developments and air pollution are on the rise (PPIC 2006). Short-term goals of this restoration project include increasing percent tree cover in the Central Valley because increased tree cover is positively correlated with decreased air pollution in a given area. The goal of this restoration project is to increase the overall tree cover in the central valley to 25% over the next 5 years. Currently the total tree cover is less than 7%, approximately ("Tree Cover"). The second short-term goal related to increasing tree cover is the successful establishment of five native California tree species that reduce air pollutants. These five species are the California Sycamore, Port-Orford Cedar, Sugarberry, Waterbirch, and Northern California Black Walnut. The long-term goals of the restoration are to reduce the overall amount of air pollutants in the central valley by 50% in the next 20 years, which will in part be achieved by following attainment goals set by the San Joaquin Valley Unified Air Pollution Control District; 50% VOC reduction by 2023 in alignment with the District's 2007 Ozone Attainment plan, reduce NO_x in atmosphere by 47% by 2023 also in alignment with the District's 2007 Ozone Attainment plan ("2007 Ozone Plant"). The third long term goal is to keep PM_{2.5} (particulate matter smaller than 2.5 µm in diameter) at or below an annual 15 µg/m³ in and PM₁₀ at or below an annual 50 µg/m³ in accordance with EPA air quality standards (Esworthy 2013). The final long term goal is to reduce health-related costs in the Central Valley directly related to air pollutant caused respiratory problems by \$416 million dollars over the next by 2035, as well as reduce the number of pollution-related health events by 22,000 by 2035 (American Lung Association).

Restoration Plan

The below restoration plan is a general plan outlining the species, locations, and scales of the trees suggested to be planted in a Central Valley restoration site, with the goal of reducing air pollution. This plan does not take into account the restoration committee's financial budget, time frame, and number of people working on the project. Net air pollution reduction largely depends on the average vegetative cover of the restoration site, which is dependent on the unknown variables mentioned, though the goal is 25% tree cover.

The selection of tree species to plant is a crucial component of the restoration plan. A common public misconception is that all trees reduce air pollution in the atmosphere, and this is unfortunately not the case when analyzing net effect that different tree species have on atmospheric pollutants. VOCs are a source of air pollution and are emitted by approximately 70% of U.S trees (Smith 1974). The two main VOC compounds produced by plants are isoprene and monoterpene, and the threshold set for a low VOC emitting species is no more than 1 µg g⁻¹h⁻¹ of monoterpenes and 2 µg g⁻¹h⁻¹ of isoprene (Taha 1997). Trees above this VOC emitting threshold had a negative net effect on air pollution and were found to have

increased the amount of ozone and hydrocarbon in the local atmosphere (Taha 1997). High VOC emitting species that should be avoided are varieties of eucalyptus, willow, and oak (Cleveland 2007). Low VOC emitting species include varieties of maples, hawthorns and pines (US EPA).

It's important to consider whether or not a species is native. California's Central Valley is one of the most altered landscapes in the world. This proves to be a great challenge in restoration in the valley, because experts can't be completely sure which vegetation is native to the area, since invasive species began to take over the area in the 1700s (Wildlife.ca.gov). California invasive species have proved to cause detrimental ecosystem effects and for the purpose of this restoration site, using non-invasive species will be part of the restoration plan. It is equally important to select species that reduce specific air pollutants. California Sycamore, Port-Orford Cedar, Sugarberry, Waterbirch, and Northern California Black Walnut are all California natives with the ability to reduce specific air pollutants. The California Sycamore (*Plantus racemosa*) is closely related to *Plantus acerifolia*, which has a high impact on improving sulfur/nitrogen dioxide levels in the atmosphere (Nowak 2000). It is best suited for riparian areas and should be planted 3.5 feet apart from one another (Wilson). The Port-Orford Cedar (*Chamaecyparis lawsoniana*) is a coastal species, with a number of them occurring in the Sacramento Valley (Zobel et al. 1985). They are a top-rated species for their overall pollutant reducing capabilities and cuttings should be planted anytime between December and February (Zobel et al. 1985). The Sugarberry (*Celtis laevigata*) is best suited for wetland/riparian areas and its large spread makes it ideal for shading parking lots (selecTree). It is recommended for overall air pollution reduction and is easily propagated through cuttings (Nowak 2000). Lastly, the Northern California Black Walnut (*Juglans hindsii*) is related to *Juglans nigra*, known to reduce PM, top-rated species for improving air quality, particularly the removal of sulfur/nitrogen dioxide from the atmosphere (Nowak 2000). It's ideal for riparian landscape, and loam/sandy soil (selecTree).

Location of pollutant mitigating trees is crucial to their success. Studies have shown that the closer the trees are planted to causes of air-pollution, the larger their mitigation capabilities will be (Brack 2002). In the Central Valley, vehicles are a large source of air pollution, and contribute over 120 tons of nitrous oxides and hydrocarbons to the atmosphere every day (McPherson and Simpson). 16% of hydrocarbon emissions occur during the first few minutes that a car engine is turned on, as well as during the sun-induced heating of fuel systems of parked cars (McPherson and Simpson). Planting the large Sugarberry trees in and around parking lots to provide at least 30% shaded-cover increase air quality, as there is a direct correlation between temperature and vehicle emissions (McPherson and Simpson). In a parking lot that had 30% shaded cover, the temperature in the air was reduced by up to 2°C and the fuel tank temperature of parked cars was reduced by up to 4°C, contributing to the reduction of hydrocarbon evaporations from the vehicles (McPherson and Simpson). An additional study of carbon sequestration by trees in an urban area trees located in parks compared to trees located closer industry, roadways, and houses reduced air-pollutants at different rates (Brack 2002). It was found that the closer the trees are planted to sources of air-pollution, the larger their mitigation capabilities are (Brack 2002). As part of the restoration project, the newly

planted trees will be placed alongside highways and roads, as well as around parking lots to have vegetation shade at least 30% of the parking area.

Important selection criteria when choosing trees to be planted in the restoration project is the amount of management required throughout the tree's lifetime. Maintenance of such vegetation by means of fossil fuel powered mowers, trimmers, saws, and maintenance vehicles puts carbon back into the atmosphere. If the maintenance of the air pollution mitigating species puts carbon back into the atmosphere, there is no net reduction in atmospheric carbon by the vegetation (Nowak 2000).

Monitoring Plan

Once, the site has been restored, it is important to monitor air quality to assess whether or not the species planted are having a positive or negative effect on air quality. It is also important to develop a monitoring plan for the site's air quality before restoration has begun, so that you have data pre- and post- restoration from which you can make comparisons and analyze the success of the restoration efforts.

Much of the data used in the above restoration plan was modeled after the data collected from a large study of vegetation and air quality in the South Coast Basin, which is south of the Central Valley and includes Orange, Los Angeles, San Bernardino, and Riverside counties (Taha 1997). The study and data was location-specific and it has been suggested that air quality and net effects of pollution-mitigating vegetation is very location-specific. As a result, part of the monitoring plan on the Central Valley restoration site should include a model to determine the net effects of the trees on the site in reducing air pollution. This model should be done 5 years after the initial restoration as to give the transplanted tree ample time to grow and begin sequestering notable amounts of carbon. For example, the California Sycamore takes 5-10 years to reach an intermediate size of 20 feet, where pollutant sequestration will likely have an impact (Wilson). The site should be modeled again at 1 year intervals to track changes in pollutant sequestration as the trees mature, as well as to monitor changes in air quality due to global warming. The monitoring plan should include measurements of isoprenes and monoterpenes being released by the trees, as well as levels of the five prominent air pollutants- ozone, carbon monoxide, particulate matter, and sulfur/nitrogen dioxide. As we have seen, temperature is an important determinant in air quality, and tree pollution mitigation is effected by atmospheric temperature. Each year that the model is done, data should be collected once each season (winter, spring, summer, and fall) on days where the temperature is close to the seasonal average. By doing so, the model would be an accurate representation of net air quality impacts during different times of the year and at fluctuating temperatures.

The monitoring plan of this site is justifiable for a number of reasons. The data addresses one of the Central Valley's most important and pressing issues- air pollution. This data can be used by other restoration teams, as well as neighborhood councils, and landscape architects in the Central Valley to determine which tree species will likely be most successful in their site to reduce air pollution. The monitoring plan is also justified by the benefit that this data will provide to public health and safety. Air pollution related illnesses are on the rise. The data can be used by the government to help determine during what seasons and during what

temperatures the air quality is lowest, and mandated “Spare the Air” days can be implemented to better serve specific communities in the central valley to reduce air pollution during peak times.

The threshold for action on the restoration site is if at any point during the monitoring plan is if any pollution levels measured exceed the limit set by the EPA. Action must be taken and a percentage of new transplants must be planted on the site.

Important research questions: what will the effect of the decomposition of the tree in 100-150 years be on the overall air quality of the site? What effect on air quality will occur and will new trees have to be planted in order to reduce air pollution if the decomposition of the trees releases carbon into the atmosphere? Something else that needs to be addressed is how the data for air pollution mitigation for trees in the Central Valley compare to other air pollution models, like the one done in the South Coast Air Basin. By comparing models in different locations, one can gain a better understanding of how locations and local atmospheres effect tree air pollution mitigation.

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Mitigation of urban heat island effect

Tali Ashurov

Part 1: Project Background and Justification

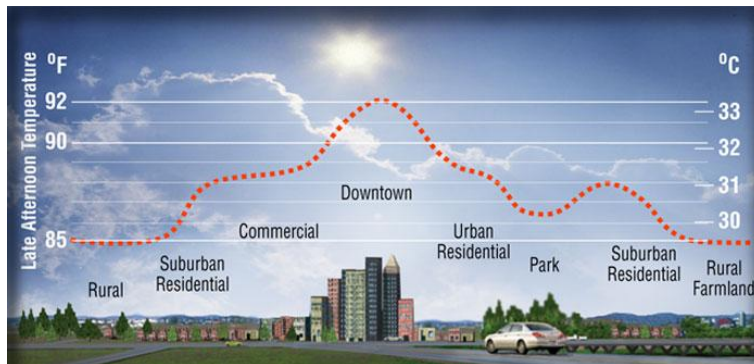


Figure 5: Urban Heat Island

Source: <https://heatisland.lbl.gov>

Problem: “The term “heat island” describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings.

Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality”

(<http://www.epa.gov/heatisland/>)

Mitigation Strategies: “Trees and vegetation help cool urban climates through **shading** and **evapotranspiration**” (<http://www.epa.gov/heatisland/>).

- **Shading** provided by “leaves and branches reduce the amount of solar radiation that reaches the area below the canopy of a tree or plant. The amount of sunlight transmitted through the canopy varies based on plant species” (<http://www.epa.gov/heatisland/>).
- **Evapotranspiration** is known as the “sum of evaporation and plant transpiration” (<https://water.usgs.gov/edu/watercycleevapotranspiration.html>). “It cools the air by using heat from the air to evaporate water. Various studies have measured the following reductions in air temperature:
 - Peak air temperatures in tree groves are 9°F (5°C) cooler than over open terrain.
 - Temperatures over grass sports fields are 2 to 4°F (1 to 2°C) cooler than over bordering areas” (<http://www.epa.gov/heatisland/>).

Based on Solano Counties’ Mediterranean climate, native, hardy, large/medium deciduous trees are typically well adapted to the environment (“low water use once established”) and provide shade and evapotranspiration to cool an area. Examples of trees that may thrive in Centennial Park include:

California Sycamore, Columnar Red Maple, River Birch, Blue Oak, Chestnut-Leaf Oak (not pictured), Village Green Zelkova, Mushashino Columnar Zelkova (not pictured), Shantung Maple (<http://www.sactree.com/trees>).



Background and Justification

Urban Heat Islands (UHI) are economically and environmentally degrading to cities worldwide as they increase greenhouse gas emissions, energy costs due to excessive air conditioning uses, and heat-induced diseases (EPA, 2013). A “heat island” is classified as a metropolitan area that is hotter than its surrounding suburban and rural areas. Oftentimes, UHI’s occur in cities as a result of excessive impermeable surfaces that replace vegetation (such as asphalt and concrete) thereby preventing water from percolating into the soil (Adler et al, 2013). Due to the lack of plants in urban systems, cooling effects that are provided by plants via evapotranspiration are reduced (Adler et al, 2013). Additionally, the presence of dark surfaces with low albedo’s (reflectivity) and tall skyscrapers that generate low sky-view factors (the amount of visible sky in between buildings) exacerbate UHI’s by trapping radiation, thus preventing it from escaping back into the atmosphere (Adler et al, 2013). The effects of heat islands can extend into cities’ surrounding landscapes by up to 10 km (Adler et al, 2013).

Literature Review

Causes of Urban Heat Islands

- Dark, sun-absorbing surfaces (such as rooftops) have low albedo, or reflectivity, suggesting that they trap incoming solar radiation rather than reflecting it back into the atmosphere. This inputs heat into the system and prevents it from escaping back out (Adler et al, 2013).
- Since urban areas typically have fewer plants than surrounding rural and suburban areas, the amount of cooling via evapotranspiration is reduced which results in hotter cities (Cadenasso, 2015).
- Tall buildings that are spatially close together form urban canopies with low sky-view factors. These “canopies” absorb and trap heat in the system (Cadenasso, 2015).
- Cities often generate more anthropogenic heat as a result of fossil fuel emissions from industrial processes, vehicles, and air conditioning units in buildings (EPA, 2013).
- Polluted air creates an urban “dust dome” that occurs when hot air rises and condenses, forming a circulation effect that traps and accumulates urban air. When strong winds blow through the city, the polluted air is oftentimes dispersed downwind into neighboring areas (Adler et al, 2013).

Urban Heat Islands in the Central Valley:

- The intensity of UHI’s differs depending upon various local climate and topographic conditions. Thus, determining cities’ climates can help urban planners identify the best-fit mitigation strategies that suit their region (EPA, 1998).
- The Central Valley’s climate is classified as Mediterranean and Mediterranean Steppe (Kauffman, 2012).
- The Steppe climate, although very hot during the summer, can support diverse vegetation such as grasslands that are not typically found in other arid climate zones (Kauffman, 2012).
- Since the Central Valley’s climate can provide vegetation with enough moisture to thrive, increasing vegetation in dry cities may serve as an effective mitigation strategy (due to evapotranspirative benefits) in comparison to increasing vegetation in humid areas (EPA, 1998).
- In the Central Valley, the heat island is affected by the landscapes’ topography suggesting that the eastern region of the valley is cooler than the western region due to the presence of the elevated Sierra Foothills (EPA, 1998).
- As a result of this, cities in the Central Valley are estimated to have an UHI of roughly 0.5-1°C from noon until 5 p.m. in the afternoon (EPA, 1998).

Consequences of Heat Islands on Cities and surrounding areas

Excessive Energy Consumption

- On average, UHI's increase energy usage (especially on hot summer days) by approximately 1.5-2.0% for every 0.6°C increase in temperature (EPA, 2013).
- Since air conditioning demands are so high during the dry season in the Central Valley, cooling units may oftentimes be overwhelmed which may lead to power outages throughout cities and their surrounding areas (EPA, 2013).

Increased Greenhouse Gas Emissions and Smog

- Since anthropogenic heat demand is greater during the Central Valleys' dry season, electrical companies must provide more power to cities in order to meet this demand, creating a positive feedback loop by releasing more greenhouse gas emissions into the atmosphere (EPA, 2013).
- UHI's exacerbate the formation of smog (also known as ground-level ozone) which is formed when air pollutants such as volatile organic compounds (VOCs) and nitrogen oxides (NOXs) chemically react with sunlight (Adler et al, 2013).
- Since there is more sunlight and hotter temperatures, more smog is likely to form in cities with severe UHI's (Adler et al, 2013).

Impacts on Human Health

- Hot temperatures and urban pollution exacerbated by UHI's may harm humans by causing discomfort, exhaustion, heat stroke, breathing difficulties, or heat-induced fatalities (EPA, 2013).
- A survey conducted by the Center for Disease and Control Prevention estimates that roughly 8,000 individuals have died from heat-related illnesses over the last 30 years (EPA, 2013).

Urban Heat Island Mitigation Measures

Shading and Evapotranspirative Cooling Via Plants in the Central Valley

- Evapotranspiration is known as the combination of both evaporation and transpiration. Evaporation is the process by which water converts to water vapor (FAO, 2015). Plant transpiration is the process by which water vaporizes inside plant tissues and is released into the atmosphere (FAO, 2015).
- Evapotranspiration cools an area by utilizing the atmosphere's heat to evaporate water from the plants' leaves (EPA, 2013).
- Evapotranspiration rates vary depending on the climate of an area. Based on the Central Valley's Mediterranean climate, large/medium deciduous trees

are well adapted to the environment, require little water for growth, and provide shade and evapotranspiration to cool cities (STF, 2015).

- Shaded areas are roughly 11-25°C cooler than unshaded areas (EPA, 2013).

Benefits of Green Roofs and Walls

- Green roofs cover rooftops with plants and can provide many benefits to reduce heat island effects.
- Green roofs can cool an area via evapotranspirative cooling (Cadenasso, 2015).
- Since green roofs have higher albedo's than dark roofs, they can reflect radiation back out into the atmosphere rather than absorbing the heat into the system (GRHC, 2014).
- Green roofs also diminish the formation of smog and reduce the spread of dust and aerosols throughout the city and its surrounding areas (GRHC, 2014).
- Green roofs can protect rooftops from harmful UV radiation which may offset diurnal temperature fluctuations in cities with severe vehicle traffic during rush hour peaks (Cadenasso, 2015).

Benefits of Solar Panels

- Solar panels are power devices that systematically convert the sun's light into electricity (Zukerman, 1997).
- Solar panels that are mounted on rooftops of buildings provide shading and reflectivity of the sun's rays thereby reducing the amount of radiation absorbed by the building (Zukerman, 1997).
- Although expensive initially, solar panels are relatively durable and require little maintenance once installed, deeming them one of the most cost-effective and sustainable forms of energy production (estimated to reduce up to 30 tons of carbon dioxide emissions in 30 years) (Zukerman, 1997).

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Part 2: Project Goals and Management Plan

The Central Valley has suffered from the effects of an urban heat island (UHI) for over several decades. In order to mitigate the impacts of UHI's, several long- and short-term goals should be implemented in metropolitan districts to diminish the harmful effects of UHI's in an effort to restore previous conditions of surrounding urban, rural, and suburban areas. Furthermore, a detailed monitoring plan should be established in order to assess the successes and failures of the actions listed below.

A. Goals

The overall goal of this restoration plan is to mitigate the harmful effects of UHI's by increasing the amount of reflective surfaces and vegetative cover present in urban systems. If implemented, these goals apply to a local spatial scale specific to the Central Valley.

Goal	Short or Long Term	Description
Plant large/medium native deciduous trees (ex: California Sycamore, Columnar Red Maple, River Birch, Blue Oak, Chestnut-Leaf Oak) to generate a cooling effect via evapotranspirative cooling and shading.	Long	Establishing self-sustaining deciduous native trees may take 10-20 years on average. However, once established, these trees require little water and maintenance, provide ample shade (typically 5-10 degrees cooler under tree canopies), and generate an evapotranspirative cooling effect (STF, 2015).
Replace dark, sun-absorbing surfaces (ex: asphalt, concrete, dark roofs) with reflective surfaces such as green roofs, green walls, permeable concrete, and white roofs.	Short	Painting dark roofs white/light grey increases the reflectivity of solar radiation thereby decreasing the amount of heat that is absorbed by the urban system. Green roofs and permeable concrete can cool the atmosphere via evapotranspirative cooling, reflecting radiation back out into the atmosphere, and retaining water in the system (Cadenasso, 2015).
Install solar panels on the roofs of buildings.	Short and Long	Though effective quickly once installed, solar panels are relatively expensive (initially) and may be a long-term goal since the government may lack the funding to install solar panels in buildings. If installed, solar panels increase reflectivity of radiation back into the atmosphere and reduce the amount of electricity generated in cities (Zukerman, 1997).
Orient buildings with high sky view factors.	Short	Orienting tall, high-rise buildings far enough away

		from one another (which increases the proportion of visible sky between buildings) such that solar radiation can escape back out into the atmosphere is an effective means of preventing excess heat from being absorbed into the system. This goal applies to new developments (Cadenasso, 2015).
Orient buildings that face the sun in the evening and face the shade in the afternoon.	Short	By spatially orienting buildings to face the sun in the evening rather than during the day, air conditioning costs are significantly reduced which thereby diminishes the amount of anthropogenic heat that is generated and circulated in urban systems. This goal applies to new developments (Cadenasso, 2015).
Reduce the amount of vehicle traffic.	Long	With less vehicle emissions and smog generated in cities, urban systems will trap and circulate fewer greenhouse gases in the atmosphere (a phenomenon known as the urban dust dome). Improving public transportation and encouraging civilians to use buses, subways, trains, etc. may be a long-term goal that depends on cities' pedestrian- and public transport-friendly infrastructure (Cadenasso, 2015).

Implementing these restoration goals relies on the cooperation of various stakeholders (including government agencies and private firms) in order to reduce the harmful effects of UHI's in cities. Mitigation efforts require the support of the government's' policy initiatives and the public's voluntary actions which may include urban forestry programs, tree protection ordinances, or educating the public through outreach programs about the importance of installing green roofs or solar panels (EPA, 2012).

B. Restoration Plan

This restoration plan aims to mitigate the harmful effects of the Central Valley's UHI on a long-term and local spatial and temporal scale, respectively.

Task #1: Plant trees to provide shading and cooling via evapotranspiration.

- a. Identify trees that are native and will thrive in the Central Valley's climate conditions.*

The Central Valley's climate is classified as Mediterranean and Mediterranean Steppe, suggesting that the region can provide diverse vegetation with enough moisture to thrive, unlike many arid climate zones (Kauffman, 2012). Thus, according to Sacramento's Shade Tree List, the California Sycamore (native species), Valley Oak (native species), and Bur Oak are well suited to the region's environmental conditions, require little water once established, and grow relatively quickly (STF, 2015). The California Sycamore is adaptable to a diverse range of soil types, and does not have large surface roots (STF, 2015). Additionally, these trees can withstand conditions that are typically representative of cities that suffer from UHI's including extreme heat and strong winds (UFEI, 2012).

Valley Oaks are the Central Valleys' largest native deciduous oak trees that grow up to 3 inches annually in optimum environmental conditions (STF, 2015). Due to the trees' large size and deep, rounded-lobed leaves, Valley Oaks can uptake large amounts of carbon dioxide during the summer and spring, thereby offsetting a large proportion of vehicle emissions during peak diurnal rush hour periods (STF, 2015). These trees also lack large surface roots (good for urban settings with excessive paved surfaces) and withstand extreme heat conditions and alkaline soils (STF, 2015).

Bur Oak trees grow at a slower rate than California Sycamores or Valley Oaks, but survive well in various soil and moisture conditions (STF, 2015). These trees are also extremely tolerant of urban conditions including abnormal precipitation regimes, excessive pollutants in the atmosphere and soil, and excessive heat exposure (STF, 2015). Due to their large size, these trees will provide adequate shade in regions that lack vegetative cover.

- b. Plant trees that are optimum for an urban setting in the Central Valley.*

Planting protocols are detailed in the Sacramento Shade Tree Planting Guide, and thus should be followed for the purposes of this restoration plan. A total of 50 trees of each species will be planted within a 10-mile radius of urban land (each tree species will be in its own 10-mile radius-- ranges must not overlap). Trees should be planted roughly 15 feet away from buildings, 25 feet between trees, and 30 feet from utility overheads (STF, 2015). A total of 50 California Sycamores will be planted around the perimeters' of approximately 30 buildings (must be within the specific 10-mile radius chosen). Specifically, Sycamores will be planted to the west of buildings to shade windows and part of the building's roof in order to effectively cool the buildings (EPA, 2012). A total of 50 Valley Oaks will be planted around the

perimeter of parking lots and in medians inside parking lots within a 10-mile radius of urban land (EPA, 2012). A total of 50 Bur Oaks will be planted in schoolyards, parks, and playgrounds within a 10-mile radius of urban land.

Risks and problems associated with tree planting:

Trees provide several services and disservices to urban communities. For example, trees reduce air pollution, sequester carbon, save energy and reduce air conditioning costs due to shading, and increase the aesthetic value of properties (Cadenasso, 2015). However, trees may also provide disservices to communities depending on citizens' perceptions and societal values. For example, planting and maintaining trees may be costly due to initial planting costs or ongoing maintenance costs associated with irrigation or disease control (EPA, 2013). Additionally, trees may be hazardous to pedestrians and cars during storms if tree trunks or large branches fall (Cadenasso, 2015). Thus, restoration efforts should begin with an assessment of trade-offs of ecosystem services and disservices to determine the community's desired outcomes in order to ensure that community members agree that the benefits of planting trees outweighs the costs. Assuming that people prefer having trees in urban settings, distributing trees homogeneously in a city is important to consider in order to ensure that low- and high-income sectors are receiving equal distributions of the services provided by trees. Trade-offs of the services and disservices provided by trees should be evaluated through an environmental justice lens (ecologically and socially) by government and private agencies prior to planting in order to avoid unequal distributions of services to certain groups (Cadenasso, 2015).

Uncertainties

Since it takes trees up to 10-20 years (on average) to fully establish and become self-sustaining, it is likely that undeveloped trees will not be effective in mitigating an UHI in the short-term. It is unknown whether or not planting a total of 150 trees within three 10-mile radii of urban landscapes will reduce energy costs (and the amount of pollutants emitted into the atmosphere) as a result of the Central Valleys' UHI in the long-term (or by how much). However, based upon several urban forestry studies, the net annual savings of energy costs from cooling effects resulting from trees are roughly \$30-\$90 dollars per tree planted (EPA, 2013).

C. Monitoring Plan

Within the first 12 months that trees are planted on the urban landscapes, continuous monitoring (every month) with high intensity is crucial to ensure that the trees are growing successfully. This suggests that trees should not show signs of pest infestations, abnormally slow growth, or other developmental anomalies during the early growth periods. Due to California Sycamores' high tolerances to urban conditions, Sycamore seedlings can rapidly grow more than 24 inches per year, and should reach approximately 10-12 feet during their first year of growth (STF, 2015; Hoyt). During the second growth period (typically 1-10 years), trees should be monitored with less intensity annually to ensure that flowers are developing at a standard rate. Seedlings will typically begin flowering 6 to 7 years after planting (Hoyt). Trees will start to produce seeds at roughly 25 years of age (Hoyt). After the

tree is approximately 10 years old, it should range from 75-90 feet high with a mature spread of 50 to 70 feet (Hoyt).

Valley Oaks have similar growth stages to California Sycamores and thus should follow the same monitoring guidelines (continuous intense monitoring for the first year, less intense monitoring from 1-10 years) as described above. Under ideal conditions, Valley Oaks can grow up to 4 feet each year and eventually reach 40 to 75 feet high (STF, 2015). Thus, during the first year of growth, Valley Oaks should stand approximately 4-6 feet high (STF, 2015). Oak trees are susceptible to contracting diseases such as anthracnose (fungus), oak leaf blister, and oak twig blight, and thus should be monitored for signs of symptoms during the early growth stages (STF, 2015).

Bur Oaks are also extremely tolerant of various soil and moisture conditions, making them favorable for planting in urban landscapes. Since these oaks grow at a slower rate than the California Sycamores and Valley Oaks, continuous monitoring with high intensity should be done every month during the first year of growth, and continue (with high intensity) every 3 months during the next 4 years of growth to ensure that the oaks are well adapted to the Central Valley's environmental conditions. These oaks should reach approximately 5-10 feet high during the first growth stage (1-5 years), roughly 30-50 feet high during the second growth period (10-15 years) and eventually 70 feet high when they reach maturity after approximately 20 years (STF, 2015). Thus, during the second growth period, monitoring should continue annually with less intensity. However, during the third growth stage, monitoring should occur every 3-5 years with minimal intensity to ensure that the trees have not suffered from sudden oak death (as a result of *Phytophthora ramorum*-- a deadly plant pathogen) or other common diseases that kill oak trees during the later stages of life (COMTF, 2015).

Additional Research

If the trees establish successfully in the urban landscapes (as described by the average growth indicator thresholds stated above), it is expected that the intensity of the Central Valleys' UHI will be reduced in long-term (after approximately 20-30 years). However, in order to improve the monitoring plan, it would be useful to know the exact locations (and types of landscapes) within the region that each tree should be planted for optimal shading and evapotranspirative cooling. Although trial-and-error restoration practices may be effective mitigation techniques in the long-term, it may be helpful to understand how these specific trees survive and function in the Central Valley early on to help speed up the long-term heat island restoration process.

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Background and Justification

Ecosystem services are vital to the function of life, when defined as a regulating service, the services provide a beneficial service for humans and contribute to our wellbeing (MEA 2005). Without ecosystem services life could not function. Pollination can be defined as transferring the pollen from a male anther to a female stigma by animals (WRI 2008) and the animals primarily responsible for pollination are bees. Though a few absolute obligate plant pollinator interactions exist, the overall mutualistic relationship that has evolved between plants and insects is that bees are vital to keep an ecosystem functioning (Kearns 1998, FAO 2009).

The need for pollinators is evident, over 75% of crops depend on pollination services to reproduce, and 35% of the crops produced worldwide need pollinators (Kremen 2011). Though some crops can be pollinated without bees, crop yields of fruits or seeds can drop to 10% (RS 2007). Pollination systems are in decline mainly from anthropogenic sources of loss or fragmentation of habitat, use of pesticides/herbicides, and invasion from nonnative plants (Kearns 1998).

Agriculture is a distinguished feature of our state's economy. California's has the largest economy in the US, of which, agriculture generates \$46.4 billion dollars for the state (CDFA - History), making California the US's largest agricultural earner (LAO 2014). In 2013, the value of California's fruit, nut, and field crops totaled \$26.22 billion dollars (California Agricultural Statistics, Crop Year 2013).

Honeybees, *Apis mellifera*, are most commonly used for pollination services when wild bees are not available (RS 2007). The value of native pollinators for crops has been valued at \$3.07 billion dollars (Vaughan 2006). In the US, 59% of commercial honey have been lost attributed to Colony Collapse Disorder, on the side of native pollinators in California, *Bombus franklini*, Franklin's bumblebee is thought to be extinct (Goulson 2015) The function of bees pollinating cannot be replicated on a large scale economically. In the Maoxian county of China, apples are pollinated by hand due to a decline of pollinators from the loss of habitat and overuse of pesticides. Farmers are switching over to other crops because the use of human pollinators is economically unsustainable (Partap 2012).

Literature Review

Facts

Pollination

Service can be provided by honeybees, native bees, butterflies, moths, hummingbirds, bats, bee flies, lizards, and other mammals. Pollination by humans is economically unrealistic due to labor costs (Partap 2012).

Honey Bees (*Apis mellifera*)

Habitat

- Mass reared pollinator for agricultural uses in commercial beehives. Considered a generalist. (NAS 2007)

Threats

- Primary threat: Colony Collapse Disorder (CCD) where colony of honey bees die off (Weber 2012)
- CCD is thought to be caused by a combination of environmental stresses (loss of habitat, poor forage areas, etc) and the *Varroa* mite (Potts 2010)
- Pesticide use: Neonicotinoids have been linked to sublethal behavior killing honeybees and most pesticides are harmful to bees. (Henry 2012), (Hoffman 2009)
- Herbicide use: Incorrect or overuse of non-selective herbicides can alter habitat by reducing foraging areas or destroying existing habitat
- Other threats: Pathogens (*Paenibacillus larvae*) causes AFB in larval honey, Invasive species (Africanized honey bee) out compete *A. mellifera* (NAS 2007)

Native Pollinators

(Bumble bee, Carpenter bee, Sweat bee, Dark bee, Hairy Leg bee, & Hairy Belly bee)
(Donovall 2008)

Habitat

Can be generalist or specialists, (Hoffman 2009).

Threats

- Primary threat: Habitat - loss of, degradation and fragmentation causes decreased population size, low density of pollinators or change community of pollinators when
- Fragmentation: Occurs when the distance of patches is greater than the range the pollinator forages or the habitat area is too small (Hoffman 2009)
- Invasive plants can alter a plant community's composition by competing with native plants for nutrients
- Grazing by ungulates can destroy nesting sites of burrowing bees or existing nests and step on bees (best done in fall). Only graze third of an area and only graze for short amount of time but allow vegetation a long period to recuperate because livestock can change the structure, plant diversity, and plant characteristics of a habitat. Controlled grazing can maintain an open, forb grassland through light grazing if controlled and with the correct number of livestock (cow-calf pairs) for the site. Match grazing livestock to the plants at a site, i.e. cattle for grasses, goats for broadleaves. (Hoffman 2009)
- Mowing can affect habitat quality by lowering bumblebee diversity. Mow once a year (Hoffman 2009). Mow to a height of minimum of 12 - 16 in. as to not destroy existing nests or overwintering queens. Mowing can be used to control for invasive weeds to prevent competition with native plants. If mowing in the months of (Mar-Sept), make a patchwork of areas at different heights. Leave a large patch unmowed for a year (Hatfield 2012).

- Prescribed burning can affect pollinators if population is small, habitat is fragmented, or there is no refuge for bees from the flames. Population recovery can take up to 20 years for bees to repopulate an area. If a burn is used, only burn a third of an area. (Hoffman 2009)
- Tilling – Have areas that will not be tilled ever to provide areas free from disturbance. (Hatfield 2012)
- Pesticides: same as *A. mellifera*
- Herbicides: same as *A. mellifera* (Hoffman 2009)

Strategies for Preventing Fragmentation of Habitat:

- Use a variety of colors, focusing on purple, blue, violet, yellow, and white with native annuals and perennials of different heights that blooming all season. Red colors will appear black to bees but can attract humming birds and butterflies (Shepard 2002).
- Pick wildflowers that are adapted to the restoration site. Always use seeds sources from the local area.
- For open meadow areas, use a seeding rate of 40 -60 seeds per sq ft for open areas (The Xerces Society 2013).
- For smaller areas, try to have 1 perennial every 18 in and annuals at 1 every foot.
- Minimum population for each plant species can be as little as 50 plants or as much as a couple hundred (Shepard 2002).
- Plant hedgerows along edges of site, walkways, or along riparian zones. Hedgerows can also provide habitat, shelter, and food for other species. This is to enhance pollinator habitat and increase diversity compared to an unmanaged borders. (Morandin 2013, Vaughn 2007).
- For spatial size, larger sites close together are better than small, isolated sites (Xerces 2014). A recommendation for a minimum size is ½ an acre, with a single species of forb in blocks of 9 sq ft or larger areas of 25 sq ft if possible for easier foraging. For density between plants of the same species, space plants as far apart as the largest plant will grow (Pendergrass 2008).

Loss of Nesting Sites:

- Do not till or flood irrigate areas of bare soil as this can disturb habitat for ground nesting bees. Protect potential nest sites like snags and pithy shrubs (Hoffman 2009).

Parasites/Pathogens:

- Pathogens are present in commercial bumblebee stocks. If commercial bumblebee stocks are use, pathogens can be introduced to native populations. Avoid use of commercial bumblebees. (Graystock 2013, Hoffman 2009)

Pesticides/Herbicides: Develop action plan to use pesticide around pollinators. Example given below.

-IPM guide (USDA 2014)

- Step 1: Identify pollinator resource concern
- Step 2: Assess pesticide toxicity to bees
- Step 3: Identify specific exposure pathways to be prevented or mitigated
- Step 4: Develop an IPM plan that protects pollinators and integrate into conservation plan

Climate Change:

- Climate change is a variable that affects pollinators on many different scales and levels creating problems that compound and add to their decline. Flowers can bloom earlier causing a change in foraging behavior, warmer temperatures can allow parasites to move into new populations, higher temp. can alter the range of a species, etc. (Potts 2010)

Invasive Species:

- Removing invasive plant species can be beneficial or harmful, invasive plant species take over ecosystems harming the system but may also be beneficial by attracting more native pollinators than native plant species. (Ferrero 2013)
- Avoid species that are fast growing, spread from seed, suckers, or rhizomes because these species can quickly take over and out compete native species. (Shepard 2002)

Knowledge Gaps:

Full effects of climate change on pollinators at all organizational levels (Potts 2010)

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Goals

A general overview of goals to maintain pollination services (Shepard 2008) are summed in 3 steps:

- 1) Survey the existing habitat and pollinators.
- 2) Integrate management practices to protect pollinators
- 3) Revitalize current habitat for pollinators

Step 1:

Survey the existing habitat and pollinators

Breakdown of Step 1 (Can be completed in 1 or 2 visits to the site)

Key Points		Notes
Recognizing Existing Potential Habitat	Survey and map the site to identify plant species, all possible pollinators species (focus is given to bees), identify areas of high value to pollinators. Areas of high value will have high amount of flowering plants.	Sol RCD has a list of preferred natives Having a map of flora is key.
Existing Plant Community	Knowing the existing plant species, plant height, times of bloom, flower color, water needs, soil types needs, and if the species attracts any potential pollinators can be assessed.	This info can be used for key management decisions.
Nesting and Overwintering Areas	For butterflies, check plant lists to see if species is a host plant For different bee species, different habitat is needed: • Ground nests. Mining bees and sweat bees (up to 70% of N.A. Species (NRCS 2009) • Wood nests. Species like leafcutters and masons bees. Found in snags • Bumble bee nests. Bumble bees nest in small chambers	(Shepard 2009) Ground nests: Not built in wet soil, only well drained. Can be mistaken for ant colonies Bumble bee nests: hollow trees, abandoned rodent holes, etc.

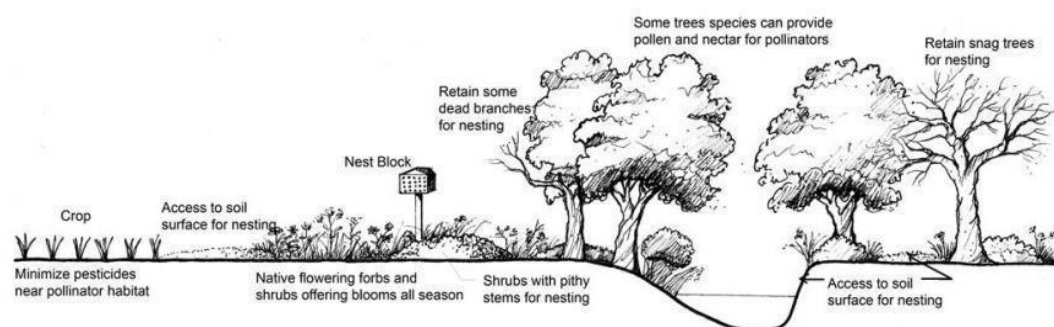


Figure giving examples of nesting sites for bees. Native flowering forbs can also be host plants for caterpillars (NRCS 2009)

The following are lists of plants suggested to attract pollinators by Xerces.org for bees in CA and Butterflies and Moths of North America (Bamona) that can be used in CA.

Butterflies and Moths (352 species specific to N. America):

<i>Anaphalis margaritacea</i>	<i>Camissonia contorta</i>	<i>Mimulus ringens</i> var. <i>ringens</i>
<i>Antennaria parvifolia</i>	<i>Chenopodium album</i>	<i>Phyla nodiflora</i>
<i>Apocynum androsaemifolium</i>	<i>Cleome serrulata</i>	<i>Polygonum bistortoides</i>
<i>Apocynum cannabinum</i>	<i>Dicentra uniflora</i>	<i>Rudbeckia hirta</i>
<i>Arabis x divaricarpa</i>	<i>Erigeron philadelphicus</i>	<i>Rudbeckia hirta</i> var. <i>pulcherrima</i>
<i>Aruncus dioicus</i>	<i>Eriogonum umbellatum</i>	<i>Urtica dioica</i>
<i>Arabis glabra</i>	<i>Eriogonum wrightii</i>	<i>Verbena hastata</i>
<i>Asclepias asperula</i>	<i>Fragaria virginiana</i>	<i>Viola adunca</i>
<i>Asclepias speciosa</i>	<i>Glycyrrhiza lepidota</i>	<i>Viola glabella</i>
<i>Asclepias tuberosa</i>	<i>Horkelia fusca</i>	<i>Viola nephrophylla</i>
<i>Bacopa monnieri</i>	<i>Mimulus ringens</i>	<i>Viola purpurea</i>

Bees (21 species specific to California):

Arctostaphylos densiflora	Frangula californica	Lupinus formosus
Asclepias fascicularis	Fremontodendron californicum	Nemophila menziesii
Cercis orbiculata	Gilia capitata	Penstemon heterophyllus
Clarkia unguiculata	Grindelia camporum	Phacelia tanacetifolia
Epilobium canum	Helianthus annuus	Salvia clevelandii
Eriogonum fasciculatum	Layia platyglossa	Solidago californica
Eschscholzia californica	Lupinus albifrons	Symphotrichum chilense

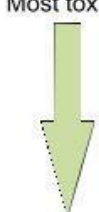
Step 2: Integrate management practices to protect pollinators

Interactions various management practices to reduce disturbance to pollinators:

1. **Use of pesticide:** Pesticide are detrimental to bees at any dose, if the effects are lethal and nonlethal. Always use a nontoxic approach first. If pesticides are used, follow all guidelines for use, use lowest amount needed. Apply at night or when flowers are not in bloom. Most labels list impact for honeybees, effects can be unknown for native bees. (Shepard 2008)

Non-toxic methods preferred to chemical pesticides	If pesticide must be used, use formulation that is least toxic. See table 1.
Can an introduced biocontrol species be used instead?	Use hand sprayers to minimize drift.
Can plant species be planted to encourage natural enemies to hunt unwanted insects?	Apply during blooming off-season or when pollinators are least active.

Table 1. Relative toxicity to bees of different pesticide formulations.

Formulation	Toxicity to bees
Dust	 Most toxic Least toxic
Wettable powder	
Flowable	
Emulsifiable concentrate	
Soluble powder	
Solution	
Granular	

1. **Fire:** If prescribed burning is a management tool, burn in small sections —30 percent of a site or less—about every 3-10 years with a low fire intensity early or late in the day to protect pollinators and allow recovery of pollinators. (Black 2006)

2. **Grazing:** Avoid high stocking rates to avoid long-term damage to forage plants. Short grazing with long period of recovery for plants is ideal. Best time is late summer or fall when flowers are no longer in bloom. (Black 2006)
3. **Mowing:** Do not mow an area more than once a year, try to mow small patches, not large areas. Avoid mowing at night and mow only weedy areas. (Black 2006)
4. **Tilling:** Should be avoided, if needed try not till nesting sites. (Hoffman 2009)

Step 3:

Ways to revitalize current habitat for pollinators

Goal	Possible Action	Outcome
Enhance an area to improve forage	Plant species that bloom year round	Provides nectar and pollen during the entire season
Restore disturbed areas	Restore edges of riparian areas	Restores habitat for foraging
Create a site for nesting	Build bee boxes	Encourages nesting for new populations

Restoration

Restoration of site a for pollinators needs to be adapted to the habitat that is dominant to the restoration site. The overall goal for non-forested habitats will be to enhance existing vegetation or create new habitat if necessary to improve foraging for pollinators and nesting sites (Black 2006).

In a park, hedgerows can be planted along roads or sides of bike trails to maximize available habitat and hedgerows will support less common native bee species in the California (Moradin 2013). Including woody species in hedgerows will create a wind barrier, can be used to stabilize stream banks, and for wildlife enhancement in riparian habitats (NRCS 2009). Site preparation for woody and forbs can be done all the same time. Invasive woody species need to be removed first, using tree wrenches

or chainsaws is recommended over herbicide, repeat cutting until the plant's reserves are emptied.

For an area, that is mainly grassland, a variety of forbs and grasses will be the forage habitat for pollinators (Hofman 2009). A mixture should be local to the area, The Xerces Society for Northern CA recommends the California Central Valley Pollinator Conservation Seed Mix, this mixture contains ecotypes mostly from Yolo County and from Butte, Glenn, Fresno, Colusa, and Contra Costa counties. (Xerces 2015). A mixture that has professionally approved will have flowers that have overlapping bloom times, of different heights, of different colors, and should have least one grass in the mix. Having flowers in bloom all season is needed to provide pollinators nectar and pollen at all times (Vaugh 2007). Plant diversity increases pollinator diversity since having a mix of flower shapes will encourage more pollinators (Vaugh 2009).

To use a mixture the site would have to be first prepared, the first step would be to till the soil and remove the invasive plant species, these can be accomplished by using some of the control given in step two, like mowing or grazing (Shepherd 2002). The best season to plant is during the fall but make sure grasses do not outcompete forbs because as stated in, NRCS 2009, " tall grasses crowd out forbs more easily than short grasses, and that cool season grasses are more competitive against many forbs than warm season grasses". Depending on the type and quantity of herbicide selected, the site may have to sit until the herbicide degrades in the soil. A broad-spectrum herbicide like glyphosate has a short half-life in the soil versus a pre/post emergent like atrazine that can remain in the soil for several months (NPIC 2010, EPA 2007). The

mixture can spread by hand or using a tractor. Apply water to the seeds to ensure germination.

Artificial nesting sites for pollinators can be created using birdhouses or bee boxes depending up the preferred pollinating species. The recommendation is to have the forage and nesting sites in the same foraging patch for bees (NRCS 2009). Patch sizes can range 0.05 to 2 acres (Hoffman 2009). Bumblebees will nest in ground, empty rodent tunnels, or woody plants. Nesting sites need to be protected from disturbances like fire or mowing to protect the organisms living within them.

Monitoring Plan (1 section)

The best way to monitor the effectiveness of a restoration for pollination services is to monitor the native bee population by monitoring their nesting and forage sites. Two methods that can be used are netting at flowers or pan trapping to quantify abundance and diversity. Pollinators can be monitored during spring, summer, and fall to find preferred habitat during those periods (NRCS 2009). No direct method to quantify a pollination restoration as a success was found, only a guideline best quoted directly from, Williams 2011, "Restoration of pollination may be possible without restoring pollinator species identical to those of reference sites. The restoration goal should be toward species rich communities to promote redundancy of pollination among plants." I would suggest picking an offsite area that is remnant of the park before human habitation and roughly equal in size to the area restored for pollinators. Run a transect(s) there during the summer months for 3 years. See the Donovall method outlined below for size and number of transects. Record the pollinator species present and number of each individual for each species. Calculate the species richness to have

a measure of species diversity off site. Use the same method on the restored site during the summer months for 3 years after to compare species between sites to see if species richness increased or decreased (Williams 2011).

The success for pollinators will depend on the improvement of habitat so make sure plantings survive until the plants are able to produce seed. The plantings should be watered and cared for, may need to be watered for up to two months. Site maintenance will consist of watering the plants (best time is in the morning) and keeping invasive weeds under control (mowing, tilling, etc).

During the first two years, if any plant species identified as a noxious weed, exceeds 10% of canopy cover, action needs to be taken to control the weed. Once native plants have established and are seeding on their own, any plant identified as a noxious weed, that covers 30% of canopy cover, needs action taken to remove the weed (adapted from Sheet 2008).

Weed control can be done during watering to save time. Drought can occur and may make seed germination and seedling survival difficult (NRCS 2009). California is in a drought so make sure plantings are well watered. If 10% plantings fail to grow after a month or two, look for signs of water stress (wilting of leaves).

Timing		Notes
Pre-Restoration Visit		1) Map out vegetation, identify forage and nesting sites. 2) Identify pollinator species present. 3) Identify plant species, take plant samples if needed.
During restoration	Ensure irrigation lines are working properly.	Note changes in the nesting and forage sites.

After restoration, 1 week follow up	Areas that have been seeded need to be closely monitored to ensure survival and successful transition to new site. Check for weeds.	Make sure planted species are receiving adequate water and free from herbivory/competition from weeds
2 week follow up		Same as above
1 month follow		Same as above, check for disturbances in any created artificial nesting sites.
Subsequent monitoring can be done when irrigating is done	Site should be maintained until the native species planted are producing seed on their own.	Perennial species can take a couple of years to establish.
At least once during Spring, Summer, Fall conduct a pollinator sampling.	The Citizen Scientist guide is specific to bees. Select areas that are potential nesting or forage sites for pollinators.	Conduct a survey of pollinators using method outline in Donovan 2008.

Method from Donovan 2008 summed.

Set up at least a 250 ft transect for an area under 2 acres, if greater than 2 acres, use 2-3 transects divided between a length of 600 - 750 ft. Note wind speed, temp in shade, and cloud cover. Set a timer to 60 min and note the bee species present and if you can, the flowers the bees are visiting.

Further Research and Improvement:

No spatial references were found to suggest times to check for monitoring of pollination services. Native plants will need time to establish and have an initial flowering.

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Weed control

Paola Pomeroy

Part 1: Project Background and Justification

The control of invasive plants is crucial in a restoration program; this is because reducing the population of unwanted species will make resources available for the species we are trying to restore. It is important to be familiar with plant populations and the role they play within their ecosystem, also consider growth habitat and the various ways of dispersal. Controlling annuals from perennials can be very different therefore we must be familiar with the invasive species before we formulate a weed control protocol. Reducing invasive plant population is a long term process that will require monitoring for several growing seasons to attain the depletion of soil seed bank and allow native species to thrive. In this section we incorporated a brief guide of how to control the three key invaders of Centennial Park. The meaning of a weed can vary depending to the person you are talking to and the situation they are experiencing, but overall most people agree that weeds are unwanted species, plants out of place. Invasive species acquire such terminology because most likely they have a negative impact on human activities (Ghersa, et al. 1996). Also weeds can interfere with more than one ecological function, and that is why it is important to be familiar with the various types of weeds affecting each case. This is in order to best formulate a plan for control (Lembi & Ross, 2009). Furthermore every year a lot of resources are devoted to weed control. In rangelands across the United States weed control can be as much as \$2 billion, and up to \$20 billion in agricultural fields (Westbrooks, 1998).

Species Name:	Growth Form and Life Cycle:	Control Recommended:	Plant ID:
Teasel <i>Dipsacus</i> <i>sp</i>	Annuals, biennials, and perennials. Teasel begins as a rosette, and then it bolts up to 3m tall and then flowers. Flowering can be from April to October. Soil seed bank is short lived, but due its wind pollination dispersal can be very wide.	Shallow tillage to promote germination of weeds in the seed bank. Follow this mechanical practice with herbicide control. It is recommended to use post emergence herbicides before spring when plants mature and can contribute to the seed bank. Focus on decreasing plant density, while preventing seed production.	

Perennial Pepperweed <i>Lepidium latifolium</i>	Long-lived perennial, that reproduces sexually and asexuality through roots. Stems vary from .5 to 1.5 meters tall. Growth form erect semi woody especially at the base. Foliage is light green and smooth. Flowering from early spring to early summer.	The application of glyphosate can make the control of pepperweed very effective. Be careful not to spray plants that are desired. Also avoid over spraying, this will kill the plant immediately, but it will very likely recover. On the other hand if you applied as indicated and allow a few weeks for translocation, the chances of the plant's recovery is lower. Continue to apply post emergence herbicide until soil bank is depleted. Keep in mind that controlling pepperweed will be a long term process, requiring monitoring.	
Chinese Tallow Tree	Rapidly growing tree that can get up to 6ft. tall. This invasive tree can quickly destroy and take over native trees.	Direct application of herbicides is required. According to the size and age of the plant application can vary. Younger plants can be treated with a foliar application, while stem injection is recommended for older plants. Allow few weeks for the herbicide to translocate.	

In the Central Valley weed control practices can vary from agricultural fields, to big restoration sites and all in between. The science of weed control requires us to consider the environment where the invasive is causing disturbance, rather than just looking at the given species individually. This is because the problem does not end with the eradication of the unwanted species; we also have to consider what would be the faith of the land once weeds are eradicated. Consider further environmental issues than can be linked to weed control, like erosion due to the lack of vegetation (Berger, 1990). There are other issues that can also impact the land, such as new invasive species colonizing. Therefore it is also important to be aware of weed population dynamics, and successional species (Hatfield, et al. 1998). Weed control is crucial for ecosystem services; this is because having noxious weeds will limit the resources available for desired species. When dealing with big spatial areas it is best to approach weed control with an Integrated Pest Management (IPM) approach. As the name describes it IPM is the incorporation of various methods of weed control, in order to obtain better results and cause less ecological impacts. By incorporating more than one method for control we maximize success rates (DeWerff, et al. 2014). If we achieve to control hot spots of invasive species, this can allow native species to repopulate the region. When formulating weed control for restoration there are many challenges, given that eradication of the invasive species is only a small part of the

overall goal (Viers, et al 2012). Furthermore keep in mind that the type of control you chose to eradicate invasive species will also have an impact on the given environment. There are various ways to control weed populations. The type of invasive, and magnitude of the site will determine the best control type. There are cultural, biological, and chemical practices among others. When selecting the best way to control invasive species keep in mind environmental conditions, since it will determine which species needs to be prioritized for control. As an example during dry years, control of annual grasses is on top of the list given their potential to cause fire hazards. Also consider the impact humans have on the given site, and how they can contribute/prevent invasive species dispersal (Ghersa, et al. 1996).

Methods of Weed Control:

When it comes to weed control within ecosystem services we need to be aware that in the process of eradicating the invaders, we can also have a negative impact in native populations. It is important to be aware of tradeoffs to best formulate a plan that causes little ecological disturbance; consider that the overall goal is to achieve a point where the ecosystem is able to control invasions on its own. In order to achieve such point of sustainability is necessary to consider a long-term plan that incorporates various approaches for weed control. By having more than one approach we maximize chances of success, and also we can achieve more than one goal (DiTomaso, 2008).

Preventive Control: Preventing the dispersal of invasive species is a key element of weed control; by preventing dispersal we are also reducing seed count, and minimizing disturbances. It is important to be aware of paths of seed dispersal of invaders, and disrupt them from establishing. Planting trees and shrubs is a good example of disrupting pathways of seed dispersal, the dense canopy will both filter incoming seeds but also will block light needed for germination. If weeds are detected at an early stage they can be eradicated before they add to the soil seed bank, and cause a greater problem (Sheley, 2011). Quite often the prevention of further dispersal is underestimated but a systematic preventive approach can save a lot of time and money, and also can reduce the chances for future invasions. This is because weed populations not only compromise the balance of the environment and reduce its productivity; they often involve high economical inputs. It is also very important not to spread invaders as we sample/tour the site, especially in areas with little or no exposure to the invaders (Westbrooks, 1998).

Mechanical Control: Involves the physical act of weed removal. Mechanical control varies according to our goal; it can be selective or non-selective. Mechanical methods vary in complexity, and they can be incorporated to maximize results. If done properly mechanical control can be very effective and less harmful for the environment than chemical control (Lembi & Ross, 2009).

- *Hand pulling.* As the name describes it this is the action of hand pulling weeds, this process is very labor intensive. This is good to control small annuals and biennials in reduced areas. It can be consider the most primitive method, but it can be useful when only trying to control a limited population. Hand pulling can be very effective when populations are detected early and

still in the establishment phase, also it can be the most ecofriendly weed control technique (Ghersa, et al. 1996).

- *Tillage*. This process causes soil disturbances and exposes plant-growing structures so they desiccate with the sun. This can be a great approach when dealing with small annuals and biennials; also consider that there are summer annuals and winter annuals. This is important to keep in mind given that the best time to tillage is before plants mature and produce seeds; winter annuals produce seed in spring before their cycle ends, and summer annuals produce seed in late fall. Given that tillage can be very aggressive cultivation of the land should occur before the introduction of desired plant species, this would give them a head start and a better chance to outcompete the invaders. (Canali, et al. 2013).
- *Mowing*. This method can be very effective when controlling annuals and biennial weeds. This method has the main goal of disturbing the plant before it produces seeds. This process has to be repeated twice within a growing cycle, at the beginning of the growing cycle and at the end of it. This in order to maximized success rates by preventing the invaders from seeding. This process should be repeated for at least 5 growing seasons to allow desired vegetation to establish. Although this can be effective you also have to consider the dispersal of seeds while mowing (Ghersa, et al. 1996).
- *Solarization*. This process consists of covering the soil with clear plastic with the overall goal of raising the temperature to kill weeds and seeds within the topsoil. For this to be effective the solarization process has to occur for several weeks to assure that weeds and pathogens are killed (Lembi & Ross, 2009) Solarization is more effective when is done during the hottest months of the year, and under no cloud or fog conditions. In Central California such period is from June to August, but in Southern California solarization techniques can be implemented since early May to late September. It is important to have a smooth bed and a well moist soil before applying the clear plastic to obtain better results. One of the trade offs when using solarization is that we are also killing beneficial microbiology within the soil, but it is still a great non-chemical solution to control fungi, bacteria, nematodes, and weeds (UC IPM, 2008).
- *Mulching*. Process of adding mulch with the goal of blocking light for seeds in the soil seed bank, this prevents seeds from germinating. This is widely used for home gardens, but it can be very expensive for bigger projects. It is important to get mulches that are certified weed free, to prevent adding to the soil seed bank (Gopinath et al. 2009).

Biological Control. Controlling invasive species by introducing natural predators. Biological control can be done with small insects and even mammals such as goats and cattle. Timing is extremely important when using biological control, also be aware of the grazing preferences of each animal. Furthermore consider the dispersal the grazing animals will cause; as they feed they can also spread seeds (Blossey, 1993).

- *Grazing*. An implementation of different types of livestock can be incorporated in order to achieve more than one goal. If the overall goal is to

decrease fire hazards and control annual grasses, we should introduce geese or cattle depending on the scale of the site. If you desire to control broad leaf vegetation sheep can be incorporated, while for woody and shrubby plants goats will work best. Time of introduction will vary according to the target crop and chosen livestock, overall is best to introduce grazers at early stages of vegetative growth this in order to prevent further seed dispersal (DiTomaso, 2000).

Note: Ideally in order to preserve ecosystem services intact or cause little disturbance as possible, the usage of pesticides and herbicides should be avoided. Although the usage of herbicides is not encouraged, in cases where native vegetation is not able to outcompete the invader it might be the only way to help the desired species reestablish.

Chemical Control. Usage of herbicides to control weed populations, different chemical compounds cause plant senescence. Although herbicides might cause the most environmental impact, the benefits exceed the risks. When using herbicides it is very important to keep in mind the plant maturity and its stage of development, this will determine the best mode of action (Dervine, et al. 1993). It is important to consider plant metabolic pathways and susceptibility to chemicals. This will determine the best way to apply herbicides, and how they will translocate. When selecting chemical control keep in mind herbicide resistance, and best mode of action. When using herbicides essential to follow the Material Safety Data Sheet (MSDS), the manufacturer's safety data sheet will also tell you what protective equipment is necessary to wear and precautions needed (Bekker, et al. 2003). Before we proceed to incorporate a weed management plan, it is important to set action thresholds to determine what kind of approach should be taken. Also it is very important to identify when does the invasive become an economic threshold to determine future control (USEPA, 2014). The control of invasive plant species is crucial for the replenishment of the land given that invasive species reduce the resources available for desired species. One of the many characteristics that invaders possess and makes them such an ecological threat is that they disperse quickly, and aggressively displace native vegetation as they colonize (Corbin, et al. 2004). Furthermore invasive species make a serious threat for biodiversity within a given environment. Overall invaders limit the productivity of the land, and reduce the services provided by the ecosystem (Westbrooks, 1998).

Goals

- I. Prevent further expansion of invasive species, and minimize spread by focusing on protecting non-infested areas. The importance of protecting areas that have not been exposed to the invasive is often underestimated, but it can make a difference by reducing future infestations. Focusing on preventative techniques with a good systematic plan has been estimated to minimize later expenses for weed control. Systematic control includes promoting diversity, tillage practices, and management of effective irrigation among others (Sheley, 2000). Crop diversity increases the resilience of desired species

against invaders, opposed to having only one type of vegetation. Furthermore if we implement drip irrigation on desired plants, we reduce the amount of invasive species germinating and also limit them to smaller regions that can be easier to control (Labrada, 2003).

- II. Protect services provided by the ecosystem by considering tradeoffs of weed control. In some cases it might be more effective to target a single invasive species for control before reintroducing vegetation, particularly when the invasive is taking up a lot of resources. Approach control first, and then reintroduce vegetation (Hobbs & Suding, 2009). Implement long-term practices that allow for 'maximum diversification of disturbance' this requires the implementation of diversity among crops opposed to monocultures (USEPA, 2014).
- III. Approach weed control with Integrated Pest Management (IPM) techniques. IPM approaches include biological, cultural, mechanical, chemical control, among others. By approaching control with an IPM technique we can focus on completing more than one goal. Also by approaching control from several angles we can focus on minimizing the impact to the given environment. Implementing IPM techniques has proven to be very effective for long-term control practices (DiTomaso, 2008).
- IV. Help the ecosystem to reach a point of self-sustainability to decrease the cost of weed control. Before introducing desired species it is important that we control the invaders first, this in order to give native species a head start allowing them to repopulate. In order to reach a point of self-sustainability and decrease costs for weed control, it is very important to promote biodiversity. Ecological diverse ecosystems are more resilient to invasions (DiTomaso, 2000). In the 1950's weed control for agricultural practices was estimated to be \$5.1 billion, by the 1990's such number was estimated to be up to \$20 billion and such number keeps increasing. In rangelands the economical input for weed control is estimated to be up to \$2 billion a year across the United States. Furthermore invasive species not only have a negative economical impact, they can also compromise the integrity of desired crops and in some cases they can even be harmful for livestock (Westbrooks, 1998).

Restoration Plan

- *Preventive Control*

As the name explains it, preventive control has to do with prevention techniques that minimize or stop the spread of the unwanted species. There are various ways to prevent further dispersal (Sheley et al. 2001).

I. Avoid human and livestock contact with the invasive, this in order to minimize dispersal. This is extremely important especially for invasive species that possess awns, barbs or hooks that can get attached to clothing or animal fur.

II. Consider ways of seed dispersal, and deviate or interrupt such a pathway. This can be achieved by identifying major ways of spread; this information is already available for several species. Increasing the canopy of desired vegetation in such pathways, this to decrease the amount of invasive species that get to establish

(Labrada, 2003). Planting a variety of vegetation between trees shrubs and forbs can be a way to disrupt such pathways; the dense canopy will act as a filter interrupting spread paths. Furthermore vegetation lower to the ground will compete with seeds that land in such space, reducing the amount of invaders. Consider species that will thrive in the region. *Quercus lobata*, and *Quercus wislizenii* are tree species that are well adapted to the climate of the Central Valley, while *Baccharis pilularis* is a good example of shrub that will thrive in the area (Howard, 1992).

III. At the preventive stage is very important to be aware of invasive populations while they are at the establishment phase and before they begin to disperse. Early detection of new invaders is crucial; this is because at early stages the level of disturbance is very low. This will allow for a quick recovery, also the impact to the environment due to weed control is very minimal. Early detection and rapid response is a method that has become more popular in recent years, but we have to consider that this approach might not work for some species such as yellow star thistle. Still early detection and rapid eradication can be a great approach to control Scotch thistle, spotted knapweed, French broom, among others (DiTomaso, 2008). It is also very important to identify key invaders such as *Ficus carica* or common fig, such species can act as an ecological engineer and degrade conditions for native populations while allowing invaders to establish. Figs trees have been invading the riparian forest across the Central Valley, and the foothills (Hoshovsky & Randall, 2000).

- *Reduce Nitrogen Content Within Soil Profile*

Exotic annual species tend to thrive better under soils with high nitrogen contents; in order to minimize the rates of invasion it is crucial to reduce the levels of nitrogen within the soil content. Removal of nitrogen fixing invaders is key to allow native vegetation to reestablish (Zavaleta, et al. 2014).

I. Stop/Eradicate the spread of nitrogen fixing plants. Legume species or members of the Fabaceae family are examples of nitrogen fixing organisms. Furthermore nitrogen-fixing plants are capable of modifying the biota and make variations in nutrient availability, such as the case of *Vicia sativa* and *Vicia hirsute* (Balhorn, 2013). We can reduce nitrogen-fixing plants by mechanically removing them. The scale and accessibility of the site will determine the type of tools needed for the removal of the unwanted species. In some cases the best way to mechanically remove weeds is by cultivating the land. By performing shallow tillage we expose growing parts of the invasive to the desiccating environment. Avoid tillage to control perennial pepper weed, given that it tends to encourage population growth rather than deplete the soil seed bank. It is best to till before the invasive is producing seeds, this in order to avoid increasing the soil seed bank. Each species has different flowering times, therefore it is very important to be aware of the growing cycle of the invader. Also keep in mind the landscape conditions. Tilling on a wet landscape will cause soil compaction, and performing this practice on a very dry soil can damage our equipment. (DiTomaso, 2008).

II. Which invasive species should be prioritized is going to be determined by the goal we are trying to attain and the primary long-term use of the site. Incorporating IPM techniques are great to approach control, and have shown to be the most effective way to control infestations (DiTomaso, 2008). In cases when the invader is

highly compromising the integrity of the site, chemical control might be the best way to control the infestation. This is because at some point native population simply cannot outcompete the rate at which the invader is colonizing. Even though chemical control can have a greater impact to the environment than preventative techniques the benefits will exceed the harm (Dervine, et al. 1993). It is important to check for native habitat such as small mammals and pollinators, and try to cause minimal disturbance to their living area. Also consider herbicides that would have little ecological impact. There are a wide variety of organic herbicides, some examples of organic herbicides include Weed Pharm 20% acetic acid) a non selective grass killer herbicide, C-Cide (5% citric acid) is a non-selective herbicide good to control poison ivy and small trees, GreenMatchEX (50% lemongrass oil) which is a non-selective herbicide of broad spectrum among others. Even though organic herbicides can be very effective to control weed populations, it is important to consider that unlike conventional herbicides they do not have residual activity in new emerging vegetation. Therefore application to new emerging plants is required every time, this would require more intensive process than just conventional herbicides but it will cause less harm to the environment. Also consider price difference when choosing herbicide preferences, organic herbicides are more expensive and will require more applications. (Lanini, 2012).

III. Soil solarization is a good alternative for a non-chemical practice. Solarization tends to work better for small-scale projects such as home gardens and around the edges of agricultural fields. Soil solarization consist on covering the soil with a clear plastic after the land has been cultivated, this with the goal of increasing the temperature of the soil and kill soil born pathogens. This practice leaves no residues at all, and it can kill pests with in the top 6 inches of the soil. When using solarization to control grasses, the grass should be mowed as low to the ground as possible and if possible rototilled. It is best to implement solarization during prolonged sunny periods. It is important to consider that solar radiation varies according location.

Table 1. Average Daily Solar Radiation (Langley's/day)

	<i>Davis</i>	<i>El Centro</i>	<i>Soledad</i>	<i>Santa Maria</i>
May	629	694	557	575
June	685	710	598	608
July	688	644	597	612
August	616	617	529	559
September	501	549	442	456

(Elmore, 2014).

- *Biological Control*

Biological control focuses on introducing natural predators to the unwanted species. Biological control is a slow process that works best with the incorporation of other management practices. Introducing insects and livestock on target unwanted species, can facilitate reestablishment of desired species. Grazing is one most well known weed control biological practice but there is still little information about it. This is because there are a lot of factors to be considered such as the magnitude of the site, animal used, stocking rate, and timing. The invader will determine which species has to be introduced for predation, also when incorporating livestock keep in mind feeding preference (DiTomaso, 2000). Even though grazing is one of the most popular biological control there are several natural enemies that can be incorporated according the type of pest. In order to have successful attempts we should consider the natural habitat of the invader to best select the predator to control it, also consider tradeoffs. Introducing a predator to control an invasive species can have an effect in more than one species, keep in mind that the introduced species might also prey on desired species. Negative impacts can occur if we do not assess all of the possible outcomes (UC IPM, 2008).

- *Rehabilitation of the Land*

The primary goal is to encourage biodiversity to decrease the potential for future invasions. Functional communities have more resilience competing with invasive species, than areas that have monocultures or lack a diverse plant community. According to the needs of the land and resources available; we can choose from a passive rehabilitation form, or an active approach. Passive rehabilitation is more cost effective but it requires the seed bank of native species to be sufficient, given that reestablishment depends on the existing community. When the resident vegetation is not sufficient to repopulate a site, introducing vegetation will be required and that is an active approach. Vegetation can be reintroduced in the form of seeds, transplants or pole planting when dealing with woody species (DiTomaso, 2000). It is important that seeds or plants are collected or propagated from sources within the site we are trying to restore, this is because plants will have the same ecological adaptations to the given environment maximizing the rates of success. If the site does not offer sufficient amounts of seeds collect from a model site that has conditions similar to your site. If you desire to purchase seed material make sure the seeds come from a reliable source. It is fundamental to reintroduce vegetation after the eradication of the invaders this to avoid new infestations, and erosion problems (Hobbs and Suding, 2009). Rehabilitation technique is a good approach when trying to control yellow star thistle, without any competitors yellow star thistle will continue to emerge. This process has proven to be really effective when done after mowing the desired area, and the moisture content of the soil is low rather than moist. Desires plant species should be encouraged or introduced after controlling yellow star thistle (UC Davis IPM, 2007).

Monitoring Plan

After the eradication of invaders and reintroduction of desired species, monitored visits will be required to assure the success of our project. This is especially crucial to continue with our cultural practice of prevention techniques, as

mentioned before early detection and rapid eradication is a key element of weed control. Due to lack of continuity a lot of restoration practices fail, therefore it is very important to monitor the progress of the site. The magnitude of the project will determine the period required for monitoring, also some vegetation types might require more attention than others (Sheley, et al. 2001). Monitoring is crucial to maximize the rates of success. It is recommended to monitor for at least five growing seasons, this in order to better evaluate species interactions. Given that a lot of restoration practices are a long-term goal it is very important to keep a collection of data of each visit to the site. Also it is very important to make notations of progress and difficulties you might face, this to allow for improvement. The monitoring face is just as important as the process of rehabilitation itself. (DiTomaso, 2000).

- Surveys and monitoring are also long-term approaches, which will increase the rates of success of native species outcompeting invaders.

I. It is important to have well-organized data sheets that are easy to read, and replicate.

II. Make notations of changes in habitat (e.g. population growth/decrease, etc.) This is especially important to analyze if our desired species is able to outcompete the invader, also this can be very helpful when analyzing more than one type of rehabilitation form. Furthermore make notations of growth stage of plant populations, and remove new invaders that might emerge since last removal. This is especially important until we can assure that native populations will be able to outcompete the invader.

III. Monitor your progress of your introduced/control vegetation with photopoints (repeated pictures of the same location, under similar conditions) this in order to have consistent and accurate data. Having visual data will allow you to further evaluate the site, also you can access such data at anytime you might need to.

IV. Pay close attention to ecosystem services, and how invasive species have an effect on such functions. Make observation of how such services increase or decrease, and what situation cause such change. Furthermore make observation on the biological response of the present community, both of initial and introduced populations.

V. Be familiar to the locations where infestations are most likely to occur, and evaluate if the control practices being used are effective for such location. Also be aware of changes in populations due to climatic conditions, change in seasonality can promote certain invaders to colonize and can also have an effect on its control. In many cases invaders can be more resilient to drought conditions than desired species.

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Open space/recreation/educational opportunities

Maya Argaman

Part 1: Project Background and Justification

Pros	Cons
Being outside can reduce a range of chronic diseases such as obesity, diabetes type II, high blood pressure, and coronary diseases [Lestan, 2014].	Humans walking in recreational areas cause severe impact on the soil, thus influencing the rest of the ecosystem. Trampling compacts the soil, leading to the soil particles squeezing together, reducing porosity. This loss of pore space reduces aeration and ability of water infiltration, making it difficult for plants to obtain nutrients and water from the soil. Severe compaction leads to increasing surface runoff, which causes soil erosion and further degrades the land [Cole, 1993].
With proper planning, closures in certain areas due to weather, susceptibility to erosion, and overall sensitivity to disturbance can avoid damage to ecosystems	It can discourage people from visiting the greenways if certain parts are closed for a certain season, time of day, or in a specific area
Public green spaces provides opportunities for people to escape their daily routine and engage with the outdoors	Human disturbance from trampling can crush, bruise, shear off, and uproot vegetation. These plants that are vulnerable to damage may have reduced height, stem length, leaf area, flower and seed production, leading to less successful reproduction [Cole, 1993].
Furthermore, studies have proven that utilizing green space as child correlates to maintaining healthy habits into adulthood [Lestan, 2014].	Providing public green space for human use leads to behavior change, habitat modification, pollution, and direct disturbance of animals in the region. Many animals respond to human presence with a change in behavior, such as cessation of foraging, fleeing, or altering reproductive behavior, which can impact the species survival, growth and reproduction [Taylor Knight, 2003].

Pros and Cons of Balancing Recreation with Conservation

Pros and Cons of Designing Pathways for Recreation

Pros	Cons
Having wide trails promotes a healthier lifestyle by allowing people to run, walk, or bike through the area	Wider trails encourages higher human activity, which can lead to higher risk of disturbance by trampling, vandalism, direct interaction with animals
Using wider pathways as the baseline can give more flexibility for narrowing and altering the trails to avoid vulnerable regions and alter width during sensitive months [Cole, 1993].	It could take lots of time and money to design wide trails that avoid sensitive zones while still providing enough space for recreation

Pros and Cons of Concentrating High Impact Areas in One Specific Area

Pros	Cons
Studies have proven that when most of the environmental impact is restricted to specific regions, the soils and vegetation only a few yards from these high impact zones are completely undisturbed [Cole, 1993].	The vegetation, soil, wildlife, and water quality will be severely disturbed in the area that contains the parking lot, bathrooms, visitor center, and so on
If high impact recreational areas are dispersed, more disturbances occur in vulnerable areas, causing higher widespread damage [Cole, 1993].	It may be difficult to design all these facilities in one area depending on the shape, topography, and location of the green space relative to roads
By concentrating high use zones in specific regions, managers are able to keep larger areas undisturbed [Cole, 1993].	Habitat modification due to new high impact recreation areas can cause birds to search for new places to nest. Pollution from unsuitable disposal of garbage can encourage certain populations to grow and persist, crowding out other species that have great ecological importance [Cole, 1993].

As populations become more urbanized and focused on indoor lifestyles, implementing public green spaces provides opportunities for people to escape their daily routine and engage with the outdoors. Being outside can reduce a range of chronic diseases such as obesity, diabetes type II, high blood pressure, and coronary

diseases. Furthermore, studies have proven that utilizing green space as child correlates to maintaining healthy habits into adulthood [Lestan, 2014]. Furthermore, trail-based recreation can offer ecosystem with an increased proportion of native plants, and plant cover and density [Johnson, 2014]. Despite the benefits that outdoor recreational areas provide, impacts from these activities can have significant impacts on the surrounding ecosystem, such as erosion, vegetation damage, wildlife disturbance, and reduced water quality. Understanding the relationship between recreation and conservation is critical for both people and ecosystems to thrive in co-existence.

Impacts of Recreation on Ecosystems

Outdoor recreation and tourism are the fourth leading cause of listed species [Solomon, 2015]. Recent assessments have suggested that recreation may have pronounced effects on wildlife individuals, populations, and communities by affecting behavior and fitness and by altering interspecific interactions. For example, if hikers trample an area and the soil becomes compacted, plant growth may decline because of less favorable growing conditions, erosion may be accelerated due to the sparser vegetative cover, and these eroding sediments may increase the siltation of nearby water courses, and the silty water may reduce stream quality for fish habitat [Cole, 1993]. The interconnected nature of ecosystems reflect the need to manage recreational areas with the understanding that these activities have long-term implications on ecosystems.

Impacts of Recreation on Soil

Humans walking in recreational areas cause severe impact on the soil, thus influencing the rest of the ecosystem. Trampling compacts the soil, leading to the soil particles squeezing together, reducing porosity [Cole, 1993]. This loss of pore space reduces aeration and ability of water infiltration, making it difficult for plants to obtain nutrients and water from the soil. Severe compaction leads to increasing surface runoff, which causes soil erosion and further degrades the land.

Impacts of Recreation on Vegetation

Human disturbance from trampling can crush, bruise, shear off, and uproot vegetation. As a result, plants could have reduced height, stem length, and seed production, leading to overall lower productivity and less overall cover compared to areas that remain undisturbed [Cole, 1993]. Human activity can alter the plant community as well, as species that are tolerate of trampling can become more dominant because of less competition with species that are more susceptible to damage by trampling. Recreational activity can also lead to an introduction of exotic plants that can severely harm the native plant community. Seeds of exotic species can be carried into greenways by recreationists, dogs, horses, or straying livestock, or introduced by birds, water, or wind [Cole 1993]. This can lead to cascading impacts on wildlife that rely on natives for critical food and habitat.

Impacts of Recreation on Wildlife

Providing public green space for human use leads to behavior change, habitat modification, pollution, and direct disturbance of animals in the region. Many animals respond to human presence with a change in behavior, such as cessation of foraging, fleeing, or altering reproductive behavior, which can impact the species survival, growth and reproduction [Taylor Knight, 2003]. Habitat modification due to new recreational areas can cause birds to search for new places to nest. Pollution from unsuitable disposal of garbage can encourage certain populations to grow and persist, crowding out other species that have great ecological importance. Lastly, direct interaction between recreationalists and animals can cause varying responses and behavior changes as well [Cole, 1993].

Impacts of Recreation on Water

The most significant effects of recreation on water are indirectly through disturbance of soils and vegetation [Cole, 1993]. For example, compaction of soil from human trampling leads to increased runoff and erosion that ends up as sediments in our waterbodies. Because water quality is largely dependent on indirect effects, the topography, soil, vegetation, and hydrology of the region greatly impact the waterways. For example, waterbodies are more susceptible to contamination if they are not frequently flushed out by large quantities of water and if they lack chemical properties capable of buffering pollutants. Thus, small water bodies and streams with low flows have a greater vulnerability than larger ones with higher flows [Cole, 1993].

Human Behavior Influencing Ecosystems

As discussed earlier in this report, recreation can have significant impacts on wildlife, vegetation, and abiotic factors, and this can largely be stemmed from the fact that people do not perceive the impacts of their own outdoor activities. For instance, trail users drastically underestimate how closely they could approach large mammals without flushing them [Taylor Knight, 2003]. Furthermore, some recreationists assumed they do not affect wildlife because they did not see any animals [Johnson 2014]. It's also important to note that each additional user may have a small yet cumulative impact on the environment [Taylor Knight, 2003].

Using Education to Influence Behavior

Influencing behavior through education and interpretation is one of the strategies with the greatest potential for long-term success. Understanding the basis of the perceptions mentioned previously, managers can use education to encourage positive changes in behaviors. Informing recreationalists about specific ecological impacts of trampling, littering, and other human behaviors can significantly reduce harm to the ecosystem. F Using interpretation, such as posting signs about spawning fish, nesting birds, and native plants, can positively influence behavior as well as it informs the visitors about how their presence makes an impact [Cole, 1993].

Planning and Management of Trails to Avoid Impact

All of the disturbances outlined above can be minimized through careful planning and designing of the trail and recreational areas. Primarily classifying different zones based on human impact, ecological sensitivity and value is crucial for planning recreational areas. It is particularly important to pay attention to sensitive riparian zones and subsequent edge effects when designing these zones of sensitivity. Examining how the trail impacts the ecosystem on a spatial and temporal scale is critical in determining zones as well. For example, understanding the migration months of native birds, what areas are critical habitat for rare native plants, what season is most popular for people to come, and where most of the activity will be concentrated are just some of the factors that play a role in determining trail location and design. Furthermore, having a long term vision with implementing the trail is critical, as shifts in vegetation, wildlife, water and soil quality can occur from direct and indirect human disturbances, climate change, changes in the community wants and needs, and so on [Cole, 1993].

Once zones of sensitivity are mapped out, implementing buffers that increase in width relative to the susceptibility of damage is key in avoiding direct negative impact on the surrounding area. Furthermore, it is particularly important to pay attention to riparian to upland transition zones. Ensuring that there is a wide enough buffer from the trail to these areas is crucial to avoid risk of compaction and erosion which can lead to sediment entering the water, compromising the water quality, vegetation, critical wildlife, and the overall wellbeing of the vulnerable riparian ecosystem. Providing a wide buffer as a baseline for the trail also provides flexibility over a long-term scale if human activity increases, causing a shift in the vegetative and wildlife communities. Using physical buffers like rocks, logs, and dense vegetation along with interpretive stops provide barriers that avoid human interference with the ecosystem. Furthermore, designing the trail away from these sensitive zones while still providing a diversity in settings is another option to avoid damage. For instance, designing bridges that stray from erosion-prone soil, creating “spur trails” that offshoot from the main trail to provide limited entry to sensitive zones, or completely fencing off areas that are known to contain critical nesting habitat for native birds are viable options to minimize human disturbances [Cole, 1993].

Once the trail and buffers are in place, maintaining the trail is crucial for minimizing the negative implications of human behavior. Providing mulching materials like woodchips, gravel, and rocks helps mitigate high impact zones while maintaining proper infiltration rates and high soil quality. Planting native vegetation such as shrubs, grasses, and forbs that are resilient to trampling can work both as a buffer and a way to maintain vegetative balance as well. Understanding what areas are prone to landslides or surface runoff and forming water bars on the trail can mitigate water quality. These are just some of the management strategies that can be implemented to ensure that abiotic and biotic factors are in balance. Maintaining a long-term vision while understanding the interconnected relationship between abiotic and biotic factors in an ecosystem with direct and indirect human impacts is

critical in ensuring that the benefits of both the community and the environment are fully met [Cole, 1993].

Part 2: Project Goals and Management Plan

Goals

The first goal of my restoration site is to understand the baselines for substantial water quality, soil quality, vegetative cover, and maintain these baselines throughout implementation of recreational areas. By observing and understanding the baseline of the region before human use increase, managers can effectively monitor and manage the area for a long timeline.

Designing the trail to avoid the risk of reduced soil and water quality is another key goal. If it is not possible to avoid these areas, managers should build bridges, add water bars, use steps, and switchbacks. Because water quality is largely dependent on indirect effects, the topography, soil, and vegetation of this riparian region greatly impact the waterways. For example, water bodies are more susceptible to contamination if they are not frequently flushed out by large quantities of water and if they lack chemical properties capable of buffering pollutants. Thus, small water bodies and streams with low flows have a greater vulnerability than larger ones with higher flows [Cole, 1993].

Designing effective boundaries and trails that discourage off-trail activities will influence positive human behavior. Trampling, especially in sensitive off-trail areas, can cause major detrimental impacts. Severe compaction leads to increasing surface runoff, which causes soil erosion and further degrades the land. However, discouraging off-trail activity can be achieved by creating an easily navigable trail that people feel comfortable going on, fully ensuring that people know where the trail is, and making sure it is large and smooth enough for people to walk or bike through. Furthermore, creating a defined boundary for where the trail is through dense vegetation, rocks and logs can influence where people will go.

Effectively using education and interpretation can change visitor's behavior to reduce impact on wildlife, vegetation, soils, and water for a long time. Trail users drastically underestimate how closely they could approach large mammals without flushing them, while some recreationists assumed they do not affect wildlife because they did not see any animals [Johnson 2014]. As a result, many animals change their behavior, such as cessation of foraging, fleeing, or altering reproductive behavior, which can impact the species survival, growth and reproduction [Taylor Knight, 2003]. However, by using interpretive stops along the trail, visitors can understand the impact of their activity on the local ecosystem, the importance of the area's natural resources and ecosystem services it provides and what they need to do in order to ensure minimal impact on the ecosystem is key [Cole, 1993].

These goals provide a framework for balancing recreation and conservation, but it is only fully effective with baselines, using a combination of the restoration methods outlined below, and maintaining a long-term mindset as an ecosystem fluctuates in sensitivity over time.

Restoration plan

Designing zones with concentrated human activity helps reduce disturbance throughout the region. Studies have proven that when most of the environmental impact is restricted to specific regions, the soils and vegetation only a few yards from these high impact zones are completely undisturbed. If high impact recreational areas are dispersed, more disturbances occur in vulnerable areas, causing higher widespread damage. Furthermore, if managers increase use levels in areas that already have high impact, then will be little negative effects, while minimizing disturbances in many low impacted regions will have significant positive effects. By concentrating high use zones in specific regions, managers are able to keep larger areas undisturbed. This approach is especially important in sensitive riparian zones, so designating concentrated human activity as far as possible, preferably on the edge of the greenway, is key to reduce disturbance. An example is by forming established parking lots with limited parking at the edge of the greenway, with restrooms, the visitor center, and bike racks all in the same region [Cole, 1993].

Creating a buffer is one key component in my restoration plan. Setting boundaries that are wide enough for recreational use provides human enjoyment and preservation of the surrounding ecosystem. When initially determining the width of the boundaries, its important to make sure that regions that are less sensitive to human disturbance are wide enough for high impact human activity. Another important strategy is to increase the width of the buffer as sensitivity of natural resources, ecological values, and human activity increases. Using physical barriers like rocks, logs, and dense vegetation are all suitable ways to encourage people to stay in designated areas [Cole, 1993].

Determining the physical location of trail is key for maintaining a balance between conservation and recreation. It is critical to understand where people want to go, and encourage ways for people to stay on the trail. One strategy is to observe how people originally use the area and plan a trail based on this behavior, but keeping in mind the impacts that trails can have on the surrounding ecosystem. For example, if a riparian trail is created on a steep slope with erodible soil, then sediment will most likely enter the water. Using wider pathways as the baseline can give more flexibility for narrowing and altering the trails to avoid vulnerable regions and alter width during sensitive months. Furthermore, if the trail is transitioning from the upland to riparian, it is important to reduce erosion potential from people shortcutting the trail by hiding the views of switchbacks, creating barriers with rocks or brush, and using stairs. However, if wet soils or steep slopes are unavoidable, managers can create bridges over these vulnerable areas, but it is a costly approach [Cole, 1993].

Once the physical location of the trail is determined, it is important to maintain the

trail itself. Placing mulch such as wood chips, gravel, and rocks on the surfaces helps with areas that have high concentration of trampling. If over time impact of trampling increases, managers might want to consider paving the area with asphalt or concrete rather than move the trail to undisturbed resilient paths. It is critical to ensure that natural drainage systems are not disturbed, as agricultural runoff from fertilizers containing high nitrate levels can have lasting effects. Using mulching materials such as wood are ideal because they permit infiltration of the soil, reducing risk of erosion and runoff into water bodies. Furthermore, in areas that are particularly prone to surface erosion and high precipitation events, forming water bars can help mitigate the impacts of these events as they divert water away from the trail [Cole, 1993]. By continually maintaining the trail's physical surface, especially during seasons with high popularity of recreationalists, managers can prevent degradation of trail quality.

Using resilient vegetation is a good strategy to avoid damage by recreation. Studies have proven that mature trees, grasses, shrubs and forbs are generally highly resistant to trampling, while seedlings and lichens are more vulnerable to damage. This is shown through one particular trampling study that proved that 10 times as many passes by hikers were needed to make the same amount of damage in a grassland compared to a closed-canopy forest [Cole, 1993]. Planting resilient vegetation in areas that are prone to human disturbance and erosion is another key approach in maintaining the overall health of the greenway.

Prohibiting certain activities based on a temporal scale is another approach to avoid damage. For example, the Long Trail in Vermont is closed during the spring mud season, utilizing television stations to broadcast the seasonal closure. This strategy can be implemented during California's wetter months, as soil is vulnerable to impact from human activity, forming puddles and adding more trails that can impact infiltration. Furthermore, ground-nesting birds and other wildlife found in California's valley also have varying temporal behaviors that can be susceptible to disturbance at specific times of the year. This is seen in the Boundary Waters Canoe Area in Minnesota, as loons who had lower human interaction had more surviving offspring [Cole, 1993]. On a smaller time scale, some animals are much more active at certain times of the day, so ensuring that the park is open only at specific times could reduce the likelihood of direct interaction between humans and wildlife [Cole, 1993].

Using a reactive approach rather than a preemptive approach is another way to manage greenways. For example, if areas surrounding picnic sites have lost their vegetation and erosion is occurring, managers can react by bringing in new soil and more resilient vegetation. This strategy is an effective short-term solution, but the same issues will continually appear if managers do not address the long-term, underlying issue of high usage. By combining this reactive strategy with actions geared towards addressing the true issue, proper restoration of the site is possible [Cole, 1993].

Monitoring

Understanding the threshold of impact from human use is a crucial foundation for balancing recreation and conservation. In general, the amount of impact increases rapidly when human use is introduced, at a certain level of use the amount of impact slows down. For example, “once trampling exceeds relatively low threshold levels, vegetation loss and soil compaction are pronounced regardless of the amount of use”. Another example is through a study of the effects of skiers on moose in Alberta that proved that the moose initially moved away from the trails when skiing occurred, but they did not move any farther as the number of skiers increased [Cole, 1993]. Knowing these thresholds of human impact on the ecosystem is important for designing a space that balances recreation with conservation.

For soils, monitoring of erosion is key, and if erosion is occurring after the implementation of the trail, then managers must plant vegetation, re-evaluate the trail by observing slope, distance from riparian zone, and people’s walking pattern. Monitoring for soil moisture every month and after precipitation is important as well, as soils that have low moisture cannot withstand dense vegetation, making it more vulnerable to erosion, while soils that are high in moisture are more susceptible to stress from trampling. Maintaining moderate soil moisture is key, and monitoring soil moisture and erosion seasonally, extensively in the wet and dry seasons, can ensure healthy soils [Cole, 1993].

Monitoring water quality every season and after precipitation events with equal intensity by examining the sediment load that enters the waterways and the amount of phosphorus, nitrates and other pollutants could be an indicator of human impact on the ecosystem. For example, “a high level of phosphorus was observed in a lake in Canada after it had experienced a twentyfold increase in recreational use” [Cole, 1993]. Using the EPA’s TMDL as a threshold, if the level of pollutants exceeds the maximum, managers could evaluate location of restrooms, the trail, and soil quality, as these factors could be an indicator of indirect impacts on the water [Cole, 1993].

Monitoring vegetation through surveying the distribution of native plants on a seasonal basis with constant frequency is key, and if certain plants are disturbed by loss, using signs, closing off sections of the trail, and utilizing interpretation is an effective way of ensuring these plants remain unaffected by humans. Monitoring wildlife through surveying populations and observing any change in behavior intensely prior and once human activity is introduced can give managers a baseline for how wildlife is impacted. If certain species are more sensitive at certain times and places, ensuring that human activity are reduced through interpretation, restricting activity, and closure of areas are all effective ways of reducing human disturbance [Cole, 1993].

The central question of my topic revolves around whether or not human activity is negatively impacting the ecosystem. By knowing what the baseline of abiotic and biotic factors are before human disturbance and monitoring for how these factors shift once a trail has formed can be a good indicator of how human impact has

influenced the ecosystem. Furthermore, understanding how the community wants to utilize this area is essential. This is possible by heavily monitoring the soil, water, vegetation, and wildlife extensively months prior to trail building, after precipitation, during heavy amounts of human use, and periodically once the thresholds for these factors are fully understood and maintained.

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APPENDIX- ASSIGNMENT DETAILS

Project Details

Project Scope- The focal experience of this class will be to develop a restoration handbook for Solano County Resource and Conservation District, focused on their Vacaville sites. These projects balance a number of goals, including: (1) decreasing invasives and increasing natives in riparian, upland, and creek habitats, (2) preventing floods, erosion and fires, and (3) accommodating recreational activities. In order to manage for multiple goals, it is critical to bring together the latest information on each goal, and to use this information to develop management plans that can achieve multiple goals. This is where you come in. Each student will rate their preferred topics from the list (separate handout), and based on these rankings, will be assigned a given topic. You will research this topic, summarize your key findings, and make a management plan based on that information (see details below). Students working on similar goals will then work together to:

1. Develop management plans that can balance multiple goals (each goal represented in the group). This is not always possible through one approach, but is often possible by varying management goals and practices over space and time. When some goals conflict, it may be necessary to provide multiple management plans, each with different goals (and then the RCD will have to prioritize one set of goals over others).
2. The group will present a short summary of their topics and management plan to the class.

After the group presentations, as a class, we will discuss management options that encompass as many of these goals as possible. All individual projects, as well as a class synthesis, will be compiled and sent to Solano County RCD.

General approach- The project will be divided into different stages, which will allow you to develop the project step-by-step. In addition, we provide extensive feedback on the 1st versions you turn in, which provides you with the opportunity to resubmit an improved project (your project grade would then be the average of your 1st and 2nd submissions). The project has been designed this way to reflect actual restoration planning- where each step of the planning process is improved based on feedback from various stakeholders. Thus, the first version you turn in for each section should reflect a serious attempt to “get it right”, and will be graded for overall quality. If you choose to resubmit an improved draft, its grade will be based on overall quality and how well you address suggestions you received on your first versions of each section. Details on each step are below.

Writing style- The project is intended to be a brief overview of the key issues involved in your selected restoration topic. As such, it is entirely appropriate to touch on key points through the use of bullets and numbered lists, as long as you are conveying enough information for the reader to follow along with your logic and story. Remember, this is a professional document that will be used to inform managers—be sure your writing is clear, concise, and professional. Be sure to cite all reference sources, including websites, newspaper articles, journal articles, books, etc. Provide complete information for each reference at the end of each section (for most sources that includes author, date of publication, article/chapter title, journal/book title, publisher, city of publication, page numbers). See below for more details about proper citations. See handout on avoiding plagiarism.

Specific requirements:

Below you will find guidelines for addressing your target restoration goal in each section of the project. Different goals will require some different information, or have different information available. If after a thorough search, you cannot find some of this information, make it clear that this is a current hole in our knowledge about the subject. The guidelines below will fit most projects, but feel free to expand on certain topics, add certain components that are critical for your goal, or briefly describe why a given topic is not relevant to your goal. You're encouraged to look at examples from previous years (available in the resources folder on smartsite) as examples of what is expected. The sections of their papers were not identical to this year's assignment, but most of the key information/approaches are still valid to your assignment.

Part I: Literature review: Project background and justification

Part I should focus on YOUR specific goal- providing the conceptual background that will be needed to make a management plan. Do not cover the background of riparian, wetland or upland systems that is provided in class—rather, the background on your specific goal. In this part, you should NOT yet focus on our project site.

A. Background & Justification: 1 paragraph

- Why do we care about this goal? (e.g. this invader decreases native diversity and lowers the depth of the water table).
- Why is this restoration goal important and interesting? For example, what is your target goal's conservation value, its importance in agriculture and/or the environment?
- What is the current state of your target goal? (Not necessarily at our project site, but overall). For example, it is declining?

- What is the history of degradation of your goal? (e.g. This was a widespread native plant in riparian systems eliminated from most of its range. It is only still present in perennial streams of the Central Valley, where average population sizes have been reduced by 90%).

B. Literature review - this should be presented as a 2-4 page fact sheet, not including references (e.g. see examples on Smartsite). This fact sheet must be clearly organized into key topics (which may vary project by project). Formatting can range from bulleted phrases to short paragraphs summarizing each key point, but must clearly convey the main message to unfamiliar readers. Unlike examples on Smartsite, each key fact requires citations immediately following it, and a full reference list must be included at the end of the document. Key topics that should be covered:

- What are the main factors affecting your goal? (Biotic, abiotic, human land use, etc.). Consider all topics covered in class- at the levels of physical site conditions, organism, population, community, ecosystem, landscape, socio-economic, global change, etc.) Some specific examples include:

For species/ community types:

- o Specific characteristics of your species- germination controls, seed bank dynamics, environmental tolerances and preferences, key mutualists and competitors, pathogens, etc.

- o Specifics needed from ecosystem- what are your species requirements in terms of: inundation depth or duration or frequency, location (in relation to creek vs. upland, depth from water table, etc.), phenology (timing of activity, particularly in relation to timing of water flow)

- o How does your goal respond to: climate change, grazing, fire, nearby plowing, herbicides/pesticides? other potential management actions?

For ecosystem services: ~~and what~~ key processes/ components of the ecosystem that naturally provide

this service? (e.g. key species, disturbance regimes, topography, etc.) One way to think of this is how does provision of this service naturally vary over the landscape? What are the key controllers over that?

- o What are the key disruptions by humans to the natural processes that sustain that service?

- o What are the key enhancements by humans to the natural processes that sustain the service? Or how can human activities substituted for the natural processes?

- o How does your goal respond to: climate change, grazing, fire, nearby plowing, herbicides/pesticides? other potential management actions?

It is critical to be as specific as possible about the factors that can increase or decrease your goal, and your goal's dependence on site conditions and timing of management/key life stages. For example: ground nesting bird X requires brush-covered habitat that is not subjected to flooding, grazing, or feral cats from February through May.

- For all of the above information, focus on potential: constraints, non-linearities/ thresholds, interactions, feedbacks

- What scale (spatial and temporal) do these controls operate over?
- What restoration/management options have been effective or ineffective? Do these ~~changes~~ ^{change site} project-to-project?
- What are key gaps in our knowledge that limit effective restoration planning?
- Other relevant information

While the presentation of

section will be brief, it needs to highlight the most important aspects of your topic, derived from your comprehensive review of our existing knowledge on your topic—this requires considering multiple sources of information. This is particularly critical because it is common to draw very different conclusions about restoration effectiveness at different sites. It is critical that you base this review on trusted sources (e.g. peer reviewed literature and government reports) and emphasize specific facts—avoid citing opinions or propaganda that you may find on the web, and avoid speculation or vague comments. For example, rather than making a vague comment about an invader decreasing ecosystem health, an example of a proper description: because the invader has higher evapotranspiration rates than natives, invasion dries up vernal pools faster, thus disrupting the period of inundation needed for a specific native species of interest.

Part II: Goals and management plans- focused on your target topic

Part 2 again should focus on YOUR assigned topic (not the overall class project), and will be focused on California's Central Valley, in general (not the actual project site). Your goal(s), restoration plan, and monitoring plan should be specific, clear, and actionable. For example, rather than saying seed will be collected and spread on the site—you need to be specific about where it will be collected (what type of site), and what seeding rate you will use. Similarly, if you suggest using grazing or fire as a management tool, you need to be specific about the timing of the fire, the frequency (every year?), and how much flexibility there might be in this plan (refer to specific examples given in lecture #3).

A. Goals: Outline the key goal(s) relevant for the restoration of your focal topic (a list or table is fine, as long as you have descriptive phrases about each goal). Be sure to be explicit about the spatial and temporal scale of these goals (and in many cases, it may be appropriate to have different goals focusing on short- vs. long-term, small- vs. large-scale). Discuss the potential for restoring these goals, giving careful consideration of tradeoffs, feedbacks, interactions, and thresholds.

B. Restoration plan: Describe your restoration plan(s) and be sure to justify your choices. If possible, discuss a few different restoration options (which will really help fit your project into the class' multiple goal plan), and the relative effectiveness of each. Points to include:

- specifics on methodologies (e.g. genetic sources of seeds, seeding in vs. transplanting, density and configuration of introductions, frequency and intensity of manipulated disturbance regimes)
- the temporal and spatial scale of your plan
- monitoring techniques (pre- and post-restoration) and “thresholds of action”, justify the measurements and thresholds selected as indicators (For example, with complete failure of reestablishment of a population you plan to..... versus with species establishment at only small, sporadic locations, you plan to). Be sure to be specific about when you will monitor, for how long monitoring must occur (and will it be of equal intensity the whole time, or change over the years?). Again, be sure there is enough detail to be actionable.
- potential problems you might encounter, and how you might adjust the plan along the way if you encounter those problems
- a description of the risks and uncertainties associated with your plan
- highlight research questions that need to be answered in order to improve the plan
- what research questions could be answered by this restoration project (or by comparing a suite of similar restoration projects)

your restoration design allow for those to be tested? (e.g. the presence of control plots, replicate treatments, etc.)

This section should be approximately 4-7 double-spaced pages (not including references), and must be written up in paragraph form (will not be in fact-sheet form). The plans must be based on the literature review you did in part I. Be sure to refer to specific information about the ecology of your goal to justify your plans. Cite references as appropriate.