2017 ENH160 PROJECT: SOLANO COUNTY RCD RESTORATION PROJECT POND C (DIXON, CA)

Report by Students of University of California, Davis

Restoration Ecology Lab (160L)

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INTRODUCTIONTO 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 theneed 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 wide diversity of interacting goals and constraints, and the potential for trade-offs and win-win scenarios
    - 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
- providing background information on the Pond C project.

The overall goal of class project was to develop a restoration handbook for Solano County RCD's Urban Greening Program. Each student was incharge 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 surveyed the sites for their ecological potential, and presented that information to the class. Our ultimate goal was to develop some overall management options 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. Results of these discussions can be found in the "project synthesis" section.

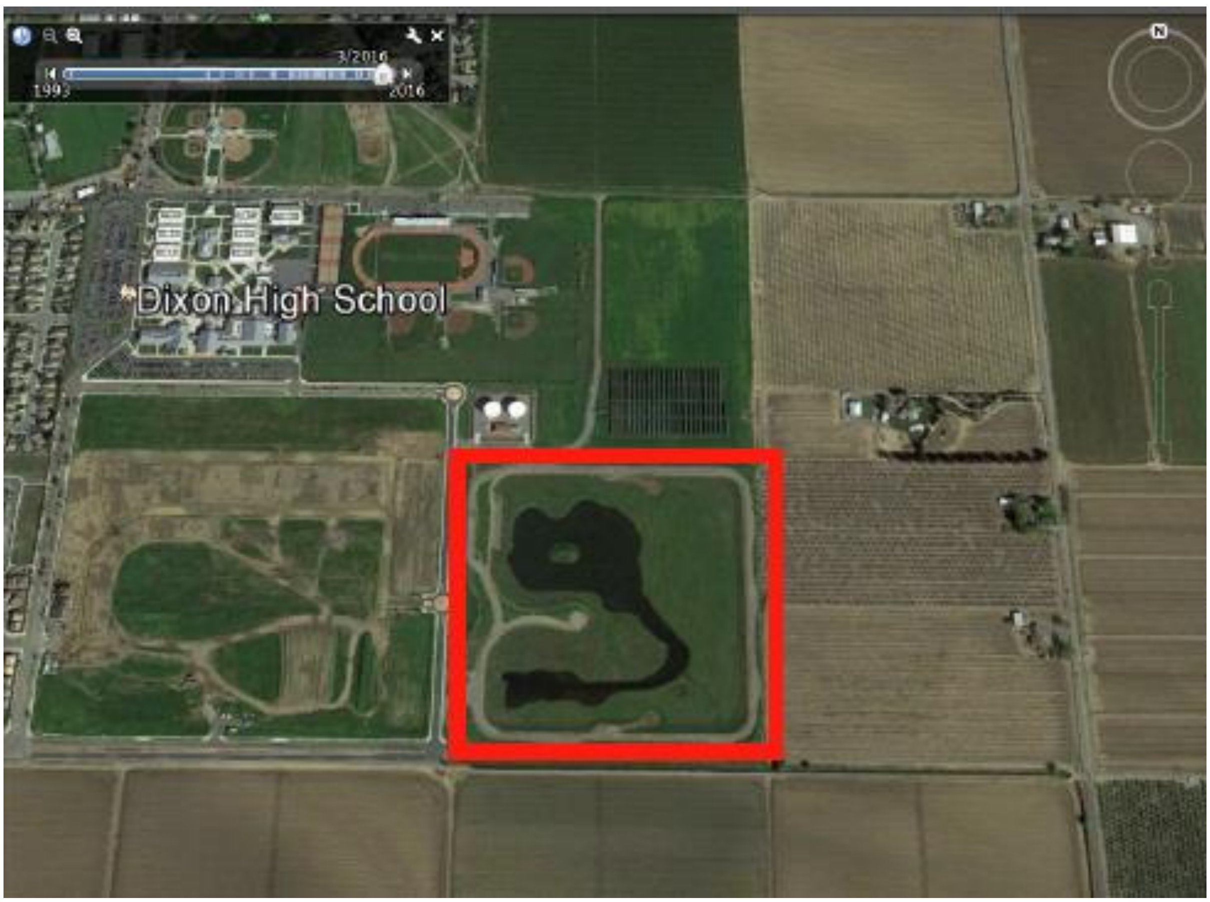
A full description of the students' assignment can be found in Appendix I.

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 grasslands, 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. I am very proud of all of the hard work, open minds and synthetic thinking that the students invested in this project.

INTRODUCTION

POND C SITE HISTORY

Pond C is a 30-acre site that functions as an off-channel detention basin for flood and erosion control for the city of Dixon, California. This pond was installed in 2007 on formerly agricultural land with the intention that this pond would serve as a full wetland mitigation/restoration project as well. While some native grasses and trees were planted following construction, the economic crash ultimately led to the abandonment of the restoration and management of this site. The Solano Resource Conservation District has acquired a grant to improve this habitat over two years from 2017-2019.



SOLANO COUNTY RCD SITE GOALS

-Provide flood control

-Enhance water quality

-Enhance native plant, wildlife and bird habitat

  -Wetland: Native rushes and sedges

  -Seasonal riparian floodplain and wetland slopes: Native shrubs, trees, grasses and ` forbs

-Upland: Native shrubs, trees, grasses and forbs

-Decrease/minimize invasive species

-Trail: 1-mile perimeter trail, small ADA-accessible interpretive trail

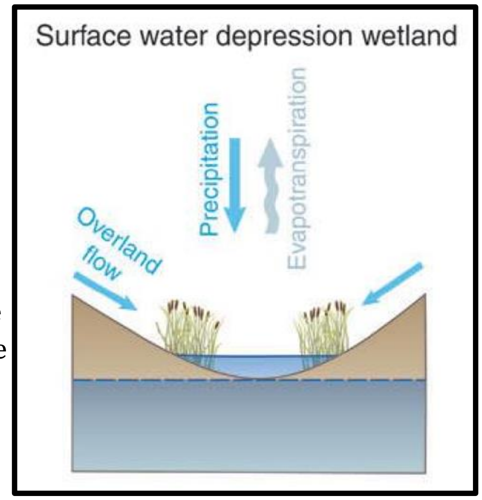
POND C SOIL CHARACTERISTICS

Yolo silty clay loam (Ys): Well-drained, susceptible to hardpans from tillage or heavy equipment, neutral pH

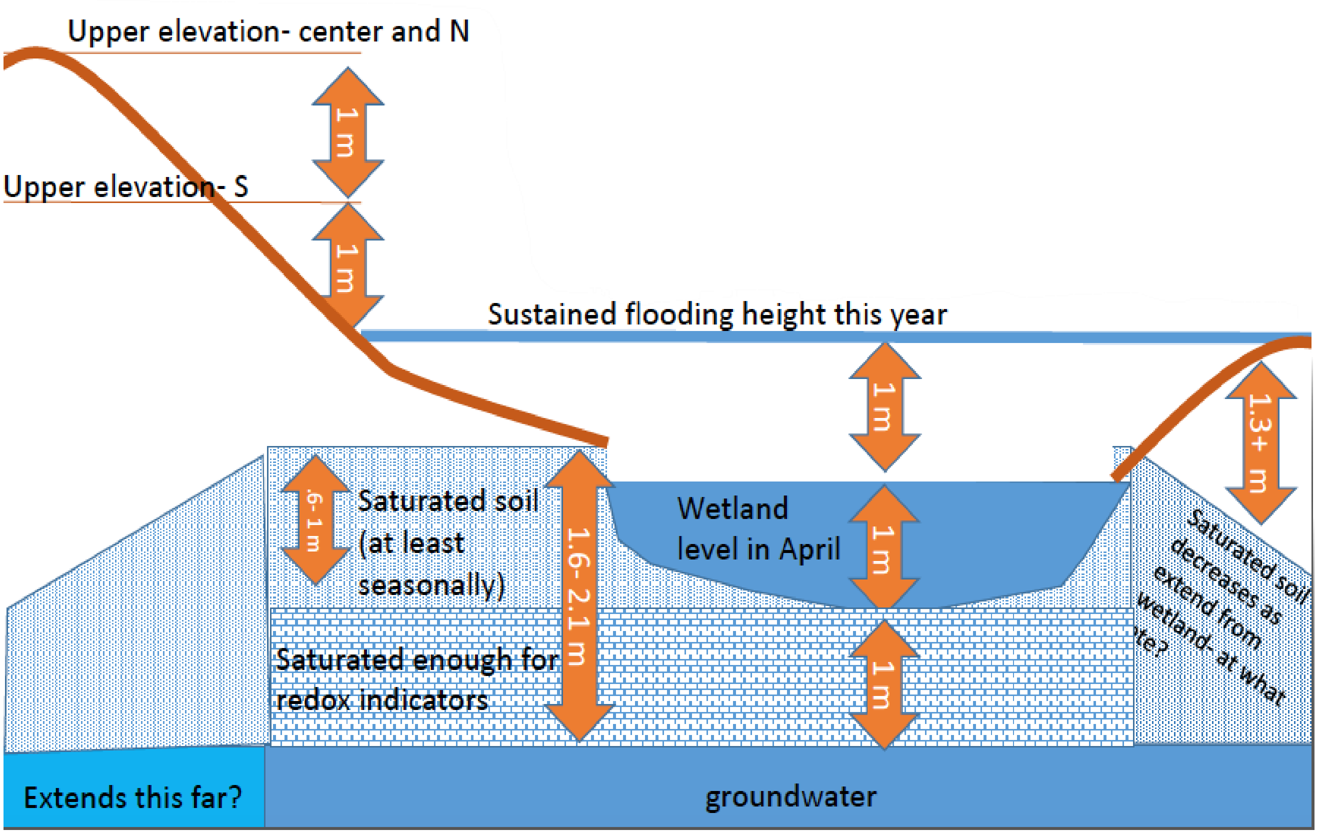
Brentwood clay loam (BrA): Moderate to well-drained (slower deep drainage), moderately alkalaine

POND C HYDROLOGY

GROUNDWATER: Standing groundwater, if found, was located far below the level of the wetland, even at the wetland's edge. This is unexpected and most likely due to the way the wetland was constructed, leading to a surface water depression wetland.

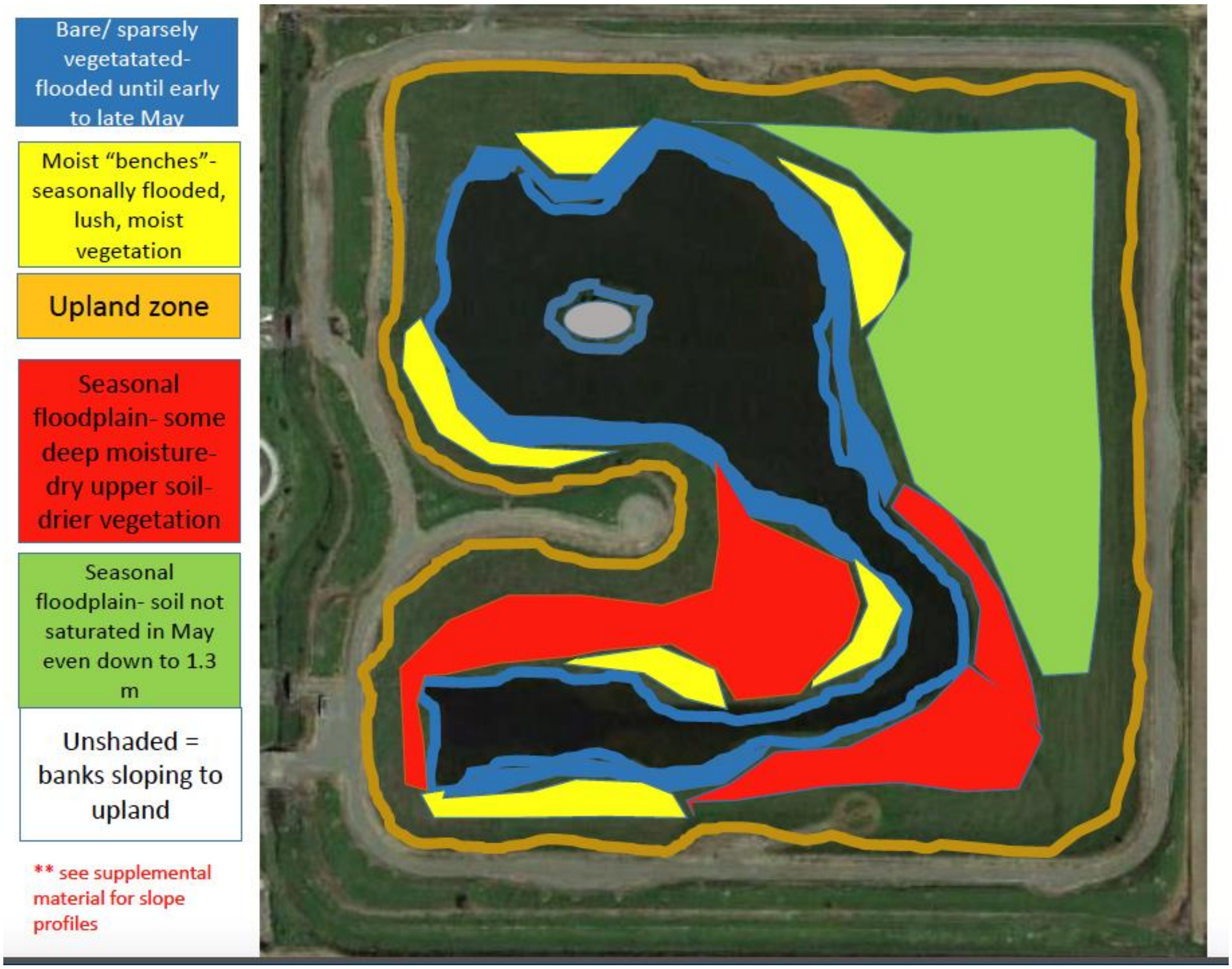


While groundwater was only found deep beneath the soil surface, there is a zone of soil saturation that begins at the wetland edge and extends into the upland. In the seasonal floodplain areas, there is at least seasonal deep soil saturation at 20-53 cm depths (but the surface soil is mostly dry). The depth at which this saturation zone is found decreases with distance from the wetland.



Areas that are likely flooded most years are mostly devoid of vegetation. In some cases this is bare sediment, in others, it is matted dead vegetation.

POND C SITE HYDROLOGIC ZONE MAP


Bare/ sparsely vegetatated- flooded until early to late May
Moist “benches”- seasonally flooded, lush, moist vegetation
Upland zone
Seasonal floodplain- some deep moisture- dry upper soil- drier vegetation
Seasonal floodplain- soil not saturated in May even down to 1.3 m
Unshaded = banks sloping to upland
** see supplemental material for slope profiles

POND C VEGETATION

In the wetland zone:

-there is a lot of bare ground in areas that were flooded in early April and have since dried

-very few wetland species (e.g. Juncus) present

-2 small willows

-Dominated by non-native species (especially grasses) that are often indicative of upland settings

-One of best native performers in low-lying “benches” (in yellow) is Elymus triticoides

In the seasonal floodplains:

-Dominants were similar across 3 broad transects (Avena fatua, Bromus hordeaceous, Convolvulus arvensis, Festuca perenne)

-Common natives include: Elymus triticoides, Lupinus bicolor, Stipa pulchra)

In the riparian zone/ upper areas of seasonal wetlands

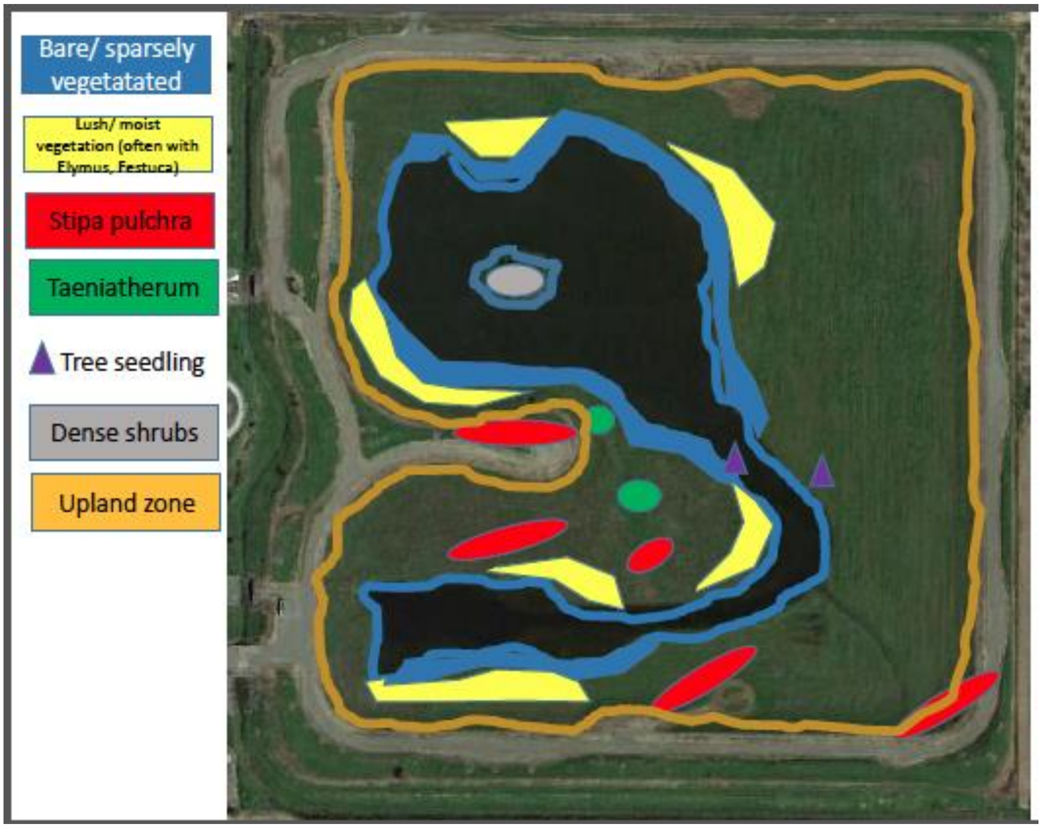
-Mostly non-native grasses (e.g. Avena, Festuca, Bromus diandrus, Hordeum)

-Mustard common bordering the road

-Common natives: Stipa pulchra, Elymus glaucus, Elymus triticoides

-There are particularly good areas of Stipa pulchra on the banks rising from the wetland, and on the low-lying plateau just north of the southern reach of the wetland

Woody species-mostly on island, along ditch/canal just outside of site



POND C WILDLIFE

Birds most obvious/prevalent

Some small mammal activity/ burrowing-especially on slopes and in areas with dense grass

Jackrabbit

No/few herps(just a tadpole)

Bees

Water quality

> -Low Dissolved oxygen (0-4 ppm) is a concern, even for warm water aquatic life, levels shouldn't be below 5. Ideal for most fish is 7-9 (most can't live below 3)
>
> -pH is ideal for most aquatic species (their range 6.5-9)
>
> -PO4 and NO3 are below levels of concern

Birds		Wildlife Indicators	Mammals	Miscellaneous
Canada Goose American Coot Mallard, adult and juvenile Rock Pigeon Semipalmated Plover Brewer's Blackbird Cinnamon Teal Unspecified Gull European Starling Northern Harrier Swainson's Hawk Gadwall Anna's hummingbird European collared dove Great egret Northern mockingbird Hawk sp.	Black-necked Stilt, adult and juvenile Black Phoebe House Finch Red-winged Blackbird Brewer's Blackbird Sparrow, unknown species Barn Swallow American Crow Common Raven Western Kingbird Killdeer Turkey Vultures	Unidentified canine footprint Goose egg Goose scat Goose footprint Unidentified rabbit scat Sparrow scat Animal burrows Animal bones Animal carcass Unidentified egg shells Praying Mantis egg case	Gopher Burrowing small mammals Jack rabbit Voles Ground squirrels	Skimmer Dragonflies Midge (adult and larvae) Cranefly (adult) Unspecified fly Blue-fronted damselfly Unspecified damselflies Unspecified tadpoles Water scavenger beetle Red eared Slider Water boatman Beetle larvae Aquatic worms Aquatic snails Mayflies larvae Bees Lady bug

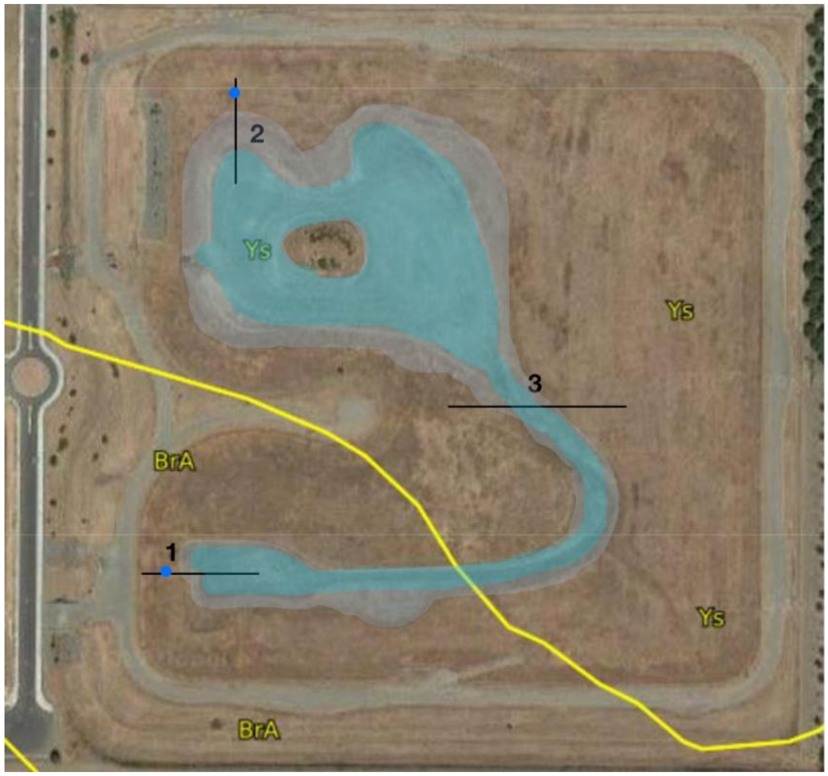
TOPIC-SPECIFIC LAB SUMMARIES

The goal of the laboratory section was to collect all of the 'on the ground' information to create the knowledge base at the Pond C 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, Riparian Slopes, and Seasonal Wetland).

The following group lab reports outline various site characteristics using the current conditions and species composition found at the Centennial Park in Spring 2017. Based on the results of these monitoring projects, these lab reports determine habitat sustainability for various restoration activities.

ENH160L Final Report: Group Written Synthesis: Wetland Hydrology

Zheng Chen, Emily Howard, Kelsey Ray



Map of the transects at the Pond C location with soil designations

Introduction

From March 2017 to May 2017, we, the wetland hydrology group, went to the Pond C project in Dixon to assess the hydrological properties of the site. We set up three transects for measurement the first week. The transects were selected based on three criteria: continuity though ecosystem designations (i.e. upland, riparian, and wetland), proximity to water inlets and outlets, and soil type. We made sure to select at least one transect in each soil type to take into account changes in hydrology due to soil texture variations, then in order to account for spatial variability we selected one transect at each the inlet, the middle, and the outlet. During the three weeks of data collection, we measured the reachable water depth of the wetland, the depth of the water table near the water's edge, the recession of water over time, and the slope of the transects. We want to use the data from our measurements to answer the following questions, which are the goals for our group:

1. Which areas are typically saturated most of the year and which areas have prolonged dry periods?
2. At what depth is the water table located?
3. Does the soil show signs of soil redoximorphic features?

Another general goal for the assessment of hydrology is we hope our data could give managers a general idea about the condition of the wetland. When choosing the candidates for revegetation, understanding the hydrology of the system will lead to better decision making.

Methods

Based on our goals, we took several measurements over the course of three weeks in order to determine the temporal hydrologic variability. The methods we used to measure inundation consisted of a simple observational measurement of the distance from a point at the water's edge to a point which was determined by visual inspection for vegetation matting and drift deposits consistent with wetland inundation. These were measured at maximum distance during week three on each of our transects. (Table 1)

The slope measurement (height change) is done through clinometer measurements, from the edge of the water to the edge of the inundation measurement. For this measurement we used a meter stick at each point then used a clinometer, taking the measurement in degrees. By using trigonometric functions, we calculated the change in height based on the measurement of slope. (Table 1)

The water depth profile was measured by tape measure and meter stick, moving into the water in increments of 0.5 meters. At each point, we measured the depth of water from the bottom of the pond to the surface continuing out into the water as far as it was safe to go. The water recession measurement was taken each week, which consisted of placing a flag at a stationary starting point with measurements to the water edge, showing the extent of water recession as the wetland dried up. (Figure 1)

The depth to the water table is measured using an auger 0.5 meters away from the water's edge along transect 1 and transect 2, we drilled until we reached the water table (where the water begins to pond at the bottom of the hole) and measured how far down it was. (Table 2) Soil redox was observed during drilling, observations included the accumulation of red, black, or gray colors in the soil.

The water recession was measured from a point marked "0" during week 1 to the location of the water's edge at week three. Measurements were taken with a transect tape, measurements for transect 3 may be distorted as a result of the transect being at an angle to the water instead of perpendicular like the other two transects. (Table 3).

Data Summary

<u>Soil Redoximorphic Features</u>

(See soil redox photos in the photos section)

Depth at which redox was obvious enough for observation

- Transect 1: Redox features found at approximately 1 m.
- Transect 2: Redox features at 0.67m

There is a layer of sandy material between clay layers that is potentially due to the construction of the wetland.

Table 1: Inundation Distance and Height

Table 2: Depth to Water Table Change (Slope Calculation)

Inundation Distance and Height Change

Transect	Inundation	Height Change
T1	20.5m	1.184m
T2	22.0m	1.251m
T3	46.9m	1.3m

Distance from water's edge in week 3 to the

Water Table

Transect	Soil Type	Depth
1	Brentwood Clay Loam	2.175m
2	Yolo Silty Clay Loam	1.65m

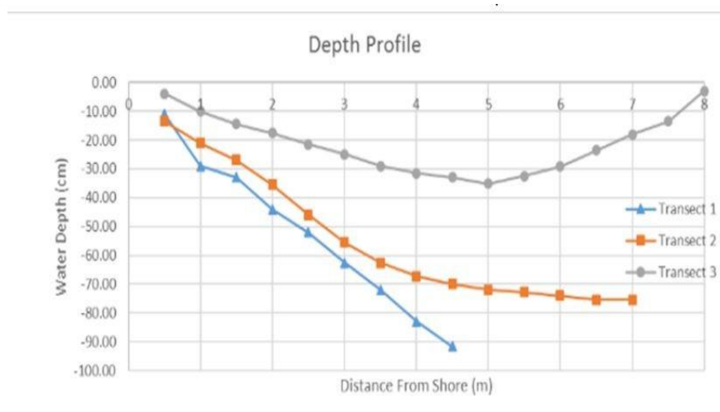
Table 3: Water Recession Profile

Water Recession

	Week 1	Week 2	Week 3
T1	0	n/a	4m
T2	0	2.5m	8.1m
T3*	0	12m	25m

*taken at an angle to continue riparian transect, values may not be entirely representative. How far the water can recede during dry season (at points it can be completely dry)

Figure 1: Water Depth



Results

The site consists of two soil types, Yolo Silty Clay Loam and Brentwood Clay Loam.

Transect 1 sits on Brentwood Clay Loam and transect 2 sits on Yolo Silty Loam. Yolo Silty Clay Loam has a lower water table than Brentwood Clay Loam does. Plus, the redoximorphic features in the soil suggest that even if the water table is low in both soils, there was enough time for saturation in the past for soil to develop the redox features.

The low water tables near the water's edge limit the potential vegetation candidates. If the plant is drought intolerant, a deep root system is necessary for plant survival, especially if the plant is away from the water's edge, where the water table depth could be deeper than measured the water edge. The water recession table, included above, suggests that water retracts fast in just the three weeks of data collection we had.

According to additional information from Dr. Eviner, who visited the site in February, water recession started in February, most likely to do drainage and evaporation. As the storms cease and the temperatures warm approaching summer, the water will begin to retract much faster. This shows that the wetland is ephemeral and meant to be used as a storm drainage basin during the winter, and dry up during the summer.

The change in inundation distance and height change table indicates that during

the flooding event, the water can go as high as 1.3 meters above the current water level and recede just as much. The potential vegetation at different locations along the transects will need to follow the gradient of standing water depth and and depth of water table. Plants near the water's edge need to be able to withstand submerged conditions as well as dry conditions throughout the year, while the plants at the edge of inundation need to be able to extend their roots deep enough to reach the water table.

Figure 2 and 3 are pictures of soil samples we collected during measurement of depth of water table. Both soil samples shows signs of soil redoximorphic feature. In figure 3, the black region should be concentrated Mn^{4+} due to the re-precipitation process after the soil drains. In figure 2, the greyish region (marked by red cycle) is another indication of soil redox. The greyish color is produced by the reduction of Fe^{3+}. Fe^{3+} is insoluble but when it is reduced to Fe^{2+}, the iron will dissolve into water and produce a grey-blueish color. Figure 4 shows signs of past inundation. Due to the nature of the clays in the soil, as saturated soils begin to dry due to water retraction, the soil begins cracking as the adhesion of the water particles becomes weaker and the similar charges of the clays repel each other.

Images

Figure 2 (left): Accumulation of manganese and depletion zone
Figure 3 (right): Accumulation of iron and manganese

Figure 4 (below): Auger hole with soil cracking

Management Considerations

Based on the hydrology, this wetland is ephemeral, with storm surges during the wet season and very dry conditions during the dry season. Our measurements show that the water receded at least 2 meters a week while signs of previous inundation extended into the upland areas. This means that area deemed 'wetland' is subject to saturation, as well as dry periods, in multiple cycles throughout the year. This should be taken into account when deciding on the type of wetland vegetation and their function. The surprisingly deep water table and soil's ability to hold water (based on the redoximorphic features) should also be considered.

Challenges

There was a severe time limitation due to how long it took to reach the water table each week. Since we did not have access to lab tests, we were unable to complete tests such as percolation time, water quality, or analysis of water residence time. With only three weeks of data, we can't determine with any statistical significance whether our data reflects the typical conditions of the area. With more time, we would have liked to conduct more transects along the water to better display the water depth profiles along the entirety of the wetland.

Unresolved Questions

1. Measure hydraulic residence time during the flooding event in order to define mitigation strategies to offset the sudden fluxes of high concentration of contaminants.
2. How quickly does water percolate and how does that affect the hydrology of the site?
3. Water quality considerations should be taken into account in terms of nutrient loading, sediments, and potential urban contaminants in the water

ENH160L Final Report: Group Written Synthesis: Wetland Vegetation

Jillian Hagenston and Rebecca Spranger

INTRO

Questions that guided sampling:

- What is the distribution of major species (native and not) in the area?
  - Where are the patches of natives?
  - Where are the patches of invasives?
  - How much percent cover do the native and invasives take up?
  - What is the frequency of appearance for each species, native and invasive?
- Are there major communities of native species grouped together? In what areas are these communities located?
  - In what areas would it be best to place wetland species for restoration?
  - Based on communities found, which types of species should be placed where?

Our main goals were to assess the populations of species present at the site, including their general distribution and densities, and develop ideas to decrease and further limit the spread of invasives and how to implement plans to increase the populations of native wetland species. Restoration goals should include diminishing invasive species populations and increasing the presence of wetland species that can be sustained year-round; eventually, the vegetative wetland population should include high concentrations of wetland natives within and along the perimeter of the wetland that can out-compete invasives, filter inflow water (increase water quality), and assist in retention of urban runoff water.

METHODS

For sampling, we used a combination of transect and quadrat methods in order to randomly assess the populations of species within a limited time frame. At the designated sites we started terrestrial transects (began where riparian vegetation ended, when overlapping) that lead into the water-- we determined where the wetland ended by stopping where there was no more "mat." The mat is dead vegetation from where the waterline extended the farthest during the season, inundating non-wetland species that couldn't survive the submersion. We placed flags at 3m intervals until the wetland became too difficult to access; we failed to go far into the water after we realized that the water was too murky to accurately identify vegetation and so we have little data recorded from plants in the water-- most data came from after the water receded enough to record, and even then most of the quadrats contained mud and mat. At each flag, we used a 1mX1m quadrat to sample the species, estimating percent cover of each species in each quadrat for a total of 28 quadrats among the 5 transects. We took samples of species we couldn't identify on site for later identification; some of these we were never able to identify.

We decided on the locations of the 5 transects because they appeared to have different slopes and degrees of change between riparian, wetland, and deeper pond depth, giving us a more complete image of species distribution with respect to varying topography and habitat zones. We overlapped the transects with the Riparian Vegetation and the Wetland Hydrology groups so easy comparison could be done when analyzing data for vegetation types and water table depth. The quadrats were chosen at regular intervals along the transect to give an unbiased and accurate view of the species based upon randomized distribution. During the initial sweep, the landscape and diversity of the species within our site appeared uniform, so there was no bias (trying to sample interesting species) in deciding sampling sites; furthermore, among the zones that displayed desired topographical characteristics, we chose the individual transects at random to decrease chances of bias.

DATA SUMMARY

All species identified were recorded and their percent cover estimated. Overall percent of appearance across all quadrats was calculated (for percent covered in all land covered by the quadrat) as well as frequency of appearance (how many quadrats the species appeared in). *Figure 2* shows all species recorded as well as which transects and how many quadrats within those transects they appeared in. Transect A had the highest native plant frequency of eleven separate sightings in the 7 quadrats of that transect. Another interesting find is that *Trifolium* species was found in every transect and seen 5 times in transect A alone.

Figure 3 displays the transects that contained more than four percent native plants. Transects A, B, and C are the areas where the frequency of native plants were high. Transect A was found to have the most native plants with an average of 6.14 percent cover over all the quadrats in that transect. Transect B contained 4.74 percent native plant cover while transect C had 4.13 percent native plant cover. Looking at the site as a whole, it demonstrates that the South half of the field site comprises of more native plants seeing that both transect D and F each had less than 2 percent average native plant cover. (NOTE: If a plant was seen in a quadrat but had less than one percent plant cover, it was used in calculations as if it was 0.5 percent plant cover in order to include it in the calculations)

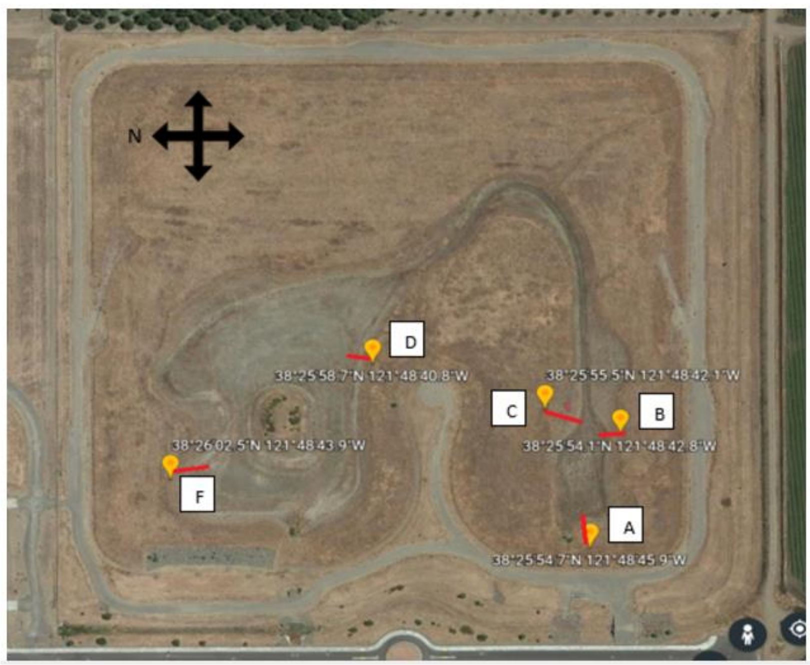


Figure 1: Map of the site including our transect locations.

Transects that overlap with other groups:
A - Wetland Hydrology
B - Riparian Vegetation
C - Riparian Vegetation
D - Riparian Vegetation
F - Riparian Vegetation and Wetland Hydrology

Species	Frequency of Appearance
Unknowns	
unk grass #2	A (1), C (1), D (1), F (2)
unk grass #3 (aquatic)	F (1)
unk bl #4	A (1)
unk bl #6	C (5), D (2), F (2)
unk bl #7	C (1)
unk bl #8	F (1)
unk bl #9	C (1)
unk bl #10	D (1), F (1)
Genera	
Taraxacum sp.	A (4), C (1), D (2), F (2)
Taraxacum sp. (dentate)	A (3)
Taraxacum sp. (soft)	A (1), C (1)
**Trifolium* sp.	A (5), B (1), C (1), D (2), F (1)
**Juncus* sp.	A (1)
Grasses	
Avena fatua	A (1), B (1), C (1), D (1), F (1)
Bromus diandrus	B (1)
Bromus hordeaceus	A (5), B (2), D (2), F (1)
Elymus caput-medusae	D (2)
Elymus triticoides (*)	A (2), B (3), C (2)
Festuca perennis	A (4), B (2), C (2), D (2), F (2)
Hordeum murinum	A (2), B (3), C (3), D (2), F (2)
Broadleaves	
Achyrachaena mollis (*)	C (2)
Convolvulus arvensis	A (2), B (2), C (1), D (1), F (2)
Conyza Canadensis (*)	A (3), B (1), C (1)
Geranium dissectum	D (1), F (2)
Potamogeton illinoensis (*)	F (1)
Rumex crispus	D (1)
Vicia sativa	F (1)
Misc.	
algae (dead)	D (1)
mat/dead	A (6), B (4), C (6), D (4), F (4)
bare/mud	A (2), B (2), C (7), D (2), F (4)

** = most spp. in genus native
* = native
Underlined = wetland species

Transect letter	Number of quadrats
A	7
B	4
C	8
D	4
F	5

Figure 2

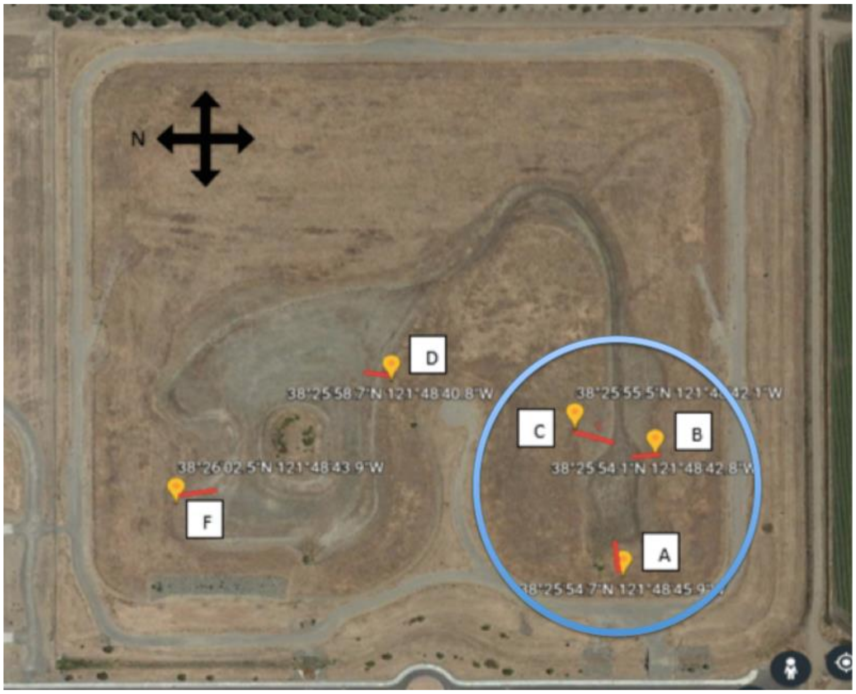


Figure 3. Map of where a majority of the native plants on the site were found during data sampling.

RESULTS

Distribution: All natives (except *Potamogeton illinoensis* found in F) found in southern region (transects A, B, and C), indicating a stronger presence of native species in the "lower" half of the wetland. Only 4 native species and 2 genera containing many natives were found of the 27 different species. Though too far out to record, we spotted some strands of *Juncus* (native) in the deeper depths off of transect D. Many of the native species were found in numerous quadrats; however, overall they had some of the smallest percent coverages**, indicating a moderate distribution of individuals but in too small populations to compete with the invasives; there were no clumped groups of natives, but rather the only natives found were interspersed in small quantities among the invasives.** Invasives were found throughout the area, more so upland on drier slopes, none were found alive in water (mostly dead or bare land in the heart of the wetland slopes). Invasives/non-natives far outnumbered the natives in area covered, frequency of appearance, and diversity; the only area where invasives weren't dominant were the bare zones that surrounded the water's edge, which was dominantly bare earth. The only zones that were consistent throughout the transects was the abrupt transition from the grassland-like invasive-dominated zone to the mostly-bare zone that was recently flooded and up to the water's edge. Invasives were found throughout the area, more so upland on drier slopes, none were found alive in water (mostly dead or bare land in the heart of the wetland slopes). Invasives/non-natives far outnumbered the natives in area covered, frequency of appearance, and diversity. Overall, there were 6 natives, 13 invasives/non-natives, 8 unidentified; 2 of these were wetland species. The highest percent coverage of vegetation were the invasive plants of the genera *Fetsuca*, *Bromus*, and *Hordium*; these were also among the most frequent in appearance, though *Trifolium*, a genus with many natives in it, was third highest in frequency of appearance.

Communities: Most species communities found together were large swaths of invasive grasses. Groups of natives were few, most being solitary and surrounded by invasives or thinly spread out among many quadrats; there were no large patches of natives found within our sample sites.

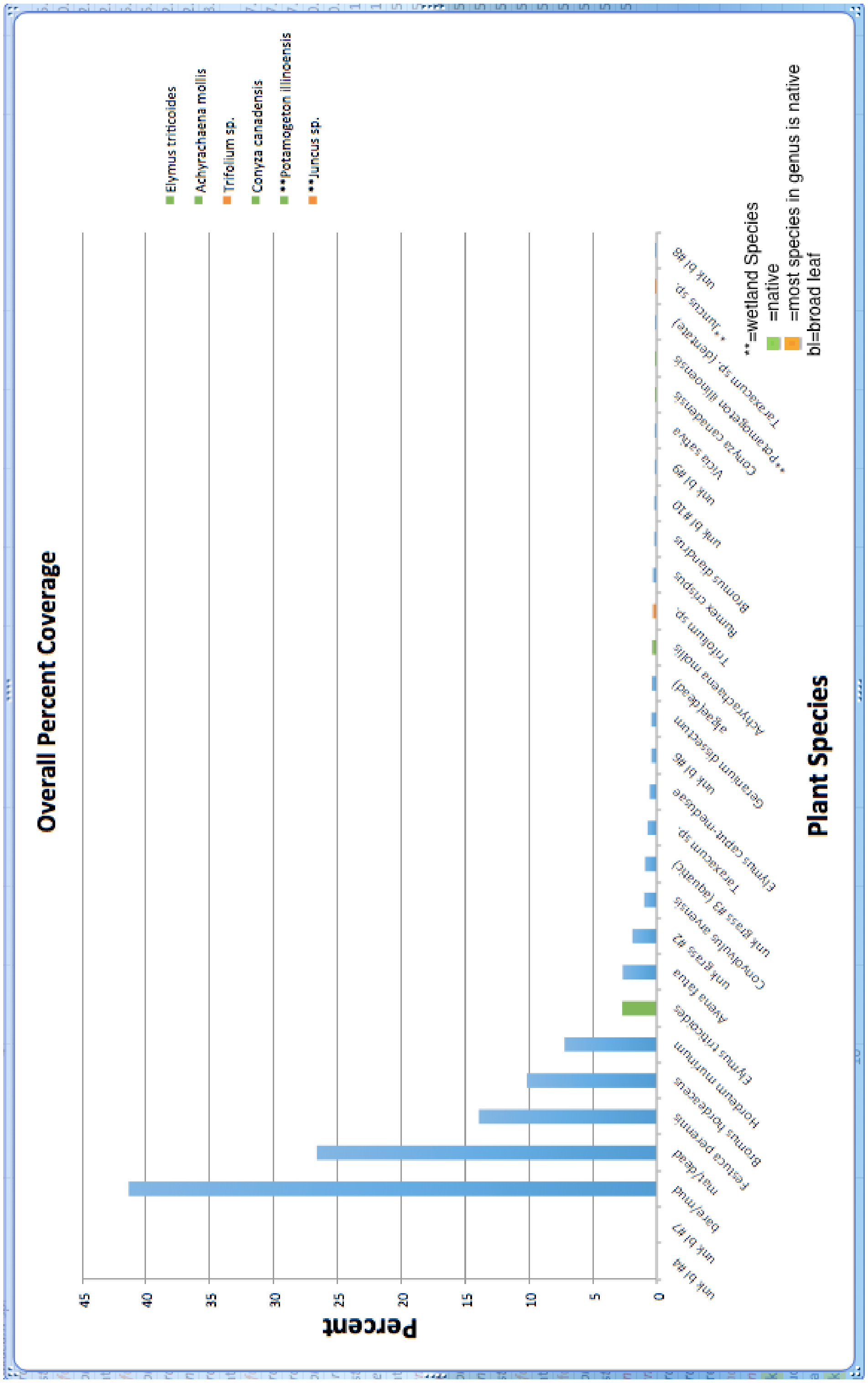


Figure 4: Overall percent cover of plant species, calculated by taking the sum of the total percent cover in all quadrats used to sample (i.e. what percent it appeared out of the total percent of land sampled by the quadrats).

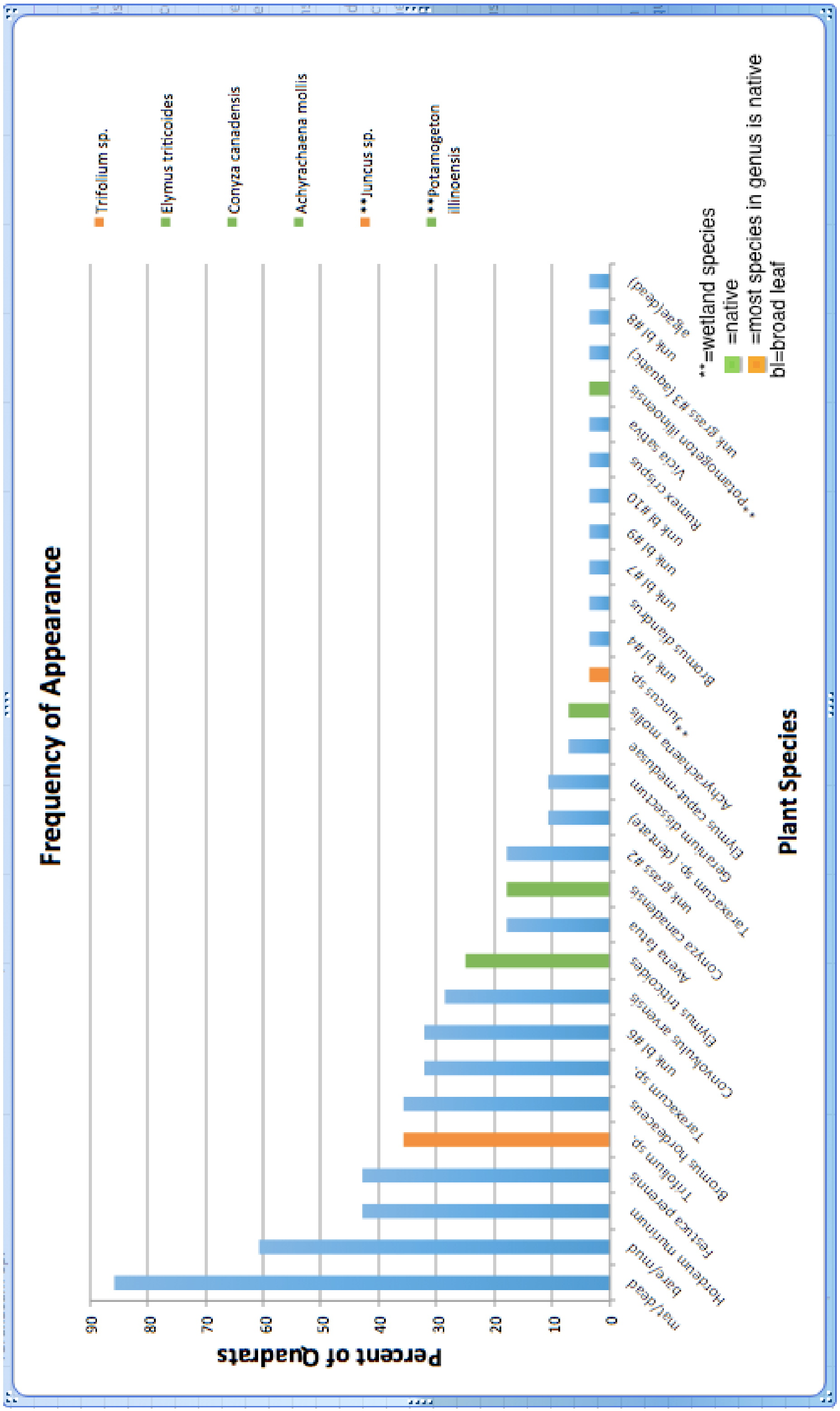


Figure 5: Frequency of appearance of species, calculated on number of quadrats out of the total that the species was seen.

Transect	Natives and average % cover per transect	Major invasives (>15% cover on average per quadrat)

A	*Trifolium* spp. 0.43% *Elymus triticoides* 5% *Conyza canadensis* 0.43% Juncus 0.29%	*Bromus hordeaceus* 21.14%
B	*Conyza canadensis* 0.13% *Trifolium* spp. 0.13% *Elymus triticoides* 4.5%	*Bromus hordeaceus* 16.25% *Hordeum murinum* 17.5%
C	*Conyza canadensis* 0.13% *Trifolium* spp. 0.13% *Elymus triticoides* 2.75% *Achyrachaena mollis* 1.13%	
D	*Trifolium* spp. 1.25%	*Bromus hordeaceus* 17.5% *Festuca perennis* 18.75%
F	*Trifolium* spp. 0.2% *Potamogeton illinoensis* 0.6%	*Festuca perennis* 26%

Table 1: Key species coverage using average percent cover in a transect. NOTE: If a plant was seen in a quadrat but had less than one percent plant cover, it was used in calculations as if it was 0.5 percent plant cover in order to include it in the calculations

CHALLENGES

Several challenges presented themselves. First, it was difficult to distinguish wetland zones from riparian zones, especially with the nearly homogenous distribution of weeds and lack of wetland plants. It was also difficult sampling within the water of the wetland habitat due to its murkiness; we had to wait until the water level receded enough to expose deeper into the wetland to sample (mostly bare and dead plants). Identifying species, especially small ones that weren't flowering, proved difficult and some were never identifiable.

SUMMARY AND RECOMMENDATIONS

- Very few wetland species were found (*Juncus* spp. and *Potamogeton illinoensis*, which are both natives), the rest were either grassland or riparian, majority of which being invasive grases.
    - This means that more effort will be needed to create the wetland habitat desired as there aren't strong native populations to start with.
- The first step should be removing the invasives on a large scale with the use of fire (there are few natives to preserve) and herbicide (wetland-suitable herbicides).
    - Since the only natives found were either individuals or very small clumps interspersed throughout the natives on-land, it is not worthwhile to try and preserve them.
    - The group of native *Juncus* off of transect D should be preserved, along with other spotted wetland species deeper in the pond.
- After the invasive populations have been reduced, planting of natives should occur.
- Surface water levels receded severely during the sampling period, so wetland species should be placed deeper in the basin to avoid water stress (lack of water) as much as possible, or utilize wetland species that can survive abnormally long seasons of drought.
- Most bare areas were at the water's edge where previous inundation had killed most plants; this would be a great location to start restoration with wetland species as there is little to no competition.
    - Perennial native grasses that can survive seasonal inundation should be placed near the water's edge and allowed to expand out for better competition with remaining invasive grasses.

- Due to being unable to identify several of the species we found, the results aren't fully accurate, but most unidentified species comprised a small percentage of cover so the impact is not significant.

Unanswered questions:

- Are the population distributions seen here the same year-round? If not, are there times when invasives are out-competed by natives?
- Deeper into the water, are there more wetland natives that could not be seen/accessed during our sampling period, such as the *Juncus* stands?
- Since there is not standing water year-round is it possible for wetland plant species to survive in this habitat?

ENH160L   Final Report: Group Written Synthesis: Wetland Wildlife

Lauren Bottoms, Misti Marsh, Raymond Niem

Guiding Questions:

- What wildlife and bird species are present within the wetland?
- What types of wildlife can the area support?
- What lower trophic level consumers, like aquatic invertebrates, are present?
- Are mosquito larvae present? Are mosquito larvae predators present?
- Are the water quality parameters within the range that can support diverse aquatic invertebrate community?

Methods:

We determined the location for sites based on the physical characteristics of the wetland. We chose 5 sites within the wetland. At each site we completed a point count bird survey, and a 50 meter transect that was parallel to the water's edge which we used to look for wildlife and wildlife indicators.

An invertebrate study was done at Site 3 and Site 5.The sample was taken at a depth of approximately 0.5 m using a 500-micron D-Net with a sweeping method to cover one square meter. We completed three sweeps next to each other that are all 1 meter in length. To avoid collecting a large amount of sediment we used an undulating sweep and elutriated the sample. All invertebrates that were captured were counted, identified, and recorded. Identification was limited to order or family. We did not intentionally kill any organisms and returned them to the place of their capture in a timely manner.

Water quality testing, using a Low-Cost LaMotte Water Monitoring kit, was done at Site 1, Site 2, and Site 4. Each site was sampled one time. Water was collected using a collection bottle that was placed under water horizontally at a depth of 10 cm. The cap was removed. After bottle was full the cap was replaced and then the bottle was removed from the water.

We also completed two broad "Sample within Zone" surveys in which we walked the perimeter of the wetland and recorded any wildlife or signs of wildlife we observed.

At each site, we completed a bird point count. We did each point count for a total of 15 minutes. Every effort was made to ensure that each bird in our sample area was counted either by visual or song identification and that each bird was not double counted. Any birds that were not seen within the 15 minutes were included into the broad "Sample with Zone" surveys. If any birds were not easily identifiable, we referenced a birding field guide for aid in identifying the species.

Results:

<table>
<tr><td colspan="3">Sample Within Zone Results:</td></tr>
<tr><td>4/17/17</td><td></td><td>5/8/17</td></tr>
<tr><td>Argia apicalis male Blue-fronted damselfly
Unspecified damselflies
Unspecified tadpoles
Hydrophilidae - Water scavenger beetle
Tyrannus verticalis - Western Kingbird
Circus cyaneus - Northern Harrier Buteo swainsoni - Swainson's Hawk Cathartes aura - Turkey Vultures Charadrius vociferus - Killdeer
Agelaius phoeniceus - Red-winged blackbirds
Branta Canadensis - Canada Goose
Goose Egg
Fulica americana - American Coot Anas platyrhynchos - Mallard Himantopus mexicanus - Black-necked Stilt
Unspecified fly
Midge (adult)
Tipulidae - Cranefly (adult)
Libellulidae - Skimmer Dragonflies
Charadrius semipalmatus - Semipalmated Plover

</td><td></td><td>Libellulidae - Skimmer Dragonflies Unspecified Damselflies
Small unidentified fish (possibly Hesperoleucus symmetricus)
Himantopus mexicanus - Black-necked Stilt with two offspring
Branta Canadensis - Canada Geese
Charadrius vociferus - Killdeer
Agelaius phoeniceus - Red-winged blackbirds
Passer domesticus - House sparrow
Ardea alba - Great egret Unspecified warbler
Hirundo rustica - Barn swallow Carpodacus mexicanus - House finch Corvus brachyrhynchos – American Crow Mimus polyglottos - Northern mockingbird
Trachemys scripta elegans - Red-eared slider
Unspecified canine tracks
Unidentified grasshopper or katydid
Fish bones near shore
3 unidentified eggshells
2 resembled a black-necked stilt eggs in size and appearance
1 resembled a mallard egg in size and appearance
1 egg approximately 2 cm in length
Praying Mantis egg case
Unknown tadpoles (approximately 1” in length)</td></tr>
</table>

Water Quality Testing Results:			
Date:	4/24/17	4/24/17	5/8/17
Location:	Site 1	Site 2	Site 4
Dissolved Oxygen:	>0 ppm but <4 ppm	>0 ppm but <4 ppm	>0 ppm but <4 ppm
Phosphate:	<2ppm	<1ppm	2ppm
Nitrate:	<5ppm	<5ppm	5ppm
pH:	8-9	8-9	8-9
Water Temp:	26 Celsius	26 Celsius	28 Celsius
Overall Water Quality Rating: Fair-Poor			

Aquatic Invertebrate Collection Results:		
Date: 05/01/17		**Date**: 05/08/17
Location: Site 3		**Location**: Site 5, Southeast side of site
16 Hemiptera Corixidae (Water Boatman)		33 Hemiptera Corixidae (Water Boatman)
7 Annelida (aquatic worm)		19 Diptera Chironomidae (non-biting midges)
11 Gastropoda (lunged snails)		5 Coleoptera (beetle larvae possibly Dytiscidae)
5 Diptera Chironomidae (non-biting midges)		12 Ephemeroptera Baetidae (Mayflies)
1 Coleoptera (beetle larvae possibly Dytiscidae)		

Wildlife Indicators:

Site 1		
Day: April 24, 2017	Time: 15:05	Temperature: 65℉
Wildlife Indicators	**Appearance**	**Location away from Transect (in meters)**
Canada Geese scat	Multiple dried white and green scat, size 3-6 cm (12).	5-6M
Unidentified Bird scat	Multiple white scat splatters approximately .5-1 cm in length (6) on rocks and near tunnel.	25M
Sparrow scat	Multiple small white scat .5-1 cm in length (9).	20M
Unidentified canine footprints	Trail of canine tracks walking westward for 1 meter. 3-4cm in length.	19M
Unidentified rabbit scat	Multiple small, light brown rounded scat (4).	19M

Site 2		
Day: April 24, 2017	Time: 15:59	Temperature: 65℉
Wildlife Indicators	**Appearance**	**Location away from Transect (in meters)**
Unidentified rabbit scat	Multiple small, light brown, rounded scat (12).	3M
Sparrow scat	Multiple white and black scat splatters approximately .5-1 cm in length (5).	3M
Canada Geese footprint	Many Canada geese footprints 5-7 cm in length, walking toward and away from water.	4-5M
Insect burrow	Multiple small, .5 cm diameter burrows along water's edge.	0-25M

Unidentified bird tracks	Smaller bird tracks, roughly 2 cm inch in length, gathered around water edge.	12M

Site 3		
Day: May 1, 2017	Time: 14:59	Temperature: 87℉
Wildlife Indicators	**Appearance**	**Location away from Transect (in meters)**
Canada goose scat	Dried, white scat 3-6 cm in length.	1M
Canada goose scat	Dried, white and green scat 5 cm in length.	23M
Sparrow scat	Multiple small, white and black scat .5-1 cm in length (6)	25M
Unidentified canine print	2 canine foot prints walking along water's edge. 3-4 cm in length	10-11M

Site 4		
Day: May 1, 2017	Time: 15:53	Temperature: 87℉
Wildlife Indicators	**Appearance**	**Location away from Transect (in meters)**
Canada Geese scat	Multiple Canada geese scat having a mix of dry and wet. (9) Green and white colored. 3-6 cm in length.	13M
Unidentified bird carcass	Small grey feathered bird with webbed feet.	4M
Sparrow footprints	Multiple small footprints 2-3 cm in length, walking around water's edge.	13M
Sparrow scat	Multiple white and black scat (6). .5-1 cm length.	25M

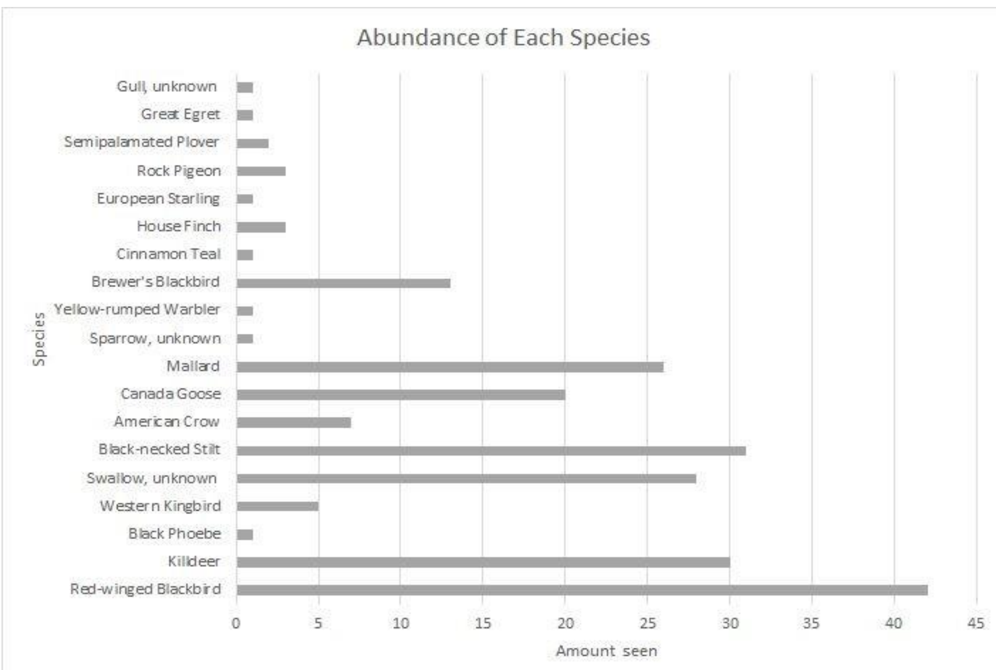
Canada Geese footprint	Multiple footprints 5-7 cm in length around water’s edge.	13M
Unidentified canine print	Canine foot prints walking along water's edge fo 1M. 3-4 cm in length	13-25M
Unidentified animal burrow	Small burrow with roughly 5 cm length opening.	5M

Site 5		
Day: May 8, 2017	Time: 14:50	Temperature: 84℉
Wildlife Indicators	**Appearance**	**Location away from Transect (in meters)**
Larger unidentified canine track	Canine tracks walking along the water's edge roughly 4-5 cm in length. Appears with another canine track.	0-10M
Smaller unidentified canine track	Canine tracks walking along water’s edge roughly 3-4 cm in length. Appears with another canine track.	0-10M
Praying mantis egg sack	Long 1-2 cm egg sack with brownish color and ridges on sack.	5M
Unidentified bird feathers	Small white ruffles.	24M
Unidentified animal bones	Multiple small, skinny white bones cleaned from flesh.	14M
Sparrow scat	Multiple small white and black scat with .5-1 cm length (25).	1-10M
Baby black neck stilt baby	Unattended baby black neck stilt.	7M

Bird Species Present:

- American Crow
- Black-necked Stilt, adult and juvenile

- Black Phoebe
  - Brewer's Blackbird
  - Canada Goose
  - Cinnamon Teal
  - European Starling
  - Great Egret
  - Gull, unknown species
  - House Finch
  - Killdeer
  - Mallard, adult and juvenile
  - Red-winged Blackbird
  - Rock Pigeon
  - Semipalmated Plover
  - Sparrow, unknown species
  - Swallow, unknown species
  - Western Kingbird



Challenges:

Although we were able to survey many different species, there were some constraints that limited us. One of the limitations that we faced was the timing of when we surveyed the sites. Typically we arrived at each site at around 3-4 pm, which was usually the hottest time of the day. Since the timing was so disadvantageous, we may have missed species that are present at the site or there may have been a higher abundance of species.

Another limitation that occurred was that there was a time constraint. We had a limited amount of time that we were able to spend on each site in a given day and were only able to visit the site 3 times for data collection. Had we been given more time, we would have most likely seen more wildlife. Another limitation that we faced was that it was visually difficult to many of the wildlife and indicators. Many of the birds were at a far distance away from us and made it difficult for us to identify what species they were. It was also difficult to see indicators as many of them were small or blended into the environment.

Conclusions:

The aquatic invertebrate study revealed that there were some invertebrates present that are somewhat tolerant to stressors, but overall most the organisms were very tolerant to stressors such as poor water quality. This assemblage of invertebrates is indicative of poor water quality.

Water quality results support this conclusion and revealed that the dissolved oxygen is lower than it needs to be to support a diverse invertebrate community. To increase diversity of aquatic invertebrate and fish community, dissolved oxygen levels will need to increase.

Although water quality was poor, the sample within zone broad survey indicated that a variety of birds and invertebrates are present along with some reptiles, amphibians, mammals, and fish.

The greatest diversity we saw at the site was in the bird species present, which may be a good indicator of the sites ability to support wildlife.

ENH160L Final Report: Group Written Synthesis: Riparian Hydrology

Brittany Krone, Elissa Chapkin, and Cricket Swanson

Key Questions:

1. What is the proximity of the transects from the inlet and outlet?
2. What is the water depth from the surface?
3. Where are the saturation zones?
4. Where are the swales and how does the hydrology differ in these locations?
5. Which areas show signs of inundation?

Methods:

Three sites were sampled. The first transect is just south of the outlet on the southwest corner of the site (DW01). The total transect length is 14.5 meters and this zone is on Brentwood Clay Loam Soil. This area was chosen because it will likely be dry when there have not been continuous rainy days. The next transect is west of the curve in the central area of the wetland (DW02). This transect is on the Yolo Silty Clay Loam soil and the transect representing riparian is 15 meters long. The third transect is on the northwest corner near the inlet (DW03). We measured this transect because we suspected that the zone it is in would have more available water due to urban runoff throughout the year. This transect is on the Yolo Silty Clay Loam soil and the transect representing riparian is 43 meters long (see Figure 1). These sites include the slopes above the wetland flood area where riparian plants would be planted for restoration. In addition to slope and length of the transect, we also measured the distance from the beginning of the transect to the water's edge as well as the distance from the transect to the inlet and outlet (see Table 1).

- Proximity of transects from the inlet and outlet was measured in meters with transect tape, using google maps, or noted as greater than 100 meters.
- Transect tape was also used to measure the distance of the transect from the water, starting from the first flag of the transect closest to the water.
- Swales were determined using the slope of the transect, which was measured with a site level and telescoping measuring rod.
- Inundation areas and saturation zones were determined based on observations of obvious matted vegetation and swales.

Results:

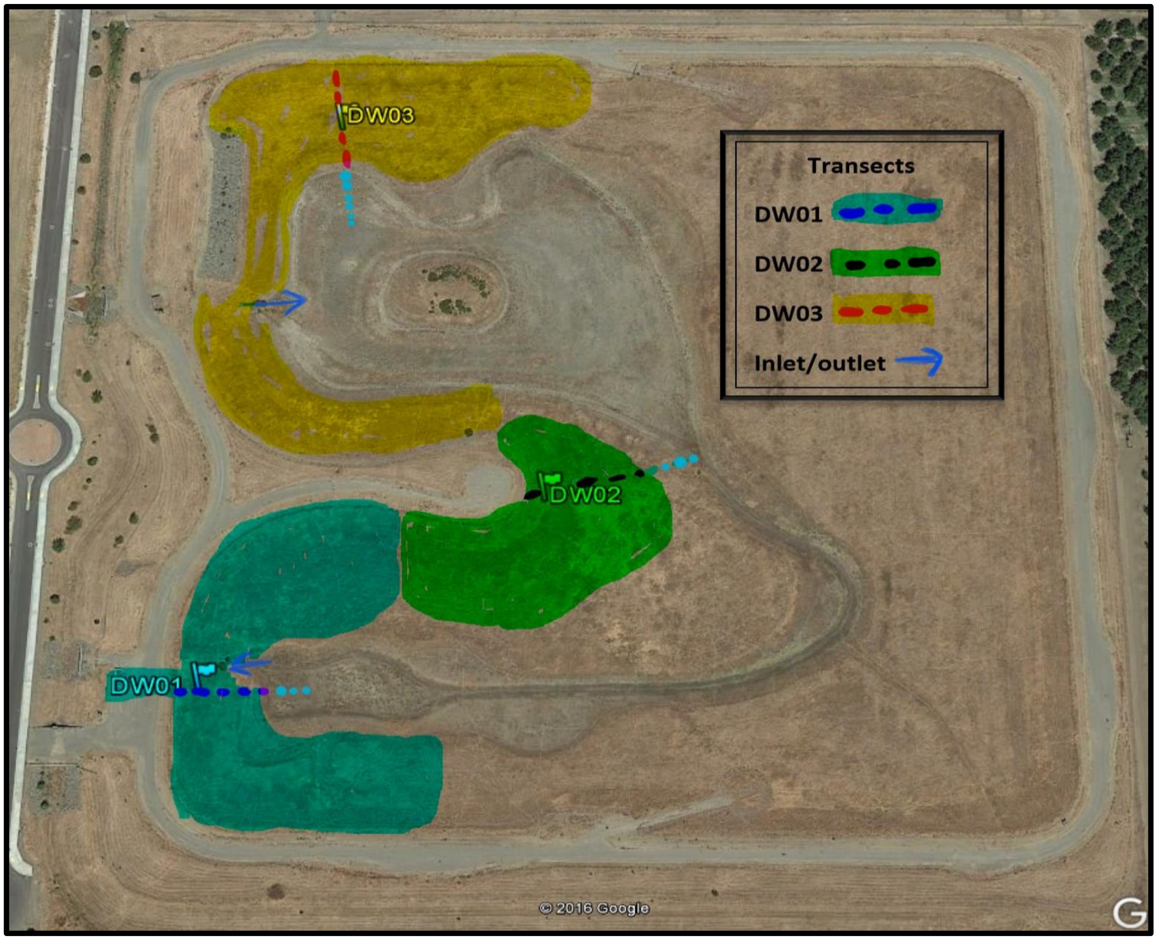

DW03
Transects
DW01
DW02
DW03
Inlet/outlet
DW02
DW01
© 2016 Google

Figure 1. Areas of transects highlighted to show similar zones.

Site ID	Length of transect (m)	Distance of first point to water's edge (m)	Distance of first point to inlet (m)	Distance of first point to outlet (m)	Water depth from surface (m)	Inundation Notes (Observed on 5/8/17). Observations begin at first point of the transect, nearest the water's edge.
DW01	14.5	14.83 (4/24/17)	>100	13	2.17 (Wetland)	Matted vegetation and cracked soil (first 2.0 meters of transect)
DW02	15.0	41.00 (5/1/17)	>100	>100	-	Matted vegetation and cracked soil (first 4.0 meters of transect)
DW03	43.0	9.00 (5/1/17)	88.3	>100	1.65 (Wetland)	Matted vegetation (first 12.5 meters of transect)

Table 1.

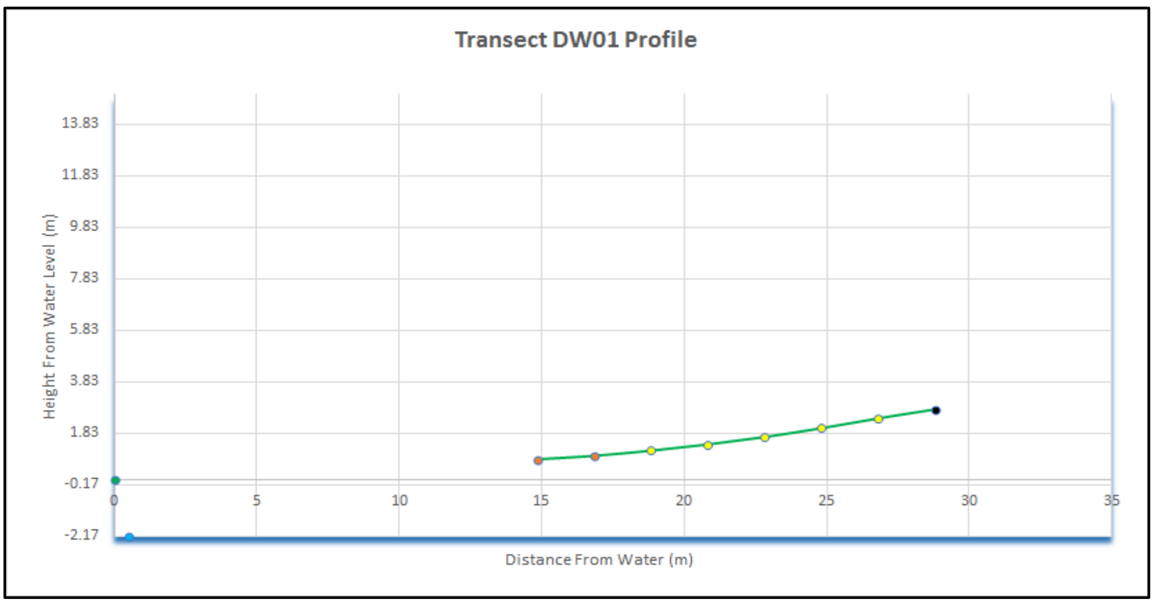


Figure 2. The water table (blue line), measured near the waterline, is 2.17 meters deep. The riparian profile begins 15 meters from the waterline on 4/24/17. The total transect length is 14.5 meters. The total rise within the transect is 1.96 meters and was 2.76 meters from the waterline. Yellow dots represent flags, orange dots represent flags within inundation zone, and the black dot represents the fence at the top of the transect.

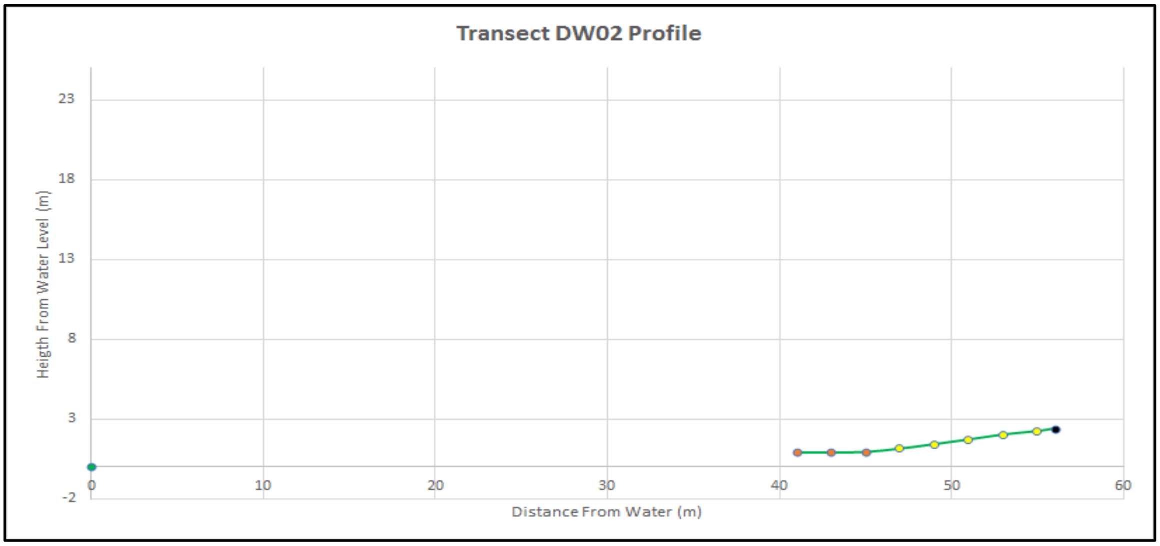


Figure 3. The waterline is 41 meters from the first point on 5/1/17. The total transect length is 15 meters. The total rise within the transect is 1.47 meters and from the waterline was 2.38 meters. Yellow dots represent flags, orange dots represent flags within inundation zone, and the black dot represents the fence at the top of the transect.

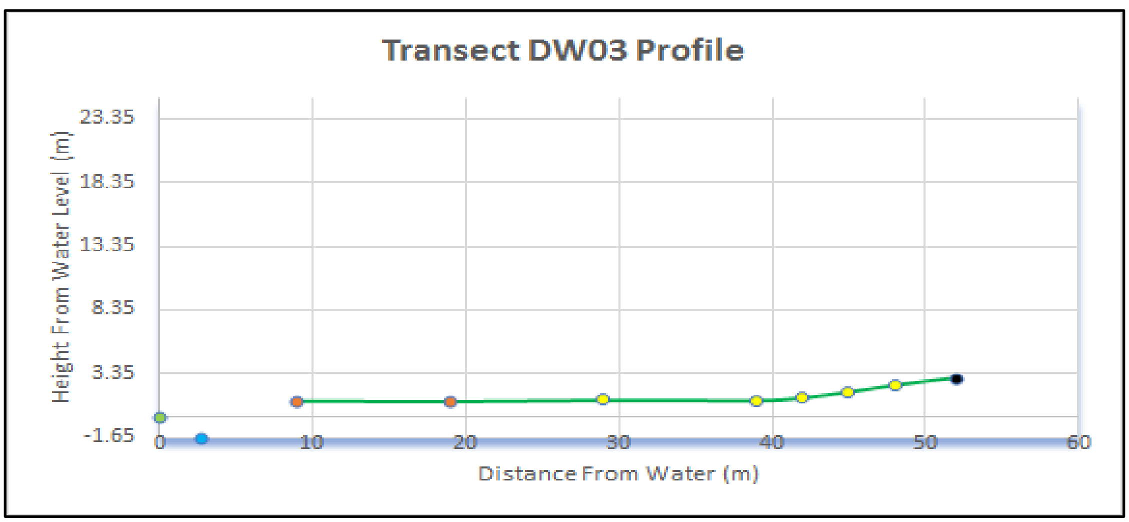


Figure 4. The water table (blue line), measured 3 meters from the waterline, is 2.07 meters deep. The riparian profile begins 9 meters from the waterline on 5/1/17. The total transect length is 43 meters. The total rise within the transect was 1.8 meters and from the waterline was 3 meters. Yellow dots represent flags, orange dots represent flags within inundation zone, and the black dot represents the fence at the top of the transect.

Summary of Findings:

The water table depth may be deeper than a typical wetland area because the wetland we studied is manmade. Given the depth of the water table near the water surface (~2 meters), we believe the hydrology to be that of a surface water depression wetland (see Figure 5). Based on this and the depth at which the water table was measured in the wetland area, we recommend plant species that have an ability to reach a water table deeper than 2 meters and those that are capable of enduring periods of inundation as well as drought. The slope was at most 0.19 (a rise of 0.38 meters over 2 meters), suggesting slope should not be an issue for plantings. Signs of inundation were greatest near the first two points of each transect and at the toe of each slope. Species more tolerant of periodic inundation should be selected for these areas.

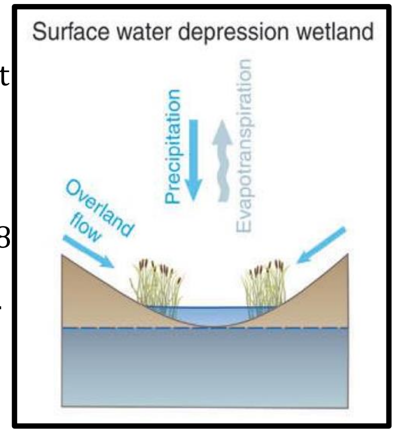


Figure 5.

Challenges/Revisions/Unresolved Questions:

When reviewing our data and the methods we used to measure them, we found a few things that could be further explored at the site. The depth of the water table is unknown along the transects due to the depths at which it is was found along the water's edge (1.6-2.1 meters) and the limited measuring depth of the available tools (8 feet). Knowing the water table depth in the riparian zone would allow for better species selection in the higher and drier areas of the site. Additionally, as a revision, we noted signs of inundation on the last day of sampling only when we could have noted these signs and distance from the water to the beginning of all three transects on each day of sampling to show how much and how fast the water and vegetation cover changed.

<u>ENH160L Final Report: Group Written Synthesis: Riparian Vegetation</u>

Compiled by: Emily Morgan, Mick Tiago Van Eck Dos Santos, Drew Wolter

Core Research Goals:

1. Survey species currently present at the site
2. Understand the relative species composition across the landscape
3. Recognize hotspots in landscape for key native and or invasive species

Methods and Materials:

<u>Data Collection</u>: To measure plant diversity/richness and percent coverage of invasive/native species, we used the transect-quadrat method. We first determined 4 representative transects at the site using flags. Along each transect, moving from the bottom (wetland zone) to the top (upland zone), we sampled 5 different points using a 1m2 quadrat. In total, we measured 18 quadrat samples and identified a total of 18 plant species. Photo monitoring was used to document the progression of site phenology and assess how the changes could influence data collection and results.

<u>Equipment</u>: 1 m2 quadrat subdivided into 25 squares; Smartphone for photographic monitoring; GPS Unit; Stringline and Stakes; Transect tapes; Flags (multiple colors for invasives and various relec natives from past); Plant Identification books; Sharpees.

<u>Calculations</u>: To present an overview of the present plant community, we used the Simpson's Index (SI) for calculations. This is a measure of diversity which considers the number of species present, as well as the relative abundance of each species.

<u>Transect Locations:</u>

Figure 1 Transect locations (starts counter clockwise from bottom right)

Challenges

We had to amend our original sampling plan and measure less quadrats (about half of the intended) due to time constraints. As shown in the photo monitoring, many of the grasses senescence during the 3 weeks of sampling and their changes in phenology made it difficult to make percent cover, percent thatch, and relative abundance to remain constant across all three data collection days.

Data and Results:

Species Present (natives bolded): *Avena sativa, Geranium dissectum, Vicia villosa Medicago polymorpha, Convolvulus arvensis,* ***Lupinus spp.****, Tragopogon porrifolius, Hordeum jubatum, Ambrosia psilostachya, Erigeron canadensis,* ***Nassella pulchra****, Bromus diandrus,* ***Elmus Glaucus,*** *Achyrachaena mollis, Lolium rigidum, Hordeum murinum, Brassica raphanus, Lactuca serriola*

Quadrat Data:

Figure 2 Illustrating the varying diversity that is found per quadrat in each transect

Species with highest relative abundance per transect:

Transect 1: *Avena sativa, Lolium multiflorum*

Transect 2: *Avena sativa, Lolium multiflorum,* (satellite population: *Hordeum jubatum*)

Transect 3: *Avena sativa, Lolium multiflorum* and *Lolium rigidum*

Transect 4: *Avena sativa, Bromus diandrus, Lolium rigidum*

As seem in figure 3 below, the community at the time of observation was composed of **94%** annual invasive grass species. The data gathered is not representative of what may be found during this sites summer community. For example, winter grasses such as the Avena and Lolium found, were starting to senesce through the course of three-week observation period. While summer grasses such as the Hordeum, along with Convolvulus a competitive broadleaf, were both found at the early stages of vegetative growth.

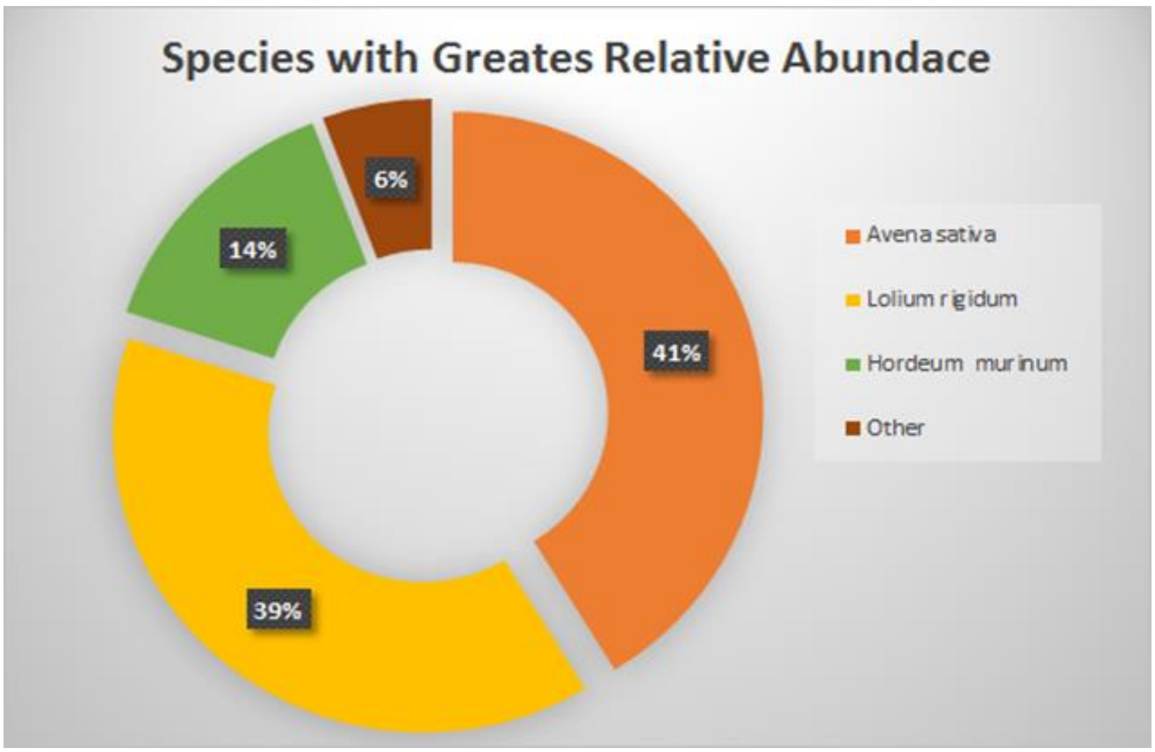


Figure 3 Community Composition per Relative Abundance

Photo Monitoring:

Figure 4 Captures the phenological progression during the three-week observation period (Trans 2).

Summary/Conclusions

From the data retrieved it was clear that invasive species dominated the site. Not with standing, 3 native species were identified throughout our transects (with no more than 10 individuals per transect), while other could be present on different locations where no samples were taken.

Due to the severity to the invasion of non-natives, surveying or ecological monitoring should include the direct objective of identifying persistent populations, sprouting seedlings and key indicators of ecosystem community composition shifts to evaluate the success of restoration goal and management plan chosen.

ENH160L Final Report: Group Written Synthesis: Riparian Wildlife

Anna Britzman, Chrisitne Russo

Guiding Questions:

- Which areas can support which types of animals?
- Where are hotspots on the landscape for key native or invasive animals of interest?

Equipment:

- Flagging tape, Transect tape and pins (for marking transects), GPS (for locating transects), binoculars (for viewing wildlife), Clipboard, data sheets, pencil. Compass, Watch, Guidebooks (for recognizing species), Set of aerial photos/maps

General Information

· We sampled at non-ideal times of the day, given that wildlife is most active in the early morning when temperatures are cooler and there is less human disturbance. Therefore, the species recorded may not represent the full diversity present on the site. The approach we used was a broad, systematic sampling of the site noting sightings and indicators of wildlife.

Methods:

11 Transects were monitored

- Each transect was 20m in length, starting at the top of the riparian slope, then heading down towards the water. We used flagging tape (labeled with the group name and waypoint number on the GPS) and marked gps points at the starting point(0m) and ending point (20m) of each transect.
- Each transect was observed one time over a 10 minute intervals.
- Since there were two people collecting data, one person monitored site range(mostly birds and mammals), while the other monitored transect range(mostly insects). Further description below.

Site Range Survey Protocol (mostly birds and mammals)

· Point Count Method and Opportunistic Sightings of Birds and Mammals

o At each transect, the observation point chosen was at the highest elevation of the transect, where the 0m tape is placed. There was one observation point at each transect due to the short distance of the transects, and therefore similar siting perspectives along a transect.

o For 10 minutes, the observer noted the identity and position of each bird/mammal species seen or heard. Since there is only one observer, this reduced the chance of recording the same individual bird twice.

o   The observer records their name, date, weather, waypoint number, start time, finish time, bird/mammal species name, number of birds/mammals observed, method of observation (sight or sound), and location of animal (as described below) on the data sheet
o   The distance from the point of data collection (where data was collected), to where the bird was sighted was recorded; we recorded the distance in ranges, 0-15m, 15-30m, and 30-50m.
o   Birds/mammals seen or heard over outside of the allotted 10 minute intervals were recorded as "opportunistic bird sightings", and are noted as such in the data sheet.

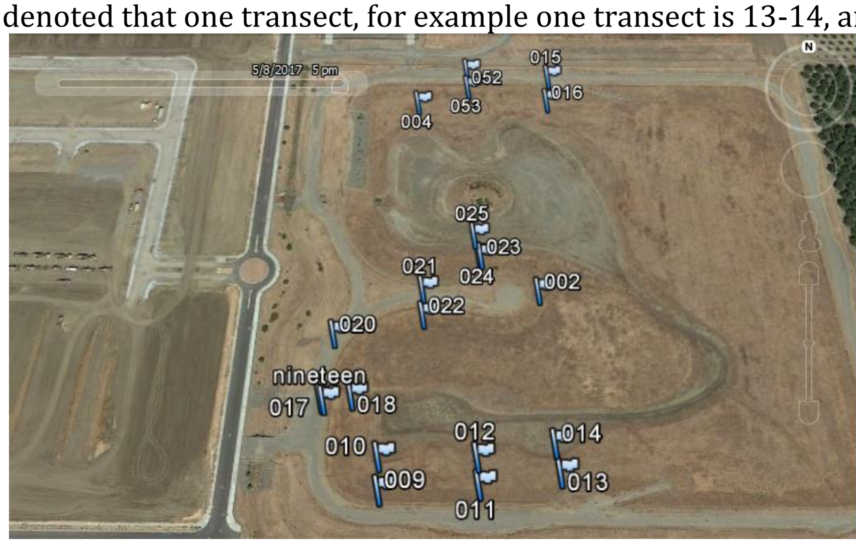
Transect Range Protocol (mostly insects)

·   For 10 minutes at each transect, one team member observed the signs of wildlife and present wildlife along the 20 meters of the transect, we also observed within 15cm of each side of the measuring tape for signs of wildlife. The observer slowly walked along the length of the transect and recorded all organisms seen; they moved grass and dense vegetation aside to avoid bias against critters in the understory close to the ground

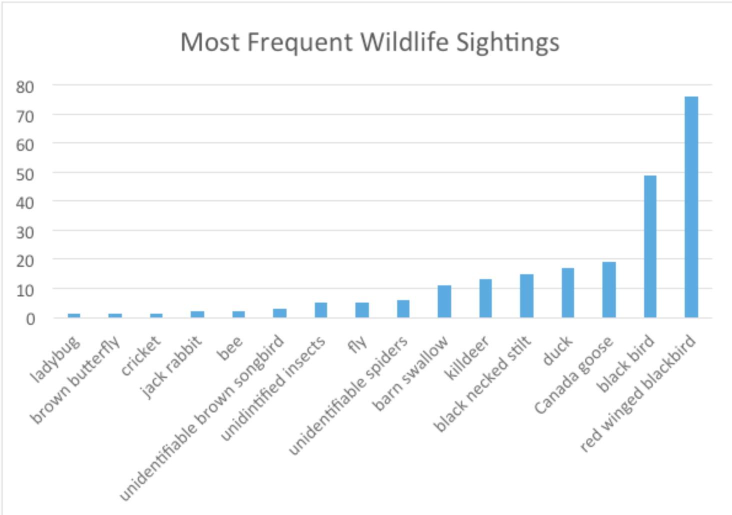
·   If notable wildlife is seen outside of the 10 meter range from the transect, they were recorded as "opportunistic sightings" on the data sheet.

Location of transects:

Transects were set up in various locations around the study site, residing in riparian areas. These locations can be seen in the photo below. All transects have two waypoints each denoted that one transect, for example one transect is 13-14, and so on.



Dominant species and common locations:



Birds

- Red winged blackbird (native)- 76 - Near shore, flying over site.
- Blackbird (native)- 28 - Near shore, flying over site.
- Black Necked Stilt (native)- 13 - On shore, near water
- Canada goose (non-native)- 19 - Flying overhead and in water
- Duck (species unknown)- 17 - In water

Mammals

- Jack rabbit (species unknown)- 2 - No common pattern

Insects

- Ladybug (species unknown)- 2 - No common pattern
- Bees (species unknown)- 2 - No common pattern
- Spiders (multiple unknown species)- No common pattern
- Brown Butterfly - No common pattern
- Crickets(sounds recorded)
- Flies-several spotted all over restoration site

Highlights & Potential Restoration:

- Monitored during non-ideal times(afternoon, hottest time of day), so not much wildlife was spotted, likely more occupies the site than was spotted.
- Some birds sighted were outside the limits of the site.
- Maintain habitat for dominant bird species such as red winged blackbird and black necked stilt.
- Providing more vegetation along edge of water and middle island to provide shelter and shade for bird and wildlife species.

Conclusion:

In summary we were able to collect some useful data on the bird species and limited wildlife, including the quantities that visit and reside in our site and where they can be found. We monitored 11 different transects and collected data for 10 minute intervals. The dominant species spotted were red winged blackbirds, blackbirds, black necked stilt, canada goose, ducks(species unknown), Jack rabbit, ladybugs and bees. It's wise to note that we monitored during non-ideal times, in mid-afternoon when most wildlife commonly is not out. Because of this, our data is dominantly focused birds and less so on insects and other wildlife. This is not based on a bias towards birds, just on the fact that we were not able to collect sufficient data on insects as they were not present. This information could more easily be collected if monitoring during early morning or late evening when temperatures are lower and insects are more active.

ENH160L Final Report: Group Written Synthesis: Seasonal Floodplain Hydrology

Roberto Maravilla, Christina Nowak, and Megan Stover

**Note: This group was formerly called "Upland Hydrology", and uses this name in the report*

Introduction

The hydrology of our restoration site in Dixon, CA has important implications for what species can survive at the site and what services or functions the system can provide. In order to capture a snapshot of the hydrology in the seasonal floodplain zones, the upland hydrology team sought to discover the **depth to groundwater** and to find **which areas show signs of inundation in the past year**. We used a variety of methods to record this data including: recording signs of inundation according to the Minnesota Board of Water & Soil Resources' "Hydrologic Monitoring of Wetlands" guide, digging boreholes into the soil profile, and taking line-level measurements along a transect.

First, we surveyed our site and chose locations to establish three transects. Since the soil type is uniform across the seasonal floodplain zone, we chose to distribute our transects according to distance from the wetland edge. Our first transect started on saturated soil near the wetland edge and stretched 50 meters up into the seasonal floodplain. The second transect began at the edge of a side drainage channel in the southeast corner of the site and stretched 40 meters to the site boundary. The third transect we made 50 meters long completely in the seasonal floodplain zone of the site. We purposely placed this transect in an area with noticeable microtopography to illustrate the variability of this zone. Along each transect sample points were established every 5 meters for line-level measurements and to record details about vegetation & signs of inundation.

Once we began our monitoring, we searched for any standing water present and signs of recent inundation. No standing water was recorded at the site during our sampling period, but we could compile a checklist of signs of inundation.

Then, we measured groundwater depths at our established transects. Due to time constraints, we were only able to dig one hole at each transect. We chose to dig these holes at the point on each transect that was closest to the wetland channel.

Our last step at each transect was to record the topography along the transect using line-level measurements. Line-level measurements were made by holding a string level above the transect. At each 5 meter marker, the distance was measured between the string and the ground. These measurements along each of the transects combined with each transect's borehole data provide insight into depths to groundwater without having to dig boreholes every 5 meters.

Challenges

Many of the challenges that we encountered while surveying the site were related in one way or another to time constraints. We aimed to auger to groundwater, but due to our inability to dig down much farther than 100 cm per visit, we were not successful in reaching the water table. We reached saturation at the first 2 transects, but not at the final transect.

In addition to deeper auger holes, we would have liked to have set additional transects. In particular, we would have laid a transect at the northern end of the site, as we were unable to collect any data pertaining to that area. Additional transects would have allowed us to gather a broader range of information, providing a more thorough picture of the site's upland hydrology levels.

The soil at the site was compacted. This was likely due to heavy equipment machinery used to shape the site in the prior years, along with a long drought followed by more recent heavy rains. The compaction of the soil contributed to slow auger progress.

Visiting the site once per week may have skewed the data collection slightly. Taking samples with several days/weeks in-between may have given false readings that can be attributed to varying levels of water evaporation. Ideally, we would have collected the data in the same week. In the future, it may be beneficial to revisit and test the same transects throughout the year, determining saturation levels at the peaks of winter and summer seasons, and comparing to current data.

Without concrete evidence of the location of the water table, estimations were necessary. These estimations were calculated using the depth to saturation and line-level measurements. Again, had we had more time, we may have reached the water table, providing us with more accurate data.

We also experienced a small amount of technical difficulty when the GPS tracking device we used failed to report full data for Transect 2. We could salvage some of the points, filling in the rest from memory, limiting inaccuracies to the best of our abilities.

Data analysis

Line level calculations were used to estimate the depth to groundwater. We used the formula "A + B - X = Z" to make assumptions about the distance to saturation (assuming saturation levels are constant through space). "A" represents the height of the line level at the auger hole, “B” is the distance to saturation, and “X” represents the height of the line level at the corresponding meter measurement. For instance, at Transect 2, the height of the line level at the auger hole was 84 cm. The depth to saturation found using the auger was 23 cm. At the 5 meter mark on the transect, the height of the line level was 55 cm. Therefore, by using the formula 84+23-55= 52, we can assume that soil saturation lies 52 cm below the surface at the 5 m marker (“Z”). The formula was then repeated for the remaining meter markers. On transect 3 however, saturation was never reached, so we had to assume that the distance to saturation was greater than 138 cm along the entire transect. Please refer to **Table 1** below for complete list of site measurements.

Results

Transect 1 was laid out on April 24, 2017 after a recent rainstorm. Its borehole was located approximately 1 meter from the water’s edge in what we assumed to be saturated soil. After a depth of approximately 105 cm, the soil appeared to become drier indicating that the standing water was not connected to the water table. We dug down to a total depth of 125 cm without reaching the water table. By early May, the standing water near Transect 1 had receded several meters, and it is likely that the water table is far lower than previously expected. The data from our line-level measurements was used to estimate depth to saturation along the transect and is available in **Table 1**.

Transect 2 was laid out on May 01, 2017, by this time there hadn’t been significant amounts of rain for about the past 2 months, and the standing water at the site was visibly lower. The initial flag for the borehole on this transect was intended to be dug at the water's edge in a side drainage channel; 3 weeks later, however, the water had already receded out of the drainage channel. At a depth of 23 cm we reached saturated soil. We reached a depth of 100 cm without reaching the water table. There was sufficient time for a second borehole at the opposite end of this transect. The second borehole was dug to a depth of 70 cm, at which saturated soil was found. The data from our line-level measurements was used to estimate depth to saturation along the transect and is available in **Table 1**.

Transect 3 was laid out on May 08, 2017 near the center of the seasonal floodplain far from the remaining standing water at the site. It had not rained in at least a week by this point in our data collection plan. The borehole for this transect was dug to a depth of 138 cm without reaching saturated soil. The data from our line-level measurements was used to estimate depth to saturation along the transect and is available in **Table 1**.

Figures, Maps and Data

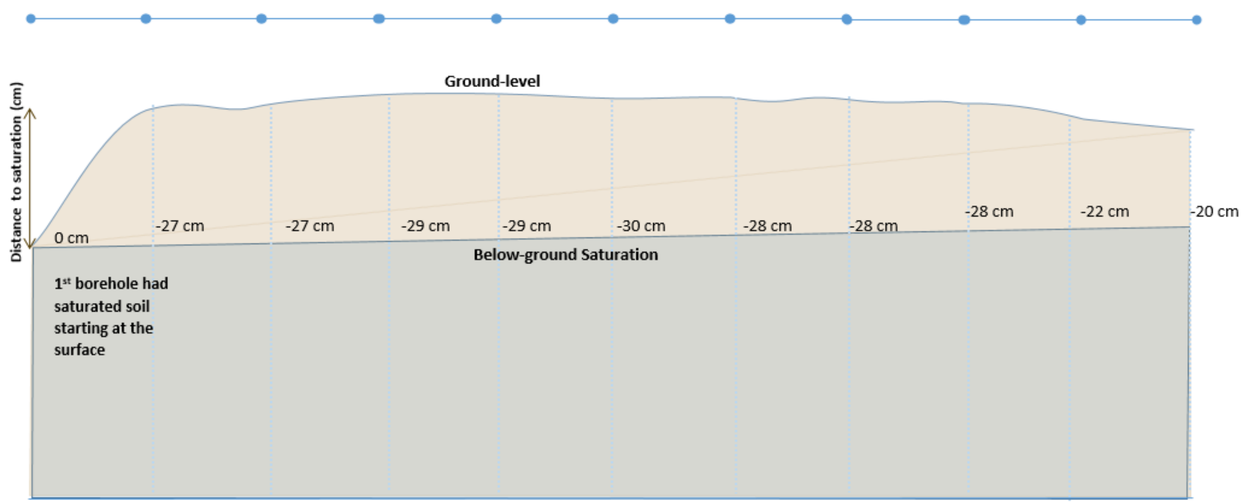


Figure 1: Cross-section of transect 1

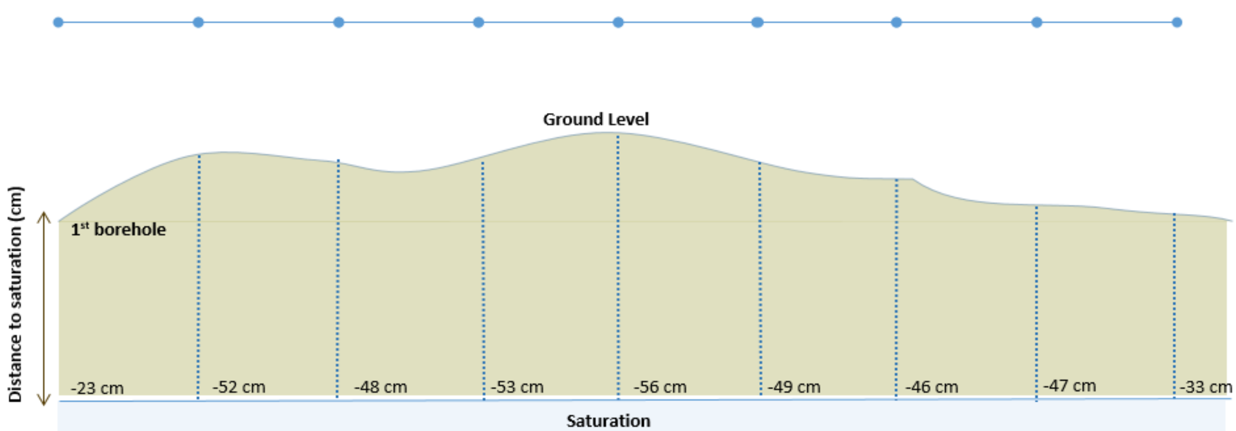


Figure 2: Cross-section of transect 2

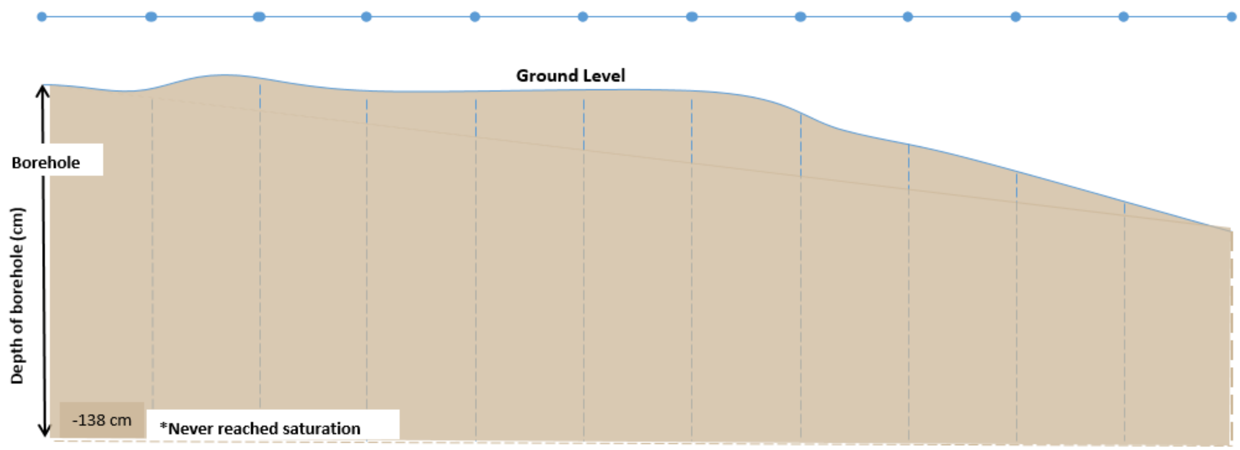


Figure 3: Cross-section of transect 3

Map 1: Satellite image of field site with seasonal wetland habitat marked out in red. Numbers with white backgrounds denote the identity of transects. Numbered flags are the locations of the GPS waypoints used to record the location of the transects. The bore hole for Transect 1 located at flag 11, the initial borehole for Transect 2 at flag 27, and for Transect 3 at flag 9.

Saturation Elevations						
	Transect #1		Transect #2		Transect #3	
	Height from line to ground	Depth to saturation	Height from line to ground	Depth to saturation	Height from line to ground	Depth to saturation
0 meters	48	0	84	-23	61	>138 cm
5 meters	21	-27	55	-52	64	>138 cm
10 meters	21	-27	59	-48	61	>138 cm
15 meters	19	-29	54	-53	60	>138 cm
20 meters	19	-29	51	-56	60	>138 cm
25 meters	18	-30	58	-49	60	>138 cm
30 meters	20	-28	61	-46	60	>138 cm
35 meters	20	-28	60	-47	64	>138 cm
40 meters	20	-28	74	-33	65	>138 cm
45 meters	26	-22	X	X	70	>138 cm
50 meters	28	-20	X	X	77	>138 cm

Table 1: Data collected at field site. All measurements are in units of cm. *Height from line to ground* was measured using the line-level method and *depth to saturation* was measured using a measuring tape with 0 cm located the at the opening of the borehole.

Transect 1 Recent Inundation Notes Date: 4/24/17	
0 meters	Matted vegetation, clearly satrated, no standing water (1 meter from standing water
10 meters	Slightly matted vegetation, live vegetation, dry, high grasses
20 meters	Slightly matted vegetation, live vegetation, dry, high grasses
30 meters	Fewer signs of matted vegetation, soil cracks
40 meters	Patches of matting, more vegetation varieties
50 meters	Patches of matting, more vegetation varieties

Table 2: Signs of recent inundation recorded every 10 meters for Transect 1. For all other transects signs of recent inundation were recorded every 5 meters.

Transect 2 Recent Inundation Notes	Date: 5/1/17
0 meters	Dry, green vegetation, some matting
5 meters	Dry, green vegetation, some matting, shin-height grasses
10 meters	Dry, green vegetation, more matting, shin-high grasses
15 meters	Dry, green vegetation, some matting, shin-high grasses, more variety of vegetation (3 or so)
20 meters	Knee high grasses, matting under grasses
25 meters	Even more variety of vegetation, still dry ground, matting underneith some waist-heigh grass, matting under grasses
30 meters	Shin-high to knee-high grasses (short to tall), vegetation beginning to dry and turn golden, matting
35 meters	Gasses drier, even less green, thigh high, less matting, various vegetation
40 meters	Dry brush (bushes), dry and drying grasses, thigh-high, little matting

Table 3: Signs of recent inundation for Transect 2.

Zone 3 Recent Inundation Notes Date: 5/8/2017	
0 meters	Green, varying vegetation, some matting underneath, shin height grasses
5 meters	Green, varying vegetation, some matting underneath, varying height grasses (shin to thigh)
10 meters	Golden/dry grasses- varying in length, some matting underneath
15 meters	Golden/dry grasses- varying in length, some matting underneath
20 meters	Golden/dry and green grasses- varying in length, some matting underneath
25 meters	Green varying veg., some matting under, grasses in height (shin to waist)
30 meters	Mix of green and golden grasses (thigh hight), some matting, less variety of other veg.
35 meters	Thick, thigh high golden and green grasses, very little matting, very little variety
45 meters	Dry, golden, blown over, knee high grasses, very little other veg., very little matting
50 meters	Dry, golden, blown over, knee high grasses, very little other veg., very little matting

Table 4: Sign of recent inundation for Transect 3.

Conclusion

After analyzing the results of our monitoring data, there are more questions we would like to answer. Ideally, taking many more borehole samples **all the way to groundwater** would provide a more complete picture of the groundwater profile across the restoration site. It would also be helpful to focus on the northeastern portion of the seasonal floodplain since we primarily focused on sampling in the Phase 1 section of the site. Additionally, more boreholes taken during different seasons would illustrate the water table in time as well as space. Taking samples at other times of the year would also provide data on standing water depth and extent that could be used to infer details about microtopography and plant-water availability across the landscape. In the long term, it would be helpful to understand the effects of compaction on plant root growth and how local residential development will affect the hydrology of the site. Ultimately, these unanswered questions cause us to ask: can the hydrology of this site sustain plant growth with minimal human management in the long term?

Our most prominent finding is that groundwater is much deeper than anticipated, especially in areas near the wetland edge where a shallower water table would be expected. Given our data, it is likely that surface water and the water table will be disconnected for large parts of the year. Furthermore, this disconnect occurs during the driest part of the year when plants will rely strongly on groundwater -- though it might be connected during the wet season or very wet years. Microtopography across the seasonal floodplain is highly variable and will probably provide “hotspots” of water availability as water collects in depressions after rain storms. However, we must also consider that compaction from construction has likely decreased water’s natural infiltration rate in these soil types. These factors will strongly affect the types of plants that can survive on the seasonal floodplain. Hardy, drought-tolerant plants would likely tolerate the hydrologic conditions in this zone.

<u>**ENH160L Final Report: Group Written Synthesis: Seasonal Floodplain Vegetation**</u>

Shelbie Spencer, Emma Steer. Zachary Emerson

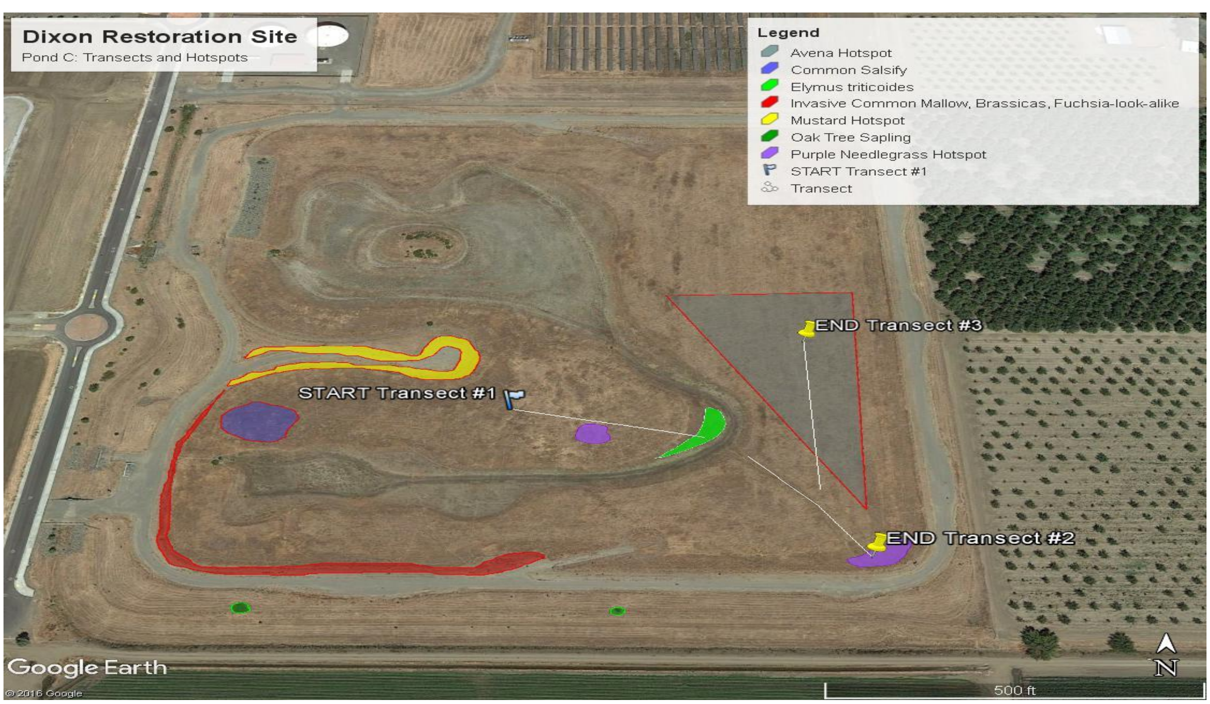
**Note: This group was formerly called "Upland Hydrology", and uses this name in the report*

Key Guiding Questions

- What type of vegetation occupies the area of the site now (i.e. natives & exotics)?
- Where in the landscape do species of natives and non-natives occur, and in what amounts?
- What are the key native species at the site and where exactly do they occur (hotspots)?

Methods

For our methods, we took samples from three 100 meter transects in the two major seasonal floodplain areas of our restoration site of interest; Pond C in Dixon, California. For each transect, we added 50 cm^2 quadrats at intervals of 10 meters, to record the gradient of species and density within different parts of the seasonal floodplain area. At each quadrat we recorded a rough estimate for percent cover by looking at present species within the quadrat and deciding which species were most present by visible density and cover. We performed this method of percent cover for each species within each quadrat to accumulate enough data to calculate total cover for each species in the entire area covered. To distinguish between our three transects, we used yellow and orange colored flags to mark our group's data to make sure other groups knew we were occupying that specific space. Lastly, we used various plant ID books such as: the Jepson Manual, the Introduction to California Spring Wildflowers of the Foothills, Valleys, and Coast (California Natural History Guides), and the Field Guide to Grasses of California (California Natural History Guides), to assist with accurate plant identification.



Challenges / Revisions

The biggest challenge faced in the field was identifying all of the species in the quadrats. Despite backgrounds in botany, there were many invasive species that were not recognized at first, because they were in various stages of development. Even with ID books, it was quite difficult to identify particular plants, especially down to the exact species. In these cases of uncertainty, an alias was created for the unknown species, the percent cover estimation was recorded, and the professor or CalFlora was later consulted to further identify the species of concern. At first, there were many uncertain species, but as time progressed the vegetation at the site became more familiar and plants were recognized much faster. There was only one species that was left unknown in the data, even with the assistance of the professor, various plant identification books, and the Internet. Luckily, it was a rather insignificant plant in terms of percent cover as it was occupying a minimal percentage of one quadrat in transect two that had previously been inundated.

The areas selected for transects were not always able to fit 100m, so transects 1 and 3 did not have 10 quadrats. A rough estimation for percent cover was recorded in the field, and the Daubenmire cover classes were later assigned in the GIS lab and used to calculate overall percent cover of each species.

Data Analysis

The top native species overall at the site from our data collection were:

- *Nassella pulchra* (Purple needle grass)
- *Lupinus bicolor* (Miniature lupine)
- *Elymus triticoides* (Creeping Wild Rye)

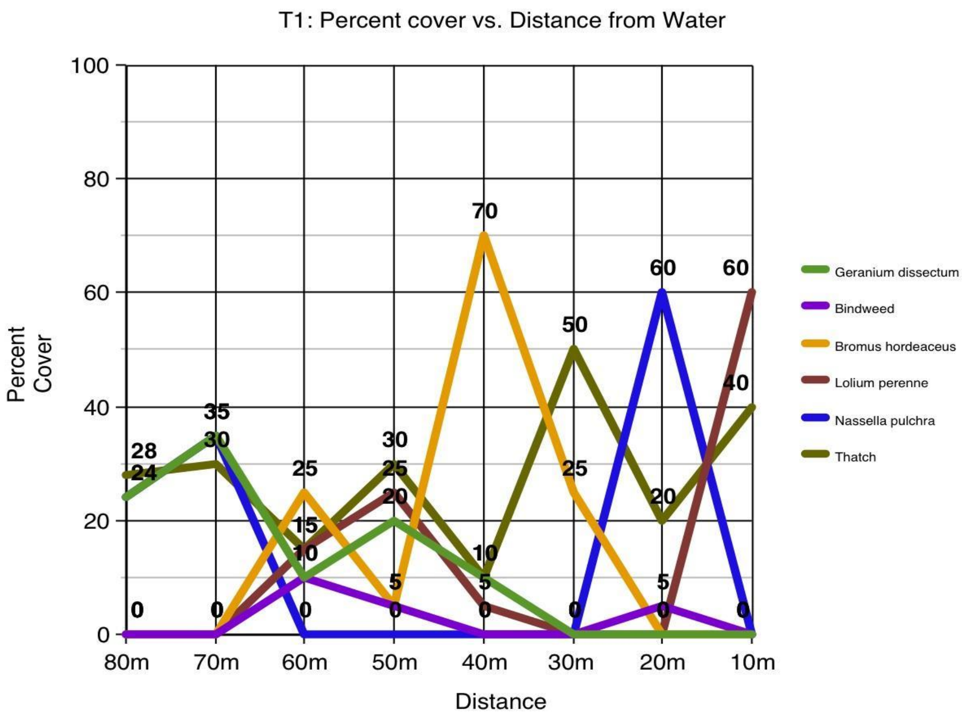
The top invasive species overall at the site from our data collection were:

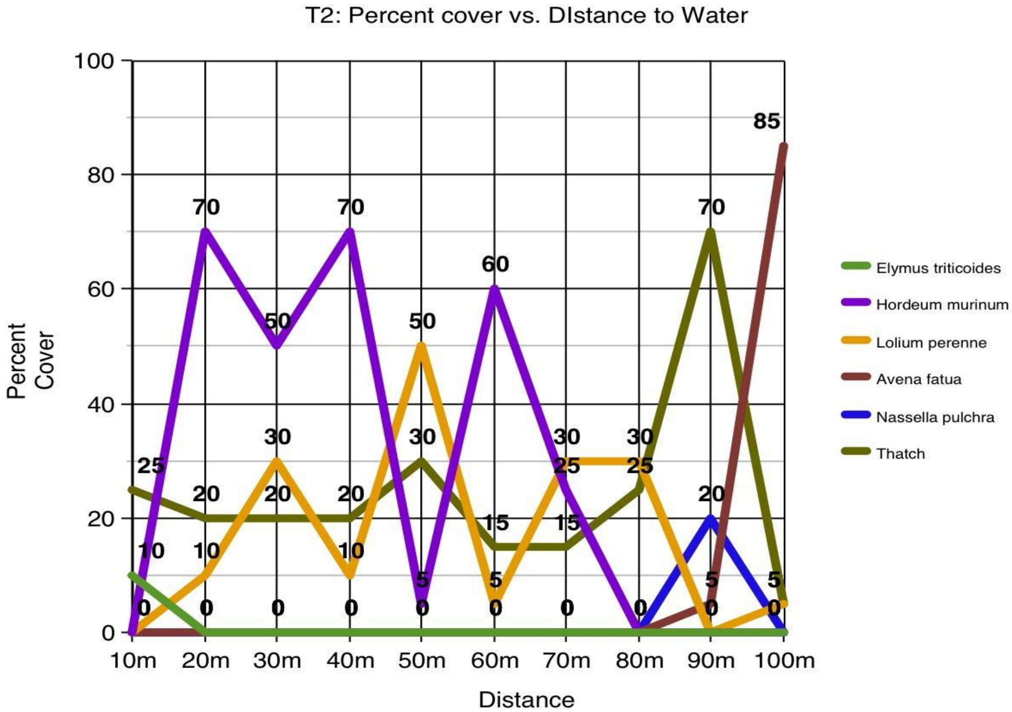
- *Convolvulus arvensis* (Bindweed)
- *Brome spp.* (Bromus hordeaceus)
- *Avena fatua* (Wild Oats)
- *Geranium dissectum* (Cut-leaved Crane's-bill)
- *Lolium perenne* (Italian ryegrass)
- *Hordeum murinum* (False Barley)

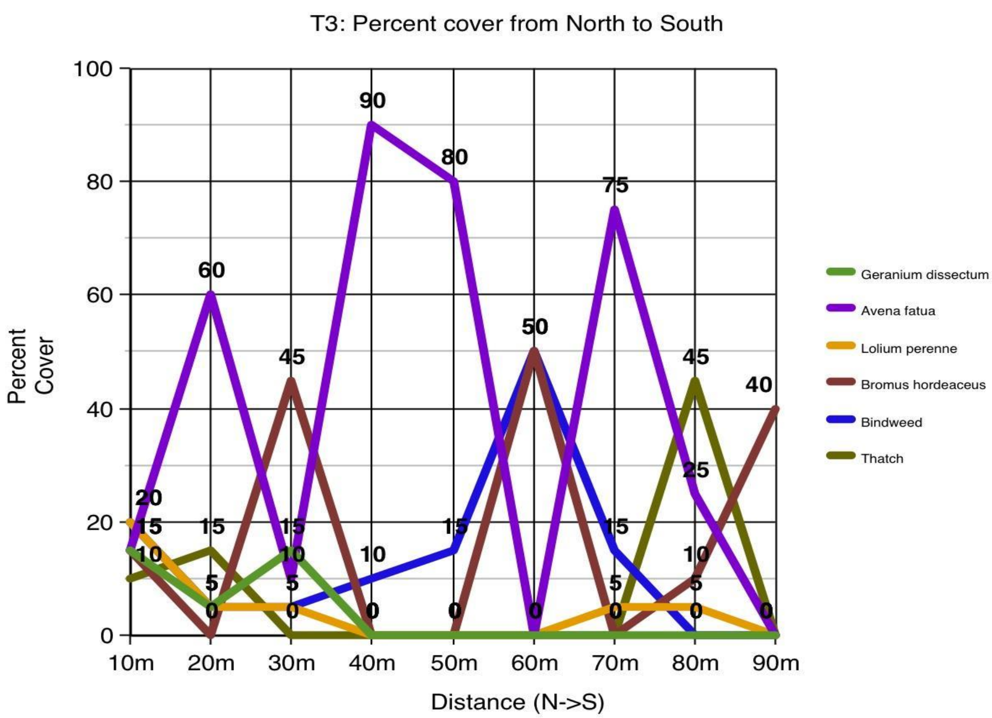
Transects 1 and 2 had higher uniformity of distribution across species percentage in comparison to transect 3. For example, in transects 1 and 2 all of the cover classes fell within 1 and 2 (0-25%), while in transect 3 Avena was the predominant invasive and occupied 25-50% of the range, which ranks it in cover class 3. Transect 1 and 2 also had a higher native species presence than transect 3. Additionally, transects 1 and 2 were closer to the water/seasonal floodplain, while transect 3 was in the drier area of the site.

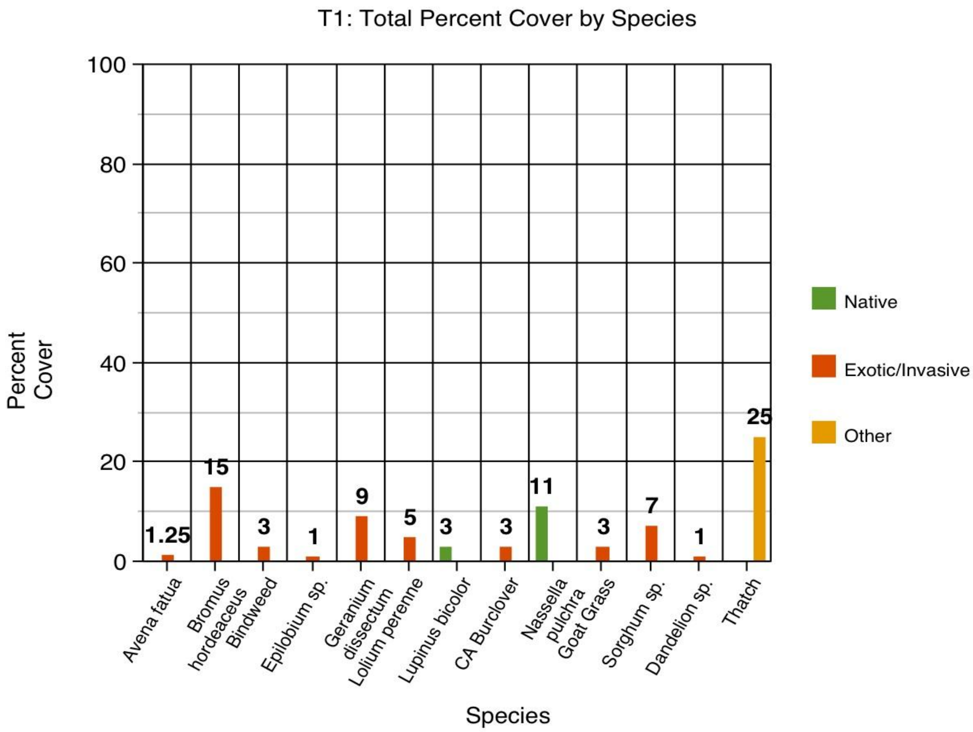
Graphs

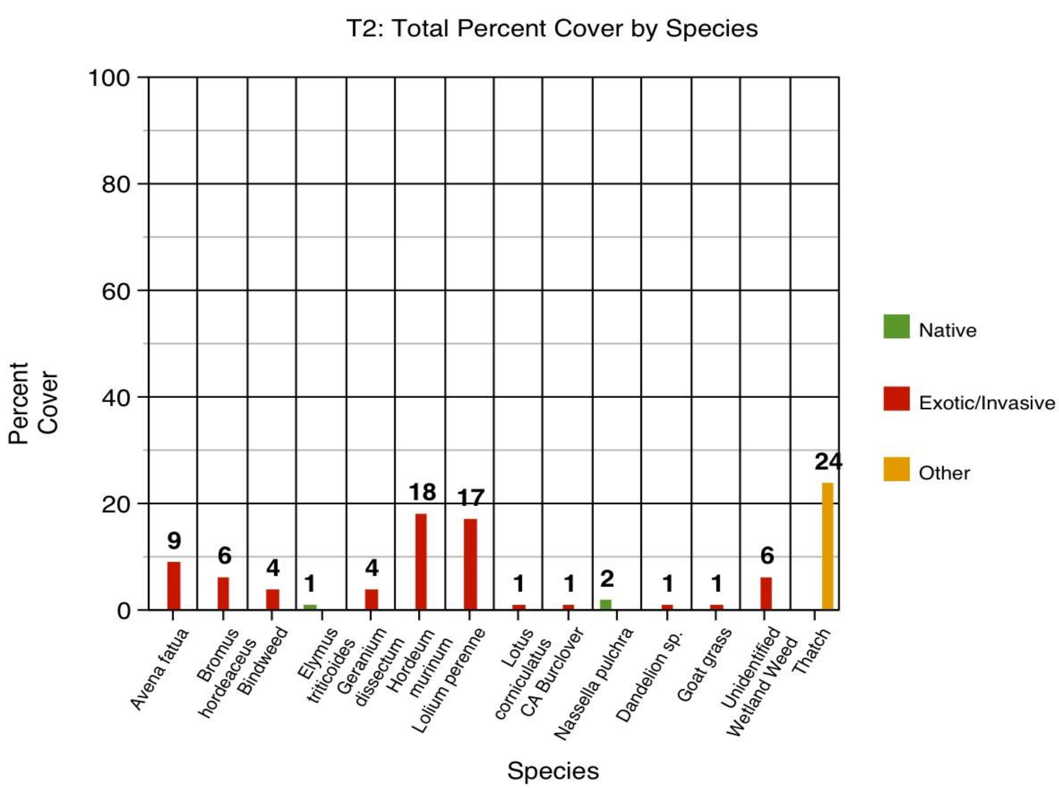
The first three graphs are highlighting species trends with distance from water, as we recorded from each of our transects. The third transect (Graph #3) is from north to south and therefore has no change in water distance as we remained parallel to the water source the entire time. Graphs 4-6 showcase the total percent cover by species across each transect.

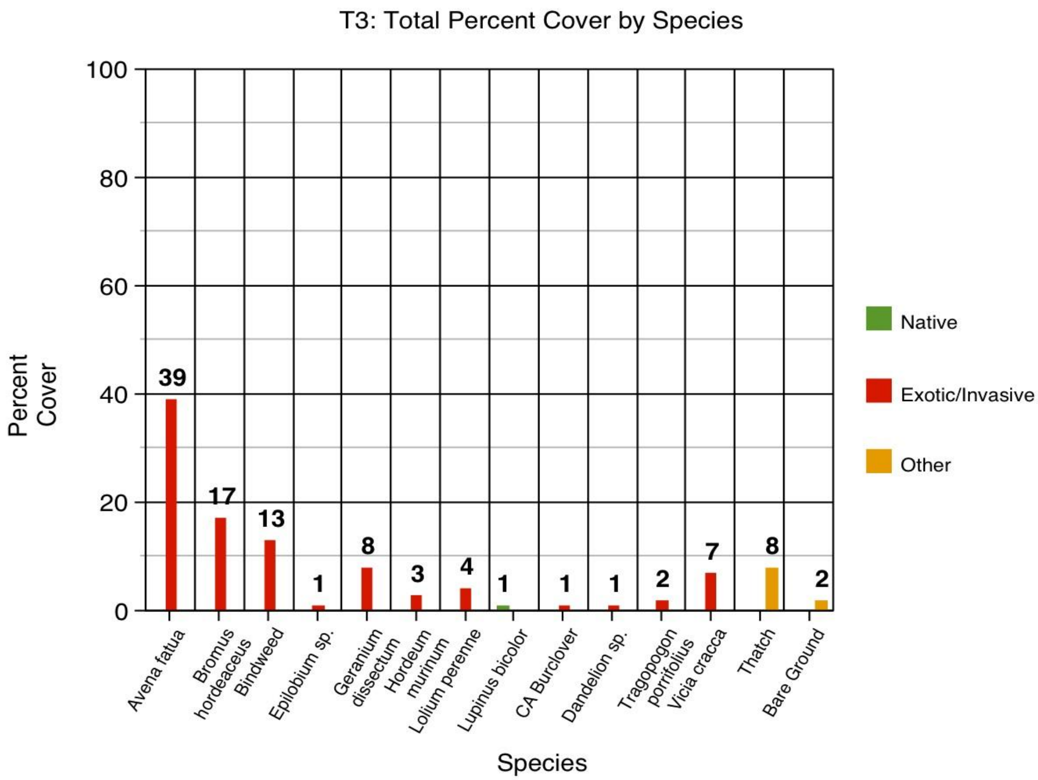



T2: Percent cover vs. DIstance to Water
Percent Cover
Distance
10m 20m 30m 40m 50m 60m 70m 80m 90m 100m
0 20 40 60 80 100
Elymus triticoides
Hordeum murinum
Lolium perenne
Avena fatua
Nassella pulchra
Thatch


T3: Percent cover from North to South
Percent Cover
Distance (N->S)
10m 20m 30m 40m 50m 60m 70m 80m 90m
0 20 40 60 80 100
Geranium dissectum
Avena fatua
Lolium perenne
Bromus hordeaceus
Bindweed
Thatch


T1: Total Percent Cover by Species
100
80
60
40
20
0
Percent Cover
1.25
15
3
1
9
5
3
3
11
3
7
1
25
Avena fatua
Bromus hordeaceus
Bindweed
Epilobium sp.
Geranium dissectum
Lolium perenne
Lupinus bicolor
CA Burclover
Nassella pulchra
Goat Grass
Sorghum sp.
Dandelion sp.
Thatch
Species
Native
Exotic/Invasive
Other


T2: Total Percent Cover by Species
100
80
60
40
20
0
Percent Cover
9
6
4
1
4
18
17
1
1
2
1
1
6
24
Avena fatua
Bromus hordeaceus
Bindweed
Elymus triticoides
Geranium dissectum
Hordeum murinum
Lolium perenne
Lotus corniculatus
CA Burclover
Nassella pulchra
Dandelion sp.
Goat grass
Unidentified Wetland Weed
Thatch
Species
Native
Exotic/Invasive
Other



Results

Transect 1	Percentage of total	Cover Class	Range of Coverage
Avena fatua	1.25%	1	0-5%
Bromus hordeaceus	15%	2	5-25%
Convolvulus arvensis	2.75%	1	0-5%
Epilobium sp.	0.63%	1	0-5%
Geranium dissectum	8.60%	2	5-25%
Lolium perenne	5%	2	5-25%
Lupinus bicolor	2.60%	1	0-5%
Medicago polymorpha	3%	1	0-5%

Nassella pulchra	11.00%	2	5-25%
Aegilops sp.	2.50%	1	0-5%
Sorghum spp.	7.40%	2	5-25%
Taraxacum sp.	0.13%	1	0-5%
Thatch	24%	2	5-25%

Transect 2	Percentage of total	Cover Class	Range of Coverage
Avena fatua	9%	2	5-25%
Bromus hordeaceus	5.70%	2	5-25%
Convolvulus arvensis	3.25%	1	0-5%
Elymus triticoides	1.00%	1	0-5%
Geranium dissectum	3.50%	1	0-5%
Hordeum murinum	18%	2	5-25%
Lolium perenne	17%	2	5-25%
Lotus corniculatus	1.00%	1	0-5%
Medicago polymorpha	0.25%	1	0-5%
Nassella pulchra	2%	1	0-5%
Taraxacum sp.	0.05%	1	0-5%
Aegilops sp.	0.05%	1	0-5%
Unk. wetland weed	6.00%	2	5-25%
Thatch	24%	3	25 - 50%

Transect 3	Percentage of Total	Cover Class	Range of Coverage

Avena fatua	39%	3	25-50%
Bromus hordeaceus	17.00%	2	5-25%
Convolvulus arvensis	13.00%	2	5-25%
Epilobium sp.	0.50%	1	0-5%
Geranium dissectum	7.70%	2	5-25%
Hordeum murinum	2.70%	1	0-5%
Lolium perenne	3.80%	1	0-5%
Lupinus bicolor	0.50%	1	0-5%
Medicago polymorpha	0.50%	1	0-5%
Taraxacum sp.	0.50%	1	0-5%
Tragopogon porrifolius	1.60%	1	0-5%
Vicia cracca	6.60%	2	5-25%
Thatch	7.70%	2	5-25%
Bare ground	2.20%	1	0-5%

- = Non-Natives/Invasives
- = Native plant species

Conclusions

The restoration site is mainly composed of invasive plants such as: *Avena fatua, Geranium dissectum, Hordeum murinum, and Convolvulus arvensis*. These invasives were seen within almost every transect and were heavily scattered throughout the landscape mosaic of the site. In retrospect, did discover few dense patches of thriving *Nassella pulchra* within our transects 1 and 2. However, the other native plants we observed within our transects were few and far between with varying densities. Where in the landscape do species of natives and non-natives occur, and in what amounts? Based on our presented data we observed a higher density of native plants in transects 1 and 2 as opposed to transect 3. Which is interesting because both transect 1 & 2 either lead up to, or away from the water. Which means we could interpret this as a positive correlation to distance to the waterway. Transect 3 is our only transect that is not in close proximity to the waterway and it exhibits a low density of native plant species, and is mostly invasive dominant. Based on our data there is an intense amount of various invasives within the site, and this specific zone of the site will require heavily restoration efforts to rid the site of these invasive plants. For our potential restoration efforts of the site, we could use various methods to aid native plant success and longevity such as: prescribed burning to clear up the seed bank of invasives, implementation of cultivation before implementation of new species, and shallow tilling of the site to aid with mixing the seed bank to promote species diversity.

ENH160L   Final Report: Group Written Synthesis: Seasonal Floodplain Wildlife

Ajay Rajamani, Elisa Fernandes-Mcdade, Emma Liffick

**Note: This group was formerly called "Upland Wildlife", and uses this name in the report*

Methods

After initial walkthrough of the site, we decided to survey along two main transects: the long diagonal transect from the North to the South of the plot, and the transect along the Northeast edge of the plot. We also surveyed two additional transects in conjunction with the Upland Hydrology group. We chose these transects because they represented the gradients in distance from the edge of the plot, distance from the wetland, and the range of micro elevations that exist within the upland areas. All transects ran through the Northeast, Central east, and/or Southeast sections of the site. Birds were surveyed separately at 3 points along the elevated eastern edge of the site, which allowed us to see across all of the upland area.

Birds:

We sampled birds at 3 separate locations, marked on figure 1. One location was sampled per day. Using binoculars, researchers stood at the observation point and counted birds for 10 minutes, recording observations in the field notebook.

Terrestrial:

We used transects to survey for non-bird animals. A map of these transects is shown in figure 1. Researchers walked the length of each transect and noted any animal sightings and signs, such as burrows and scat. We also noted any opportunistic sightings of wildlife not on the transects, such as jackrabbits running through the upland area.

Data points were taken on a handheld GPS device in the field, then downloaded onto a computer. Points were then mapped on Google Earth. Counted observations were logged in a field notebook, totaled, and tabulated on Excel.

Challenges

Our main challenge was having any observations limited to mid to late afternoon. Many of the animals potentially at the site are most active at dawn and dusk, and were likely missed during our survey. We had to rely heavily on other signs of animal activity like tracks, burrows, and scat for information about what animals are potentially present. This, however, was made more difficult by tall vegetation which hid signs of wildlife underneath. Because of these challenges, the wildlife at the site was likely underrepresented and not inclusive of all species present.

Results

Figure 1: Upland transects and bird monitoring points. Blue markers indicate old burrows, green markers indicate fresh burrows, and pink markers indicate scat sightings. Bird observation points are indicated by yellow pushpins.

Observation Type	**Number Observed**
Fresh Burrow	9
Old Burrow	18
Scat	2
Jackrabbit	2

Figure 2: Total transect observations

Species	**Scientific Name**	**Total**
House Finch	*Haemorhous mexicanus*	5
European Starling	*Sturnus vulgaris*	60
Gadwall	*Anas strepera*	4
Western Kingbird	*Tyrannus verticalis*	7
American Crow	*Corvus brachyrhynchos*	6
Common Raven	*Corvus corax*	4
Barn Swallow	*Hirundo rustica*	86
Red-winged Blackbird	*Agelaius phoeniceus*	37
Turkey Vulture	*Cathartes aura*	1
Killdeer	*Charadrius vociferus*	13
Black Necked Stilt	*Himantopus mexicanus*	7
Anna's Hummingbird	*Calypte anna*	1
European Collared Dove	*Streptopelia decaocto*	2
Great egret	*Ardea alba*	1
Northern Mockingbird	*Mimus polyglottos*	1
Mallard	*Anas platyrhynchos*	2
hawk sp.		1
duck sp.		1
Brewer's Blackbird	*Euphagus cyanocephalus*	4

Figure 3: Total bird point observations

Key Findings

Many common Central Valley bird species were present at the site. Threatened Swainson's Hawks and Tricolored Blackbirds have also been recorded in the area. The only non-bird animal we observed were two Black-tailed Jackrabbits. Burrows observed also indicate the presence of ground squirrels and voles. Most of the burrows were observed in the middle of the upland area where the brush is tallest and near the slopes around the edges of the site. No herps were observed.

Conclusions

Birds were the most abundant and diverse animals in the site, while mammals were observed at much lesser frequency, and herps not at all. To attract a greater diversity of species, restoration of the site should include planting shrubs and trees to provide cover and perches for mammals and birds. We observed birds foraging for food and taking it back to the orchard adjacent to the site, indicating that the site is not currently providing sufficient nesting locations. Planting trees and shrubs would remedy this, as would installing nesting boxes for native birds, specifically Tree Swallows. There may still be more species present at the site--potentially native and/or threatened species-- that we were unable to detect due to the timing of our observations. Further surveys should be conducted at dawn and dusk and during the winter months for a more complete assessment.

Table of Contents

Wetland and Lower Riparian Woody Species

Restoration of Wetland Woody Species in California

By: Cricket Swanson

Background and Justification

Riparian corridors and wetlands maintain the resources to encourage biodiversity as they act as the buffers between land and water. A few benefits of a healthy riparian zone or wetland include stabilizing soil, removing excess nutrients, reducing sun exposure, providing forage and habitat, flood control, filtering and storing surface water, ground water recharge, and carbon storage, which helps regulate climate. The impacts of roads, construction, agricultural runoff, urbanization, land-use change, the spread of invasive species, and over grazing can affect the wetland or riparian zone's efficiency. As the climate continues to change, adapted techniques to different conditions are needed to increase restoration success. Currently in California, an estimated 90 % of both riparian and wetland ecosystems have been lost and many of those remaining are degraded. As California's Mediterranean climate moves toward longer periods of drought with fewer more intense rain events, establishing woody species in restoration projects will become more difficult without careful planning, preparation, and monitoring.

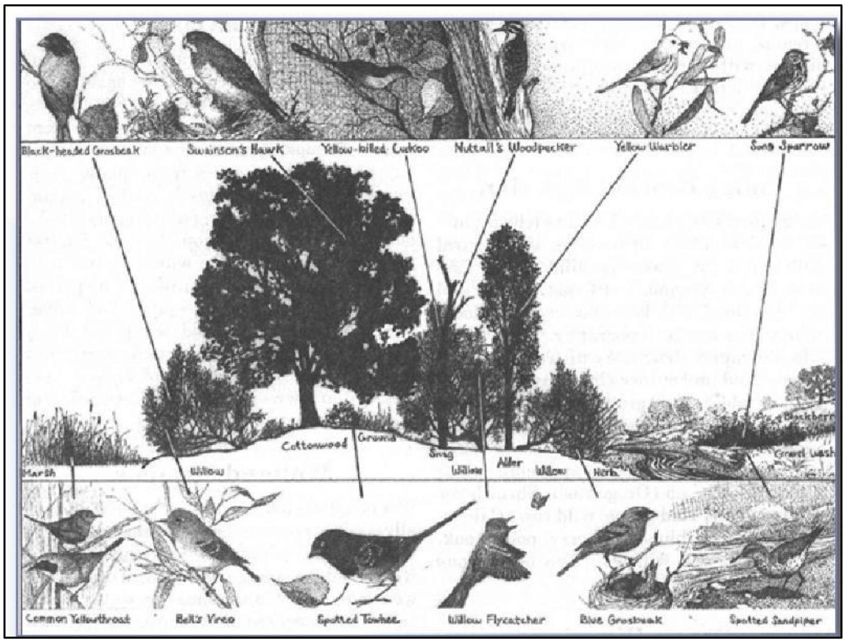
Objective

- Restore woody species in Central California's wetlands.

Goals

- Improve water quality
  - Nutrient management, temperature, pH, turbidity, dissolved oxygen
- Rare species enhancement and protection
  - Lists found at the California Natural Diversity Database
  - Yolo basin special status plants found
    - Mason's lilaeopsis (*Lilaeopsis masonii*), Suissun marsh aster (*Symphyotrichum lentum*), Delta tule pea (*Lathyrus jepsonii var. jesonii*).
- Increase plant species diversity
  - Native species and/or functional species

- Increase soil infiltration (roots)
- Increase soil organic matter (detritus).
- Enhance recreation
    - Trails, signs, and aesthetics.
- Improve and protect wildlife habitat



Birds in Riparian habitat (River partner 2007)

Site Prep

- Site Assessment: The California Rapid Assessment Method (CRAM) is a statewide, standardized method to monitor wetlands (Griggs 2009).
    - Map present plant species (Water Agency. 2013)
        - Invasive, rare, and desired
    - Hydrology
        - Water table depth, period of inundation, and surface water profile.
    - Wildlife survey and habitat assessment
- Permits and Regulations: key regulations from River Partners 2007
        - National Environmental Policy Act (NEPA)
        - National Historic Preservation Act (NHPA)
        - California Environmental Quality Act (CEQA)
        - State Water Resources Control Board
        - U.S. Army Corps of Engineers (Corps)
        - State Code of Regulations- lists unacceptable species
        - California Department of Pesticide Regulation
        - OSHA regulations and requirements- worker health and safety
        - California Environmental Protection Agency (CalEPA)

- Weed Management: Control weeds before planting
  - Invasive Woody Species
    - Arundo (*Arundo donax*) and Tamarisk (*Tamarix* spp) (Griggs 2009).
      - Decline of woody species is associated with salinity (salt cedar induced) and water availability/drought. Exotics impact resilience (Griggs 2009).
    - Ailanthus altissima (tree of heaven), Cytisus scoparius (scotch broom) (Water Agency 2013).
  - Chemical
    - Habitat® near water bodies, and Garlon™ for invasive woody species (River Partners. 2007).
  - Mechanical Removal
    - Hand pulling, machine pulling/removal
  - Mowing early and frequently for annuals and late fall for perennials before planting and/or around desired species.
  - Selective Browsing: goats can help keep down woody invaders if managed to select for undesired species.
  - Disking is more for annuals and some seedlings
  - Burning before planting.
    - Best results when done two years in a row or in combination with other management (chemical, biological, or mechanical.)
- Install irrigation
  - Flood site before planting to moisten soil (Hoag 2001)

Precautions

- High flow events and low light can increase seedling mortality (Shafroth 1998).
- Woody species can limit floodway capacity (Water Agency. 2013)
- Defer grazing for one year to allow plants to establish (Hoag 2001).
- Wetlands are particularly vulnerable to invasions after disturbance (Zedler 2004).
- Machinery can greatly disrupt habitat, consider life cycles of desired species before implementing management.
- Avoid disking/heavy machinery when soil is wet to prevent compaction (River partners 2007).
- Nursery stock is the leading spread of pathogens into restoration sites; find clean stock (Swiecki 2017)

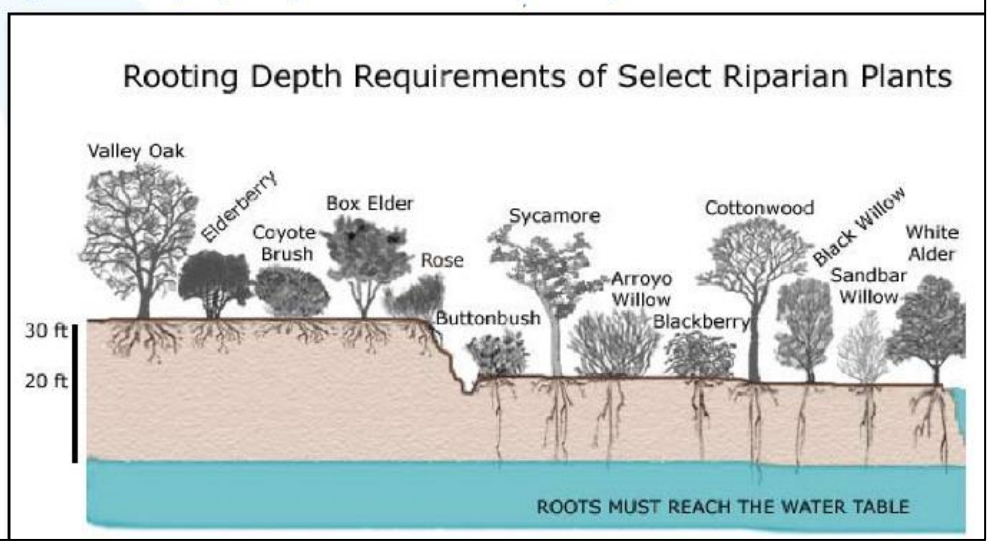
Woody Plants Species

- Commonly used/present

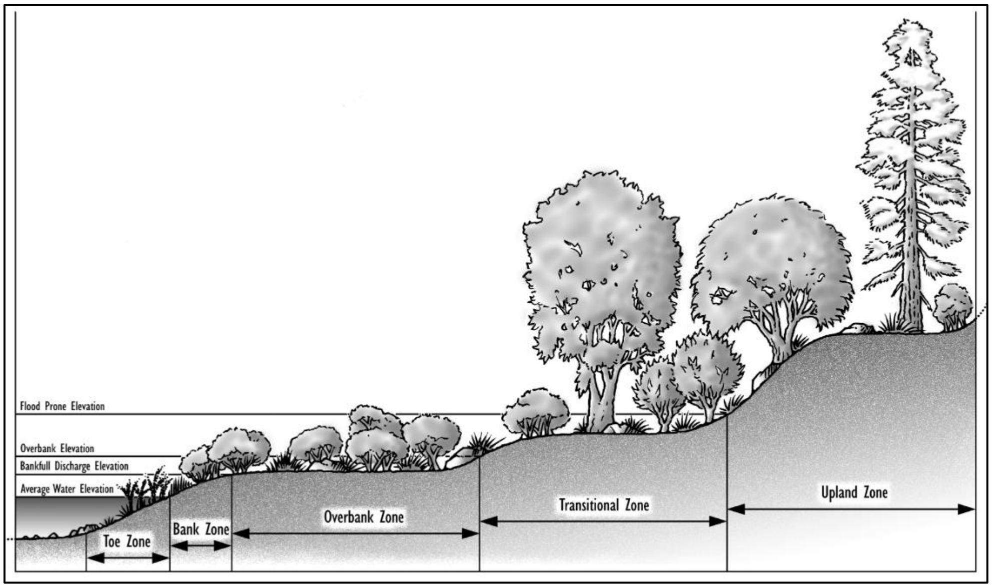
- o *Salix gooddingii, Salix exigua, Salix lasiolepis, Salix lasiandra, Populus fremontii, Cephalanthus occidentalis, Alnus rhombifolia, Platanus racemose, Fraxinus latifolia, Acer negundo, Quercus lobate, Sambucus Mexicana, Baccharis pilularis, Rosa intermontane, Juglans Hindsii,* and *Aesculus californica*.
- o In the southwest, *Salix* dominance in low-elevation sites, and codominance of *Salix* and *Populus* at mid elevations (Busch 1995).
- o Dry Creek plants: Mulefat; Sandbar Willow; Cottonwood; White alder; Arroyo Willow; Valley Oak; Hinds Walnut; California Bay; Elderberry; Coast Live Oak; California Box Elder; Buckeye; and Red Willow.
  - ▪ Terrace establishment dominated by Box Elder, Live Oak, Ash, and Walnut. Swale establishment dominated by Ash and Walnut. Bank establishment dominated by Box elder (McBride 1984).

- Zones
  - o Defined by proximity to water, water table depth, frequency of inundation, and slope.

Figure 7: ***Rooting Depth Requirements of Select Riparian Species***



(Griggs 2009)



Zones (Hoag 2001)

- Tolerances
  - Species selection considerations
    - Drought, flooding, and water table depth

Table 1: ECOLOGICAL TOLERANCES OF RIPARIAN PLANT SPECIES

	HYDROLOGIC TOLERANCES			
Species	**Water Table Required**	**Maximum Depth to Water Table**	**Tolerates Long Duration Flooding**	**Drought Recovery*** **
Black willow *Salix gooddingii*	Yes	3 meters	Yes	Yes
Sandbar Willow *Salix exigua*	Yes	2 meters	Yes	Yes
Arroyo willow *Salix lasiolepis*	Yes	3 meters	Moderate**	Moderate
Red willow *Salix lasiandra*	Yes	7 meters	No	No
Fremont Cottonwood *Populus fremontii*	Yes	7 meters	Yes	Yes
Buttonbush *Cephalanthus occidentalis*	Yes	3 meters	Yes	Yes
White alder *Alnus rhombifolia*	Yes	<1 meter	No	No
Western Sycamore *Platanus racemosa*	Yes	7 meters	No	Yes
Oregon Ash *Fraxinus latifolia*	No		Yes	Yes
Box-Elder *Acer negundo*	No		No	Yes
Valley Oak *Quercus lobata*	No		Yes	Yes
Blue Elderberry *Sambucus mexicana*	No		No	Yes
Coyote Brush *Baccharis pilularis*	No		No	Yes
Rose *Rosa intermontana*	No		Yes*	Yes
Blackberry *Rubus ursinus*	Yes	3 meters	Yes*	No
Creeping rye grass *Leymus triticoides*	No		Yes	Yes
Basket sedge *Carex barbarae*	No		Yes	Yes
Mugwort *Artemisia douglasiana*	No		No	Yes
Gumplant *Grindelia camporum*	No		No	Yes

*If top is above water, **many stump-sprout after top-death, ***Recovery after drought induced leaf-drop

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- Planting Methods
  - Seed, transplants, and cuttings
    - Seed
      - Acorns in fall, directly, and from local clean source
    - Transplants
      - Wood shrubs and trees best established through planting plugs or from containers (Hoag 2000).
        - 1:1:1 soil mix of sand, vermiculite, and peat
        - Inoculate with mycorrhizae

- Any time of year if soil can be kept moist. Best in spring or fall when soils are moist.
- Some seedlings are intolerant of shade, such as *Salix* and *Populus* (Friedman 1995)

- "Wildling" transplants taken from clean local source (Hoag 2000).
  - Trim back if taken in summer months to decrease water stress.
- Plant woody species parallel to flood flows (River partners 2007).
- Cuttings (Populus and Salix): dormant wood.
  - Plant right side up (common mistake); 2/3 length of cutting in ground.
  - Larger diameter cuttings have higher survival rate.

- Timing
  - Cuttings of cottonwood and willows collected in January or February when the trees are dormant (River Partners. 2007). Cuttings should be planted in February and March. Nursery material in cool moist conditions, fall or spring (River Partners. 2007).
  - Acorns planted directly at high density in fall (River Partners 2007).
  - Spring and/or fall for various plantings, with seasonal monitoring.

Table 11. Standard planting materials and times for woody species

Species	Nursery Grown		Direct Planting		Standard Planting Time
	Seeds	Cuttings	Seeds	Cuttings	(primary method)
Arroyo willow	2	2		1	Feb-Mar
Black willow	2	2		1	Feb-Mar
Fremont cottonwood	2	2		1	Feb-Mar
Sandbar willow	2	2		1	Feb-Mar
Box elder	1				Oct-Apr
Buttonbush	1	2			Oct-Apr
California blackberry	1	2		2	Oct-Apr
Coyote bush	1	1		2	Oct-Apr
Elderberry	1				Oct-Apr
Oregon ash	1				Oct-Apr
Western sycamore	2	1			Oct-Apr
Wild rose	1	2		2	Oct-Apr
Valley oak	2		1		Nov-Dec

1 – primary method, 2 – secondary method.

(River Partners 2007).

- Density
  - Varies by size of plant and desired habitat
  - Plantings of around 200 trees per acre in Drumheller Slough.

Table 3. Woody species to be planted at the Drumheller Slough Unit, Sacramento River National Wildlife Refuge

Common name	Scientific name	Species composition (%)	Density (plant/acre)	Total Number
Tree Species				
Arroyo willow	*Salix lasiolepis* Benth.	4	7	953
Box elder	*Acer negundo* L.	5	10	1,315
Elderberry	*Sambucus mexicanas*	13	26	3,345
Fremont cottonwood	*Populus fremontii* S.Watson ssp. fremontii	5	9	1,180
Gooding's black willow	*Salix goodingii* C.R. Ball	3	7	859
Oregon ash	*Fraxinus latifolia Benth*	9	18	2,335
Valley oak	*Quercus lobata* Nee	12	24	3,124
Western sycamore	*Platanus racemosa* Nutt.	4	8	1,056
Total Trees		**55**	**109**	**14,167**
Shrub Species				
Buttonbush	*Cephalanthus occidentalis*	2	3	437
California blackberry	*Rubus ursinus* Chain. & Schldl.	13	25	3,253
Coyote bush	*Baccharis pilularis* DC.	10	19	2,507
Mule fat	*Baccharis salicifolia*	2	3	372
Poison oak	*Toxicodendron diversilobium*	3	6	806
Sandbar (narrow-leaf) willow	*Salix exigua* Nutt.	2	5	592
Wild rose	*Rosa californica* Cham. & Schldl.	13	25	3,277
Total Shrubs		**45**	**86**	**11,244**
TOTAL		**100**	**195.0**	**28,405**

(River Partners 2007).

- Protections
  - Mulching keeps moisture and suppresses weeds, but can be expensive (River Partner 2007).
    - Around upland trees to avoid loss during flooding events
    - Local clean source with attention to pH.
  - Nurse shrubs and trees
    - Pre-existing vegetation can facilitate woody species establishment. Neighbor effects especially significant in semiarid areas. (Gomez-Aparicio 2009).
  - Irrigation for first three years improves success (River partner 2007)
    - Type based on soil texture (Griggs 2009).
      - Sandy soils need sprinklers or drip
      - Silty-clay soils by flood-furrow
    - Amount determined by different plant soil moisture requirements (Griggs 2009).
    - Wean plants off to minimize shock and allow deep root development. Development varies.
  - Plant protectors guard against herbivory (see table below).
    - For rodents and browsers
      - Milk cartons, Hog wire, chicken wire or temporary fencing around plantings (River partner 2007)
    - For underground protection
      - Root cages with gopher wire

Table 12. Summary of Herbivore Control Methods at the Drumheller Slough Unit.

Herbivore	Type of Damage	Comment on measure(s) or plant response
Beaver	Cut down woody species to build dams	Dismantle dams or, if damage becomes severe, herbivore removal Woody species can stump sprout
Deer	Browsing sapling Use trees to rub velvet off antlers	Install heavy-gauge metal hoops and garlic deterrent. Saplings can resprout
Ground Squirrels (*Otospermophilus beecheyi*)	Dig up and shred plants and protectors. Eat the bark of willow and cottonwood saplings and limbs.	Flooding or disking can reduce populations.
Pocket Gophers (*Thomomys bottae)*	Eat root systems (probably killing more saplings than any other vertebrate pest).	Control of weed cover allows predators to hunt gophers. However, gophers can persist in an open, weed-free field. Frequent disking, weed mulch control or flooding reduces populations. A variety of birds will prey on gophers if given the opportunity. Raptor perches and owl boxes may increase predation.
Rabbits and Hares	Browse early spring growth.	Most seedlings resprout.

Table represents examples of herbivores, impacts, and potential management response (River partners 2007).

- Monitoring
  - Timing for establishment varies; surveys should be done years 2 and 5 (Water Agency 2013)
  - Daily irrigation monitoring may be needed in spring and summer to establish appropriate rate (Griggs 2009).

Follow up Management

- Annual management report (Water Agency 2013)
  - A summary of maps, monitoring results, actions (weed control, grazing, replanting, irrigation), and recommendations.
- Regular monitoring
  - The California Rapid Assessment Method (CRAM) is a statewide, standardized method to monitor wetlands (Griggs 2009).
  - Vegetation, hydrology, and wildlife surveys
- After disturbance assessments (Water Agency 2013)
- Maintenance
  - Replanting failed seedlings
  - Invasion control ongoing (Chemical, mechanical, and biological)
  - Clearing areas to allow for natural seedfall establishment of local Salix and Populus on bare full sun spots (Friedman 1995).

Measuring Success

- Criteria
    - 5 criteria that should be met for successful restoration.
        - 1. Have a guiding image of the healthier site (Reference site).
        - 2. Site condition must be measurably improved.
        - 3. The system must be self-sustaining and resilient, requiring minimal maintenance.
        - 4. No lasting harm on ecosystem shall be caused during construction phase.
            - Examples include: avoiding soil compaction, avoiding destruction of key species, time management for multiple goals to harm as little as possible (understanding trade-offs), maintaining functional diversity, avoid introducing pathogens and invasive plants, and keeping integral feedbacks intact.
        - 5. Pre- and post- assessments will be completed and made publicly available (Palmer 2005)
    - Survivorship: percent survival
    - Cover area: percent cover of natives
        - 100% ideal, though often not feasible therefore a greater than 50% native cover is considered successful (River Partners 2007).
        - Functional diversity may be more realistic goal
    - Hydrology: representative of wetland areas (signs of inundation andsaturation, soil conditions).
- Indicators of success
    - More than vegetative success need to be measured to quantify mitigation/restoration success. Hydrology, fauna, and soil conditions should be considered (Kentula 2000).
    - Ecosystem services functional (Kentula 2000).
        - Water quality- monitored seasonally (Water Agency 2013)
            - pH recommendations 6.5-9 (EPA)
            - dissolved O_2 > 4ppm to support aquatic life (Water agency)
            - turbidity and sedimentation
        - Vegetative success and diversity
            - At least 70% survival to be considered successful (Griggs 2009)
            - Survey done after 2 and 5 years (Water Agency 2013)
        - Hydrology function (often)
        - Habitat use (periodically based on desired species habits)
- Timing of success
    - How long to measure success?

- 15-20 years suggested to measure restoration success (Mitsch 1996).
- 1-5 years to observe initial seedbank establishment and seedling survival (Water Agency 2013)

Summary

Clear goals are the key to a great restoration plan. Common goals include, improve water quality (nutrients, turbudity, pH, temperature), increase flood capacity, increase functional diversity, increase habitat (birds, amphibians, aquatic *invertebrates)*, and to protect rare species. With solid quantifyable objectives, steps can be made to assess, improve, and monitor the state of the site. Having baseline data which includes hydrology, vegetation, and wildlife, allows for changes overtime to be measured and compared. Having a reference site allows for seasonal goals to be quantified through comparisons over time. Site assesment is essential for monitoring success; understanding the baseline hydrology, species distribution, and water quality allows for more educated species selection and placement. Existing vegetation can act as nurse plants to help woody species establish in harsh environmental conditions. Choosing locally grown/harvested species means the species are already adapted to the area and that local gentics are being preserved. It is also important to avoid contaminated stock often found in nurseries. For central California, woody species most commonly used in riparian and/or wetland restoration include, *Salix gooddingii, Salix exigua, Salix lasiolepis, Salix lasiandra, Populus fremontii, Cephalanthus occidentalis, Alnus rhombifolia, Platanus racemose, Fraxinus latifolia, Acer negundo, Quercus lobate, Sambucus Mexicana, Baccharis pilularis, Rosa intermontane, Juglans Hindsii,* and *Aesculus californica*. Each species has different functions (habitat, forage, shade), tolerances (drought, flood), and requirements (depth to water table, exposure, space) to consider. Irrigation for first three years is recommended to increase success for plants in a Mediterranean climate (River partner 2007). Water should be slowly reduced over time to allow the plants to develop deep roots to tap into the water table. Monitoring frequency for success after implementation is lacking in most projects due to inadequate baseline data and/or funding (Zedler 2000). Its recommended that monitoring be done for 15-20 years before success can be completely assessed (Mitsch 1996). Most plans did not include a timeline to measure success or establishment. Success is based on clarity of goals and measurability of achieving these goals. Indicators may include water quality comparisons, native vegetation percent cover, habitat use through wildlife surveys, hydrologic functions, soil conditions, and percent survival of planted species. In mitigation projects a 70 % survival is the minimum to be considered a success, though timelines for sustaining this population were not specified. Follow up management, including weed management, and monitoring is essential for determining success and maintaining the desired state.

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Cottonwood (Populus fremontii)

Jillian Hagenston

Background and Justification

The cottonwood (*Populus fremontii*), also called Fremont's cottonwood or the Alamo cottonwood, is a native hardwood tree species in the Salicaceae family. It grows predominantly in riparian habitats from western Texas to California, including New Mexico, Arizona, Nevada, and Utah (Taylor, 2000). Though populations are in decline, it has no special protection status in California, though a variety of it is protected as very rare in Texas (Pataki et. al, 2005). Distribution has been severely limited as cottonwood is only in a small fraction of the scope it once inhabited (Pataki et. al, 2005). In the Sacramento Valley alone, over 98.5% of its riparian habitat has been destroyed since 1850 (Braatne et. al, 1996). The cottonwood serves as the foundation of riparian forests in semi-arid regions, such as those in CA as it add diversity, stabilizes banks, provides wildlife habitats, and is quick at colonizing and growing, to name a few (Rood et. al, 2003). Riparian systems, though only 1% of the landscape in North America, are vital ecosystems that provide vast diversity and protection, especially for bird species (Braatne et. al, 1996). In historical records, the Fremont cottonwood dominated Central Valley riparian woodlands throughout CA (Taylor, 2000). Cottonwoods are vital to these habitats and must be protected and integrated into the systems as both are facing rapid decline despite their importance. Cottonwood is a fast-growing tree perfect for restoring arid riparian landscapes with regular disturbance regimes.

Literature review

Growth Characteristics:

- Cottonwood is deciduous, ranges from generally 19.7 – 112 ft high, sports a rounded/cylindrical crown, and has roughly 19-7 – 12.8 ft trunk diameter (Taylor, 2000).
- Cottonwood is a phreatophyte, a plant with deep rots that draws its water from the water table (Pataki et. al, 2005).
- Rooting depth ranges from 3 to deeper than 5 m (Braatne et. al, 1996).
- Reproductive maturity is reaches between 5-10 years, its lifespan is upwards of 130 years (Braatne et. al, 1996).
- Plants are dioecious with the sex ration being mostly balanced, though there are cases of male- or female-dominated subregions (Braatne et. al, 1996).
- The inflorescences are catkins of either male or female flowers (Taylor, 2000).
- Mature stand densities range from 50 to upwards of 400 trees/ha (Braatne et. al, 1996).
- Cottonwood has a large canopy that supports a diverse plethora of organisms, especially in the arid deserts of CA (Hultine et. al, 2015).

- Establishment in riparian habitats usually follows flood and deposition events along alluvial plains (Pataki et. al, 2005).

Reproduction and Early Growth:

- Flowering occurs between February and March, corresponding to springtime riverine flow peaks; seed dispersal is between March and April with seed viability between 1-3 weeks and germination 24 hours/bare (Braatne et. al, 1996). Seed viability drops to 2-3 days if wetted. Some seeds may not be viable upon dispersal but will become viable within a few days.
- Seed release and subsequent dispersal corresponds strongly to seasonal hydrology, specifically with the peak runoff of snowmelt-driven rivers (Stella et. al, 2006). This is due to temperature patterns acting as a coordinator between seed release and spring snowmelt runoff pulse.
- Seed banks are not maintained between years (Stella et. al, 2006).
- The main method of dispersal is by wind and water via their fluffy cotton-like hairs (Braatne et. al, 1996). Most of the seeds land within a few hundred meters of the dispersal site (mother plant), but the potential for long-distance dispersion exists.
- Germination is rapid, with cotyledons expanding within 24 hours; seedling roots usually grow 4-12 mm/day (Braatne et. al, 1996). Full sunlight is necessary for seedling leaves to emerge.
- Germination is favored along floodplains (Asplund & Gooch, 1988).
- Seedlings establish predominantly on alluvial sediments (Braatne et. al, 1996).
- Once germinated, most seedlings fail to survive due to flash flooding that occurs in riparian habitats along rivers (Asplund & Gooch, 1988). The presence of protected locations along banks and a constant source of water increase germination success.
- Asexual reproduction usually occurs in crown breakage and tree fall due to environmental damages; buried broken branches can sprout with vigorous shoots (Braatne et. al, 1996).

Range:

- Cottonwood can be found in riparian habitats from Texas to New Mexico, Arizona, California, Nevada, and Utah (Trouillas & Gubler, 2016). In California, it is largely present in the San Joaquin and Sacramento valleys.
- Cottonwoods are usually found at elevations below 2000 m (Trouillas & Gubler, 2016).
- Within the broad characterization of living habitat, the cottonwood distribution is mainly located to the margin of streams, rivers, and reservoirs (Hultine et. al, 2015).

Habitat/Requirements:

- The presence of mature cottonwoods along secondary channels, near obstructions, and further up the bank along main channels indicate the presence of protection from scouring (due to flooding mixed with the presence of gravel/particulates) allows for establishment and maturation of cottonwood seedlings (Asplund & Gooch, 1988).

- Mature trees predominantly exists along the main channels of the riparian habitat while seedlings/saplings more commonly inhabit the wide floodplains (Taylor, 2000).
- Even during dry years, a constant source of water, usually underground percolation from the nearest body of water, is needed (Asplund & Gooch, 1988).
- Cottonwood is vulnerable to drought until root depth reaches seasonal water tables around 2+ meters down (Braatne et. al, 1996).

Tolerances:

- Mature cottonwoods can survive an excess of scouring due to debris, gravel, and rocks being carried by flood waters (Asplund & Gooch, 1988).
- Considerable grazing in study locations shows that there appears to be no directly adverse effects on the populations of mature cottonwood (Asplund & Gooch, 1988).
- Cottonwood, as a riparian species, is extremely drought intolerant and cannot tolerate water potential below -2MPa throughout the soil (Pataki et. al, 2005).
- Dry conditions lead to reduced photosynthesis and transpiration as well as xylem cavitations, which can lead to plant mortality (Rood et. al, 2003).
- While it can tolerate salinity to a degree, salt concentrations above 2000 mg/L reduce growth and transpiration (Pataki et. al, 2005).
- Seedlings, saplings, and mature trees are tolerant of inundation (3-4 weeks or more) and siltation, eliminating many competitors (Braatne et. al, 1996).
- They tolerate the annual range of 9 – 67*F (Taylor, 2000).
- Soil needs to be well-draining, alluvial sandy/sandy clay loams (Taylor, 2000).
- Cottonwood is a shade-intolerant species and will eventually be succeeded by more shade-tolerant species (Taylor, 2000).
- Fire disturbance may favor seedling regeneration by exposing the understory and allow light to penetrate while also exposing the mineral soils (Taylor, 2000). However, cottonwoods are not fire-dependent and fires can actually be damaging to the species due to their infrequency.

Interactions:

- Cottonwoods and willows (*Salix* spp.) act as ecological pioneers for barren and semi-arid riparian sites, establishing as dominant tree species (Rood et. al, 2003).
- Cottonwoods act as riparian pioneer species in the San Joaquin Basin in CA along with Goodding's black willow (*Salix gooddingii*), and narrow-leaved willow (*Salix exigua*) (Stella et. al, 2006).
- Saltcedar is an exotic invasive halophyte that tolerates much higher levels of salinity than cottonwood and secretes salts, salinizing upper soil layers and making it uninhabitable for natives (Pataki et. al, 2005). It can also tolerate drought stress and declining water table more than cottonwood.

- Saltcedar (*Tamarisk spp*.) is the main competitor with cottonwood, often replacing stands where cottonwood mortality has occurred (Hultine et. al, 2015). Saltcedar replacing cottonwood has corresponded to increased fire, reduced biodiversity, and disruption of mutualisms with natives.
- Cottonwood is undergoing massive diebacks from the fungi *Cryptosphaeria pullmanensis* and *C. multicontinentallis* (Trouillas & Gubler, 2016).
- The disease transmitted through the fungi may be encouraged by recent weather pattern changes, increased drought and lowered water tables, lessened natural flooding, and intensification of agriculture (Trouillas & Gubler, 2016).
- To may bird species, cottonwoods are vital habitats: nesting sites in the crown and trunk, foliage cover, and foraging habitats (Taylor, 2000). Hawks, the bald eagle, and woodpeckers have a special affinity to the tree species.

Management considerations:

- Being a phreatophyte, cottonwood is vulnerable to cavitation and embolism when air becomes trapped in its tissues (Pataki et. al, 2005). This usually occurs when there isn't enough water available to the root system.
- Due to climate change, there will be an increase in frequency and severity of droughts, leading to increase cottonwood mortality across its native ranges (Smith & Finch, 2015).
- Cottonwood has been declining due to drought stress (heavily impacted by water table decline from human activities), decreased flooding, salinity stress, and interspecific competition (Pataki et. al, 2005).
- Another product of climate change, temporally displacing monsoons and temperature fluctuations throughout the season will likely limit germination and increase mortality (Smith & Finch, 2015).
- Threats to the cottonwood include overgrazing (though this only kills seedlings, mature trees appear to be tolerant of grazing), water diversion (leading to drought conditions), clearing the land for domestic settlement or agriculture, encroachment by exotic plants, flooding by reservoirs, mining for gravel, and harvesting the trees themselves for their wood (Braatne et. al, 1996).
- Mature cottonwoods are disturbance-adapted organisms (in reference to seasonally fluctuating water levels and flood damage) and are therefore vulnerable to human-caused disruptions to the disturbance regime, such as those that disrupt usual flood patterns (Stella et. al, 2006).
- Cottonwoods require seasonal disruption in the form of flooding, a constant water table, scoring from debris in the water, and can benefit from the occasional fire management (Asplund & Gooch, 1988).
- Cottonwoods express rapid early growth, making it beneficial to use for revegetating sites—it is recommended to be used where saltcedar has been removed (Taylor, 2000).
- Cottonwoods act as excellent erosion controls and are beneficial to integrate as buffer strips around streams, rivers, lakes, and ponds (Taylor, 2000).

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<u>Management Plan for Cottonwood (*Populus fremontii*)</u>

Goals:

The cottonwood is an important native riparian tree found in much of southwestern United States including the Central Valley in California, which acts as both habitat, bank erosion control, and a buffer for invasives, such as saltcedar. However, this species is very drought-sensitive and should not be implemented into sites that experience frequent water stress. The main restoration goal for this tree would be to establish a self-maintaining population along the edges of bodies of water, such as seasonally flooding rivers and water retention basins. Establishment and efforts directed towards this goal will fluctuate depending on the environmental conditions of the site, the presence of invasives (such as saltcedar), and the need for it as habitat. Cottonwood restoration goals should include the following:

- Establish or maintain self-sustainable populations of cottonwood in riparian zones with densities at or above 50 mature individuals/ha (short-term: create or maintain viable cottonwood populations) (Braatne et. al, 1996).
    - Populations must include reproductively mature adults that can maintain population levels once reaching sexual maturity within 10 years (Braatne et. al, 1996).
    - Second-generation seedlings must be able to survive without assistance at a rate of at least 10% (seedling survivability is very low; sapling survivability is low, too, but more successful than seedlings)—note: exact percentages of seedling survival rates were not found, therefore an estimate of 10% survival is used (Borman & Larson, 2002).
- Improve environmental conditions to increase probability of establishment and survivability of cottonwoods (long-term: change conditions such that cottonwood populations can last at the site and self-regulate for generations).
    - Remove water-limiting factors to the site: barriers, water diversions, retention zones; cottonwoods require constant sources of water.
        - Natural settings: ensure water is not diverted from the site, i.e. remove natural barriers or divert excess water.
        - Urban settings: remove artificial barriers, create drainage systems to divert urban runoff to the site.
    - Limit presence of invasives and utilize the fast growth rates of cottonwood to out-compete invasives and limit future invasions.

Before enacting the restoration plant (in the next section), the desired restoration site should be surveyed. The survey(s) should assess the following:

- Determine if any cottonwoods are present and, if so, at what maturities (seedling, sapling, reproductively immature adult, mature reproductive adult).
- If there are any common invasives (i.e. saltcedar) that would limit the proliferation of the cottonwoods—determine overall size and densities of invasive populations (Hultine et. al, 2015).

- Hydrology including seasonal fluctuations (surface water level and its changes), water table level (along water's edge and radiating from it to determine the water table of the site), if the area is subjected to continuous or severe seasonal drought, salinity of the water (and soil) (Pataki et. al, 2005; Stella et. al, 2006).
- Soil type (preferred: silt and sand), severity of erosion (if any—cottonwood can stabilize but debris could harm seedlings), any present pollutants in the soil (Smith & Finch, 2015).
- Temperature range of site (winter lows to summer highs) and how this affects water levels.
- Presence of grazing, burning, flooding, and other disturbance regimes (Stella et. al, 2006).

<u>Feasibility</u>: The main threat to cottonwoods is lack of water. Considering California's drought-heavy summers, the survivability of young cottonwoods could be low and therefore new populations difficult to establish. However, once the water table is reached by root systems, restoration of cottonwoods seems more reasonable, so the focus should be on planting seedlings and saplings. Chances of success are increased by integrating irrigation from the start to be removed as the population matures as well as adjusting local environmental standards to divert more water flow to the populations, if necessary.

Restoration Plan:

To restore a site, first check the environmental conditions (recorded in the previously mentioned survey(s)) to determine if any pre-restoration adjustments need to be made:

- If water levels are low, follow water to source to determine the cause of low water levels and how it could be remedied; often natural flood regimes and water flow is disrupted by anthropomorphic actions which can be adjusted/undone (Stella et. al, 2006).
- Remove any invasives that could be detrimental to the establishment of cottonwoods; saltcedar being a prime example, and if present check salinity of water and soil—high levels of salinization may need to be addressed to allow for cottonwoods to grow (Hultine et. al, 2015). If the salinity is high (>2000 mg/L), remove the saltcedars and allow 3 months for the contaminated water to be washed away. If there are high concentrations of invasives present (>50% cover) and no cottonwoods or desired natives, then initiate a burning or mass tilling; if there are desirables present then avoid burning and instead till extensively around the desirables (Asplund & Gooch, 1988). During restoration, continually remove large invasive plants that could compete with cottonwoods.

After site conditions are met, initiate planting of cottonwoods:

- Seedlings or cuttings are best planted in well-draining soil of alluvial sandy/sandy clay loams/fine gravel substrate within 5ft of the water's edge (Taylor, 2000). Planting cottonwoods in areas where the water table is below 3m is not recommended as it cannot survive drought without being able to access the water table eventually (Braatne et. al, 1996).

- Seedlings can either be grown in nurseries from seeds, preferably from existing trees if there exist any sexually mature trees on-site, or taken as cuttings; due to the low germination rates using direct seeding on-site would not be recommended (Braatne et. al, 1996). Cottonwoods can be asexually propagated by taking 2'-3' stem cuttings (recommended from ground shoots), preferably from existing trees if there are any on-site, and simply placing them 1/3 of the way into moist soil and there is a high chance the cutting will root on its own (Braatne et. al, 1996). For each ha, plant seedlings or cuttings at 8ft intervals following the water line; another row can be placed alternating between the first row but 5ft from the waterline. Mature individuals should be around 80ft apart to ensure no intraspecific competition for light, as cottonwoods grow to around 50ft across and need full sun for healthy growth as pioneer species; survivability of seedlings is low and, while no number was given, I estimate that at minimum 10% seedlings survive (Braatne et. al, 1996; Taylor, 2000). Set up irrigation if needed so that the soil around the seedlings/cuttings maintains moistness around the root system (especially important for cuttings) (Borman & Larson, 2002).
- If there's grazing, seedlings must be protected until the lowest branches are around 5ft off the ground to protect them from damage; burnings should be prevented as seedlings grow and are not recommended with cottonwood stands, though mature stands can tolerate the disruption of light fires (intense flames can kill). Fire can be used to clear out undergrowth before planting if the site is heavily infested with competitors/invaders (Taylor, 2000).
- Seedlings are very intolerant of droughts; they will be vulnerable for the first year until growth accelerates the second year and by the ends of the second year the roots begin to reach around 3m long and can access the water table (Borman & Larson, 2002). After that, irrigation can be removed and seedlings allowed to be self-sufficient and access the water table for their water source. Prior to irrigation removal, slowly decrease the amount of water supplied through irrigation (1/2 after first year down to none the end of the second year). The timing and extent of irrigation would be site-specific, but daily drip irrigation to maintain moist soil around the seedling/cutting would increase survival chances.
- Once seedlings are established, periodic visits (see Monitoring Plan below) will include removing invasives from around the seedlings and saplings until they are mature enough to out-compete the invasives.

If seedlings fail to establish ensure they're getting adequate water; if they fail to establish due to damage from flood events (as seedlings can be damaged/killed by severe flood events), plant older saplings along the banks instead—these will act as buffers once mature which can protect seedlings and prevent erosion of the banks (Asplund & Gooch, 1988).

If continued drought occurs and cottonwoods fail to establish self-sufficiency overall (surviving without artificial irrigation) after 5 years, steps should be taken to increase water flow to the area (such as diverting water from other sources), waiting until drought seasons pass (could be indefinite), or consider using other species that are more drought tolerant in lieu of cottonwoods (unless cottonwood restoration is the goal of the site). If only sporadic sites fail to populate throughout the overall site, utilize cuttings from the surviving individuals and re-plant in the barren sites; it could be that the individuals were not suited for the environmental conditions but the survivors are adapted, or that there is a specific problem with those barren spots and, if the second generation fails to take hold, further study can examine the qualities of the bare spots to determine the cause and potentially remedy it.

Monitoring Plan:

The populations of cottonwood should be monitored tri-yearly to determine success—during the reproductive season (March), after new seedling establishment (June), and finally near the end of the growing season (September) (Braatne et. al, 1996). This allows for observing the number of reproductively mature adults, established seedlings, and surviving saplings, respectively. At each visit, record the following:

- Number of seedlings, saplings, and mature cottonwoods (main determinant of success—if the population increases throughout the years and/or maintains above 50 individuals/ha with new generations of seedlings and saplings able to establish without human intervention then the population would be considered self-sufficient).
- Water table depth around main population groupings (if there is a constant drop in water table level, the population is threatened; a stable water table depth through drought and flood at or less than 3m deep is ideal) (Pataki et. al, 2005).
- Encroachment of invasive species (smaller species are not an issue for mature cottonwoods, but competitors such as saltcedar and small invasives that colonize common seedling and germination zones—usually flat banks that are always wet—are considered a threat).
- Colonization of other pioneer species that usually arrive with cottonwoods, i.e. willow species (establishment of these will affirm the success of the cottonwood colonization) (Rood et. al, 2003; Stella et. al, 2006).

New populations should be monitored and potentially added to in order to maintain the lowest frequency of species (50 per ha) for 13 years so that the original seedling have reached sexual maturity (between 5-10 years) and the minimum first 3 years of reproducing and seed dispersal can be monitored to view successful reproduction and new generations of cottonwoods have established (Braatne et. al, 1996). The site should be revisited less frequently after initial colonization has occurred, once every 3 years and during droughts to check the survivorship with water stress. Highly successful populations would be higher than 300 individuals/ha, though depending on the specifics of the site this number could be much smaller due to space limitations, drought conditions, competition, and desired layout of the restored site (Braatne et. al, 1996).

Further Research:

I was unable to locate the exact percentages of seedling and sapling survival rate as well as germination rates of dispersed seeds—this could prove very useful in the future for determining exactly at what frequencies saplings should be planted. For research, by monitoring species densities throughout time from initial seedling establishment to mature individuals, the survivability rates could be established.

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The California Wild Grape (*Vitis californica*)

Amanda Lukas

A. Background + Justification.

The California wild grape (*Vitis californica*) is a plant important for many ecosystems, the wine industry and a useful plant for restoration and flood control. *Vitis californica* is a plant found in different ecosystems and it is an important source of food for birds, small mammals and coyotes. (Howard1993) The California grape is also important for the wine industry and is the ancestor of the Roger's Red grape which is a prized, ornamental grape.(Dangl et. al1994).The California grape has already been recommended for flood control and restoration due to the fact that it grows and spreads quickly and is also drought resistant. (Golder1984) It is neither endangered or threatened.(Calflora2017)

B. Species Information

1. Range**:**

- The California wild Grape(*Vitis californica*) is endemic to southern Oregon and California. It can be found on the coast and ranges from Douglas County, Oregon to San Louis Obispo, California. It can also be found in the Cascade Mountains, Sierra Nevada mountains, Klamath Mountains and the Central Valley of California.(Munz1973)

2. Habitat Requirements:

Soil:

pH	5.2-8.2
Maximum salinity	3.1
Minimum depth	27cm
Soil texture	Fine, medium or course
Maximum $CaCO_3$	4%

Table 1. California wild grape Soil Requirements(Calflora2017)

Environment:

Elevation	0-1640 meters
Precipitation	11-91 inches
Wet Season	3-8 months
Temperature Range	39-64 F
Lowest December Temperature	26 F
Highest July Temperature	98 F
Accumulated Temperature	68-236 F
Growing Season	3-8 months
Hardiness Zones	7b-10a

Table 2. California wild grape growth factors(Calflora2017)

- The California wild grape can tolerate a wide range of temperatures, elevation and precipitation. The California wild grape can grow in fine, medium or coarse soil but cannot tolerate very acidic soil or high levels of limestone. (Calflora2017)

3. Growth

- The California wild grape is a fast-growing shrub/vine. It grows 6-12 meters tall and .3 meters wide. (California Native Plant Society2010)
- The California wild grape is a winter deciduous plant which means that it loses its leaves in the winter. The grapes that remain will often turn sour.(California Native Plant Society2010)

4. Reproduction:

- The California wild grape is a unisexual plant. (The Jepson Herbarium2017)
- The California wild grape is pollinated by local bees but, its most common pollinator is butterflies.(California Native Plant Society2010)
- The California wild grape flowers in the spring and its grapes grow in the late summer. (Calflora2017)

5. Natural Disasters:

- Because the California wild grape can survive well in different in levels of precipitation, it is known to do well in a drought.(Calflora2017)

- The California wild grape has survived in areas with natural fires and seeds will stimulate after small fires.(Fites-Kaufman et al.2006)
- The California wild grape has been found in active flood plains shortly after floods.(Harris1987)
- The California wild grape does not do well when temperatures get very hot or it is over-exposed to sunlight. (Pearcy and Gamon1989)

6. Ecosystem Roles/Species Interactions:

- The California wild grape is an important part of the following ecosystems: Douglas-fir, Ponderosa pine, Redwood, Western hardwoods, Chaparral - mountain shrub, Wet grasslands and Annual grasslands. (Howard1993)
- The California wild grape can provide both canopy cover and up to 30% ground cover in ecosystems.(Barbour2007)
- The California wild grape is an important source of food for endemic birds and coyotes. (Howard1993)
- The California wild grape is popular for local butterflies and bees.(California Native Plant Society2010)
- The California wild grape can be an aggressive plant and kill oaks and cottonwood trees once vines have established in canopies.(Howard1993)

7. Human Interactions:

- The California wild grape is considered a noxious weed in states like Ohio where it is not native.(Natural Resources Conservation Service2000)
- The California wild grape has a close connection to the wine industry and has been made into wine and jellies.(Howard1993)The California wild grape may still be present in wine cultivars due to the fact that it's roots were used to save the European wine industry from disease in the late 1800s. (Howard1993)
- The California wild grape was crossed with Vitis vinus to create the "Rogers Red" grape which is currently a popular ornamental grape in yards. (Dangl et al.2010)

8. Past Restoration:

- The California wild grape has been suggested for past restoration of flood plains due to the fact that it grows quickly and can survive well in both drought and temperate climates. (Goldner1984)
- The California wild grape has also been suggested for past restoration due to the fact that it attracts a large number of insects and may therefore, start an important part of an ecosystem again for insectivorous birds, reptiles and amphibians.(Hosner1962)

Management Plan

A. Goals:

The California wild grape(Vitis californica) is a native, vine species that is found throughout the Central Valley along streams, springs and in the upper, woody communities .(California Native Plant Soceity2010) Due to the fact that the California grape is an important food source for native animals, the California wild grape will need to be a part of the ecosystem. Therefore, the main restoration goal is to determine when it is the best time to introduce the California wild grape into the restoration site/ecosystem. This will be based upon its growth rate, important role as a food source and its competition with other plants. Ideally, the species should be planted first due to its fast growth rate and ability to provide food. However, because the grape is parasitic to other plants, the introduction will vary with location and the other species present. If the California wild grape can have negative consequences, it should be introduced at a later time.

Overall, restoration goals should include:

1) Analysis and determination of introduction.

2) Re-introduction of the California wild grape to the wetland/riparian woody ecosystem.

3) Maintenance of the California wild grape population at healthy numbers and reproduction.

4) Monitoring of the California wild grape population for parasitism of trees and the spread of wine diseases.

B. Feasability:

These goals are feasible. The California wild grape reproduces via pollination, spreads by animals and is known for attracting a large amount of butterflies and birds to do so. Once a small population of insects and birds have established at the location, the California wild grape population should grow and maintain stable.

C.Pre-restoration goals:

- Analysis of the environment and other restoration plants/trees to determine if restoration plan A or B should be used.

- Vitis Californica has become infected with leafroll-associated virus and Grapevine A and B in the past. The California wild grape needs to be surveyed for past and current diseases.

•	The California wild grape is known to catch disease from the hybrid “Rodger’s Red” which is grown on farms. Local farms need to be surveyed for new infections and new diseases.

D. Restoration Plan:

I.	Analysis.

The California wild grape is known to have a parasitic relationship with trees and can be harmful if it gets into the canopies. (Howard1993) The first step that needs to be taken is to figure whether the ecosystem and restoration project will be dependent on a woody/tree species. The California grape will not grow well with saplings and this needs to be taken into consideration for the restoration project.

II.	**Plan A**: Without a woody species.

If the ecosystem and restoration project does not rely on a woody species, the California wild grape should be one of the first plants to be introduced into the system. The California wild grape has been suggested for the first round of restoration in the past because it is fast growing and can manipulate soil.(Goldner1984)

The California wild grape should be planted as seeds because it will need to form a deep root system.(The California Native Plant Society2010) Because it is deciduous in the winter, the seed should be planted in the late spring. The grape is known to do best in moist soil and it cannot survive high levels of acidity. (Calflora2017)Therefore, the grape should be planted near a water source but the pH should be tested before. Significant space should be placed between each seed because the California wild grape has significant secondary growth and can sprout from its fragments.(Young2016)

The California wild grape is fast-growing and after rain the plant should begin its growth. Absent from herbivory and most competition, the grape population should grow.

III.	**Plan B**: With a woody species

If the ecosystem is dependent upon a woody species, then the introduction of the California wild grape should be delayed. The California wild grape is a parasitic on trees and will damage those that are growing. The woody species should be planted first for restoration at its optimal location. Once it has reached its full- developed state, the California grape should be planted as a seed.

The California wild grape does well in both the shade of trees and the sunlight so the presence of trees should not have an effect on how or where the grapes are planted.(Calflora2017) The California wild grape will do best in moist soil and significant distance(about 2 meters) should be planted in between each seed due to the fact that the wild grape has significant secondary growth and can sprout from its fragments.(Young2016)

Monitoring Plan:

If introduced into a woodland, the California wild grape will need to be monitored for its potential parasitic effects. If the California wild grape is dominating a tree's canopy and eliminating a tree's source of light, then action should be taken. The vine cannot simply be cut because the California wild grape can continue to sprout from its fragments. To eliminate the parasitic effect, the entire plant must be killed and that can only be done at its center stem and roots.(Calflora2017) .

In addition, the vineyards of the Central Valley will need to be monitored for new diseases that can affect the California wild grape.

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Buttonbush (Cephalanthus occidentalis)

Christine Russo

Background and Justification

Cephalanthus occidentalis or more commonly know as Buttonbush, is a woody plant species native to California and found in the Rubiaceae family (Ladybird 2012). The benefits from this species are great and it contributes to supporting a diverse wildlife population. Being a honey plant this species supports various bees species, several different wasps, butterflies, moths and even hummingbirds, all of which are drawn to the sweet nectar buttonbush flowers produce (Dunning 2012). The shrubby bush that makes up buttonbush serves as coverage and an escape area for many reptile, amphibians and nesting birds (Ladybird 2012). Since wetland and riparian habitats support a large variety of wildlife and birds, buttonbush plays a large role in protecting and feeding several different species making it an ideal plant to incorporate into restoration work. Another function of this plant is ornamental, it can be incorporate along ponds and water gardens to give a nice aesthetic (USDA). Overall the state of this species is stable, since it is an effective reproducer it's population has stayed relatively abundant. There is no history of degradation.

Literature Review

Growth Characteristics:

- This species is a deciduous perennial shrub that grows 6-12ft tall and produces dense spherical clusters, commonly known as 'honey balls," with a fringe of pistols that extend out of these dense spheres (Ladybird 2012).
- They commonly produce white or light pink colored flowers and glossy dark green leaves that are resistant to fall color changes (Ladybird 2012).
- The leaves are opposite, 18 centimeter long and 7.5 cm wide, with edges that are smooth (Wennerberg 2004).
- It's effective combating erosion because the plant forms dense clusters of shrubs or small trees and has a swollen base that helps to stabilize the plant (USDA).
- Buttonbush is a fast growing species that will thrive in native landscapes if enough water is provided (Dunning 2012).

Habitat:

- Buttonbush is a common wetland and riparian species, most commonly found in swamps, floodplains, marshes, and bogs, that requires wet soils and can be found in most states within the United States and into Canada (Ladybird 2012).
- It's normal range is from Florida to Mexico with scattered plots throughout several other states such as Arizona and California (Wennerberg).
- It requires semi-regular inundation, is found around the edges of ponds or wetland habitats and cannot survive in dry arid conditions. It will likely not respond well to further climate change as it has a specific climate and moisture tolerance (USDA 2002).
- Buttonbush requires high water use, part to full sunlight and can be supported by a variety of soils types, from limestone-based to full clay soils. Though it does best in sandy, loamy or alluvial soils, favoring acidic to neutral soils and is intolerant of alkalinity (Wennerberg 2004).

Reproduction:

- Buttonbush blooms in June through September and sets fruit in September and October. Seeds are ready for collection typically in fall months after they have turned reddish-brown (USDA 2002).
- *Cephalanthus occidentalis* spreads by seed dispersal and the resulting seedling establishment (USDA 2002).
- Pollinators play a large role in reproduction

Tolerance:

- The foliage is poisonous and unpalatable to livestock so grazing is not a large issue (Ladybird 2012).
- Springtime flooding has been know to do some damage to this species as it can tolerate moderate flooding but not constant flooding (USDA 2002).
- Following high intensity burns, buttonbush is slow to resprout but will resprout within a few months after a low-intensity burn (Wennerberg 2004).
- It can tolerate water depths up to 3 feet and is intolerant to dry soils (USDA 2002).
- The abundance of this species will increase with increased water and light levels (Wennerberg 2004).

Interactions:

- Buttonbush is a very attractive species with ornamental blooms that has a nice aroma contributing to attracting pollinators.
- The seeds of this species are an important source of food for ducks and other waterfowl species.
- Like stated above, this species is a honey plant and because of its sweet nectar supports a variety of pollinators.
- Provides an escape or shelter for many amphibians and reptiles and wetland mammals (Needham 1903).
- The pollen from this honey plant is used by various bee species to produce honey (USDA 2002).

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Part 2- Monitoring Plan

Cephalanthus occidentalis or more commonly know Buttonbush is native to California and plays a large role in aiding in honey production for bees, and providing food and shelter for wildlife. This species is a honey plant, which draws a large amount of insects and birds in for a taste of the sweet nectar. This plant can be found in several different areas of Sacramento central valley as well as from Florida to Mexico with scattered plots throughout several other states such as Arizona (Wennerberg). A large amount of Buttonbush habitat is being degraded and destroyed by agriculture and water development projects. These water development projects are limiting the dispersal of buttonbush since they are not good at establishing in manmade waterways. Buttonbush establishes in wetland and riparian habitats. They are commonly found in swamps, floodplains, marshes, and bogs. Even though overall Buttonbush is not a threated species, reestablishment of lost habitat in California central valley would benefit not only this species but also to a large amount of wildlife such as waterfowl, deer, bees, butterflies, hummingbirds and more. Restoration goals for this species are as follows:

- Reintroduction at a rate of 3 plants per acre in current and future wetland and riparian restoration sites over a several years to make sure they are able to establish with fluctuation water tables. Buttonbush needs to be established at the edges of wetlands and ponds so it is able to access available water as this species needs semi-regular to regular inundation and can tolerate a water table depth of .3-.9m. This species will need to be established large-scale and in several different locations as the central valley is a hot spot for agriculture and this type of land negatively affects Buttonbush, as well as the fact that buttonbush has a hard time establishing in man made restoration sites such as the Dixon wetland restoration site.

- Limit or remove herbicide use around Buttonbush, as this species is moderately susceptible to most all herbicides. Herbicides can be aiding in the degradation of this species. Separating agricultural fields from buttonbush habitat or not transplanting buttonbush into areas surrounded by agricultural land can achieve this. This can also be achieved by implementing a buffer zone, or edge effect to limit the transfer of herbicides from agriculture sites into the restoration site. A buffer zone can be implemented by planting dense patches of tall grass along the edge of wetlands; a good species that could be planted would be the native deer grass, *Muhlenbergia rigens.*

These goals are certainly feasible with long-term monitoring. Like most restoration projects at least 3 years of monitoring will be needed to make sure the species is able to root themselves, longer if this restoration work is done during drought years as buttonbush needs regular water to be able to survive. A minimum of 3 years of monitoring is needed because buttonbush has a hard time establishing in man made waterways and additional plantings may be needed if the initial plants are not unable to establish themselves. Buttonbush needs 1-3 feet of water to establish and thrive, for restoration to be successful they will need to be established in wet areas with semi-regular inundation. Before restoration is started, it would be useful to collect data on how abundant Buttonbush still is in the central valley. Since much of their land cover has been destroyed as mentioned above we aren't sure just how much is left.

Restoration Plan:

Since buttonbush grows most successfully in areas around the edged of ponds and wetlands and can tolerate up to 3 feet of flooding, these areas would be the best places to start reintroducing the species. Seed dispersal is the main way *Cephalanthus occidentalis* reproduces but since Buttonbush seeds are a food source for many bird species it would be best to transplant 1-year-old seedlings and cuttings (USDA). To control for erosion it is best to establish plants at a two-foot spacing. If time does not permit to establish 1-year old seedlings, seeds can be dispersed and would need to collected from various locations such as nurseries and in the field; the best time to collect seeds is when the nutlets have turned reddish-brown which usually happens in early June when the blooming starts to occur, this species averages about 134,000 seeds per pound (USDA 2002). Since the germination rate is low for this species, approximately 10-20%, so we will need to disperse a large amount of seeds to make sure a good percentage is able to establish (Synder S. A 1991). I would estimate the number of seeds needed at about 5,000, but this will vary based on the number of restoration sites available to reestablish the population.

Buttonbush produces foliage that is poisonous and unpalatable to livestock so grazing will likely not be an issues and coverage would be unnecessary (Ladybird 2012). One likely threat to reestablishment of *Cephalanthus occidentalis* is lose of seeds to predation. The seeds of Buttonbush are a main source of food for ducks, geese and many other waterfowl species. We will need to disperse excesses seeds for this reason, and the fact that the germination rate is low. These two factors can make restoration efforts tough for this species. Buttonbush is a fast growing species once it's root have taken in the soil and will thrive in native landscapes if enough water is provided (Dunning 2012). We will also need to make sure that there are plenty of insects and bird species as they eat the pollen of Buttonbush and bees use the pollen to make honey. This species is critical to the success of bees so restoration efforts will need to be incorporated in areas where various bee species are found.

Agricultural land and the use of herbicides are known to have negative effects on this species. With the development of agricultural land, much of Buttonbush habitat has been destroyed. It would be wise to work with surrounding farmers to make sure restoration sites are not in potential agricultural land growth area, or areas with high amounts of runoff. Buttonbush is susceptible to herbicides so if herbicides are used with a restoration site they cannot be sprayed in areas where *Cephalanthus occidentalis* is going to be established.

It would also be wise to think about how erosion is going to effect the establishment of this species. While *Cephalanthus occidentalis* forms dense clusters of shrubs or small trees and has a swollen base that helps to stabilize the plant, the initial establishment will not start off having these swollen bases. Since we will be dispersing need the edges of ponds and wetlands, we will need to make sure there is not too much erosion or potential for erosion before the roots have time to fully stabilize themselves.

Monitoring Plan:

Since germination rates are low (no specific time found) for Buttonbush, monitoring will be needed for at least 3-5 years to make sure the plants are able to establish roots and thrive. Buttonbush usually establishes around, American beech (Fagus grandifolia), red maple (Acer rubrum), sugar maple (A. saccharum), ash (Fraxinus spp.), black oak (Quercus velutina), pin oak (Q. palustris) so we would want to make sure these species are established in the same area for Buttonbush, they are not required for the survival of Buttonbush but are common species found around Buttonbush (Synder S. A 1991).

Cephalanthus occidentalis cannot handle dry, arid conditions; they will need between 1-3 feet of water at all times to be able to survive in the heat of the central valley summers. Buttonbush can handle fluctuating water tables throughout the summer months but does need access to at least .3m of water to be able to survive. We will likely need to monitor excessively early on to make sure the invasive grasses on the site do not take over the open land before Buttonbush is able to fully establish, this is a threat to many native plant species. We will also want to monitor water levels in the first few years to make sure drought conditions do not kill this species. We can measure water table depth by using algor.

Long term monitoring of 5-10 years would be a great resource to make sure additional urban and agricultural growth does not degrade the restoration work done, or continue to destroy existing natural habitats. Since this species has a hard time established in man made waterways, conservation of natural land would be wise and helpful for the existing populations. We will want to do long term data collection of the existing population to fully understand where we are at and have complete information over the years. Continual monitoring will likely not be a resource restoration ecologist will have, so ideally 5 years of monitoring to make sure this species is able to fight for it's space and succeed. Continual monitoring can tell us how successful Buttonbush is to establishing in areas once dominated by invasive grasses, we would also be able to find out just how vital this species is to wetland and riparian wildlife within the central valley.

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Arroyo Willow (Salix lasiolepis)

Brittany Krone

Background and Justification

Arroyo willow is native to California and other northwestern states including Idaho and Arizona (USDA, 2017). The species is widespread and can be found as far as Alaska and Texas (Laspilitas, 2012). Arroyo Willow can grow as a shrub or tree depending on water and light availability, if there is high canopy cover the species will grow more tree like in order to reach the light, whereas, if more light is available it will spread out like a shrub (Riverbanks, 2017). Chemicals derived from willows have been used at nurseries to promote plant cuttings to root and the derived chemicals also helped produce Aspirin . Native Americans have had many uses for the species. The bark was used to make baskets, stakes, and ropes. The flowers were used to treat a variety of ailments as well (Sierra Streams Institute, 2017). Arroyo is often used for streambank stabilization (Laspilitas, 2012). Arroyo willow has also been used to restore riparian areas, improve freshwater fisheries, to landscape and create wetland areas (The Watershed Nursery, 2017). The species provides food and shade to a variety of wildlife including butterflies, birds and bees (The Watershed Nursery, 2017). In the Santa Margarita area it was reported that there was a major loss of Arroyo willows because of a frost (Las pilitas, 2012).

Literature Review

Characteristics

- Arroyo willows is a deciduous shrub/tree. (San Elijo, 2017)
- Male and female parts are on different plants. The flowers are catkins. Female, seed producing catkins are green and the male catkins that release pollen are yellow (San Elijo, 2017)
- The species blooming time is between February and April. The catkin flowers arrive before the leaves appear.

- Arroyo are insect pollinated and are consumed by many insects during spring which promotes birds because of the high availability of insects (Riverbanks, 2017).
- It’s classified as a pioneer species on wetland areas (Las pilitas, 2012).
- Arroyo willow can grow up to 10 m and grows erect with multiple stems (USDA, 2017).

Growth requirements

- The species can only survive if the roots can reach the water table. The species has a rooting depth of at least 26 inches. (Riverbanks, 2017).
- The species can grow under a mix of sand, loam or clay soils but does best in loamy soils (USDA, 2017)
- The willow can sustain growth under pH’s between 5.5 and 7.5 (USDA, 2017).
- The species does not do well in saline conditions (USDA, 2017).

Distribution

- Arroyo is most commonly found in riparian areas. There are communities in the Redwood forest, Mixed evergreen forest, Valley grassland and many more (Calflora, 2017).
- The species is found throughout the western U.S and at elevations no more than 2200 m (San Elijo, 2017).
- The species is found near freshwater, usually along streams or steeps (San Elijo, 2017).
- They grow in mixed riparian areas and usually with other arroyo willow communities (Riverbanks, 2017).

Tolerances

- Arroyo Willow can tolerate drought and flooding for a moderate period of time (Riverbanks, 2017), which is why the species is classified as having a high tolerance to anaerobic conditions (USDA, 2017).

- It is highly fire tolerant. When fire occurs the species will resprout rapidly from the stems (USDA, 2017).

Part II: Restoration Project

Goals

Salix Lasiolepis is a shrub or small tree native to California and other northwestern states. The species is abundant throughout California, being the dominant or codominant species in a shrub or low tree canopy in a shrubland (CNPS). The restoration goal is to establish Arroyo Willow as a dominant riparian species along the toe of the bank or on the lower slope near the bank depending on distance the surface is from the water table. Restoration goals will be based off of water table depth, soil type and soil structure conditions.

- Remove all invasive species along wetland bank and slopes through herbicides, prescribed burns or grazing depending on if any native species are present in the area. If an ample amount are present then a spot treatment will be implemented to target invasives and leave natives be.
- Establish Arroyo willow on restoration site with cuttings or container plants. The goal is to have a full percent cover of around 50% of species along wetland bank or low slope. If Arroyo willow is only shrub species then a higher percent cover would be sought for and the reverse if other native species are being added.
- Maintain the site in order to supports a wetland and wetland characteristics such as moist soil and promote bank stabilization.

The likelihood of achieving the goals depends on the ability of the site to maintain moist soils during the period of establishment. Arroyo willow cannot survive any type of dry soil until after maturity and even then it can only survive short periods.

The restoration plan will first begin by taking an assessment of the current site conditions to determine the severity of invasive species present and environmental conditions of the site. The assessment will also survey water table depth, soil conditions, and wildlife and native species already present on the site.

Arroyo Willow can be reproduced by cuttings or bare roots. Whether bare roots or cuttings they should be installed in the site between October 1st to January 1st to ensure the species gets the water needed to survive. There must be moist soil for the first few years while species in maturing. If bare roots option is utilized the roots should be grown in a container, specifically a

Treepot-4 to promote full development and straight roots (San Francisquito Creek Joint Powers Authority, 2006). Using Treepot-4 will increase likelihood of rooting and success of the transplant. If cuttings are used they should be harvested in winter when the plants are dormant. When harvesting one should be sure to check for any insect infestations and make sure the cutting is in a healthy condition. Although galls present on Arroyo willow are harmless, they should still be discarded just to be sure (Our Wetlands, Our world). Once harvested they should be planted immediately for increase chance of rooting. If this is not an option they can be stored in water in a shady area for up to 48 hours (San Francisquito Creek Joint Powers Authority,

2006). Cuttings should be 18 inches in length. When buried at site 12 inches should be buried.

Specific spacing and number of species will depend on size of the site and other factors like other species planted. *Salix Lasiolepis* is co-dominant with these species, *Acer macrophyllum*, *Baccharis pilularis*, *Baccharis salicifolia*, *Cephalanthus occidentalis*, *Cornus sericea*, *Morella californica*, *Platanus racemosa*, so if they were planned on being planted with these species there should be a lower density of Arroyo willow (CNPS). As a general rule though, the species should be planted in between trees that are planned to be installed. Arroyo willow forms dense thickets naturally so they should only be spaced about 8-12 feet apart of clusters of 2-3 (San Francisquito Creek Joint Powers Authority, 2006). I recommend 3 because the species is slow to spread vegetatively (USDA, 2017). The clusters should be a mix of male and female plants to ensure reproduction occurs. Arroyo willow is mainly insect pollinated so placing females on the low end of the slope would be beneficial to ensure seeds are not dropped in the wetland.

The site should be irrigated for at least three years between March and October to ensure establishment of the species. Depending on the site conditions the species should be irrigated between 2-4 times a month, probably leaning toward 3-4 because the site is in the central valley (San Francisquito Creek Joint Powers Authority, 2006). After the first year the site should be irrigated a little less often to ease into no irrigation and finally during the last year watering once a month. Again, the site assessment will give insight into what the conditions are and if more or less irrigation will need to be provided.

Monitoring Plan

Before the restoration plan is enforced a sweep of the site will be done to determine that all non natives are cleared from the establishing site and that there is no new growth of the invasive species.The site will ideally be monitored for 4 years once Arroyo willow is installed. The monitoring after the last year of irrigation is to be certain that the species is doing well without the additional water being provided.

The monitoring plan will include checking on percent coverage achieved, and species survivorship of a plot. The Santa Clara River Riparian Revegetation and Monitoring Handbook states that having permanent plots to track survivorship of individuals will give a better estimate than viewing the systems survivorship as a whole (Coffman, Ambrose, 2011). This method would be utilized for a large site. Another method to track plant survival is taking a census of all plants and seeing how many survive after one year (Lewis, Lennox, Nossaman, 2009). If site conditions show that they are unfavorable to the species then the site should be surveyed 6 months after installation. Percent coverage will also be taken note of yearly to see if the coverage is on track. Another factor that will be monitored is if any of the installed species have any recruitment. When monitoring occurs and it appears that installed species have died a plan to replace them will be implemented to ensure that their is an 80% survival and that the site will reach its goal of 50% coverage.

When the census is being taken during the first year the abundance of wildlife will also be observed. Any pollinators, insects or birds present will be noted. If none are present the first year an assessment of the site will be taken to survey what conditions are preventing their appearance.

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Mid- to Upper Riparian and Upland Woody Species

Valley Oaks (*Quercus lobata*)

Zachary Emerson

Valley Oak Restoration

Valley Oaks (*Quercus lobata*) represent a fundamental part of healthy riparian forests all across the Central Valley. Before colonization by Europeans, this riparian forest habitat was composed of vast populations of Valley Oak on either side of nearly every river in the Central Valley and occupied over 800,000 acres in the Sacramento Valley alone (Griggs et al., 2002). Currently, riparian forest only covers 20,000 acres and most that remains is in a degraded state (Griggs et al., 2002) .

Oak woodland and riparian Valley Oak forest were not just extensive, at one time they supported a profound amount of biodiversity, and continue, "to support more species of wildlife than any other forest type in California" (Griggs et al., 1997). Riparian forest is a hotspot for biodiversity due to it's abundance and nearness to water as well as varied and complex vegetation structure, which provides diverse resources and habitat for many plants and animals (Griggs et al., 1997). More specifically, Valley Oaks and other Oak woodland species facilitate this diversity by providing food and shelter, both directly and indirectly, to over 300 species of animals and 5,000 species of insects and arachnids (Little et al. 2001). Some species like certain Gall Wasps (such as *Andricus californicus*) or the Acorn Woodpecker (*Melanerpes* *formicivorus*) depend solely upon the Valley Oak for both of those services. That being said, there are a myriad of animals and invertebrates that feed on nearly every part of the Valley Oak, from roots to acorns. Many of these invertebrates that we may not readily notice are key food sources for often more prominent organisms found at higher trophic levels (Little et al. 2001). In addition to these direct effects on biodiversity, new research is indicating strong benefits from the significant hydraulic redistribution that Valley Oaks and other Oak species can facilitate.They accomplish this feat by extending their long taproots into groundwater sources, and redistributing the water, through shallower roots, to the drier surface layers of the fine-textured soils like the clay and silt-loams which *Quercus lobata* prefer. It is widely known that the alluvium deposited when a river floods it's banks is essential for the growth of Valley Oaks, and coincidentally this fertile alluvium is some of the most highly valued agricultural land in the state of California. Thus, agriculture has been the largest driving force behind the elimination of Valley Oaks and the degradation of riparian habitat within the Central Valley. Much of the Valley Oak stands around Sacramento were cleared for this very purpose, as well as for lumber, fuel for steamships, and other shortsighted uses in the late 1800's (Griggs et al., 2002). A large amount of riparian habitat has also been lost or degraded due to dams, levees and other massive hydrologic modifications. This lack of long term consideration continued into the 1970's when many Valley Oaks were cut down to "enhance grazing productivity" at the advising of University of California professors, and it is only until recently that we have come to understand the need for restoring this species. Unfortunately, Valley Oaks have had considerable difficulty in regenerating, and research into the issue indicates there has been a growing disparity between old and young populations, with less species to fill the middle-age gap. Given all of the above points, there is clear evidence for us to act quickly and decisively in Valley Oak restoration.

Literature Review

General

-Provides essential habitat and food for many plant and animal species. Over the long-term, few other native plants can support such an abundance and diversity of life as *Quercus spp*. Being one of the largest N. American Oaks, *Q. lobata* provides all of these services in full. (Wilken et al., 2000)

-Massive, robust root systems significantly stabilize floodplain soils and prevent erosion in extreme flooding events. (Wilken et al., 2000)

Germination/ Propagation

-Acorns are ripe when they separate readily and fall from the tree freely (usually mid-October) (Wilken et al., 2000)

-Local, unblemished acorns free of exudates and small holes made by insects should be used for germination. Acorns do not keep well, so it's best to refrigerate the fresh acorns before planting them in the winter-no later than mid-December. (anticipate on planting before the winter rains come, which the acorns depend on for germination) (Wilken et al., 2000)

-Optimal depth for germination and prevention of herbivory is 5.1 cm or 2 inches in containers and 4-5 inches deep when direct seeding (6-10 acorns per hole) (Tietje et al., 1991)

-4 inches between acorns is a good distance to reduce the impacts of depredation (Tietje et al., 1991)

-Plant large numbers of acorns (based on guidelines in Pt. 2 anywhere from 300-1500 acorns per hectare) even to the point of over planting, acorns are much less expensive than nursery stock and input methods are not impacted by seedling density. (Tietje et al., 1991)

-Continuous flooding will negatively effect the germination rate of acorns, although short-term flood events or events that subside in the spring don't seem to have a substantial impact (<1 month). (Trowbridge, 2002)

Sapling Protection

-If cattle or deer are present at the site, cages should be used to prevent grazing of seedlings/young trees. After trees surpass the browse line, cages can be removed and reused on other saplings which are more susceptible to grazing (Bernhardt et al. 1997)

Environmental Preferences/Necessary Conditions

-Prefers alluvium and fine textured soils such as clay and silt-loams (of the Colombia soil series)(Griggs et al. 1997)

-Deep fertile soil, below 1200m elevation (most abundantly found below 600m). (Wilken et al., 2000)

Grows in riparian areas with seasonal flooding, tend to be concentrated in upper floodplain in areas that experience natural inundation events (Griggs, 2002). Distance from water table of 3-5m ideal (Griggs et al. 1997) or any depth the roots can reach.

-Water needs to reach zone of root growth near water table while trees are being established, deep-infrequent waterings are best (every 10 days to 2 weeks recommended). In the second year, decrease to one every 6 weeks, and only twice in the third year. (Griggs et al. 1997)

-During the period that is crucial for seedling establishment (acorns germinate after the first winter rains) additional irrigation can be scaled back or eliminated if there is consistent and plentiful precipitation throughout the winter months. (Bernhardt et al. 1997)

-A wood-chip mulch should be applied to aid in soil temperature regulation and moisture retention. Significantly enhances growth. (Bernhardt et al. 1997)

Seasonality/Phenology

-Flowers March-April and acorns ripen between August-October (Rosatti et al. 2017)

-Good acorn production in most years, although "mast" years will periodically result in an extremely abundant crop of acorns (Wilken et al., 2000)

Growth

-Trees grow quickly during spring and summer, deciduous in the winter (Wilken et al., 2000)

-Can reach height of 12-30m, with trunk 2m or greater in width. May be the largest oaks in North America (Wilken et al., 2000)

-Can grow up to 20 feet tall in the first 5 years (on average older oaks will grow 20 feet every 10 years) and can grow to be 600 years old, although 250 years is considered a more common life span (California Native Plant Society, 2017)

Hydraulic Uplift/Carbon Sequestration

-Oak tree taproots stretch deep into the soil and can reach groundwater sources that other plants may not have access to. Hydraulic uplift is the process by which this groundwater is pumped up through the roots and redistributed among the upper layers of the soil, which would normally be much more prone to drying. Fungi and mycorrhizae are the great decomposers and nutrient cyclers of the Earth, and many form complex synergistic relationships with many plants that enhances growth and resilience. The presence of these organisms in the soil is the foundation for a multitude of healthy plants, not just Oak trees. However, when Valley Oaks improve the soil by supporting these organisms with a source of water (especially during dry summers) and thereby reducing fungal/mycorrhizal seasonal variability, they also improve the productivity of all the plants growing in a landscape. (Allen et al., 2007)

-Being large woody-species Valley Oaks play a fundamental role in carbon sequestration sequestering about 240,000 metric tons of carbon in Solano County alone. The Valley Oaks all across California sequester some 188, 199, 187 tons of carbon, which represent an incredible environmental value in the face of mounting climate change.

Species pairings/Mycorrhizal Influences

-Research indicates that *Avena fatua* negatively impacts seedling growth by reducing available soil moisture, and that native grasses, such as *Stipa pulchra* do not have as great of an impact. This means that weed control methods are equally as important as the re-introduction of native grasses to the understory (Danielsen et al., 1991)

-Obligate relationship with beneficial soil microbes called mycorrhizae, which supply nutrients and moisture to growing trees (Wilken et al., 2000)

-Research has indicated that Valley Oaks planted in forest soils which contain greater mcyorrhizal diversity show improved shoot growth (at the expense of root growth), as opposed to Oaks grown in soil agricultural with a history of agricultural use. (Berman et al., 1998)

Disturbance Regime Information

-Seedlings cannot tolerate grazing or fire. But young trees, above the browse line, are highly resistant to both of these disturbances.

-Specifically, trials using controlled burns found that only a few (around 3-4%) of Valley Oaks were killed but about 66-72% were topkilled. Fire-related top-killing in Oaks is not as severe as in other trees and they will quickly coppice after a fire in order to reclaim their previous stature. (Mean height in trees that were burned/unburned was similar after 2-3 years of growth indicating the resiliency of Valley Oaks after a fire. If trees that are 300 cm (about 120 inches) in height they have very little chance of suffering from top-kill. Therefore, even if saplings are present, fire is still a viable tool for controlling invasives in the understory. Of course, it is worth mentioning that the benefits of using fire to manage a landscape must be weighed against the stresses that it can place on plants and growth should be monitored in between controlled burns to ensure trees have a chance to grow sufficiently in the interim period (Holmes at al., 2009)

-Mature Valley Oaks are very good at tolerating long periods of inundation, especially for periods of no more than 30 days in the winter when they are deciduous and the spring when they are growing. Any longer and growth will be negatively effected (Trowbridge, 2002).

-Valley Oak does not tolerate soil compaction, therefore it is important to properly manage grazing and heavy equipment operations that drastically compact soil near or beneath the canopy cover. (Wilken et al., 2000)

-Small amounts of selective herbicides (such as glyphosate) may be employed to manage invasive weeds around the canopy cover (Griggs et al., 1997)

Disease

-*Phytophthera ramorum* or Sudden Oak Death is not a problem in *Q. lobata,* unlike many other native species in California which are severely affected. Although the pathogen may survive on Valley Oaks for up to six weeks, the plant itself does not seem to suffer ill effects. That being said, care should be taken to ensure that non-contaminated nursery stock are used, so as to not spread the disease to susceptible plants in the area. (Rizzo, 2002)

-It is possible for older trees to be vulnerable to crown rot and root rot fungi, susceptibility may be increased with soil compaction. (Wilken et al. 2000)

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Restoration Project Part 2

A. Goals

a. Planting/Collecting Acorns :
Goal: *Collect viable acorns that will create a robust and genetically diverse population.*

i. Acorns should be harvested when ripe (October-November). Acorns are ripe when they separate readily and fall from the tree freely (Wilken et al., 2000).

iii.Collect no more than 5% of seed from any given population and try to include as many individuals as possible. (Lecture)

iv. Acorns should be planted soon after collection, before mid-December, and should be stored in a refrigerator in the mean time. (Wilken et al., 2000)

v.Plant acorns at a density that has achieved robust populations in similar sites within the Central Valley, about 300-500 seeds per hectare is employed in local restoration sites with planting protocol discussed below in Restoration Plan (Griggs et al., 1997)

vi.But first, is woodland or riparian forest the desired habitat? (Woodland would mean 20-60% canopy cover, while forest is 60-100%). Expected canopy cover should vary based on acorn density/desired landscape structure. (Griggs et al. 1997)

vii.Larger acorns have been shown to grow more vigorously and reach groundwater faster (Hobbs et al. 2001)

b. Establishment and Maintenance of Seedlings:
Goal: *Promote favorable conditions for establishment of seedlings*

i. Irrigation:
In the first year, the area extending from the surface down to the water table should be saturated (every 10 days to 2 weeks recommended). In the second year, decrease to once every 6 weeks, and only twice in the third year. (Griggs et al. 1997) Watering should be progressively deeper and more infrequent as the trees grow in order to encourage deep root growth.

ii. Soil Amendments/ Mulch

The soil types present on the site are ideal for Valley Oaks and therefore need no amendments. A wood chip mulch, applied around the base of trees before emergence or immediately after is the only suggested addition. Wood chip mulch has been proven to improve plant growth through soil temperature regulation, moisture retention, and slow nutrient release. (Griggs et al., 1997)

c. Maintenance of Site Conditions:
Goal: *Ensure that populations can not only establish themselves, but self sustain without excessive input.*

*i.*As mentioned in the literature review, Valley Oaks are negatively impacted by invasive grasses, specifically *Avena* species. (Danielsen et al., 1991)

ii. On the other hand, positive impacts on growth have been observed when *Q. lobata* is grown in association with native grasses, such as *Stipa pulchra (*Purple Needle Grass), which is already present in some areas within the restoration site. (Danielsen et al., 1991)

iii. Selective removal of weeds around planting zones, with particular care to encourage the establishment of native grasses will be an important management goal. Due to the scale of the site, mowing and selective herbicide application may be necessary to realistically manage invasives. (Griggs et al., 1997)

iv. Planting acorns in rows will be a helpful strategy in order to facilitate the regular management of invasive plants and irrigation lines. (Drip and solid set sprinklers have both been used with success-volume and frequency are more important than irrigation method). (Griggs et al., 1997)

v. Another important reason for the management of invasive grasses and other weeds is the fact that they provide cover for voles and gophers, which are the main herbivores of planted acorns and seedlings. Mowing in between rows, ideally multiple times throughout the growing season, is sufficient for managing rodents if they become problematic. (Griggs et al., 1997)

vi. Mycorrhizae are an essential part of the soil ecology and have a complex and important symbiotic relationship with plants. Studies have indicated impressive growth correlated with the inoculation of certain mycorrhizal species. For Valley Oaks, only a small amount of soil is needed per planting and soil should be taken from an established stand of *Q. lobata*. Depending on access to this resource, anywhere from a few tablespoons to a handful of soil can be used per hole. This is not necessary as agricultural soil already harbors some mycorrhizae (though far less than forest soils), but would certainly be a helpful addition to the restoration project. (Berman et al., 1998)’

vii. Eventually survival percentage of at least 25% ideal, with thresholds for actions if the population gets any lower.

d. Manage Disturbances:
Goal: Ensure that disturbance, if it occurs, is managed in a way that does not adversely impact tree development.

i. Grazing, Fire and Inundation
As long as the disturbance recommendation are followed in the restoration plan, there should be no negative impacts to growth from grazing, fire and inundation- which are the main three forms of disturbance. In most cases, following the recommendations discussed below, such as employing a combination of wire cages on seedling with grazer on the landscape can actually have substantial benefits on percent survival.

i. Grazing:
Grazing can be a helpful management tool for controlling invasive plants, restoring carbon and nutrients to the soil, and other beneficial services. However, grazing in areas with *Q. lobata* seedlings greatly reduces their success rate due to direct herbivory. If grazing is to be employed on the site, it is extremely important that seedlings are protected with cages or tubing until they can grow above the browse line. If there is not a high density of herbivores on the site, it is unnecessary to protect the seedlings. (Bernhardt et al. 1997)

ii. Fire:
Q. lobata is very tolerant to short duration surface fires, such as controlled burns, however if trees are too young (below 300 cm or 120 inches) topkill will result. Topkill is rarely deadly in Valley Oak, however, fire does stunt growth and must be used at appropriate intervals in order to ensure that trees have enough time to coppice and sprout up again. In other words, allow trees to surpass their point of growth before the last fire to prevent a continuous stunting of new growth. Young trees tend to grow at a much greater rate in their 3rd year and onwards, ideally there should be no fire in these first 3-4 years to allow for sufficient growth. Trees will be more resilient to fire if this approach is followed, but as mentioned above, even very young trees below 120 inches almost always survive fire. Therefore, use fire sparingly, no more than every other year, and as trees reach a greater stature, fire frequency can be increased accordingly. (Holmes at al., 2009)

iii. Soil Compaction:
Valley Oak does not tolerate soil compaction. Minimize the use of heavy machinery around trees, and try to maintain as wide a distance as possible from the base of the trunk if the use of heavy equipment is necessary. (Wilken et al., 2000)

iv. Inundation
Q. lobata is extremely tolerant to inundation, especially during the winter and/or early spring. Mature trees can survive month long inundation or possibly longer with

progressively less tolerance as age decreases. Acorns can also endure up to 30 days of inundation with no effects on germination. Inundation outside of the natural timing (winter/early spring) can have more adverse effects on growth. (Trowbridge, 2002)

e. Feasibility

i. The goals listed here are completely realistic and have been compiled based upon peer-reviewed research taken mainly from sources such as the University of California and the U.S. Forest Service. Valley Oaks are incredibly strong and resilient trees that are well adapted to our climate in the Central Valley. It is possibly the fundamental species of Central Valley riparian habitat and need very little inputs once established. The Valley Oak is a crucial species that allows the survival of many other native plant and animal species which depend on it, more than just about any other tree species in California (Little et al., 2001). Valley Oaks are not only feasible to restore to the site, they will be a necessary addition if the site is to represent a true value to wildlife. As stated above, Valley Oaks are very resilient trees, but they are most vulnerable when they are acorns and before they grow to the third year. The methods in this document focus on techniques that will bolster Valley Oak growth in these vulnerable stages. If managers follow these guidelines, time should be the only major factor in delaying the establishment of beautiful stands of stately Valley Oaks on the site.

B. Restoration Plan

Goal: *Restore Valley Oak to the site using well-researched methods that will ensure acorns can establish and trees can eventually sustain populations with little to no human inputs.*

a. Planting/Site Selection:

i. Acorns should be harvested when ripe (October-November). Acorns are ripe when they separate readily and fall from the tree freely (Wilken et al., 2000).

ii.Collect acorns, in order to have enough for a planting density of (300-500) acorns per hectare, dependent upon desired canopy cover and site conditions. (Griggs et al., 2002)

ii. Local, unblemished acorns free of exudates and small holes made by insects should be used for germination. Acorns do not keep well, so fresh acorns are best for planting. (Wilken et al., 2000) Submerging acorns in water and discarding the ones that float to the surface is a helpful way to aid the sorting of healthy acorns, although some research suggests acorns weevils and other pest may have no significant impact on germination. (Hobbs et al. 2001)

iii.Be sure to collect no more than 5% of seed from any given population. (Lecture)

iv. Larger acorns have been shown to grow more vigorously and reach groundwater faster (Hobbs et al. 2001)

iv. In some sites within the Sacramento area, such as the Consumnes River where a dense riparian forest is the desired habitat, up to 1500 acorns per hectare have been used. (Griggs et al., 2002) If the site is 30 acres (12.14 hectares) that equates to around 3700-6500 acorns for the entire area (based off of the 300-500 acorns per hectare estimation for a woodland restoration of 20-60% canopy cover). If greater canopy cover is desired these numbers should be increased accordingly. Of course, the above acorn densities neglect the areas that are seasonally inundated and are more likely to support wetland species. (Griggs et al., 2002)

v. Fine textured loamy soils, such as those found at the restoration site, are the preferred soil type and should support a healthy population of *Quercus lobata*. (Wilken et al., 2000)

vi. That being said, harsh summers and extended drought will limit surface water in certain years which could entirely preclude wetland species. *Q. lobata* can thrive in flooded conditions for up to a month at a time and may do well at the edges of basins and swales. However, in times of drought, the deep tap root of the Valley Oak can access groundwater that many other species cannot. (Trowbridge, 2002)This versatility makes *Q. lobata* ideal for planting at nearly everywhere on the site, except for areas of

relatively high or low topography in the landscape (As long as average water table depth should be 3-5 meters and inundation occurs for no more than a month).
As mentioned above, plant in rows to make management easier. (Griggs et al. 1997)

b. Hole size/ Depth

i. Seeds must be planted deep enough to avoid detection from potential herbivores. (Tietje et al., 1991).2 inches (5.1 cm) is usually sufficient, however, if depredation is a potential problem a depth of 4 inches (10.2 cm) can help improve acorn survival without a significant impact on germination. (Tietje et al., 1991)

ii. Hole diameter should be about 10 inches (Wilken et al., 2000)

iii. Sources indicate planting 3-10 acorns per hole is optimal. Planting three acorns per hole reduces the need for thinning as well as the chances that an individual in that plot will survive and grow out. Planting ten acorns increases the survival and the amount of thinning necessary in the first two seasons (seedling should be thinned to 2 or 3 per hole at the end of the first season, and only 1 per hole by the end of the second). (Tietje et al., 1991) Six acorns per hole should be a good “middle of the road” seeding density, but if there is significant depredation due to rodents a higher planting density of 10 acorns should be employed (If a visual signs of excavated acorns are observed, or it is otherwise known that a high rodent population exists at the site, this may be a good preemptive step for establishment). Also if there are certain plantings that do not come up after the first growing season, it may be worthwhile to excavate the holes in order determine if the acorns have been removed (Wilken et al., 2000)

c. Irrigation:

i. In the first year, the area extending from the surface down to the water table should be saturated (every 10 days to 2 weeks recommended). (Griggs et al. 1997)

ii. In the second year, decrease to once every 6 weeks, and only twice in the third year. (Griggs et al. 1997) Watering should be progressively deeper and more infrequent as the trees grow in order to encourage deep root growth (Also mentioned above).

iii. These guidelines can be modified based on weather conditions. If there is an especially wet spring or winter, such as this year where we received a statewide annual average of about 30 inches of precipitation, irrigation can be scaled back during the Winter/spring season. On the other hand, during the previous 5 years of drought, irrigation should be maintained or even increased depending on the severity of the drought.

iv. It is worth noting some risks here, the first being that in a year with average precipitation to low precipitation under watering is very realistic threat to seedlings. The reverse is very unlikely (over-watering in a wet year) because Valley Oak is good at tolerating inundation. It should also be noted that mature Valley Oak has been known to drop large limbs in events where it receives too much supplemental irrigation or in a possible strong storm event. This means that extra care should be taken towards pruning mature species, especially ones near areas of heavy human foot traffic such as a path. Another risk involved with propagating Valley Oak is associated with too much supplemental irrigation as a seedling, and is part of the reason for sowing in soil, rather than a pot. Essentially if the oak grows in a pot for too long, or is growing in soils where there is no deep water only saturated surface soil (insufficient volume of water apllied/too high of a watering frequency), either ofnthese can impact the development of the taproot-which is of the utmost important in order for trees to make it through hot dry summers or tolerate drought. (Hobbs et al., 2001)

d. Disturbance Management:

i. Grazing:

Grazing can be a helpful management tool for controlling invasive plants, restoring carbon and nutrients to the soil, and other beneficial services. However, grazing in areas with *Q. lobata* seedlings greatly reduces their success rate due to direct herbivory. If grazing is to be employed on the site, it is extremely important that seedlings are protected with cages or tubing until they can grow above the browse line. If there is not a high density of herbivores on the site, it is unnecessary to protect the seedlings. (Bernhardt et al. 1997)

ii. Fire:

Q. lobata is very tolerant to short duration surface fires, such as controlled burns, however if trees are too young (below 300 cm or 120 inches) topkill will result. Topkill is rarely deadly in Valley Oak, however, fire does stunt growth and must be used at appropriate intervals in order to ensure that trees have enough time to coppice and sprout up again. In other words, allow trees to surpass their point of growth before the last fire to prevent a continuous stunting of new growth. Young trees tend to grow at a much greater rate in their 3rd year and onwards, ideally there should be no fire in these first 3-4 years to allow for sufficient growth. Trees will be more resilient to fire if this approach is followed, but as mentioned above, even very young trees below 120 inches almost always survive fire. Therefore, use fire sparingly, no more than every other year, and as trees reach a greater stature, fire frequency can be increased accordingly. (Holmes at al., 2009)

iii. Soil Compaction:

Valley Oak does not tolerate soil compaction. Minimize the use of heavy machinery around trees, and try to maintain as wide a distance as possible from the base of the trunk if the use of heavy equipment is necessary. (Wilken et al., 2000)

iv. Inundation

Q. lobata is extremely tolerant to inundation, especially during the winter and/or early spring. Mature trees can survive month long inundation or possibly longer with progressively less tolerance as age decreases. Acorns can also endure up to 30 days of inundation with no effects on germination. Inundation outside of the natural timing (winter/early spring) can have more adverse effects on growth. (Trowbridge, 2002)

C. Monitoring Plan:

Goal: *Monitor growth of trees and assess survival rate over time. Set thresholds for action and proposed actions if the restoration objectives are not met.*

a. Monitoring protocol and Frequency.

i. Assess sapling canopy cover and height every year and diameter at breast height after the 3rd year. (Griggs et al. 1997) When assessing canopy cover, it is best to do so in the spring or summer, as Valley Oaks will be deciduous during other parts of the year (Winter).

ii.Is woodland or riparian forest the desired habitat? (Woodland would mean 20-60% canopy cover, while forest is 60-100%). Expected canopy cover should vary based on acorn density/desired landscape structure. (Griggs et al. 1997)

b. Threshold for Action and Potential Actions

i. Determine the survival percentages at 1, 3 and then 6 years by dividing the number of healthy individuals by the initial number of acorns that were planted. (Griggs et al. 1997)

ii. Survival percentage should be expected to vary considerably across plots on the same site, but if the average survival percentage falls below 10% by year 5 or earlier, a second round of acorn planting should be carried out focused on areas of especially low density. Ideally a more strict threshold, denoted by a survival percentage of 15-25% by the 5th year or earlier, would require supplementation of the population at the site with nursery stock as well as planting more acorns. At this level, supplementation with nursery stock alone could be enough to stabilize the population from reaching the only 10% survival.

iii. For similar restoration projects, 50-30 individuals per hectare after 5 years (based on the initial acorn planting density of 300-500 acorns per hectare) would denote a threshold for introducing more acorns.

iv. If the above threshold is reached, intensive wildlife surveys should be conducted to determine if there is a rodent or herbivore population responsible for the decline. Visual surveys of planting areas should be undertaken to see if acorns have been unearthed from planting sites) Irrigation lines should be re-tested for proper saturation (Gypsum blocks are commercially available and can be used to determine how deep and where the irrigation water is reaching). Soil cores and samples should also be taken to ensure that groundwater is within reach of tree roots (Ideal distance to water table is 3-5 meters) and that there has not been a dramatic shift in water table height since measurements were last taken. (Griggs et al. 1997)

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Toyon (Heteromeles arbutifolia)

Karen Lomas-Gutierrez

Background and Justification:

Heteromeles arbutifolia, better known as Toyon, is a California native evergreen shrub commonly found in chaparral communities. It pertains to the Rosaceae family and it is the only species in that genus, however, there exist two other varieties: H.a. var. cerina 'Davis Gold' and H.a. var. macrocarpa **Invalid source specified.**. Known for its clusters of white flowers and bright red berries, toyon is also commonly named Chistmasberry and California Holly **Invalid source specified.**. Because of its tolerance to different types of soils and exposure, Toyon is widely utilized in restoration projects throughout California. Toyon can also be found in ornamental and native gardens, functioning as screen vegetation **Invalid source specified.**. Even though branches and berries from Toyon were usually collected and used as decorative items during Christmas, that practice is now prohibited in California**Invalid source specified.**. Toyon berries have been widely utilized by humans for various purposes such as food and medicinal uses, to make beverages, and even as bait for fishing practices **Invalid source specified.**.

Species Information

A. **Growth characteristics:**
    a) Most shrubs grow to 12-18 ft tall, and can eventually grow up to 25 ft **Invalid source specified.**.
    b) It is characterized by dark leathery leaves with serrated margins that grow about 2-5 inches. Clusters of white flowers bloom between June and July. Flowers are small with 5 petals and 10 stamens **Invalid source specified.**.
    c) Berries about a quarter inch large change from orange to vibrant red from fall to winter and serve as food to some animals **Invalid source specified.**.
    d) Toyon is expected to live from 100 to 200 years**Invalid source specified.**

B. Reproduction:

a) Toyon can regenerate utilizing both: sexual and vegetative processes. Vegetative regeneration happens during fire-free periods when Toyon is continually growing new sprouts, and after fires or other types of disturbances, it survives by sprouting from protected buds in the root crown. Sexual regeneration occurs by dispersal of seed which is mainly performed by birds and animals, although seeds can also fall directly under the parent plant **Invalid source specified.**.

b) "Toyon seed should be collected in the fall. Seedlings can be started in nursery beds using unstratified seed in the fall or stratified seed in the spring. Plants may also be propagated by grafting and by cuttings" **Invalid source specified.**

c) "Abundant seed is produced annually after the first flowering and seed production apparently does not decrease with age" **Invalid source specified.**

d) Seeds are dispersed in the late fall and winter **Invalid source specified.**

e) Fruit matures in the fall and persists into winter **Invalid source specified.**

f) Berries can be collected once they ripen and reach their characteristic bright red color, from October to January. They are then soaked in water in order to separate the seeds, which then have to be left to dry **Invalid source specified.**.

g) Seeds are very susceptible to temperature and can be easily killed by high temperature. If kept at room temperature they probably live for about a year. It is recommended to keep them in a controlled and sealed low temperature storage "One hour at 70 °C reduced viability from 99 to 33%, and 5 minutes at 120 °C resulted in essentially complete mortality… **Invalid source specified.**.

h) If seeds are naturally dispersed they are usually nondormant, but they go dormant if they are stored, and require a chilling period of 3 months at 3 to 5 °C to germinate **Invalid source specified.**.

i) "The seedlings are not very drought-tolerant and seem to need the shade and the deep litter that develops under adult shrub canopies in old stands in order to survive" **Invalid source specified.**

j) "Germination occurs readily under favorable moisture and temperature conditions, often within 10 to 40 days. Seeds germinate without the stimulus of heat or charred wood"**Invalid source specified.**.
k) Fruit set can be affected and reduced in high disturbance habitats or because of poor agricultural practices.**Invalid source specified.**

C. Range:

a) Toyon is commonly found throughout California and Baja California from sea level to 4000 ft in elevation **Invalid source specified.**.
b) It is widely found in Chaparral plant communities, growing on dry slopes, ridges, and canyons**Invalid source specified.**.
c) It is mainly found in chaparral communities, but it also thrives in woodland and forest communities **Invalid source specified.**.
d) "It is distributed in the Coast Ranges from Humboldt County southward into Baja California and in the foothills of the Sierra Nevada from central California southward into the Transverse Ranges" **Invalid source specified.**.

D. Habitat/ Requirements:

a) Toyon thrives in well-drained soils, full sun, and can tolerate long periods with low moisture **Invalid source specified.**.
b) It can be planted and survive in 19 out of the 24 different California Plant Climate Zones(7-9 and 14-24) **Invalid source specified.**.
c) Toyon develops a deep root system and thick waxy leaves that help it to adapt when amount of moisture is limited **Invalid source specified.**.
d) Toyon has moderate water use requirements **Invalid source specified.**, with a maximum artificial irrigation of twice a month during summer months **Invalid source specified.**

E. Tolerances:

a) Toyon is drought adapted, it has developed thick waxy leaves that helps it reduce transpiration Invalid source specified**.**

b) It has a high tolerance for different types of soils, sun exposure and limited amount of moisture **Invalid source specified.**.

c) It is tolerant to a Soil pH of 5.0 to 8.0 and it is also tolerant to serpentine soils **Invalid source specified.**

d) It can thrive in both, direct sun light and partial shade**Invalid source specified.**.

e) It has been recorded to survive on sites with temperatures that range in between 36.5 ° F (average coldest month) to 80.6 ° F (average Hottest month) **Invalid source specified.**

f) Toyon is relatively inflammable, which means it has a high tolerance for fire. **Invalid source specified.**.

g) It has a cold tolerance of -5 ° F

F. Interactions:

a) Toyon has not been officially classified as a dominant species, however it codominates the low and open chaparral communities in the northern Coast Range and foothills of the northern Sierra Nevada along with chamise **Invalid source specified.**.

b) It is usually a subdominant species in Coast Live oak Woodlands **Invalid source specified.**.

c) Toyon berries are consumed by birds and animals such as California quail, band-tailed pigeon, raccoon, deer, and goats. **Invalid source specified.**.

d) Toyon flowers attract bees **Invalid source specified.**

e) In terms of browsing, and herbivore interactions, it's not a crucial problem in mature plants since the leaves are not very palatable, but young sprouts are more susceptible to herbivore predators "Mature plants are rarely utilized by livestock or wildlife because of large concentrations of tannins and cyanogenic glycosides. Following fire, however, toyon produces an abundance of leafy sprouts which are much preferred by black-tailed deer" **Invalid source specified.**

f) If protected during the first 3-4 years, browsing by deer becomes a minor issue **Invalid source specified.**

g) Toyon offers nesting and hiding cover to birds and small mammals **Invalid source specified.**.

h) Toyon can be host and infected by the pathogen *Phytophthora ramorum,* which in large trees create cankers and causes foliage to go from healthy to brown in a matter of weeks and eventually cause death. This pathogen mainly affects branches and leaves in *Heteromeles arbutifolia.* ***Invalid source specified.**.*

i) "Toyon grows with *Quercus agrifolia*, *Quercus lobata* and *Quercus douglasii*. **Invalid source specified.**

j) Some plants that are compatible with Toyon and that are usully found in the same areas are : Lemonadeberry (*Rhus integrifolia*), Manzanita (*Arctostaphylos* species), Ceanothus species, Milkweed (*Asclepias species*), Giant Wild Rye (*Elymus condensatus*), Sand Aster (*Corethrogyne filaginifolia*), Sagebrush (*Artemisia californica*), Monkeyflower (*Mimulus* species), Encelia californica, Buckwheat (*Eriogonum* species), Heartleaf Keckiella (*Keckiella cordifolia*), Penstemon species, Salvia species, Blue-eyed Grass (*Sisyrinchium bellum*) **Invalid source specified.**

G. Management considerations:

a) It is very useful in rehabilitating disturbed sites due to its fast growth rate, and also because it develops a wide and deep root system that helps to stabilize and control erosion on hillsides **Invalid source specified.**.

b) "Toyon is sensitive to such herbicides as 2,4-D and 2,4,5-T. If sprouts are treated following burning, plants are killed by retreatment" **Invalid source specified.**.

c) Heteromeles arbutifolia is classified as obligate resprouter, which means that after fires it relies on sprouts to survive, and this sprouting grow from organs that are protected during a fire. It is favored by low fire frequencies, but it can adapt to a broader range of fire frequencies **Invalid source specified.**.

d) . "Extended fire-free periods are required for successful seedling establishment and population expansion" **Invalid source specified.**.

e) Goats can be utilized to graze areas where Toyon is located as a way to reduce fire hazard **Invalid source specified.**.
f) It is better to prune it a little during all year, but if a heavy pruning is desired, is best to do it August-September **Invalid source specified.**

Part II: Goals, Management and Monitoring Plan

A. Goals

a. Utilize Heteromeles arbutifolia as a colonizer to establish a new community in a restoration site due to its fast growth and tolerance to varied conditions.

b. Encourage populations of birds and mammals that consume berries since they play an important role in the spread and reproduction of Toyon. Species such as: California quail, band-tailed pigeon **Invalid source specified.**

c. Provide intensive monitoring for the first 4 years of restoration since it's when the seedlings require more protection for survival, especially from herbivores.

d. Protect young seedlings from herbivores such as deer.

e. Restore the population of Heteromeles arbutifolia in areas susceptible to erosion and hill slides, since their root system helps to provide structural support and stabilize the soil, therefore being a good strategy to avoid erosion. **Invalid source specified.**

f. Feasibility: Heteromeles arbutifolia is relatively easy to maintain and it doesn't require a lot of care once mature due to its high tolerance to stress. However, the most crucial phase is germination and establishment, therefore more intensive care is required during the first few years. If a good amount of energy and resources are dedicated to the establishment of the community, and well-defined and comprehensive restoration and monitoring plans are implemented, it is highly feasible to successfully establish and restore the Heteromeles arbutifolia population.

g. For a successful restoration project, some pre-restoration actions are necessary:

   i. A comprehensive soil survey is required in order to identify the best suitable sites for planting. It is important to take into consideration the soil pH since Toyon thrives in a pH 5.0 to 8.0 and serpentine soils **Invalid source specified.**. It would be also helpful to know the infiltration capacity of the soil since Toyon is better established in well-drained soil **Invalid source specified.**

ii. It is advisable to identify the type and extent of predator populations present on site such as California quail, band-tailed pigeon, raccoon, deer, and goats either to control or encourage **Invalid source specified.**. Some populations are good encouraging such as birds that help with the dispersal of seeds. Some other are worth controlling and regulating such as deer than can negatively affect the establishment of seedlings and wipe out the newly restored population of Heteromeles arbutifolia.
iii. It is also important to establish the origin and condition of seeds in order to identify if they will require chilling period or not, and when is the best moment to plant them.
iv. Identifying the type of ecosystem that wants to be restored its necessary in order to select the right palette of species compatible with Heteromeles arbutifolia, which can thrive in either chaparral, woodland, or forest communities **Invalid source specified.**, and is specially compatible with Quercus agrifolia, Quercus lobata, and Quercus douglasii as a subdominant species **Invalid source specified.**, and chamise as a codominant species in chaparral **Invalid source specified.**.

h. The overall restoration objective for Toyon is to reach a density of about 50 plants per acre based on similar restoration projects **Invalid source specified.**. After 3 years a 70 percent coverage should be achieved, and 75 percent coverage after 5 years. Therefore, monitoring for the first 5 years will be necessary in order to ensure the survival rate of Toyon species which ideally would be 80% or more **Invalid source specified.**.

B. Restoration Plan

a. Location

   i. It is preferable to establish Toyon population in sites exposed to full sunlight, with well-drained soils, probably along creeks, in canyons, and north facing slopes **Invalid source specified.**, and sites not higher than 4000 ft in elevation **Invalid source specified.**.

   ii. The best location to plant and establish Toyon is in the upland zones and higher slopes leading to upland zones that don't get easily saturated with water or are not exposed to seasonal flooding.

   iii. Hillside is a very good location to ensure good water drainage. Areas where rain water is collected should be avoided **Invalid source specified.**

b. Planting and establishment

   i. It is recommended to conduct controlled fire or herbicide treatments on site before planting in order to get rid of weeds and undesired invasive species.

   ii. A seed collection system should be established. Berries should be collected from October to January when they ripen to collect seeds. Berries should be soaked in water and fermented in order to soften the fruit and make it easier to separate the seeds. The use of a macerator is the recommended method to separate the seeds from the fleshy part. After washing the seeds, they should be allowed to dry. They can then be planted or stored**Invalid source specified.**.

   iii. If seeds are stored, high temperatures can damage and kill the seeds. Seeds should not be exposed to temperatures higher than 70 °C **Invalid source specified.**.

   iv. When planting, if the seeds are freshly harvested, then no chilling period is required. However, if the seeds were previously stored, then a chilling period of 3 months at 5 °C is required. If this is the case and the seeds are stratified, then it is necessary to closely monitor and conduct germination test for a period of 28 days at 20 or 25 °C to make sure the germination is successful. Seedlings usually sprout after 10-40 days. **Invalid source specified.**. If seeds are stratified, then planting is recommended to be done in spring, if they are not stratified, then it is recommended to plant them during fall. **Invalid source specified.**.

v. Because of shade, moisture and litter requirements, it's not very feasible to plant the seeds directly on the wild restoration site since the probability of survival would be minimal. It is better to establish and germinate the seeds in a nursery setting where better control and monitoring can be provided **Invalid source specified.**. Seedlings can be planted on site during fall or early winter.

vi. Plant seedlings on site in groups of 4-6 with a spacing of 6 ft from each other. The desired density is a minimum of 50 plants per acre **Invalid source specified.**.

vii. During the first couple of years artificial irrigation will be needed. It is recommended to water about the depth of 2 inches every 10 to 15 days during summer. It is not necessary to irrigate during raining season. Once Toyon is established, usually two years after planting, watering needs are reduced to 1 inch every two weeks **Invalid source specified.**.

viii. Seedlings are more susceptible to browsing than mature shrubs. It is recommended to provide herbivore protection for young seedlings. One way of achieving this is to utilize tree shelters. To ensure effectiveness, shelters should be about 0.5 taller than the height of seedling at planting **Invalid source specified.**.

C. Monitoring Plan

a. When mature, Toyon is not susceptible to browsing since it is unpalatable. Therefore, livestock animals do not present a threat to the survival of Toyon population. However, as previously mentioned, deer are predominant consumers of young seedlings, which can potentially affect and destroy the restoration project. **Invalid source specified.**. It is critical to closely monitor and protect the young seedlings from this predators for the first 3-4 years until they reach maturity and browsing is no longer a threat **Invalid source specified.**. Ideally, a 80% survival rate should be expected **Invalid source specified.**.
b. Toyon is very resistant to fire since is practically inflammable. It is considered an obligate resprouter, and it relies on sprouts to survive after fires. Fires are favorable for the population survival, in order for it to resprout. However, plants must reach maturity to successfully resprout, and high frequency fires can destroy the population, not giving enough time to resprout **Invalid source specified.**. It is necessary to monitor and control fires, and make sure they are low frequency disturbances that encourage the spread of Heteromeles arbutifolia population instead of destroying it. Toyon population would be resilient if fire-free intervals are anywhere between 10 to 100 years. Goats can be utilized to conduct grazing practices in order to reduce fire hazard **Invalid source specified.**.
c. Re-sprouting can occur as soon as 10 days after a fire if plants were located in high moisture zones, but it can also take up to six months in drier areas. If re-sprouting hasn't occurred one year after the fire, measures should be taken to replant and re-establish the Toyon population **Invalid source specified.**.
d. Toyon species do not start producing seeds until 2 years after planting took place **Invalid source specified.**, therefore monitoring and ensuring survival during the first two years is critical to encourage a resilient population.
e. Heteromeles arbutifolia does not require a lot of water, therefore a well-drained soil is optimal for the plant wellbeing. After it is established, artificial irrigation can be provided during summer and drier seasons twice a month about 1 inch in depth at the most **Invalid source specified.**.

f. Pruning in small amounts throughout the whole year is advisable, but if frequency becomes impractical, a one-time heavy pruning can be conducted from August to September **Invalid source specified.**. Suckers and dead wood can be removed during frequent small pruning practices, but if significant scaffolds and large branches must be removed, then it should be done only once a year**Invalid source specified.**.
g. Toyon is susceptible to fire blight and black mildew and should be monitored for signs of any of these conditions, such as tan or light reddish-brown liquid oozing from the twigs in early spring or grayish powder on the undersides of the leaves. In order to prevent these conditions, water should not be sprayed on foliage and dead growth should be frequently removed **Invalid source specified.**.
h. The use of herbicides should be avoided, herbicides as 2,4-D and 2,4,5-T to which sprouts are very sensitive especially after fires, and can damage and even kill the new born sprouts **Invalid source specified.**.
i. Issues that should be addressed during monitoring are:
    i. Number of surviving plants compared to number of planted plants in order to obtain survival rate.
    ii. Density, how many plants are in a given area?
    iii. Are plants being affected by herbivores? If so preventive measures should be considered such as implementation of tree shelters, fences, or netting.
    iv. Has there been a recent fire event? If so, are there any signs of re-sprouting?
    v. Is there any dead growth or are there diseased plants that need to be removed?
    vi. Monitor overall fitness, dispersal, and growth rate.

Works Cited

There are no sources in the current document.

<u>California Sycamore (*Plantanus racemosa*)</u>

Abby Lourenco

<u>Background and Justification</u>

The California sycamore (*Plantanus racemosa*) is a woody tree species native to California. A deciduous tree with broad, flat leaves and mottled gray and white bark, it is often planted as a landscaping tree, and can be found in many urban areas along sidewalks and in parks (Calscape 2017). Although this species' preferred, native habitat, riparian corridors, are threatened and diminished in the state due to current and historical land use, the California sycamore is not considered threatened due to it's successful clonal regeneration in remaining riparian habitats and use in urban landscaping (Warner 1984). This species is important to consider in restoration efforts due to it's status and intrinsic value as an endemic species to California, as well as its roles as a host plant for certain butterfly species and as a prominent shader in the riparian forest canopy (Calscape 2017). Today, the California sycamore can be found as northernmost as Redding and as far south as central Baja California (USDA 2017).

<u>Literature Review</u>

Habitat/Ecosystem Requirements:

- The California sycamore is almost always found in riparian settings such as canyon bottoms, floodplains, and stream-sides generally below 4000 ft in elevation (Calscape 2017).
- This species is found distributed in its native range from the northern Central Valley to coastal San Diego county and Baja California (USDA 2017).
- Prime California sycamore habitat in the central valley (valley foothill riparian forests), occur in areas where relatively shallow water tables are accessible to tree roots. In Yolo county, these

areas are primarily found along principal watercourses (Yolo County Oak Woodland Conservation and Enhancement Plan, 2017).

- The valley foothill riparian forest occupies approximately 5,000 acres, or one percent, of Yolo county (Yolo County Oak Woodland Conservation and Enhancement Plan, 2017).
- This species has a moderately high water requirement, requiring 11-59 inches annually. Despite this large water requirement, this species is not found immediately next to rivers and streams where water tables are very shallow (Calflora 2017).
- It is shade intolerant and prefers full sun. The species is found in the primary canopy of riparian forests (Calscape 2017).
- The California sycamore tolerates a soil pH of 5.4-8.2, and requires a minimum soil depth of 5 inches. The species tolerates all non-saline soil types, including clay and sandy soils (Calflora 2017).

Growth Characteristics:

- The California sycamore can grow up to 35 meters in height, but is more commonly 20-25 meters, with a trunk diameter of up to one meter (Calscape 2017).
- The trunk generally divides into two or more large trunks splitting into many branches, and grows in an irregular shape and orientation (Calscape 2017).
- This species is deciduous, with leaves turning color to yellow and orangish brown in the fall (Calscape 2017).
- It reproduces primarily by seed but also by clonal regeneration. Flowers are unassuming, one inch spheres that become seed balls (racemes), which hang in strings of five or more balls. Flooding is a requirement for seed germination (Calscape 2017).

- If provided sufficient water, California sycamore roots tend to grow vertically down rather than out horizontally, which is one of the reasons why this species is so popular as an urban landscaping tree (Calscape 2017).

Interactions

- The California sycamore is susceptible to anthracnose (leaf blight), a fungal disease that thrives during wet spring weather (Calscape 2017).
- Anthracnose fungus does not typically kill the tree, but can cause disfiguration of the leaves in mild cases and leaf loss in severe cases (Calscape 2017).
- Treatment for anthracnose involves applying a fungicidal spray when the leaves begin to unfold in spring, and every two weeks thereafter for the next month or two, which prevents infection (Bier 2015).
- This species is important ecologically for the Western Tiger Swallowtail butterfly, as well as for other butterfly species and hummingbirds (Calscape 2017).

Management Considerations and Threats

- Riparian habitats are extremely valuable for human land use, especially in lowlands where stream-sides are generally accessible and fertile. As a consequence, clearing, farming, and grazing have eliminated most of the natural riparian habitat and vegetation in California (Alpert 1999).
- One study found that the sites which were best for California sycamore regeneration typically were narrow, riparian corridors (canyons rather than broader bottomlands) which experienced low grazing pressure (Warner 1984).
- However, this study concluded that California sycamore success may actually be independent from grazing pressure, and that many other factors may also contribute to poor sapling

establishment (Warner 1984). The species is reported to be an unpalatable forage species (Calscape 2017).

- Although its native habitat is threatened and diminished due to human land use, California sycamore status is not considered threatened due to the fact that it exerts strong clonal regeneration (Warner 1984).
- Other disturbances which face California sycamores include ground squirrels, whose populations have increased due to overgrazing (Warner 1984).
- One study found that the California sycamore is rapidly hybridizing with introduced ornamental species (from Europe), which may be threatening the continued genetic distinctiveness of the native species. Johnson claims this is cause for concern from a conservation standpoint, due to a direct loss of genetic distinctiveness, and a potential reduction in habitat value of associated species (Johnson 2016).

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Part Two: California Sycamore Restoration Plan

A. Goals

a. As a native California woody tree species, our goal for restoring California sycamores (*Plantanus racemosa*) is to maintain and increase a self-sustaining population of this species, as the central California sycamore alluvial woodland habitat type is a very rare and threatened land cover type. According to the California Riparian Habitat Restoration Handbook, a self-sustaining population for a woody tree species is measured as a 70 percent cumulative survival of all individuals to maturation: a 7-10 year time period. As a woody tree species that grows mixed in with many other species, the USFWS suggests a target species composition of 2-4% for the California sycamore at any given site. The targeted percent cover may change with specific site use and goals (recreation, rangeland, wildlife habitat, native species restoration, etc.).

b. Long term goals:

   i. Establish 2-4% cover of native California sycamore populations at a given restoration site through transplanting (methods outlined in the restoration plan).

   ii. Improve site characteristics to favor California sycamore health and regeneration by limiting anthracnose incidences in sycamores to 30%, limiting grazing damage to 30%, and eliminating cover of all invasive species (methods outlined in the restoration plan).

iii. Monitor California sycamore populations and environmental conditions yearly after establishment for 7-10 years to ensure desired population levels and to enact preventative/protective measures, if needed.

c. Feasibility

i. These goals for improving California sycamore habitat and increasing population numbers can only be considered feasible given the budget, scale, and availability of monitoring of each restoration project. Due to the need for propagation by expensive cuttings (rather than seeds), the expense and time needed for a long monitoring period (7-10 years), and expensive invasives and grazing reduction strategies, tradeoffs between goals will have to be made according to the scale and expense of each project. If implemented on a smaller scale, these goals will be much more feasible and easier to accomplish.

B. **Restoration Plan**

a. Establish California Sycamore population

i. **Implement transplanting**: In order to establish a California Sycamore population or increase an existing one, cuttings should be planted along stream channels on low terraces of the inner channel corridor and floodplain (zones of high water availability) which have a minimum water table depth of 3-5 meters (SFEI). Propagation by cuttings rather than seeds should be used in order to minimize the introduction of hybridized sycamores. To procure cuttings, take 4-8 inch cuttings from hardwood stems during dormancy in the winter months. Approximately 300-800 sycamore seeds per acre, or approximately 210 seedlings per acre, should be planted to ensure 70% survivorship, spaced every 40 feet (USDA). Plantings should be installed between October and December when rainfall has saturated the soils on site (SFEI). Irrigation may be necessary during hot summer months to help them become established, especially in years with below average rainfall. Drip irrigation is the recommended system and should be utilized once per week during the summer months until the sycamore stand reaches maturity at 6-7 years (CALSCAPE).

b. Improve site characteristics to favor California Sycamore health and regeneration

i. **Control anthracnose**: The fungal disease anthracnose, in high incidences, can reduce the overall reproductive fitness of California sycamore by limiting seed and root sprout production. Severe damage by anthracnose may weaken trees and contribute to a lack of regeneration (Sinclair et al. 1987). However, complete elimination of this disease may not be advisable, as anthracnose infestations can cause tree limbs to die and trunk cavities to form (Sinclair et al.

1987), which provide important foraging substrate and nesting sites for birds. Careful monitoring must take place to ensure anthracnose incidences do not occur in over 30% of all sycamore individuals at site, and if so, a fungicide application such as chlorothalonil may become necessary as treatment (UC IPM). Spray fungicide on all sycamores in the spring before rainy periods as new bud growth begins to develop. If moist weather prevails, apply additional fungicidal applications every two weeks in order to protect new growth (UC IPM). Additional ways of controlling anthracnose include disposing of fallen leaves and twigs (which can spread the fungus) during the growing season and in fall (September-October), as well as pruning during winter in order to increase air circulation in the canopy and remove the previous season's infected twigs and branches (UC IPM).

ii. **Limit browsing/grazing**: Although not as palatable as other species, studies suggest sycamore regeneration success may be limited by grazing and browsing by herbivores such as deer and, especially, livestock (SFEI). In order to increase sycamore survivorship and establishment, grazing damage should not affect more than 30% of sycamore seedlings. Restoration managers should work to modify grazing patterns, as young sycamore seedling/saplings are vulnerable to grazing until they have grown above the browse line (approximately 2 meters high). On a smaller scale, reduced grazing can be achieved by exclusion fencing and/or tree guards. Though effective, these methods can be quite expensive. Tree guards should be installed around every sapling or seedling under 2 meters (SFEI). In order to limit grazing on a larger scale, goals should be discussed with ranchers in order to improve grazing management on site, such as an altered rotation schedule in order to avoid overgrazing and sycamore selection by livestock. With the aid of ranchers, livestock can be excluded from portions of the restoration site to test the effects of grazing on California sycamore establishment and differences in soil compaction, herbaceous biomass, and damage to leaves and stems, which then can be examined in order to understand their effects on natural establishment of the California sycamore.

iii. **Manage competitors/invasives**: Riparian invasives which directly compete with the California sycamore for resources such as water, space, and sunlight will need to be controlled and potentially eliminated in order to increase the likelihood of sycamore regeneration. Prevalent invasive species in central valley riparian habitats include Himalayan blackberry, tamarisk, and tree-of-heaven, and can be controlled in a variety of different ways (Griggs, 2008). On a small scale, invasives including Himalayan blackberry and tamarisk can be completely mechanically removed by hand during the early to mid-growing season. On a larger scale, complete elimination of riparian invasives may not be possible, and will have to be mechanically removed in small areas and monitored continually. Once a sycamore stand is established and matured, management methods such as grazing (during the growing season) and fire (during the fall months) can also be employed to control invasives (Griggs, 2008).

C. **Monitoring Plan**

a. California sycamore health and population at each restoration site should be monitored pre-restoration, during restoration, and post restoration. Multiple years of data will be needed in order to establish trends in recruitment and establishment, as the tree is long-lived and takes many years to reach reproductive maturity (USDA). Ideally, population monitoring should take place every year at each site, typically during the summer months in order to monitor anthracnose incidences and to access recruitment and the need for irrigation. Heavy monitoring should be conducted for the first ten years at the site in order to insure establishment. In compliance with the California Riparian Habitat Restoration Handbook, any incidence that threatens the survival of 70% of the sycamore population is considered the threshold for action. If reestablishment efforts fail, or if sycamore populations fall below 70% of the targeted goal, transplanting efforts must be renewed. Anthracnose incidences should be monitored every year and if the number of incidences rises above 30% of the current population, treatment by fungicide must be conducted. Population monitoring must also take place after flooding events in order to better understand the relationship between flooding and sycamore regeneration. Additionally, monitoring of grazing levels and it's effect on sycamore recruitment should be conducted yearly during the first ten years of establishment in order to continually improve grazing management within restoration sites. If damage or destruction by grazing affects more than 30% of the sycamore population, grazing exclusion measures must be implemented. Monitoring expenses, however, must be balanced with funding availability and tradeoffs will need to be considered.

b. Research Needs and Recommendations

i. **Relationship of flooding to sycamore regeneration**: Although the relationship is not well understood, it is generally acknowledged that flooding is necessary for California sycamore regeneration. Even-aged stands of sycamores result when floods remove old trees and a new, younger generation is generated. Methods such as reservoir pulses can mimic natural flooding regimes and spur sycamore regeneration (SFEI). It is also theorized that periodic flooding can reduce anthracnose outbreaks by washing away infected leaf litter (Johnson et al. 2016). Further study will be necessary in order to understand the best timing and frequency of flooding necessary for regeneration as specific flood timing and frequencies links to sycamore regeneration are currently not well understood. In order to improve management approaches that support California sycamore regeneration, we need to understand the specific flood requirements for large-scale regeneration. This will be essential for influencing management actions such as reservoir pulses (SFEI). This could be accomplished by investigating the ages and locations of sycamores, observing sites before and after flood events, and tracking the location and timing of new seedlings and saplings.

ii. **Hybridization of sycamores**: Propagation of California sycamore for restoration projects is typically done using seed. However, the plants produced using this technique often are hybrids between California sycamore and London plane tree. This hybridization is threatening the genetic distinctiveness of the California sycamore (Whitlock 2003). Whitlock (2003) expressed concern that sycamore hybrids may be less susceptible to diseases that cause deadwood and cavities within trunks that provide important habitats for several riparian species. To ensure that pure California sycamore plants are available for restoration projects, they must be propagated vegetatively. However, vegetative propagation of California sycamore is extremely difficult and only approximately 10% of the cuttings taken ultimately result in a plant that can be used for restoration purposes (SFEI). Vegetative propagation studies should seek to improve on this poor performance to advance the science of vegetative propagation of California sycamore and to improve the cost-effectiveness of vegetative propagation of California sycamore. Further investigation is needed to determine how hybridization between California sycamores and London plane trees may affect California sycamore regeneration and the habitat values of California sycamores and sycamore hybrids in riparian habitat. Hybridization between the California sycamore and the London plane tree has become a major challenge to restoration goals and potentially threatens the continued genetic distinctiveness of this native species. Vegetative propagation of the California sycamore has proven to be very challenging, with most attempts yielding few, if any, viable seedlings that can be used for restoration, but it remains the only means of reliably producing native stock (SFEI). Further research is needed to advance the science of vegetative propagation of the California sycamore and improve the cost-effectiveness of vegetative propagation of the California sycamore.

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Silver bush lupine (*Lupinus albifrons*)

Compiled by: Emily Morgan

Part 1: Literature Review: Project background and justification

Background and Justification

Silver bush lupine (*Lupinus albifrons*) is an important species for restoration of The Solano County Resource Conservation District City of Dixon Stormwater Detention Basin Project because of the many roles it plays in the California floristic community. According to the Calflora database, it is widespread across all of California and beyond, but is confined to North America. Even though it is not of conservation concern, it is prevalent in both scrubland and grassland communities and interacts dynamically with its habitat. It is an important plant for native pollinators (California Flora Nursery 2017) and is an important plant for the endangered mission blue butterfly (Koomas). *Lupinus* ssp. are nitrogen fixers and it important to think about this trait on multiple scales, including the immediate soil environment and its effect on total ecosystem nitrogen. There are many invasive species to try and eradicate at this site and raising nitrogen levels can create a more hospitable habitat for invasive species (Rao, Allen 2009). *Lupinus albifrons* is fire adapted and requires very little water once established, making it a good restoration candidate species. City of Dixon Stormwater Detention Basin Project will be treated with fire management before the native species are planted so *Lupinus albifrons* is equipped to thrive in the starting conditions. Project goals include making the site sustainable to survive without management and to increase native diversity. Species like *Lupinus albifrons* have the capacity to help transform this site back into a native landscape and provide habitat and ecosystem services for other native biota.

Literature Review

This is a compilation of research on Silver bush lupine (*Lupinus albifrons*) from peered reviewed journals and accredited web sources.

<u>Specific Species Characteristics</u>

Species Overview: "White-leaf bush lupine is a fragrant, 3-5 ft. perennial with silky-silver, palmate foliage covering its shrub-like form. Three inch spikes of blue to magenta, pea-like flowers adorn the blooming plant" (Lady Bird Johnson Wildflower Center)

Plant Communities: "Northern Coastal Scrub, Chaparral, Coastal Sage Scrub, Yellow Pine Forest, Foothill Woodland (Calflora). A restored Coastal Sage Scrub community would be dominated by California sagebrush *Artemisia californica* and coyote brush *Baccharis pilularis*. Additional species include purple needlegrass *Nassella pulchra*, bush monkey flower *Mimulus aurantiacus,* silver bush lupine *Lupinus albifrons* and California buckwheat *Eriogonum fasciculatumi*" (Blank 2003).

Environmental tolerancers/preferences: Planting in overly moist areas can cause mildew in the stem and foliage (Huang, Friar 2011). Requires sun and well-drained soils (Bibref, 2000).

Seasonality/phenology: Perennial that blooms April through July (Calflora). Seeds mature from early June to late July (Elkhorn 2001).

Genetics: The *Lupinus albifrons* species complex consists of a number of closely related yet morphologically variable taxa within the larger group of perennial lupine. Samples from throughout its range showed that this group has high genetic diversity between species, within species, and within populations. (Huang, Friar 2017). *Lupinus albifrons* can be morphologically indistinct from *Lupinus excubitus* (Jepson Flora Project).

Seed dynamics: Lupines are best propagated by seed but they must be planted immediately after collection or treated with stratification (Lady Bird Johnson Wildflower Center). Seeds dehisce when they dry so they distribute well. Seeds must be harvested when they are slightly immature so that the seeds open in an environment or container where they can be collected and used (Wolfolk 2001). When adequately dried, mature seeds of lupine can be stored for extended periods (Wolfolk 2001).

Germination/Propagation: Understanding natural germination controls are important for restoration so that they can be mimicked to establish new populations successfully. The National Parks Service found that hand broadcasting and raking Lupinus spp. seeds has better success than planting nursery-propagated seedlings. After the seeds are broadcasted and raked they should be covered with twiggy branches to aid in establishment. They have had some success with growing seedlings in fiber pots and set intact into the beds after removing the bottom of each pot. This reduces the handling of the lupines, which they do not like (Huang, Friar 2011).

Key mutualists: Special value to native bees and bumblebees (Lady Bird Johnson Wildflower Center). Some species of *Lupinus albifrons* are key habitat to the endangered Mission blue butterfly (Golden Gate NRA). The mission blue butterfly is threatened by habitat loss due to decline of important species like *Lupinus albifrons* because of competition with non-native species. Restoring populations of *Lupinus albifrons* could increase populations of mission blue butterfly (Koomas).

Competitors: Invasive species brought from all over the world are competing with natives like *Lupinus albifrons*. Added anthropogenic effects such as introduction of domestic livestock, changes in fire regime, and agriculture are aiding in non-native invasion (Bartolome et al. 2008). When non-native grasses invade they increase nutrient cycling in the soil that can also increase nitrogen in the soil and this creates a feedback loop that supports invasive species (Rao, Allen 2009).

Pathogens: Some lupines have been plagued by a pathogen that causes mortality in seedlings but little is know about how to prevent it. The Golden Gate NRA found that fire destroys the pathogen in some cases and enhanced lupine seedling survival in the Solstice Fire area (Golden Gate NRA).

Specific Needs from the Ecosystem

Water needs: Little to no water needs once established (California Flora Nursery 2017).

Spatial Scale needed: Recommendation for silver bush lupine *Lupinus albifrons* is size D-40 (40 cubic inches, 2.5 inch diameter, 10 inches deep) and 3 foot spacing for planting (Long-term Restoration Vision and Activities, Butters County).

Temporal scale: A perennial that will bloom within one year of planting from seed (California Flora Nursery 2017).

Response to

Grazing: Lupinus albifrons is resistant to deer grazing (California Flora Nursery 2017) and is poisonous to humans and livestock. *Lupinus* ssp. is considered a Class 4 poisonous plant, which means "ingestion of these plants, especially in large amounts, is expected to cause serious effects to the heart, liver, kidneys or brain" (CPCS).

Fire: Populations of lupine and purple needle grass were once maintained by prescribed fire by Native Americans. Replacing non-native trees and grasses with more fire-adapted vegetation can reduce risk and reduce loss of habitat in the wildland-urban interface (Golden Gate NRA).

Agriculture: Nitrogen deposition from anthropogenic activity, especially related to agriculture, can increase soil nitrogen and create soil conditions hospitable for non-native plants (Rao, Allen 2009) and create competition for native plants.

Key Gaps: Response to climate change.

Introduction:

Silver bush lupine (*Lupinus albifrons*) is a fragrant perennial herb that grows 3-5 feet tall with spikes of blue to magenta, pea-like flowers. It has silver palmate foliage that creates a shrub-like form. According to the Calflora database, it is widespread across all of California and beyond, but is confined to North America. Even though it is not of conservation concern, it is prevalent in both scrubland and grassland communities and interacts dynamically with its habitat. It is an important species for the restoration of The Solano County Resource Conservation District City of Dixon Stormwater Detention Basin Project because of the many roles it plays in the California floristic community.

Goals:

1. Establish Silver bush lupine at the Pond C restoration site.

Silver bush lupine is an important species for this restoration site because establishing it as part of the flora will help transform this site back into a native landscape and provide habitat and ecosystem services for other native biota. Seeds mature from early June to late July (Elkhorn 2001) so it is essential the plants are established well before June 1st of the planting season. Planting in saturated soils can result in mildew on the stem and foliage (Huang, Friar 2011) so ideal elevation and distance from the pond should be calculated using water table measurements, soil samples, and the initial plant surveys that indicate where the silver bush lupine is already present in the landscape. Silver bush lupine is one of many species that will become part of the native landscape mosaic. While seeding will target full coverage, seedlings will likely be mixed with other target species and will have to compete for space and resources.

This will create the desired heterogeneity that will provide habitat and other resources for a variety of biota. Seed mixtures are often based factors such as availability or price but not a lot of is known about which seeding rates will ensure a self-sustaining community (Wilkerson 2014).

2. Have a genetically diverse, self-sustained population of silver bush lupine.

One of the overall project goals is for the site to have persisting native plant populations without continued management and monitoring. This means not only initially establishing silver bush lupine, but also ensuring that at least 70% of the initial population remains 3 years after the initial planting (Las Pilitas Nursery) without supplemental seeding. Ensuring that the established population is genetically diverse by planting seed from an accredited nursery that will provide genotypic diversity that will prepare the population for variable conditions and disturbance. Due to the fact that the species complex of *Lupinus albifrons* shows high genetic diversity between species, within species, and within populations (Huang, Friar 2017), establishing a highly diverse population is feasible as long as clonal and inbred populations are avoided.

3. Monitor silver bush lupine populations for three years.

Silver bush lupine is a perennial herb so monitoring it for 3 years will give insight into whether the population is going to persist long term. Population numbers should be counted and recorded one year after seeding. A target goal of 70% of the first year population should remain after 3 years (Las Pilitas Nursery). This goal is feasible if post project monitoring can be done at the site and other restoration efforts such as eradication of invasive species is accomplished.

4. Improve habitat and community dynamics.

Even though it is not of conservation concern, silver bush lupine is prevalent in both scrubland and grassland communities and interacts dynamically with its habitat. *Lupinus* ssp. are nitrogen fixers and it important to think about this trait on multiple scales, including the immediate soil environment and its effect on total ecosystem nitrogen. The tradeoff to consider is that there are many invasive species to try and eradicate at this site and raising nitrogen levels can create a more hospitable habitat for invasive species (Rao, Allen 2009). Improving habitat and community dynamics is a feasible goal because this project is multidisciplinary and many aspects of the ecosystem are being researched and included in the final restoration plan, including soils quality, system hydrology, native plant community establishment, invasive plant eradication and wildlife interactions. All of these components will improve silver bush lupine habitat and aid in its establishment and persistence.

5. <u>Attract native pollinators.</u>

Silver bush lupine is an important plant for native pollinators (California Flora Nursery 2017) such as native bees and bumblebees (Lady Bird Johnson Wildflower Center) and is an important plant for the endangered mission blue butterfly (Koomas). Attracting native pollinators will benefit other native plants that are included in the site restoration plan. Establishing mission blue butterfly could provide additional funding, support, and protection for the site. Attracting pollinators will aid silver bush lupine reproduction and other species at the restoration site.

Restoration Plan:

1. Pre-restoration survey.

Survey the site for individuals of silver bush lupine that might already be present from the initial restoration efforts in 2007. Estimate percent cover and number of individuals. Observe where the individuals survived and are thriving and use that to inform where more individuals should be planted. A pathogen that causes mortality in seedlings is of concern in lupine seedlings but little is known about how to prevent it. The Golden Gate NRA found that fire destroys the pathogen in some cases and enhanced lupine seedling survival (Golden Gate NRA). The site will be treated initially with fire to eliminate invasive species before the natives are planted and should this should eliminate the risk of pathogens in the soil that could deter seedling establishment. Silver bush lupine is fire adapted, therefore the individuals that are already established can continue to persist.

2. Maintain/Establish individuals in the population

The National Parks Service found that hand broadcasting and raking Lupinus spp. seeds has better success than planting nursery-propagated seedlings. Acquire seed from local nurseries but they must be planted immediately after collection or treated with stratification (Lady Bird Johnson Wildflower Center). Silver bush lupine grows up to 5 ft wide and there are 43650 square feet in an acre. So at 100% germination, about 8,000 seeds/acre. Assuming germination success is about 50%, about 16,000 seeds would be needed per acre for the initial planting. There are about 9,000 seeds per bulk pound (S&S Seeds). Germination time for hard seeds is 15-30 days at 60-68 degrees Fahrenheit so they should be planted in spring when temperatures are favorable. After the seeds are broadcasted and raked they should be covered with twiggy branches to aid in establishment. Silver bush lupines are fast growing and are capable of blooming within the first year of the seed being planted (California Flora Nursery 2017). Planting in overly moist areas can cause mildew in the stem and foliage (Huang, Friar 2011), so silver bush lupine requires sun and well-drained soils (Bibref, 2000). Supplemental irrigation may be necessary once a month during the dry season for the first year until the plant blooms and is considered established. Once established, this species requires no additional irrigation as long as they are planted in areas with normal soil water retention for their range and within a soil pH of 6.0-8.0 (CNPS). For this site, normal water retention is likely anywhere outside of the wetland range. Planting silver bush lupine where the soils are saturated for extended periods of time could lead to mildewing. If mildewing occurs, delineation of saturated soils should be redefined and the areas with appropriate water content reseeded.

3. Remove competitors and pathogens.

Work with the invasive species researchers to create a plan that will eliminate invasive species and the competition that they create for native species like silver bush lupine. The planned fire treatment will likely eliminate potential pathogens that could be in the soil and prevent seedling establishment.

Monitoring Plan:

Seedling establishment should be monitored for percent coverage. Initial populations numbers should be counted and recorded 1 year after seeding. After 3 years, 70% of the initial population should remain. If not, factors that could deter seedling establishment and population persistence should be considered.

Factors that might deter seedling establishment and population persistence:

1. <u>Grazing</u>: Silver bush lupine vegetation and seed is resistant to grazing (California Flora Nursery 2017) so it does not need to be monitored for herbivory. However, it is a class 4 poisonous plant that is harmful to humans and livestock if ingested (CPCS). This could be a safety concern for Pond C restoration site because the site is intended to have public access with interpretive trails. If pets or livestock ingest the silver bush lupine they could get sick so warning signs may be necessary.
2. <u>Invasive plants</u>: The site should be monitored for invasive species pressure because invasive species brought from all over the world are competing with natives like *Lupinus albifrons*. Added anthropogenic effects such as introduction of domestic livestock, changes in fire regime, and agriculture are aiding in non-native invasion (Bartolome et al. 2008). Although the site will be treated with fire and other mechanisms, invasive plants are likely to persist and compete with the native plants that are trying to establish.
3. <u>Increase of nitrogen level feedback loop:</u> Silver bush lupine is a nitrogen fixer and has significant effects on the nitrogen levels of ecosystem. Nitrogen levels should be monitored because of the effects that elevated nitrogen can have on improving habitat

conditions for invasive species. One of the major goals of this overall project is to convert the landscape from being dominated by invasive to being dominated by native plants. Significant increases in nitrogen should be considered as a factor if the invasive species continue to persist. Eliminating a percentage of the lupine species may be necessary.

Monitoring pollinator presence through insect surveys and catchments will give insight into the pollinators that are attracted to the site. It is unlikely that the endangered mission blue butterfly will establish at the site without introduction but if it is introduced its presence should be monitored and recorded.

Research Needs:

There is very little research on the effects that climate change will have on silver bush lupine. Shifts in temperatures, hydrology, and cascade of other changes occur as a result of global climate change could have a negative impact silver bush lupine. Climate change is likely to have an effect on seasonality, which is tightly paired with the phenology of plants.

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***Aesculus californica* (California Buckeye)**

Emily Schoenborn

Part 1

Background and Justification:

Aesculus californica, California buckeye is a tree that is aesthetically appealing and to some is a hallmark of California wilderness. The California buckeye has blooms from May to July, which attracts native bees and butterflies such as, *Battus philenor* and *Papilio eurymedon*. Most of the California buckeye's value comes from nectar and pollen that feed native insects and from its strong survival skills. The California buckeye is poisonous to humans and animals which protects it from being eaten and protects its seeds. This can cause problems with European honeybees, who cannot tolerate the poisonous nectar like native bees can and may die. The California buckeye is a versatile tree can live in various ecosystems, it drought tolerant, and is fine tuned to California seasons. The buckeye leaves in February or March which is earlier than most trees and becomes dormant in summer rather than fall. These traits make the buckeye an ideal species because they will require little maintenance, while providing habitat for native insects. Due to its ability to survive and live in various ecosystems, the California buckeye is not a state or federally threatened or endangered species. Although, like with most species, land use has decreased the numbers of the California buckeye, it is not a large enough number for concern.

Literature review:

Biotic:

1. Species interactions:
   a. Native bees: Food source for native bees during flowering.
   b. European honey bees: Poisonous to European honeybees and if honey made from honeybees who visited buckeyes is high in concentration then the honey may be poisonous to humans (USDA).
   c. Butterflies: food source for butterflies during flowering (USDA).
   d. Other plants: Does well near *Baccharis pilularis* var. *pilularis, Eriogonum fasciculatum, Salvia sonomensis, Zauschneria californica, Ceanothus, Arctostaphylos manzanita, Quercus lobate and agrifolia (most Oaks in general). Does well with other native (and even non-native) plants, does not have any specific beneficial or detrimental relationships with other plants.*
   e. Animals:
      a. California buckeye is toxic and is poisonous to animals.
      b. Livestock will eat Buckeye and buckeye is graze tolerant (Howard 1992).
      c. Vulnerable to grazing when seedlings (Howard 1992)
2. Pathogens:
   i. California buckeye is a known host of *Phytophthora ramorum*, the pathogen that causes sudden oak death.
   ii. During germination, if soil temperature is below 40 degrees F, then fungal infections may occur. (Howard 1992)

Abiotic:

1. Water needs: Water availability it correlated to leaf and flower development.
   a. Drought tolerance: Has a strong drought tolerance due to its long taproot, early leafing, and early dormancy that makes efficient use of water availability.
   b. Seed water: Seed needs water for first year, during the summer it needs to be water once to three times a month, but once it's established it will not need extra water during the summer (calscape).
2. Soil needs:
   a. Type: Clay, loamy, moist, highly drained, high electrical conductivity, sandy, sandy-loam, or gravelly-loam soils (Howard 1992)
   b. pH: neutral to basic (calscape)
3. Weather: Cooler, Moist, Coastal locations.
4. Location:
   i. dry slopes, canyons, and the edges of rivers
   ii. On upper slopes, north facing (Young 2001)
   iii. Northwestern and Central western California, Cascade Range, Sierra Nevada foothills, Tehachapi Mountains, Great Central Valley, and southwestern Mohave Desert.
   iv. Riparian: Preferable location to plant Buckeye's is mid slope (Howard 1992).
5. Phenology (relation to abiotic factors):
   a. Spatial: depends on specific ecosystems

i. Mixed evergreen forest: Buckeyes can be understory shrubs
ii. Grasslands: widely scattered

b. Temporal: (Howard 1992)
   i. February-March: stem elongation and leaf expansion
   ii. First week of March: leaves fully formed
   iii. Mid May: leave started yellowing
   iv. June: leaves started falling
   v. May: Flowering
   vi. June-November: fruit development
   vii. November-December: fruit dispersal
   viii. It bears fruit when leafless therefore it must use reserved nutrients to produce fruit. Only produces 1 or 2 fruits, with normally one seed per a fruit.
   ix. Seeds may be dispersed through rivers or streams.
   x. Exceptions:
      - During wetter years, leaves full for about a month longer
      - At colder and more coastal sites, trees flowered early July and stayed full leaf into July.

Anthropogenic:

1. Human uses: Native americans at California buckeye seeds and used them as medicine as well.
2. Climate Change: The California buckeyes cycle is closely linked to water availability and weather of California. As the climate changes, it may be more difficult to buckeyes to survive. Contrary, buckeyes current cycle (leaving earlier and losing leaves earlier) could make it more prepared for climate change.
3. Effective management:
   i. Seeds: plant in well-drained soil, water throughout summer, once they're established, after 1 year, further maintenance is no longer required.
   ii. Mature: can be pruined, but is not necessary.
4. Fire:
   i. After topkill fire, sprouts from root crown.
   ii. Seeds may not survive fire
5. Services/benefits:
   i. Planted on slopes of hills or river banks, the roots can hold the soil down and prevent flooding. Especially important for decreasing erosion for rivers during flooding events.
   ii. Aesthetical appeal, it is an ornamental plant

Part 2

1) Goals:

   a) Introduce Aesculus californica to restoration site through the planting of groups of 3-4 seeds (Howard 1992) together every 40 feet (calscape.org) and a year later replant where seeds did not establish or cut down to one seed where more than one seed established. Seeds have a germination rate of 75% (Howard 1992) and when grown have a maximum diameter of 40 feet (calscape.org), therefore you could plant seeds 40 feet apart and a year later replant where seeds did not establish or plant seeds about 30 feet apart. Seeds should be planted on slopes along waterways in soils that are sandy and loamy (Howard 1992). California buckeyes prefer to be on north facing slopes and in an open site (Callahan 2005).

   b) Feasibility: California buckeyes are known for being easy plants due to little care necessary, low water intake, (calscape.org) and lack of germination treatment (Howard 1992). The low level of difficulty involved in successfully creating a self-sustaining population of California buckeyes makes introducing this species to the site very feasible. The main problem that may make this species difficult is that the seeds are not viable after a year therefore seed collection should be done as close to planting as possible (Howard 1992). Another issue may be the time frame, because we're planting with seeds it will take longer for a mature tree to form, if time is an issue then tree cuttings can be used in place (not that much information is available on California buckeye tree cuttings, so seeds is preferred method with a high germination rate).

2) Restoration Plan

   a) During September through November when seeds have dropped collect them (Young 2001). Preferably within a couple of weeks of collecting seeds, plant 3-5 seeds together in one spot (Young 2001) about 40 feet apart, half covered in soil on the upper slopes of the wetland in soil that is either sandy to loamy (Howard 1992).

      i) California buckeyes prefer to be on north facing slopes and in an open site (Callahan 2005). Seeds do not require any form of pretreatment (wildflower.org).

      ii) Seeds can be planted in an area that either receives full sun or partial sun. Immediately water these seeds (unless the soil is already wet from natural rainfall or river) and then water these seeds continually during the summer of their first year (Howard 1992).

      iii) Seeds are only viable for one year and germinate quickly, normally within the first several weeks of dropping (Howard 1992).

   b) During the first summer, the seedlings should be watered once to three times a month (calscape.org). After the first year in the fall or winter, check seeds to see which seeds have established and replant accordingly, following previously routine.

      i) If more than one seed established, then cut back to one seedling (wildflower.org).

      ii) To prevent animals such as California ground squirrels from digging up and eating seeds, protect the seeds with plastic tube covering, which may be removed around the second year (wildflower.org).

   c) If for time restraint purposes a quicker solution is necessary, then softwood cuttings from a mature plant that resides in a similar habitat to the site can be planted 40 feet apart on the wetland slope with partial to full sun in sandy to loamy soil. These cuttings do not need to be planted in November like the seeds, but should be planted closely to when they were cut and will need to be watered once a month to three times a month during their first summer (calscape.org).

i) Species is fire tolerant; tops of trees will die, but will sprout from root crown (Howard 1992).

3) Monitoring

   a) Seeds should be monitored monthly throughout the first year of planting, but during the first summer they should be monitored once to three times a month to ensure proper water (this is the same amount of times that Buckeyes need to be watered per a month during the summer).

      i) After first year, seed should be established and will no longer require care (USDA).

   b) Soil temperature should be monitored throughout the germination period, first 21 days of being planted (Young 2001), because if during germination soil temperature is below 40 degrees F, then fungal infections may occur (Howard 1992). If soil temperature is this low, then it is recommended to germinate seeds in a greenhouse where soil temperature can be controlled.

   c) If goal is met, then no further action is required because this species will spread on its own.

      i) Species will spread slowly because Buckeye has a small dispersal range due to its main form of dispersal being gravity or water (Howard 1992).

   d) In case of disturbances:

      i) Should be monitored once a month for half a year after a fire to ensure that there are sprouts on root crowns. If there are no sprouts on crown roots within first two months after fire, then seeds will need to be brought in from another area to repopulate the site (because fire makes the seeds not viable) and previously listed restoration routine should be followed (Howard 1992).

ii) During a drought, no monitoring is necessary, California Buckeyes are drought resistant due to a long taproot and a water efficient life cycle. Even when the ground water is very low due to a drought, the tree will not be able to produce fruit, but will survive (Benseler 1975).

iii) Continual monitoring of this species after initial year or when there are no disturbances is unnecessary (USDA).

e) If plant cannot establish then it is recommended to either:

i) collect seeds from a different location because the previous location may have not had a habitat similar enough to site.

ii) Check if soil is well drained, if the soil is not then the seeds should be placed in an area with soil that is sandy to loamy.

iii) Check for signs of herbivores eating the seedling, if there are signs then check for flaws in plastic tube covering. If there are no flaws in plastic tube covering, then try a different covering such as a mesh covering.

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Wetland Herbaceous Plants: Year-Round Inundation

Restoration of Freshwater Wetlands in California's Central Valley

Christina Nowak

1. Core Species and "Zones" of Wetland Vegetation

- According to (Hoag et al., 2007), these are the plant **functional types** that are adapted to different wetland "**zones**"

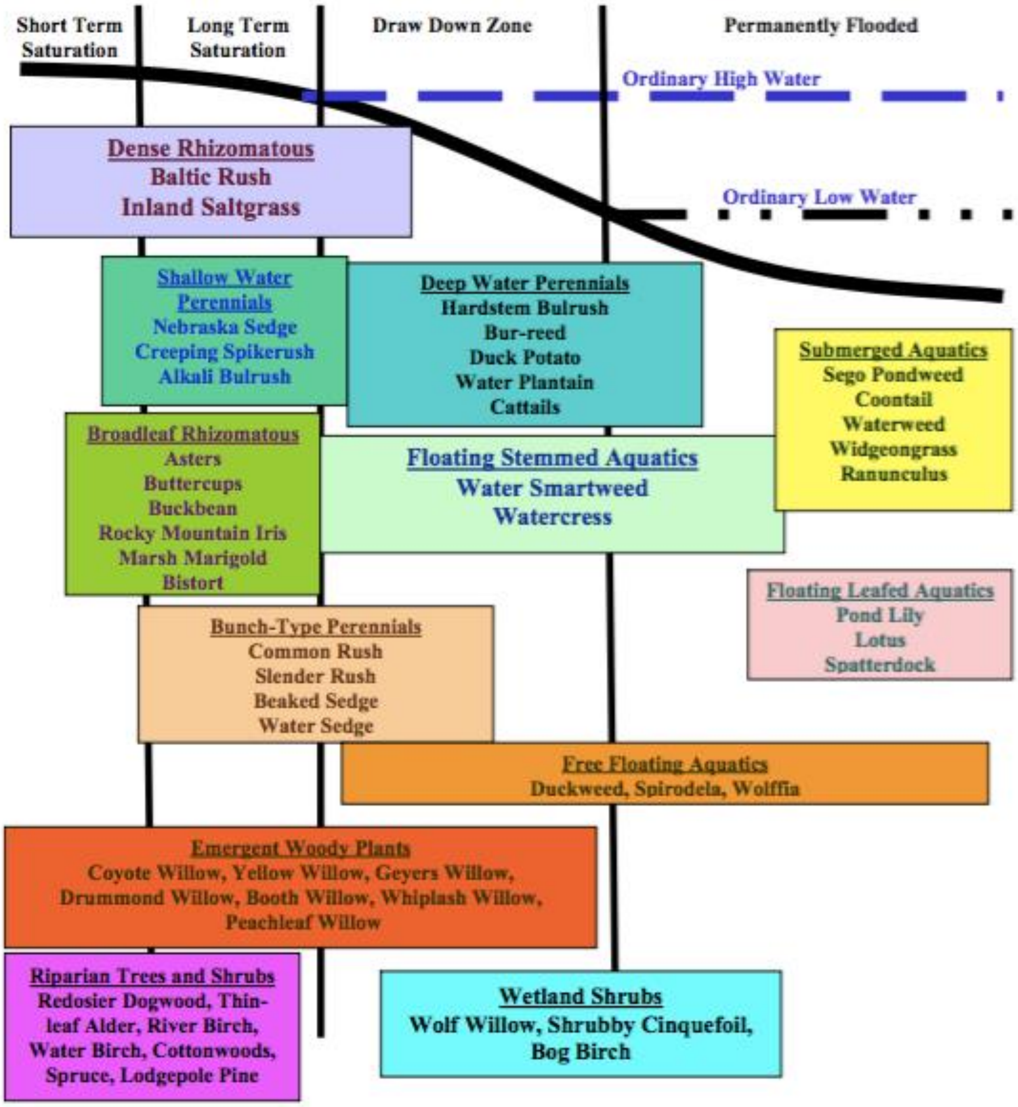


Figure 1: This is a graphic representation of different plant types and their relationship to water depths.

- The following summary of Figure 1 is adapted from Hoag et al. (2007). Species given for each functional type are examples and native Californian-equivalents may be used in their place:
    - **Emergent Plants**
        - **Dense Rhizomatous**: *seasonally saturated areas* (preferably saturated early in the season, but later dry out)
            - Found at *water's edge* and in *wet depressions* in upland areas
            - *Perennial* with dense rhizomes
            - Reproduce *by seed* and *underground rhizome* runners
            - Can be quite *drought tolerant*
            - ***Juncus balticus, Phalaris arundinacea, Deschampsia caespitosa, Agrostis stolonifera, Distichlis spicata***
        - **Shallow Water Perennials**: require annual draw down or *maximum water depths of 6 inches* during most of the growing season
            - Found in the *riparian zone*
            - Can survive periods where the water table is *more than 1 m below the surface*
            - Thick root mass that is resistant to compaction, erosion, and herbivory
            - ***Scirpus pungens, Eleocharis palustris, Carex nebrascensis, Scirpus maritimus***
        - **Deep Water Perennials**: *require draw down or maximum water depths of 12-18 inches during the growing season*; can persist in water up to 3 feet, but grow much faster in fluctuating water depths
            - ***Schoenoplectus acutus* var. *acutus, Schoenoplectus tabernaemontani, Typha* sp., *Sparaganium* sp., *Sagittaria latifolia, Alisma subcordatum***
        - **Bunch-Type Perennials (Caespitose)**: *can grow in shallow standing water, but also can withstand long dry periods*
            - Prefers flooding in the early portion of the season
            - Found in *saturated soils* and *upper draw down zones*
            - Intolerant of long-term inundation
            - ***Juncus effusus, Juncus occidentalis, Carex rostrata, Carex aquatilis***
        - **Broad Leafed Rhizomatous**: *prefers seasonally flooded areas that dry out later in the year*
            - Tolerates short inundation periods
            - Monotypic stands in *saturated soils*
            - Beautiful wildflower colors
            - Attracts pollinators
            - ***Aster* sp., *Iris missouriensis, Caltha palustris, Polygonum bistorta, Ranunculus* sp.**
        - **Emergent Woody Plants**: *tolerant of long (4-6months) to permanent inundation*
            - Can be survive in Draw Down Zone (nearest wetland), Long-Term Saturation Zone, and Short Term Saturation Zone (nearest Upland)
            - Flexible stems reduce water flow energy during floods

                - ***Salix exigua, Salix lutea, Salix geyeriana, Salix drummondiana, Salix boothii, Salix amygdaloides***
            - **Riparian Trees & Shrubs**
            - **Wetland Shrubs**
    - **<u>Floating Leaves</u>**
        - **Floating Leafed Aquatics**: *rooted in deeper water and send leaves to the surface to float*
            - ***Nymphaea odorata, Nelumbo lutea, Nuphar luteum, Potamogeton natans***
    - **<u>Submerged</u>**
        - **Submerged Aquatics**: *found in deep water (+3 feet) that never or rarely draw down*
            - Rooted in the bottom, tops float near the water surface
            - ***Stuckenia pectinata, Ceratophyllum demersum, Elodea canadensis, Ruppia maritime***
    - **<u>Free Floating</u>**
        - **Free Floating Aquatics**: *important in the process of bioremediation as they grow rapidly, absorb excess mineral nutrients (esp. Nitrogen and phosphates*)
            - Reduce evaporation of water compared to open surface
            - Small structures that float on or just under the water surface
            - Reproduction via budding
            - All nutrients are obtained from the water column
                - Might not be the best functional form if water is expected to evaporate parts of the year
            - ***Lemna minor, Spirodela polyrrhiza***
- Also see **Appendix A** for a comprehensive list of Californian Wetland plants from Las Pilitas Nursery
- According to Tsihrintzis et al. (1995) & Weber (2011), planting vegetation according to the following "zones" will manipulate the hydrology of the wetland:
    - Bottom: herbaceous freshwater species
        - Cattails, willows provide "roughness" to detain water flow
        - Macrophytes grow in the shallow, low-velocity portions of the wetland
        - **ONLY herbaceous vegetation** should grow on bottom of wetland (Tsihrintzis et al., 1995)
            - This means **regular removal of woody vegetation is required**
        - "Emergent marsh vegetation in the depression bottom" (Weber, 2011)
        - "Wet meadow vegetation at the wetland perimeter" (Weber, 2011)
            - "prevent(s) soil erosion, but also provides complexity to the wetland edge and increases habitat functions"
        - In zones of **always moist soil (**at the minimum, water inundation probably preferable) (Wilson et al., 2013)
            - Rushes (*Juncus spp*.)
            - Sedges (*Carex spp*.)
            - Bulrush (*Scirpus spp*.)
            - Cattail (*Typha spp*.)

            - Spike Rush (*Heleocharis spp*.)
            - Tules
        - Rushes, sedges and spike rushes live in seasonal ponds and have enough moisture long enough to support their life cycle (about four months) (Wilson et al., 2013)
    - Side slopes: willow woodland, mixed riparian [(Tsihrintzis et al., 1995) & (Wilson et al., 2013)]
        - Willows (Salix spp.)
        - Cottonwood (Populus spp.)
        - Alders (Alnus spp.)
            - *Considering the abnormal wetland hydrology at the site, I wouldn't recommend planting too many of these "side slope" species since they tend to use A LOT of water
        - Native grasses & forbs within the surrounding uplands (Weber, 2011)

- **Dense stands** of initial vegetation where water feeds *into wetland* will achieve sedimentation and filtration during low flows (Tsihrintzis et al., 1995)
- Sommer et al. (2001) describe wetland ecology specific to nearby Yolo Basin. These species could potentially use the Dixon site as well:
    - Wildlife include mallards, northern pintails, American wigeon (duck), green-winged teal, northern shovelers, ruddy ducks, snow geese, Ross's geese, Canada geese, and Swainson's hawk
        - "Wildlife managers seasonally flood the area in October and maintain ponds for migratory water- fowl through January"
    - Species of shorebirds (e.g., sand- pipers, curlews, and avocets), raptors (e.g., northern harriers, red-tailed hawks, and kestrels), songbirds (e.g., orioles, towhees, and bluebirds), and mammals (e.g., raccoons, skunks, and grey foxes)

2. Approaches to Restoration

The following information was compiled based upon the best available literature. Therefore, some topics have a lot of information while others have yet to be known.

- **Types of site preparation that are needed (or need to be avoided**)
    - General methods for overcoming plant establishment constraints (Zedler, 2000):
        - Provide **habitat heterogeneity, import substrate, amend soil**
        - **Minimize fragmentation** and **maximize corridors** to encourage persistence
    - "If the texture, nutrient status, seed banks, or microbiota are substantially altered, related functions are also altered" (Zedler & Kercher, 2005)
        - Targets for soil quality are site-dependent based on soil type and alterations to the site. At this site, the biggest issue to address will probably be <u>changes to structure</u> from compaction and a <u>lack of beneficial microbiota.</u>
        - An example from Zedler & Kercher shows that the highest planting restoration success on <u>compacted sites</u> occurred when the compacted soil was amended with **compost** and **high-density plantings** (2005)
    - Restore soil with low organic matter or nutrients by adding **soil amendments**

- Adding native soil to planting holes can encourage desired microorganisms (Zedler & Kercher, 2005)
    - Zedler & Kercher note that inoculum from native soil sites is better than purchasing inoculum from "supply houses" to ensure adaptation to local genotypes (2005)
- **Disking** the soil before planting enhances microtopography which "appears to enhance availability of certain nutrients as well as nutrient variability" (Moser et al., 2008)
    - In a study by Moser et al. (2008), disked sites had higher extractable Fe and Mn and **much higher ammonium-N than non-disked sites in proportion to total Nitrogen**
        - Potential explanations: greater soil moisture from disking creates higher anaerobic conditions for N mineralization **or** exposure of organic N substrate for microbes as a result of soil inversion
    - Disking will likely promote diversity, productivity, nutrient heterogeneity, and accumulation of organic matter which will serve to enhance ecosystem stability and resilience (Moser et al., 2008)
    - Disking is recommended because it is a low-cost method, but other methods that create microtopography may be used (e.g. excavated hummocks/hollows) (Moser et al., 2008)
    - Increasing microtopographic heterogeneity has been shown to **improve plant establishment** (Zedler, 2000)
- **Groundwater recharge** will be crucial at this site
    - Assist GW recharge by <u>slowing water flow with vegetation</u> and providing <u>sandy substrate</u> to promote infiltration (Zedler, 2000)
- **Removal of excess sediment**
    - Will concentrate "the available water more to the original footprint of the depression, where the most highly impermeable soils occur. Although the surface area will be less, the storage depth will tend to increase" (Weber, 2011)
        - This could benefit the site since our hydrology monitoring indicates that the surface water and water table are disconnected currently

How to plant species

- "In stressful sites, tight clusters of plantings can be more effective than low-density plantings" (Zedler & Kercher, 2005)
- "Give priority to native wetland plants **collected or grown from material within the Major Land Resource Area** of the constructed wetland location" (NRCS, 2010)
- Transplant **larger and/or older** individuals to hasten plant maturity (Zedler, 2000)
- Plant **cover crops** to use space and light, thereby reducing early dominance by weeds (Zedler & Kercher, 2005)
- Conduct **pilot plantings** to identify suitable habitats and plant more broadly in later stages (Zedler, 2000)
- Plan for **future resilience**: retain all desired native species somewhere in the landscape rather than strictly defined vegetation "zones" (Zedler, 2010)
    - Given the information on wetland vegetation zones in section 1, perhaps plan plantings adaptively according to both inundation "zones" and groundwater data from the lab
    - Increase resilience by diversifying native species (Zedler, 2010)

        - Provide **genetic variation** for **future** selection (Zedler, 2000)
    - "Large sites with heterogeneous microtopography and patchy resources could accommodate experimental plantings of many native species, various genotypes, assemblages that differ in species richness, and combinations that include multiple functional groups" (Zedler, 2010)
        - There is potential for this at the Dixon site since there is high variation in micro-topography & water inundation around the "permanent" wetland

- **Protection for plants**
    - Hoag & Tilley (2007) have a great document on inundation scheduling and how to adjust water levels to ensure plant growth success. The following guidelines are adapted from them. Additionally, see **Appendix B** for useful charts on appropriate inundation levels for different plant types:
        - Too much water during the growing season will stress the plants, limiting growth and establishment
            - Young plants are more susceptible to stress from too much water than mature plants
        - "Establishment success of herbaceous emergent, shrubs and trees is often increased if **water levels are controlled the first one or two years to allow only short flooding periods and saturated substrates**"
            - Plant establishment is the **most critical time** for accurate water management within the wetland
        - Below is a suggested inundation schedule to follow to help plants establish. Again, **Appendix B** illustrates this schedule.
            - **Week 1:** Water 2-3cm high after first week of planting will inhibit the germination of any terrestrial species that may be present in the wetland
            - **Weeks 2-4:** Lowering the water level after the first week will **expose the mud surface and stimulate any wetland seeds** that were brought with transplants (if used) and increase the rate of spread of the transplants. Leave the substrate exposed for 15-20 days after draw-down.
            - **Week 4:** Once the substrate has remained exposed, raise the water level to 3-5 cm for a week.
            - **Weeks 5-7:** Lower the water levels again to expose the substrate. Leave the substrate exposed for 15-20 days.
            - **Week 7:** At the beginning of Week 7, raise the water level to 10-15 cm for 3-5 days. From this point on, the goal is to gradually keep raising the water level so the wetland adjusts accordingly.
            - **Weeks 8-10:** Raise water to a total height of 15-20cm, be careful **not to raise the water level over the emergent veg. to avoid anoxia.** Leave the water at this level for 15-20 days.
            - **Weeks 10-12:** Continue to raise the water level to a total height of 30-50 cm if plants continue to grow without showing stress; **the goal is to**

inundate the transition zone between the wetland and upland as much as possible to control any invading terrestrial species

- **Weeks 13-14:** At this point, the wetland has developed some resilience and so water levels can be lowered as low as 5-7 cm if water resources are not available. If plants show signs of stress or weed control is needed, water levels can be raised and lowered accordingly from this point forward.
- "During the second spring at the restored site (i.e. the year after the first growing season), raise the water level again to flood most of the transition zone. Maintain this level until warm weather sets in and new growth has started"

▪ "Once the wetland is **well established** [as soon as the 16th week after planting or longer if plants take longer to reach maturity, see **Appendix B**]**,** the water levels can be manipulated to maintain the desired conditions for your system"

- *Week 16 marks "maturity" of the wetland when a specific schedule does not need to be strictly followed; this is a general supposition and may differ at our site depending on how long plants take to reach maturity or how much groundwater is available to support plants*

▪ *"**Wetland plant communities are dynamic and require a <u>fluctuating water level</u> to remain healthy and to function properly**"

- **Approaches to invasive management** (limitations on certain herbicides, limitations on disrupting the bank, etc.)
  - Remove invasive species **by hand** or **mechanically** (Zedler, 2000)
  - Control weeds by **smothering with black plastic** or **mulch** (Zedler, 2000)
  - When weed problems arise, you can **raise the water level to "suffocate" them** (Hoag & Tilley, 2007)
  - Byun et al. (2015) found that invasive plants, specifically *P. australis*, were controlled **mostly by direct flooding**
  - **Dense cover of wetland plant species** is enough to resist invasion when propagule pressure from non-natives is low to medium. A combination of dense native cover and flooding is even more effective as preventing invasion (Byun et al., 2015)
    - Note that biotic resistance by native wetland species is most effective when they are planted in their "natural" zones (i.e. the zones where they tolerate a certain level of flooding)
  - Considering that invasive plants tend to be intolerant of flooding, one can then arrange wetland plants according to expected water levels in the wetland and the inundation zones specified above.
  - Species richness (i.e. diversity of wetland species planted) also confers biotic resistance to invasion (Byun et al., 2015)
- **Aspects to be cautious about (e.g. erosion control approaches, etc.) / Key regulations one needs to plan restoration around**
  - A **period of maturity** may be required to fully remove/filter pollutants (Tsihrintzis et al., 1995)

- **Pollutant saturation** may occur after a certain length of urban storm water filtration (Tsihrintzis et al., 1995)
  - Nutrient removal may be addressed by <u>adjusting water residence time</u> or <u>harvesting plants to remove nutrients</u> (Zedler, 2000)
- **Sediment removal** from runoff is a key service provided by the wetland
  - Achieve sediment removal by <u>slowing water flow</u> and providing a basin to <u>trap heavy sediments</u> and allow clean-out (Zedler, 2000)
- **Introduced disturbance** (from increased nutrient load) due to higher surface runoff from urban areas – be wary of the effects of years with high residential runoff (Zedler & Kercher, 2005)
  - Could lead to eutrophication

3. Considerations for Future Monitoring

- Baseline data with frequent sampling (Zedler 2010)
  - **if detailed data cannot be obtained**, at least mark initial boundaries between native and invasive veg. to show later shifts
- A Guide to Developing Watershed Plans created by the U.S. EPA recommends adopting a "circular" management strategy (2013)
  - This consists of implementing monitoring protocols, collecting and analyzing results, then deciding whether to make changes in management or maintain protocols
- There are several measurements to monitor in a wetland system: **chemical** measurements**, physical** measurements**, biological** measurements. The following has been adapted from the USEPA's "A Quick Guide to Developing Watershed Plans" (2013)
  - **Chemical measurements:** levels of dissolved oxygen, suspended sediments, nutrients, metals, oils, and pesticides
    - These measurements monitor "constituents in water, sediments, and fish tissue"
  - **Physical measurements:** temperature, flow, water color, condition of streambanks
  - **Biological measurements:** abundance and variety of plants and wildlife, ability of test organisms to survive in sample water
- The **timeline** of monitoring can be adjusted according to team members available and/or funding. A previous successful USEPA case study recommends the following (USEPA, 2013):
  - Habitat (including vegetation), wildlife, macroinvertebrates sampled **yearly during summer**
  - Water quality & chemical measurements taken **weekly over a span of 30 weeks from April to October** at the site *and* upstream/downstream of the site
  - Physical measurements may be recorded during water quality monitoring
- **Data analysis** should be conducted **at least annually for the first few years** to determine "status, changes, trends, or other issues" that may arise (USEPA, 2013)
  - Analyses could include **routine summary analysis** and **intensive analysis** (USEPA, 2013)
    - <u>Routine summary</u>: tracks progress, assesses data quality relative to measurement quality, early feedback on changes or problems in the wetland system
    - <u>Intensive analysis</u>: provide larger idea of wetland response to conditions at the site over time

- “t-tests comparing indicator levels before and after implementation”
- Water quality monitored above and below the site
- Comparison between wetland site where management was implemented and a reference site where it was not implemented
- Trend analysis can provide insight into gradual changes
- “Sophisticated statistical techniques such as analysis of covariance might be required to control for the effects of variations in weather, streamflow, or other factors”

- “Impacts of changing the temporal pattern of wetness and dryness are rarely known in detail, the complexity of the relationships suggests that natural hydroperiods are critical to wetland function; the question is how much they can be altered before services decline” (Zedler & Kercher, 2005)
    - It’s critical to monitor general hydrology and groundwater to understand the implications of not being initially connected to groundwater and observe how the wetland responds in the coming years
- “Extreme events associated with longer term climate change will further reduce diversity by shifting the more tolerant species to stronger dominance (reducing evenness) and by extirpating some populations more rapidly than they can reestablish (reducing richness)” (Zedler 2010)

4. Summary

1) “Zones” of wetland vegetation (assuming water is present year-round)
    a) Different species tolerate different inundation levels according to their physiologies
    b) Creating a planting design that arranges plants according to “zones” can maximize the control of water flow and nutrient filtration
    c) Zones also help control *where* this happens in the landscape/restoration project site
2) Priority to vegetation **collected locally** (seed, cuttings, etc)
    a) Consider soil type similarities and differences between where parent material is collected and our Dixon site
3) Planting **dense stands** initially is especially **helpful at stressful sites**
    a) Slow water flow
    b) Achieve higher interception of sediment
    c) Resource acquisition
4) Plan for **future resilience**
    a) Retain all desired native species somewhere in the landscape rather than strictly defined vegetation “zones”
    b) **Development** and **climate change** could change the hydrology of our system in the future which would affect where plant species can survive -- *may be different from where they will be planted*
5) Dynamic wetland plant communities require **fluctuating water levels** to remain healthy and function properly
    a) Plants have different requirements at different life stages, adjusting water levels can optimize growth at each stage

6) Monitor **yearly (at a minimum) for the first few years**; adjust strategies according to management goals and wetland response

Appendix A: Core Species Used in California Wetland Restoration

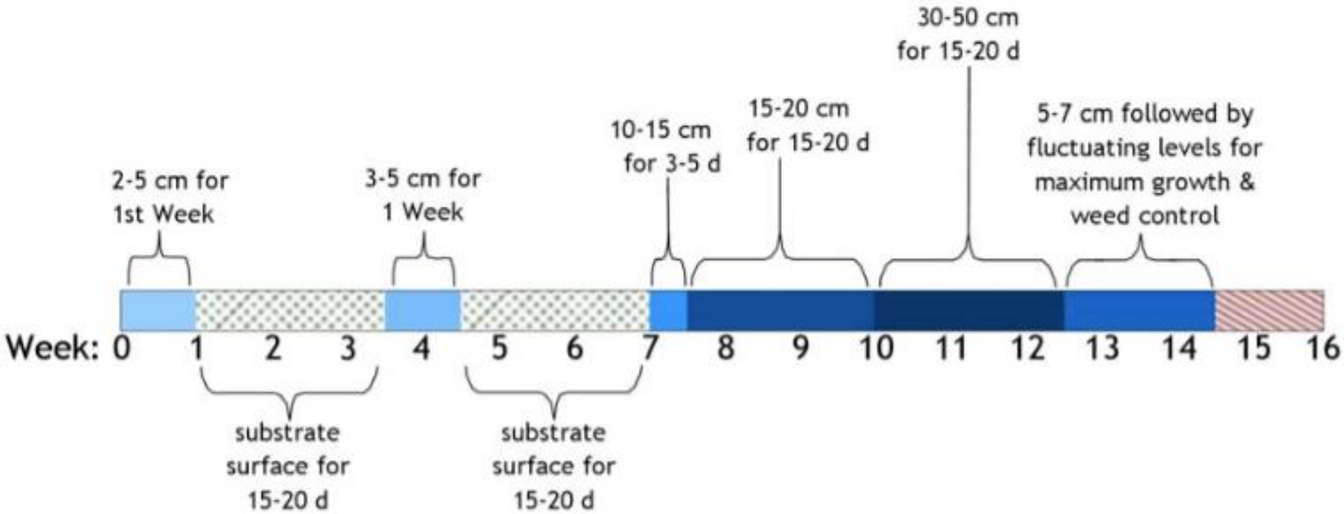
Also see **Appendix C** for a CA Wetland plant list from the U.S. Army Corps of Engineers.

- According to the **Las Pilitas Nursery website** (http://www.laspilitas.com/nature-of-california/communities/freshwater-marsh/plants?community_plants_page=2):
  - *Alnus rubra* (Red Alder)
  - *Anemopsis californica* (Yerba Mansa)
  - *Artemisia douglasiana* (Mugwort)
  - *Artemisia dracunculus* (Tarragon)
  - *Aster chilensis* (CA Aster)
  - *Bidens laevis* (Joaquin Sunflower)
  - *Calamgrostis canadensis* (Blue-joint)
  - *Carex fracta* (Fragile Sheathed Sedge)
  - *Carex senta* (Rough sedge)
  - *Carex spissa* (San Diego sedge)
  - *Cyperus eragrostis* (Nutsedge, Umbrella Sedge)
  - *Deschampsia elongata* (Slender hairgrass)
  - *Elymus glaucus* (Blue Wildrye)
  - *Epipactis gigantea* (Stream Orchid)
  - *Equisetum hymale* (Scouring rush)
  - *Gnaphalium microcephalum thermal* (Feltleaf everlasting)
  - *Helenium puberulum*
  - *Heleocharis macrostachya* (Common Spike Rush)
  - *Heleocharis palustris*
  - *Hibiscus californica* (Rose-Mallow)
  - *Hordeum brachyantherum* (Meadow barley)
  - *Juncus balticus* (Baltic Rush)
  - *Juncus dubius*
  - *Juncus macrophyllus* (Long leaf rush)
  - *Lobelia cardinalis* (Cardinal Flower)
  - *Parnassia palustris californica* (Grass-of-Parnassus)
  - *Pluchea odorata odorata* (Salt Marsh Fleabane)
  - *Populus trichocarpa* (Black cottonwood)
  - *Potentilla anserina ssp. pacifica* (Pacific Silverweed)
  - *Rubus ursinus* (Pacific blackberry)
  - *Sambucus Mexicana* (Tapiro)
  - *Scirpus californicus* (CA Bulrush)
  - *Scirpus maritimus* (Alkali Bulrush)
  - *Sidalcea oregana* (Checker)
  - *Sisyrinchium californicum* (Yellow-eyed Grass)
  - *Spergularia marina* (Salt-Marsh Sand Spurry)
  - *Stachys ajugoides ajugoides* (Persnickety Pink Hedge Nettle)
  - *Trifolium* (Clover)
  - *Typha domingensis* (Southern Cat-Tail)
  - *Zauschneria PHAT Margarita* (CA Fuchsia)

Appendix B: Inundation Levels for Different Wetland Plant Types & Inundation Schedule

Here is a simple chart to help determine what water depths common wetland plant species need:

Plant Growth Form	**Average Water Depth (in.)**
Submergents (e.g. pondweeds, elodea, milfoil, etc.)	**>36**
Floating Leaved (e.g. lotus, water lily, spatterdock)	**18-120**
Herbaceous emergents (e.g. bulrush, spikerushes, cattails, etc)	**0-36**
Shrubs (e.g. willows, dogwood, buttonbush, etc) Note: water should be around the shrubs no longer than 3-4 months MAX	**0-8**
Trees (e.g. willows, cottonwood, sycamore, etc) Note: water should be around the shrubs no longer than 3-4 months MAX	**0-8**



***Week 16 marks "maturity" of the wetland when a specific schedule does not need to be strictly followed; this is a general supposition and may differ at each site**

Appendix C: National Wetland Plant List – California

The following link provides a 35 page document of wetland plant species found in California:
http://wetland-plants.usace.army.mil/nwpl_static/data/DOC/lists_2016/States/pdf/CA_2016v1.pdf

Additionally, the following link has a description of Indicator Status Ratings which will be helpful in interpreting the list:
http://wetland-plants.usace.army.mil/nwpl_static/index.html

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Freshwater aquatic weeds in the California Central Valley

Liu, Bimin

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A. Background & Justification:

The effect of the aquatic weeds on the ecosystem is a series problems in the world (Bates 1976). Weeds are considered to be a category of undesirable, economic pest. (Jonh,1997) The aquatic weeds pose a threat to native biodiversity and cause unacceptable damage in both ecological and economic terms. (Shogren,2000) Because of their Adaptability, persistence and dangers, they have particularly complicated effect on local communities (Raghavan,2001). There are countless species exist in different kinds of habitats. With the development of science and technology, human activities intensified. Meanwhile, more and more invasive weeds are challenging the resilience of the ecosystem. Scientists are not only working on recording the new invasive species, but also looking for more effective ways to control aquatic weeds. Our goal is to analyze the distribution of weed species, choose the target weeds wisely and take comprehensive utilization of biological, chemical and other means to control the weeds.

B. Literature review

1.species

Definition：The aquatic plants that disturbing the laws of the ecosystem, interfering with activities of other organisms are called the aquatic weeds.(Skdorkewicj,2004) (if, in any specified geographical are, its populations grow entirely or predominantly in situations markedly distrubed by man (without, of course, being deliberately cultivated plants))

Classification：(Lacoul,Freedman,2006) which is similar with the classification of aquatic plants:Emergent species; Floating-leaved hydrophytes ; Submerged hydrophytes ; Free-floating hydrophytes. Thus, it is of great important to develop different control schemes for different types of weeds.

Characteristic:

There are tendencies for aquatic plants to reproduce vegetatively rather than sexually (Sculthorpe, 1967) and their high rate of assimilation of nutrients (Spencer and Bowes, 1990) results in rapid growth and increase in biomass.

(1) Emergent plants are rooted in the soil but have leaves and inflorescences above the surface of the water, grow mainly along river banks, borders of lakes and in shallow water in general. (Elsevier,1977)

Aggressive growth can block lake or pond access, foul beaches and migrate into once clear waters. Cattails are a common example of an Emergent plant.

As invasive species, emergent plants like Cattails can actually eliminate vital shallow areas used by fish for breeding and prohibit recreational activities.

(2) Floating-leaved weeds--Rooted floating weeds float on the surface and are rooted on the bottom.

(3) Submerged weeds are plants that grow entirely underwater.

(4) Free-floating weeds.

With a sexual reproduction and the features of the shape, these weeds can gain high growth rate. They Obstruct waterways and seriously affect fisheries. (Howard,1997)

2.Why is aquatic weeds control necessary?

Plants are natural and important components of the aquatic environment. Microscopic plants (algae) form the base of the aquatic food chain. Larger algae and plants provide habitat for fish and food organisms, and all plants produce oxygen as they photosynthesize during the daylight hours. However, excessive growths of these plants can have a detrimental effect on a body of water and its inhabitants.

Many shallow, nutrient-rich ponds, lakes, and drainage ditches provide ideal conditions for abundant aquatic weed growth.

Some of the problems caused by aquatic weeds are as follows:

- Interfere with or prohibit recreational activities such as swimming, fishing, and boating.
- Detract from the aesthetic appeal of a body of water.
- Stunt or interfere with a balanced fish population.
- Fish kills due to removal of too much oxygen from the water. Oxygen depletion occurs when plants die and decompose. Photosynthetic production of oxygen ceases, and the bacteria, which break down the plant material, use oxygen in their own respiration. Fish kills in summer are frequently caused by die-offs of algae blooms. Fish kills in winter occur when snow accumulates on ice cover. Light is blocked thus preventing photosynthesis by any living plants or algae. Decomposition of plants that died in the fall causes further oxygen depletion. Fish kills also can be caused by insecticide runoff, ammonia runoff from feedlots, and diseases.
- Produce quiet water areas that are ideal for mosquito breeding.
- Certain algae can give water bad tastes and odors.
- Impede water flow in drainage ditches, irrigation canals, and culverts, causing water to back up.
- Deposition of weeds, sediment, and debris, can bodies of water to fill in.

3.Habitat and resistance

(1) This topic focus on the aquatic weeds that exist in freshwater ecosystem, including rivers, streams, lakes and ponds. (John，1987)

(2) Different kinds of aquatic weeds can exist in the same system at the same time.

(3) disturbance：Drought, Fire and predators

weeds have strong anti-interference ability. Even the old community of weeds are destroyed. The new aquatic weeds can spread quickly and take control of the place.

What’s more important is that the native plants have risk of being damaged under the stress. Thus, scientists should be exceptionally caution when using these disturbances to control the weeds.

4.The factors that control the growth and distribution of aquatic plants:

(1) The depth of water.

The depth of water is related to the height of aquatic plants and the brunch. The process involves two variables: the degree of eutrophication in water and the sun. They jointly control the growth of aquatic plants. (Strand,2001)

(2) Sediments: Some aquatic macrophytes draw the necessary material from the sediments like phosphorus(Carignan,1980). Emergent plants meet the criteria.

(3) Eutrophication: There is a positive feedback between aquatic weeds and eutrophication of water bodies. It can also be considered as synergistic. The death of aquatic weeds exacerbates the eutrophication of water bodies. Eventually leading to the collapse of the resilience of the ecosystem. (Patel,2012)

(4) The aquatic weeds have strong power to disperse to distance by three major vectors: water, wind and animals.

These are factors that cannot be controlled by human beings easily.

(5) Predators: Insects, fishes, ducks and so on. Many species live on the aquatic weeds. It is significant to find the suitable predators.

5.Threat ! -Invasive aquatic weeds

(1) Here are the lists of Possible Invasive species in California:

water hyacinth, hydrilla, purple loosestrife, Uruguayan water-primrose, creeping water-primrose, yellowflag iris, giant salvinia, Brazilian waterweed, anacharis, Eurasian watermilfoil, parrotfeather, giant reed

（California invasive plant council）

(2) Increasing numbers of invasive aquatic weeds

Compared to the work in 1993 that there are 1025 non-native species established in California, at least 33 additional non-native species are established in the state in 1997(John,1997).

(3) The invasive aquatic weeds will break the balance of the original systems and bring more invasive animals, like insects. (Hestir,2008)

(4) It’s efficient way to detect invasions that do occur so the aquatic weeds can be eradicated or contained before they spread. (John,1997)

6.Ways to control the aquatic weeds

(1) Biological control

Fungi: Use fungal pathogens to infect specific aquatic weeds. (Barreto,2000) Eventually scientists are able to successfully extract the concentrated fungal pathogens.

Arthropod: A decrease in the number of parts of the weeds was observed after the release of arthropods. Forno,2000)

Advantage: Reduced use of chemical reagents.

Disadvantage: Complex processes, countless possibilities (perhaps fungal combinations to disease), pre-working hours unpredictable. There are also threats to species invasions (arthropods, fish, etc.)

(2) The use of herbicide to control aquatic weeds have a long history in America. (Klingman,1961) The working principle includes poisoning the roots of weeds and destroying their photosynthesis. (Folmar,1979)

(3) Some new techniques to eradicate the aquatic weeds:

The novel use of a biodegradable jute material to kill the weeds and restore the local ecosystem. (Joseph ,2010)

Compared to the herbicide, the new materials are not so efficient and lack of field verification.

7.scale that these controls operate over

Because it’s difficult to control aquatic weeds. The most widely used method is herbicide, which leaving a threat to the environment. Herbicides have been put into use in the United States for the first time trying to control the water hyacinth.

The other methods are still in the laboratory stage. And they are only applied to use in farmland, waterway and small-scale freshwater ecosystems.

8.New Problems：

The arise of herbicide-resistant weeds worldwide. (Heap,1997)

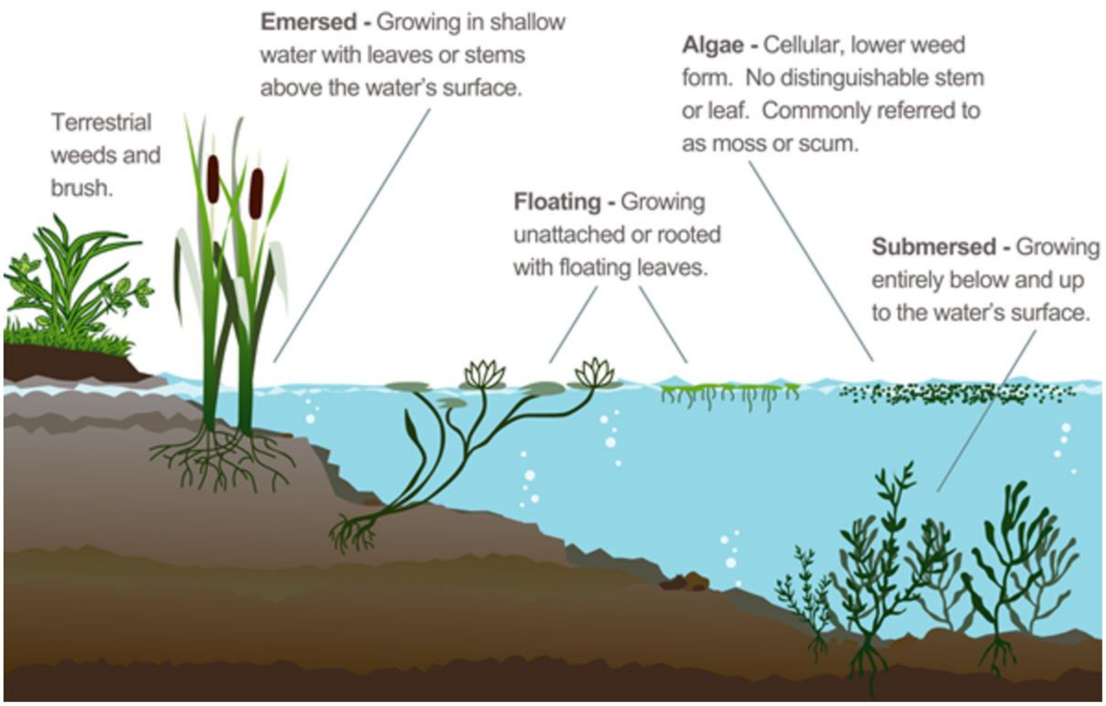
Changes in groundwater resources have led to changes in geography and hydrology. (Faunt,2015) The level of the groundwater is related to the level of the underground water.

The use of herbicides and the accumulation of different kinds of herbicides in the estuary will cause unexpected chain reaction. There is evidence that herbicides have a negative impact on coral ecosystems by inhibit the light(Willis,2007).

9.Limitation:

Scientists have not yet found a safe and effective removal of a variety of weed herbicides. So how do we ensure that the interaction of different herbicides in complex freshwater area will not cause damage to the local ecosystem?

The spread of aquatic weeds is too wide. And the spread of weeds is too fast to track. The next step is to study the feasibility of a rapid follow-up program.



INVAS Biosecurity - Invasive and Aquatic Weed Control Limited

Restoration Plan

Goal:

Weeds are considered to be a category of undesirable, economic pest. (Jonh,1997) During the process of reviewing the literature, we clearly recognize the dangers and complexity of aquatic weeds. Thus, we establish a comprehensive scheme, including pre-restoration, restoration and Long-term effective monitor.

1.The pre-restoration goals should be to survey the sites.

In this project, fresh water mainly refers to ponds, lakes, rivers and streams and so on.

•Water situation:

·The depth of water: Water depth is related to oxygen content, light factor.

·The area of surface of water: It decides that what kind of machine can be used to remove the weeds. It is difficult for people to operate large machines in small ponds.

•The map of runoff:

·A special map will help us to consider the problem from a holistic perspective.

·Keep unpredictable variables within a specific range.

•The history of the invaders:

·To understand the scale of the invasion from the original region. Including the scope of the invasion and the speed of proliferation.

·To provide ways to cut off the spread of aquatic seeds.

2.The restoration goals:

•Determine our target aquatic weeds:

· If the aquatic weeds take over 25% of the surface area, it can be considered to be the weed which can seriously interfere with freshwater recreation and threaten aquatic life. In order to reduce the interference with the local ecology, we have to make the ideal and most effective use of control resources.

•Reduce the size of the population of aquatic weeds:

·It is important that we need to stop aquatic weeds from damaging freshwater resources as soon as possible. In early stage of removal of weeds, eliminating over 70% of aquatic weeds is considered to be successful.

·In large-scale freshwater ecosystems, we use mechanical means to remove aquatic weeds. This work will be carried out at an early stage, and the working hours will be determined by the area. Herbicides are supposed to kill over 80% of the target weeds.

However, for larger infestations on larger water bodies, mechanical control has proven ineffective mainly because limited areas can be harvested each day and target weeds grow rapidly.

·It's important to plant the native aquatic plants. During the first two years of restoration, the cover of native plants need to raise up to 50% of the area.

If we cannot, we must focus on control the growth area of the weed and prevent its spread.

•Replace aquatic weeds with native aquatic plants to ensure establishment of native species.

·Increase amount of native aquatic plants. We have to keep the balance of the freshwater systems.

·The new plants should provide food and habitats for the native species. What's more, they may help improve the water quality.

·The new aquatic plants prevent intrusions.

•Long-term monitoring

·One year of monitoring can only test the results of the initial removal of aquatic weeds. Some seasonal weeds must be monitored in specific season. The cover area of invaders of next spring should be controlled under 20%. The number is supposed to decrease over time.

·Two years of monitoring can control a small number of annual aquatic weeds which breed with seeds.

·Long-term monitoring can prevent the reestablish and propagation of aquatic weeds. It's successful that the same invasive species are not found in the same ecosystem for over 3years. However, more invaders may be seeking the opportunity to occur at the area.

·Manual cutting and repeated application are the most effective ways during long-term monitoring. It may cost a lot money to hire the workers.

Restoration Plan:

1.Identify the aquatic weeds

It is significant to identify the aquatic weeds.

Here is a list of common aquatic weeds in California:

(Aquacide, California invasive plant council, Weed research and information center)

Category	Name of Aquatic weeds	Priority option (Arranged in order)
Submersed weeds	Milfoil; Parrot Feather; Coontail; Elodea; Hydrilla; Bladderwort; Brazilian elodea; Curly-Leaf Pondweed; Clasping-Leaf Pondweed; Horned pondweed; Bushy Pondweed; Leafy Pondweed; Sago Pondweed; Large-Leaf pondweed; Floating-Leaf Pondweed;	Chemical control (Aware of the protection of native species); Biological control (difficult and expensive); Physical control(expensive);
Emersed weeds	Purple Loosestrife; Water Willow; Water Primrose Smartweed; Bulrush; American Lotus; Spatterdock; Cattail; Water Pennywort; Pickerelweed; Water Chestnut; Reed Grass;	Mechanical control (In-depth field trips); Biological control; Chemical control;
Floating weeds	White Water Lily; Water Shield; False Loosestrife; Duckweed;	Chemical control; Biological control; Mechanical control; Physical control
Algae weeds	Filamentous Algae; Chara; Planktonic Algae;	Chemical control; Mechanical control; Physical control;

2.Mechanical control

•Early attempts to combat aquatic weeds centered on such equipment as mechanical harvesters, shredders, dredgers and cutters. The use of mechanical harvesters continues today. People have invented more convenient and more advanced tools.

•It is easier to remove the floating weeds and algae weeds. But workers have to catch up with the growth rate of the weeds.

For emersed weeds and submersed weeds, sometimes people can leave the decomposed plant material in water. The material can reduce dissolved oxygen levels in the water.

(1) Cut the submersed and emersed weeds with an underwater mower, a mechanical weed harvester or other machines.

(2) Cut the ditchbank weeds with tools.

(3) Burn the ditchbank weeds. (Murphy,1989)

(4) Dredging and deepening shallow shoreline areas limits weed growth indirectly by exposing a soil layer that may be nutrient-poor or impervious to plant roots, and by decreasing the amount of sunlight available to plant life.

•Special mechanical control: Mechanical defoliation (Suitable for small water bodies).

3.Biological control:

•There are three different approaches to control the aquatic weeds:

classical (Julien and White 1997): The common method involves the introduction of natural enemies from their native range to control invasive aquatic weeds.

Non-classical (McFadyen 1998): This method involves the mass rearing and periodic releases of resident or naturalized agents to increase their power to eliminate the weeds.

Conservation (Goeden and Andres 1999): This method involves identifying and manipulating factors to increase the amount of potentially native of introduced enemies of the weeds.

The methods that mention above can be flexible in the process of restoration.

Table 2. Notable examples of aquatic weeds managed fully or partially by biological control agents [a]

Weed	Agent(s) most responsible for success	Country(~ies) where most successful [b]
Alternanthera philoxeroides	*Agasicles hygrophila* (beetle)	Australia, USA
Eichhornia crassipes	*Neochetina eichhorniae* and *N. bruchi*(weevils)	Australia, India, Kenya, Sudan, Thailand, Uganda, USA, Zimbabwe
Lythrum salicaria	*Galerucella calmariensis* and *G. pusilla* (beetles)	Canada, USA
Pistia stratiotes	*Neohydronomous affinis* (weevil)	Australia, Zambia, Zimbabwe
Salvinia molesta	*Cyrtobagous salviniae* (weevil)	Australia, Fiji, Ghana, India, Kenya, Namibia, Papua New Guinea, South Africa, Sri Lanka, Zambia
Several submerged weeds	*Ctenopharyngodon idella* (fish, carp)	USA, several countries in Europe, the Middle East, and Asia

[a] See Julien and Griffiths, 1998, for details of insect agents released, field performance of agents, country of origin of agents, key references, and other information.
[b] "Success" represents a general recognition that the weed is no longer a major problem.

•Once we decided the agents, we have to prepare for the next step. We have to make sure that there are enough materials to begin a colony. Establishment of agents one of the key steps during the process.

Here are several types of biological control agents:

Figure from "Are we on top of aquatic weeds? Weed problems, control options, and challenges"

(1) Arthropods:

Biological control of the floating macrophytes water hyacinth, water lettuce (Pistia stratiotes L.), salvinia (Salvinia molesta D.S. Mitch.), and red water fern (Azolla filiculoides Lamarck) by insects has been achieved in most countries where it has been attempted (Julien and Griffiths 1998, Hill 1999).

Scientists are still working on the topic:

C. japonicus can control Buddleja Davidii. (Kriticos and Watt,2007)……

(2) Fish:

Consumption of aquatic weeds by fish depends on a variety of factors (Pine and Anderson 1991, Sutton and Van- diver 1998). We need to consider the impact of water quality on the growth of fish, and we have to consider whether the fish will change the fresh water quality.

One example is the grass carp. Grass carp tend to feed in relatively shallow areas and near the surface of a water body, preferring to graze on the soft tips of tender submersed aquatic plants. (Cuda,2008)

The difficulty is that is hard to control the diet of the fish and the activity area of the fish.

People should considerate the consequence of introducing the fishes to control the aquatic weeds.

(3) Pathogens

Actually, using pathogens is the ideal way to remove the aquatic weeds.

However, only one pathogen has been deployed as a classical biological control agent of an aquatic weed in the world.

Cercospora piaropi Tharp (Tessman et al. 2000) against water hyacinth

Many pathogens are still in the laboratory stage.

What’s more, the use of pathogens is easy to cause controversy in the human society.

•Then we need long-term monitoring.

4.Physical control

People use physical means to change the environment into the state that is not conducive to the growth of aquatic weeds. For example, people can prevent weeds from getting nutrient or performing photosynthesis.

(1) Burning exposed vegetation and water-level fluctuation. (Charudattan,2001)

(2) A common method is the use of water level manipulation. Lowering the water level of a pond can be an easy way to control nuisance aquatic weeds. For example, overwinter drawdown is especially effective against cattails. And this is mainly to help restore a stunted fish population.

(3) A less-common technique is the use of dyes, which cause the water to become opaque and limit sunlight to the submerged plants. Water dyes are not effective on floating or emergent plants and must be replenished as needed.

There are many physical methods that can be used to control weeds, such as sand-gravel mixture, polyethylene, polypropylene, synthetic rubber, burlap, fiberglass screens, woven polyester, and nylon film. But they have a lot of limitations so that they cannot be used widely.

5.Chemical control

•It is one of the most mature and the most widely used method.

About a dozen of the more-than-300 synthetic herbicides on the market in the United States are registered for use in water.

Most herbicides are short-lived (10 days or less), but others are persistent (30-90 day withdrawal from use).

(1) Analyze the problems:

As we mentioned above, we identify the problem species and other species present. And we have to think about the density, stand, or scope of problem and stage of weed growth.

Hydrology is an important factor to the program.

(2) Select the herbicide

We have to considerate the safety, effectiveness and selectivity of the herbicide.

The choice of herbicide is also related to cost and law in the specific project.

For example, algae (filamentous and single cell) problems are typically treated with herbicides containing copper. Submersed plants (coontail, elodea, and pondweed) are often treated with Fluridone and Diquat. Floating plants (duckweed) can be treated with Fluridone or Diquat. Emergent plants (cattail and bullrushes) are effectively treated with Glyphosate (Rodeo, Pondmaster).

On the basis of the previous investigation, we must handle the residual chemical substances.

•There are also many problems about the use of herbicides. Chemical may substances penetrate into the soil. (Simsiman,1974) Chemical substances spread in the water and are enriched in areas such as estuaries. Frequent use of herbicides can cause the resistance of aquatic weed.

Integration of biocontrol with other applicable techniques should be achieved in a manner that maximizes the effectiveness and benefits of biocontrol.

When using herbicides, treat one-half of the water body at a time to allow fish freedom to move to untreated, oxygen-rich areas. The best season to use herbicides is early spring. Because the cool water will slow the decay of herbicides. And aquatic weeds grow actively in this season.

6. Over 100 invasive aquatic weeds are recorded in California, and the number is still raising.

It’s important to use historical reference sites to look after native aquatic plants. And based on the latest information of hydrogy, scientist are able to draw a map of restoration.

During the restoration, scientist design different patches to transplant different aquatic plants in spring. At the same time, using machines or tools to eliminate the aquatic weeds is an efficient way to provide enough resources for native species to grow. Because other ways (such as biological control) may do harm to the growth of these native plants. The early goal is to make sure that over 60% of the native plants can grow.

Monitor:

Monitoring is the systematic collection, recording and analysis of observations over time. It’s harder to control the weeds. Because even after apparently successful weed control, reinvasion by weeds from buried seeds or other underground organs may occur before any native plants dominant the area.

•Photography: To achieve a large area in the field of view, the cameras should have a wide-angle lens and take photos from a vertical position. (B Auld,2009) Considering the growth rate of the weeds, the interval time of taking photos should be set between 1 day and half a month.

•Using the photos and GPS, we can draw an overall map. This should show the relationship of different patches. The maps mainly indicate the changes in vegetation cover over time.

Weed maps are produced from data collected at discrete intervals on a regular grid. Data are analyzed with the aid of computer software to generate a map of the weed’s distribution and levels of infestation. Weed maps are often used to target weed control measures to high priority (most weedy) areas, or to track incidence of invasive exotic weeds over a wider region.

•Measuring plant populations

It is of great significance to estimate the abundance and distribution of different plant species.

During the wetland restoration, native plants like cattail are designed to transplant in specific areas in order to increase the amount of wetland vegetation. However, improper handling and monitoring may lead to the loss of control. Some aquatic plants may become the weeds which affect the local ecology and economy. The aggressive growth of these plants must be under monitored. The measurements should be taken at random points on each visit or at points that are revisited. Both native aquatic plants and invaders should be recorded.

At the same time, scientists may decide some deliberate position for sampling, especially at the edge of different habitats and at the edge of a weed infestation.

To be more precise, here are some specific data that can be measured. For example, the cover of plants and the number of the plants.

·Regular surveys are conducted to catalog aquatic plants and rank them according to their abundance in spring and fall.

·Regular sampling of fresh water, people detect weed propagation or herbicide residues. (This is mainly used to detect the density of algae weeds, which is float on the water and rely on the eutrophication. Besides, the data of quality of water can be used to verify the side effect of different herbicide.) Adequate funds and workers are required!

•Minimum Weed-free Period

After transplanting the native plants, there may exist some aquatic weeds which we have to monitor. Our goal is to eliminate and prevent the invaders, so we have to pay attention to the minimum weed-free period.

In practice, the minimum weed-free period for a given native plant varies widely with the weed species composition, weed density, soil conditions, weather, climate, and the vigor of the native plant itself.

Aquatic weeds, especially emergent plants, that form a closed canopy effectively hinder the growth of most weeds emerging after the plant's minimum weed-free period. Crop shading and competition can also reduce the number of seeds these late-emerging weeds set by 90–99% compared to the same weed species growing in full sun.

•Timing

The use of machinery and chemicals is controlled by human beings.

When using the biological ways to control the aquatic weeds, the key activity is monitoring the agents. The screening, introduction, establishment, and spread of agents. For the emerged aquatic weeds, several insects and fish can be used as agents. After the short time of releasing the agents, usually during the first year, the population of the agent should be recorded every month. If the number of populations reaches 60% of the maximum capacity of the environment, while the growth rate does not decline, scientists have to eliminate the agents in weeks. Or if the number of populations does not reach 50% of the target in two years, scientists still have to reduce the amount of the agents gradually. The time of eliminating the agents depend on the specific species of the agents. What's more important is to assess agent densities and their impacts on target plants and aquatic plant community response, for both degree of control and for non-target impacts, will increase the likelihood of accurate assessment. This can be done with the help of photo, map and visit.

After the initial weed control treatment, a visit (usually two to six months) is desirable to specifically check on the efficacy of the weed control method. Standing dead plants should be recorded as such or as litter.

Subsequent visit should be annual if possible and may be made to coincide with flowering times of plants. For some seasonal annual weeds, scientists have to visit at specific seasons. (Syrett et al. 2000, Blossey 2004).

No matter what method is used, the longer the monitoring period (in years), the more likely the changes and trends that are observed, are meaningful.

Research questions:

1. The limitations of agents. What would happen to the agents when they are out of food?

Monitoring the density of agents and the movement of agents. These species will adapt to the local ecosystems.

2. The negative effects of herbicides.

The negative effects of cross-use of various herbicides. By sampling the species, we can monitor the residues of chemical substances in each species. Gene sequencing of special aquatic weeds is a good way to study the mechanism of herbicides resistance.

3. How to stop seed propagation?

Although we have a lot of advanced technology, such as remote sensing, we still do not have efficient way to monitor the transport of seeds. Not to mention the aquatic weeds that are breeding by rhizomes.

4. Reduce expenses.

It cost a lot to control aquatic weeds.

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Alkali bulrush (Bolboschoenus maritimus)

Alexander Blumenfeld

Part I: Species Background and Justification

Alkali bulrush (*Bolboschoenus maritimus*) is a perennial grass that is native to California. It is a pioneering species, meaning that during primary succession it is able to establish itself well before having to compete with climax species. During this time, it is able to provide desirable services for a site in the process of restoration, such as erosion control from wind (Natural Resources Conservation Service). Its probability of survival in the Central Valley of California is high due to its ability to grow in a wide range of soil textures and acidity, brackish and fresh water, withstand temperatures ranging from 26 to 109 degrees Fahrenheit, and endure periods of flooding and drought (Calflora). Alkali bulrush is heavily rhizomatous. This enables the plant to not only regenerate from seeds, but also from rhizomes. Regeneration from rhizomes makes Alkali bulrush resistant to fires. Although the plant burns, the rhizomes survive and begin sprouting new plants within one week after a burn. Being a rhizomatous plant, it is also able to support the growth of beneficial bacteria that will aid in wastewater treatment. In California, Alkali bulrush populations are not in decline and are found distributed widely along the coastline and inland. While it is susceptible to being outcompeted by climax species in the long-term, Alkali bulrush is an optimal species for an establishing wetland site in the Central Valley due to its high tolerance to local conditions and services provided in erosion control and wastewater treatment (Natural Resources Conservation Service).

Literature Review

Growth characteristics:

- Alkali bulrush is a rhizomatous perennial (Natural Resources Conservation Service).
- Can grow to be 5 feet tall and form dense stands, having several leaves less than a half inch in width growing along the lower two-thirds of the plant. Sessile flowers grow in a dense cluster from tip of the stem (Natural Resources Conservation Service).
- Bloom period is in August and September (Calflora).
- Fruits brown seeds, three-quarters of an inch to an inch and a half long (Natural Resources Conservation Service).

Reproduction:

- Alkali bulrush is capable of regenerating from tuber-forming rhizomes (Forest Service).
- Seeds may be dormant in soils for long periods until conditions become moister, and can remain viable for many years (Forest Service).
- In a restoration project at Lake Mead Recreation Area, Alkali bulrush was able to establish and spread quickly, with an 88 percent survival rate giving it high value as an option for an early successional restoration site (Forest Service).
- It sprouts in early spring, and will resprout in fall if soils become saturated again (Forest Service).

- Production of alkali bulrush will increase in spring, summer, or early fall with water level fluctuations of 6 to 8 inches (Forest Service).
- Spreading and reproduction is noted to be best when the water table is 4 inches from the surface (Natural Resources Conservation Service).
- After a fire, it is able to begin sprouting as quickly as one week later from rhizomes (Forest Service).
- In a greenhouse, seeds will grow successfully if conditions are kept between 90-100 degrees Fahrenheit and soil is kept moist. It is important to maintain moisture in soil until plants are transplanted to new site (Natural Resources Conservation Service).
- One option for bringing Alkali bulrush to a site is transplanting wild plants from another site. This method works well, as long as the plants are not collected from areas with undesirable plants that could relocate to the new site (Natural Resources Conservation Service).

Range:

- Alkali bulrush is native to California and distributed widely throughout, largely along the coast (Calflora).
- In the US, it is found throughout states west of the Mississippi River, and along the East Coast (Natural Resources Conservation Service) (Forest Service).

Habitat/Requirements:

- Alkali bulrush is an obligate wetland species found in marshes, transient wet spots, pond margins, and backwater areas. It can be found in freshwater and brackish sites (Forest Service) (Natural Resources Conservation Service).
- It will grow on a variety of differing soil types ranging from fine clay to silt loam to sand (Natural Resources Conservation Service).
- On average, Alkali bulrush grows best in water depths ranging between -6 and +5 inches (Forest Service).
- It grows best in alkaline or saline sites. Optimal salinity levels average between 3,000 to 7,000 ppm. Salinity levels exceeded 7,000 ppm will reduce reproductive success (Natural Resources Conservation Service) (Forest Service).
- Other plants associated in a plant community with Alkali bulrush include common reed and cattail (Forest Service).

Tolerances:

- Alkali bulrush is found at low to mid elevations ranging from -215 to 4265 feet (Calflora).
- Annually it permits 3 to 43 inches of precipitation, and a wet season of 0 to 8 months (Calflora).
- It is capable of managing a winter low of 26 degrees Fahrenheit to a summer high of 109 degrees (Calflora).
- Soil suitability ranges from a very strongly acid pH (4.8) to a strongly alkaline pH (8.6) (Calflora).
- For short periods of time it is tolerant of up to 3 feet of standing water, as well as periods of drought and flooding (Natural Resources Conservation Service).
- Able to survive fires by sprouting from rhizomes (Forest Service).

Interactions:

- Alkali bulrush is a pioneering species, which means in lieu of disturbance it can be outcompeted by climax species (Forest Service).
- In frequent fire, Alkali bulrush can become a dominant species due to its ability to regenerate from rhizomes after a fire (Forest Service).
- Environmental concerns due to insects or diseases are not a problem for Alkali bulrush (Natural Resources Conservation Service).
- Palatability of Alkali bulrush is low, and the plant is not notably used for food except by beavers and muskrats (Natural Resources Conservation Service).
- It does provide nesting cover for waterfowl species, and muskrats and beavers will make use of shoots for building materials (Natural Resources Conservation Service).

Uses:

- Alkali brush is an excellent species for a restoration project early in succession. It is able to provide services such as wind and wave erosion for soil (Natural Resources Conservation Service).
- Most notably beneficial in a site that receives wastewater, due to its ability to produce rhizomes which support the growth of beneficial bacteria that will aid in wastewater treatment (Natural Resources Conservation Service).

Part II: Restoration Goals, Management, and Monitoring Plan

Restoration Goals

Alkali bulrush (*Bolboschoenus maritimus*) is a perennial wetland grass endemic to California. It is a significant species to a wetland in primary succession. The main restoration goals for Alkali bulrush include:

- Plant Alkali bulrush that will be self-sustaining, and act as a pioneering species to help establish an early wetland (Natural Resources Conservation Service).
- Manage and monitor Alkali bulrush and planting to ensure the grass shows a high rate of survival
- Ensure survival of Alkali bulrush early on to reduce the risk of invasive species taking over in the area (Sweetman et al).
- Capitalize on its ability to provide services such as wind erosion for newly exposed soil at a site (Natural Resources Conservation Service)
- Make use of its ability to produce rhizomes that grow beneficial bacteria that will aid in wastewater treatment (Natural Resources Conservation Service)
- Establish populations of Alkali bulrush to provide habitat for waterfowl and other species, promoting greater biodiversity at the site (Natural Resources Conservation Service).

These goals are feasible if Alkali bulrush is successful in populating early on in the wetland's succession. Given that the species is a pioneering species, and could be outcompeted by climax species over time, it is most important to monitor the site in its early stages to ensure that Alkali bulrush is surviving and productive in providing the necessary ecosystem services while it can persist.

Restoration Plan

- Planting
    - Seed collection
        - Collect seeds from populations near restoration site, from varying areas to increase likelihood of genetic diversity. Ideally, local seeds that are genetically diverse will have increased resilience to common environmental challenges faced in the area. Using seeds with low genetic diversity could increase potential for inbreeding depression, decrease plant production, and decrease resilience of species (Sweetman et al).
    - Propagation
        - Seeds can be germinated in a greenhouse. In soil, press seed in lightly so that it is in good contact with the soil but is not covered. Conditions ideal for germination are moist soil and heat (89.6ºF to 100.4ºF). Seeds should germinate in roughly one week. To ensure a high rate of survival, soil should be kept moist until plants are transplanted (USDA).
        - Collecting wild plants and transplanting them directly into the site is an additional method to propagate alkali bulrush. In this case, it is critical to not acquire transplants from weedy areas, to prevent undesired species from establishing at the restoration site. In one study, wild collected transplants had a higher rate of survival than greenhouse propagated transplants (Natural Resources Conservation Service).
    - Establishment
        - The most effective way to establish a new stand of Alkali bulrush is through planting plugs. Plugs are to be spaced 12” to 18” apart, and will fill in by the first growing season. Saturated soil in the initial phase of establishment will

result in highest rate of survival. Saturated soil and fluctuating water levels are imperative to successful establishment of species (Natural Resources Conservation Service).

- Potential problems
  - It is possible that an effort to propagate Alkali bulrush at a new site will be unsuccessful, either by a low survival rate or no survival. In this circumstance, it is important to first address any environmental conditions that could be contributing to the species death, such as prolonged periods of drought or inundation (Natural Resources Conservation Service). In this case, current conditions may not be appropriate for propagating the species and it is best to wait until conditions are better. Additionally, a poor survival rate or no survival could suggest inferior seeds, or ones that are not suited for the local conditions. In this case, acquire seeds from a different source in hopes of the seeds being more resilient.
- Risks associated with plan
  - The only feasible risk associated with the plan is human disturbance of pre-existing habitats when planting the species. Otherwise, the species is native to the area and will either survive or not survive at the site, but in any case will not do harm.

Monitoring Plan

- Early and frequent monitoring will be necessary to assess how Alkali bulrush establishes. Survivorship, percent cover, and method of propagation can be monitored to measure the species success. Alkali bulrush is a perennial grass, which means that monitoring can be done any time. In one study, application of Alkali bulrush to a site showed an 88% survival rate. After one month, the cover rates nearly doubled. At a nearby site, cover rates more than doubled. Monthly monitoring is a timetable that can be used to monitor the success of the species spread at the new site (Forest Service). If propagation is entirely unsuccessful, a cost/benefit analysis will be performed, and the result will determine whether or not the species is replanted at the site or avoided.

Research Question

- In an effort to improve this plan, a better understanding of temporal and spatial scale is needed.

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Phragmites australis americanus

Tobias Mueller

Part I

Phragmites australis americanus

Phragmites australis, also known as the common reed, is a cosmopolitan warm season perennial plant with a range that now covers every continent except Antarctica (Tilley, 2012). It is found in at least 75% of United States wetlands (USGS, 2016).

Recently the species has been split into several distinct subspecies. *Phragmites australis australis*, a non native plant in the united states, it is a vigorous competitor, and is problematic as an invasive in many parts to the US. It has been known to take over aquatic systems, outcompeting native plants and leading to decrease in diversity. It is a serious problem and is currently proliferating in many wetland habitats.

The second subspecies, *Phragmites australis americanus*, is native to the United states and is not nearly as competitive as its invasive cousin. It is common in many wetland ecosystems and provides essential habitat for many organisms (USGS, 2016). It does not have a tendency to form monocultures like those found in *Phragmites australis australis*. A third subspecies is also present in the United States but its presence is confined to the gulf states extending down to Central America and is not present in California. This report will focus on the California native *Phragmites australis americanus.*

Ecology

Plant morphology

- Can grow to a height of 2-6 meters (Magee, 2005)
- Mainly propagated through underground rhizomes and aboveground runners. Runners can expand over 10 feet in a season if conditions are right. (Tilley, 2012)
- Prefers to grow in wetland-upland interface (USGS, 2016).

- Rhizome depth depends on soil conditions but can extend over 2 meters to reach the water table (USGS, 2016).

Life history

- Growth starts in late winter/early spring and continues until first frost (USGS, 2016)
- Average lifetime of a single rhizome is 4.5 years but can live up to 6 years (Haslam, 1972)
- Maturity is reached 2-4 years after germination from seed, clonal reproduction can occur at any time. (Haslam, 1972)
- Seed production is possible although highly variable. (McKee, 1996)
- Due to clonal reproduction, single strands can survive for centuries (USGS, 2016)

Reproduction

- Clonal reproduction is achieved through above ground runner and below ground rhizomes (Tilley, 2012).
- Expansion within a site is through clonal reproduction, dispersal to new sites through sexual reproduction (Tilley, 2012).
- Can produce up to 2000 seeds per year (Avers et al. 2014)
- seed germination in field is rare (McKee, 1996)

Plant interactions

- No pests in the United States are currently known for phragmites (Tewksbury, et al., 2002)
- Forms dense stands though will not form monocultures or outcompete plants (USGS, 2016)
- Known to stabilize shoreline soil through rhizome production and reduces erosion (USGS, 2016)
- Improves water quality through filtration and nutrient removal (USGS, 2016)
- Provides ideal habitat for many animals and good nesting sites. Used by muskrats, insects and many birds (such as yellowthroat warbler, marsh wren, salt marsh sparrow, red-winged blackbird, and many wading birds) for food and shelter aswell foraging areas (USGS, 2016)

Tolerance

- Can tolerate pH from 3.7-8.7 (USGS, 2016)
- Grows in fine to coarse soil types. Prefers firm mineral clays but will do fine in most soil types (Magee, 2005)
- Grows best when water level fluctuates from 6 inches below to 6 inches above soil level. (Magee, 2005)
- Can withstand frequent and prolonged flooding. Death will occur however after being under 1 meter of water for over 3 years (USGS, 2016)
- Can withstand high salinity. Some ecotypes grow in salty tidal marshes (Hellings, 1992)
- Susceptible to severe frost, could lead to death (USGS, 2016)
- Can inhabit tidal and nontidal wetlands, riparian areas, springs, and marshes
- Can grow from sea level up to 7000 ft (Tilley, 2012)

Management

- Can resist top burning. Will resprout from rhizomes. Fire followed by long flooding could kill plants due to lack of oxygen to roots (USGS, 2016)
- No biocontrol agent currently known. There are several potential species in europe however but none have been approved or seriously tested. (Tewksbury, et al., 2002)
- Glyphosate or imazapyr treatment is the recommended method to control populations. Apply in late summer/early fall. Treatment works better on young plants. Yearly repeat of application necessary to kill all plants present. (Avers, 2014)
- Mechanical treatments (tilling) will decrease growth but will not kill plants (Avers, 2014)
- Mechanical treatments or burning in the spring / summer can stimulate growth (Avers, 2014)
- Young plants are soft, nutritious, and good fodder for grazing animals. Established mature plants are tough and not eaten by grazing animals. (Tilley, 2012)
- Over grazing year round could kills plants. (Magee, 2005)
- During dormant winter season, dry plants can pose potential fire hazard (USGS, 2016)

Subspecies australis

The subspecies australis is a voracious invasive. It is extremely adapted to almost all wetland habitats and forms dense monocultures that will readily outcompete other wetland plants (USGS, 2016). It has been shown to reduce local biodiversity of both plant and arthropod communities and furthers effects of biodiversity loss are assumed to propagate through the ecosystem (Silliman, 2004). This is not a problem with the native subspecies which often forms heterogeneous stands.

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Part II

Overview

Phragmites australis is a charismatic and important reed found in many California wetland ecosystems and native populations are estimated to be in over 75% of California wetlands (Calflora, 2017; USGS, 2016). However, two subspecies are currently found in central California, *Phragmites australis australis* and *Phragmites australis americanus. Phragmites australis australis* is a devastating invasive and should be removed from any site of restoration if found to be present. Prolonged surveying may be required to ensure its continued absence and prevent its reintroduction. *Phragmites australis americanus,* on the other hand, is a beneficial reed, native throughout the United States, and provides ideal habitat for many animals as well as preventing erosion by stabilizing the soil of wetland banks (Tilley, 2012). The native phragmites should be reintroduced to wetland sites to recreate the natural wetland ecosystem, provide soil stabilization, and establish prime habitat as well as food for many animals. Once established, a site cover of 0-10% is considered low for a native *Phragmites* stand and 50% cover is considered medium site coverage (Hunt et al, 2017).

The primary goals for Phragmites restoration are as follows:

A. Establish a population of *Phragmites australis americanus* that covers >20% of the site within 5 years with stands consisting of a minimum of 20 shoots per square meter. This is indicative of good establishment of a stable population at the site.
B. Ensure the absence, or complete removal if required, of *Phragmites australis australis.*

Restoration Plan

A. Surveying of site

a. Survey of hydrology

The hydrology of the site should be observed over a multiyear period to fully understand how various areas, in and around the wetland, are inundated and dried throughout the year. The water table of the site should be estimated in years of extreme rainfall as well as drought to understand where the ideal area for restorative Phragmites planting is. Data should also be collected on year round water pH, salinity and temperature as well as air temperature to asses if Phragmites will grow on the site and where it will grow best. Water should have a pH between 3.7-8.7. The ideal site for Phragmites will have the water table fluctuating between 6 inches above/below the soil level where it is planted (Magee, 2005). It is essential to ensure that the water table is not over two meter below the site of planting and that the planting site is never inundated with water for a period of over 3 years straight (Magee, 2005) (Tilley, 2012). Additionally the water should never freeze throughout the year (USGS, 2016).

b. Survey for existing Phragmites australis

A survey should be done of the site for any existing Phragmites stands present and all stands found should be identified to subspecies. A detailed list of characteristics for determining the subspecies present on site is included at the end of this document.

i. If it is determined that Phragmites stands are present on the site, they should be removed immediately [methods are addressed in section B below].
ii. If it is found that *Phragmites australis americanus* is present on the site, measurements should be taken on the percent cover of the plant across the site as well as the estimated stem density to see if further restoration is needed as per project goals [see goals above].

B. Removal of Phragmites australis australis

Full removal of *Phragmites australis australis* can take several years of repeat chemical application. Glyphosate or imazapyr should be applied to cut stumps and as a foliar spray in the late summer to early fall and should be reapplied continuously on an annual basis until all plants have been removed from the system (USGS, 2016; Saltonstall, 2005). No rhizomes of *Phragmites australis australis* should be left present on the site as they can quickly resprout and overtake the whole wetland forming monocultures of over 200 stems per square meter and reducing site diversity (Tilley, 2012).

C. Planting of Phragmites australis americanus

a. Acquiring Plants

Rhizomes of *Phragmites australis americanu*s should be ordered from a nearby nursery. The closer the growth conditions are at the nursery to the site of restoration the better. While the two sites do not have to be identical, care should be taken to never take a saltwater plant and transplant it to a freshwater system and vice-versa, this will lead to poor viability and possibly the death of the plants (Tilley, 2012). Rhizomes should be taken from as many clonal lineages as possible to ensure genetic diversity on site and planted in a heterogenous pattern to promote diversity.

b. Planting on the site

Rhizome sections of 12-18 inches should be planted in the early spring (after the last frost) at the wetland-upland interface. Rhizomes cutting should be planted in weed free soil after tilling to a depth of 4-6 inches. Rhizomes should be planted 4-6 inches deep with a spacing of 1 foot between plantings (Tilley, 2012). For Shoreline erosion control, a series of three parallel rows of rhizomes should be planted with a spacing of 40 inches between parallel rows (Walker, 1997).

These goals are feasible but will require short term monitoring (~3 years) to fully understand the hydrology of the site prior to the planting of Phragmites. This will help to ensure maximum establishment of Phragmites in the shortest time. Phragmites is however able to withstand extreme changes in hydrology and establishment should not be a problem in any wetland system. If *Phragmites australis australis* is present complete removal of the plant however could be difficult but is essential for restoration to proceed.

Post restoration management

A. Ensure proper establishment of phragmites stands

a. For 5 years following planting, Phragmites stands should be checked in the spring to assess viability and establishment. Stands may seem sparse for the first few years after planting but should establish into dense stands after several years (Swearingen and Saltonstall, 2010). Within 5 years, 25% of the wetland-upland interface should be inhabited by Phragmites with an average stem density of over 20 stems per square meter. If at any point more than 50% of the previous year's growth dies, additional rhizomes should be planted to fill the spot of the dead plants (Magee, 2005). If the stands are smaller than desired, mechanical thinning should be performed in the spring to stimulate new growth (USGS, 2012).

b. For 3 years after introduction, the stands should be checked after winters to ensure that any major frost events have not killed the plants present on site. After 3 years, older established rhizomes will be frost resistant and further monitoring for frost damage should not be necessary.

c. If the site is grazed, ensure that grazing does not occur year round as non-stop grazing can lead to poor performance or even death of Phragmites stands (USGS, 2016).

B. Monitor for Phragmites australis australis

a. If there was a presence of *Phragmites australis australis*, yearly monitoring for the next 3 years after treatment is required to ensure that all plants have been killed and will not resprout. If new growth of *Phragmites australis australis* is found, chemical treatment should be restarted.

Characteristics useful for differentiating between native and introduced *Phragmites australis*.

Table reprinted from: Swearingen, J. and K. Saltonstall (2010) Phragmites Field Guide: Distinguishing Native and Exotic Forms of Common Reed (Phragmites australis) in the United States. Plant Conservation Alliance, Weeds Gone Wild.

Character	Native	Introduced
***Ligule length**	>1.0 mm	<1.0 mm
***Lower glume length**	3.0 – 6.5 mm Most >4.0 mm	2.5 – 5.0 mm Most <4.0 mm
***Upper glume length**	5.5 – 11.0 mm Most >6.0 mm	4.5 – 7.5 mm Most <6.0 mm
***Adherence of dead leaf sheaths**	Loose, drop off easily	Tight, remain on dead stems
***Growth form (stem density)**	Typically in mixed communities, stem density may be low to high, dead stems less likely to persist to the next growing season.	Often grows as a monoculture, stem density is high, dead stems often persist to the next growing season.
Culm texture	Smooth, shiny	Dull or flat color, slightly ridged
Culm color	May be dark red at nodes and internodes, where exposed to UV. May be green as well.	Typically green, occasionally see some red color at the lower nodes
Spots on culms	May be present	Not present, mildew may be present
Leaf color	Lighter, yellow green to dark green	Typically darker green, but may be lighter in saline areas

*Indicates most diagnostic features.

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<u>California bulrush (*Schoenoplectus/Scirpus californicus)*</u>

Zheng Chen

<u>Background and Justification</u>

California bulrush (*Schoenoplectus californicus* (C.A. Mey.) Palla), is a common native perennial herbaceous plant in coastal fresh water wetlands (USDA Plant fact sheet). It can quickly form dense colonies via rhizome reproduction (Thullen et al., 2002 & USDA datasheet). It provides habitat and food for wetland animals. California bulrush could be utilized in multiple ways, including erosion controls, wetlands restoration, and ethnobotanical purposes (USDA Plant fact sheet). Wetland restoration or construction is the most common reason for people's interest in this plant, especially when it comes to wastewater treatment. It has been widely used as tool for nitrogen removal in wastewater and improving water quality. However, the dense wetland is problematic at some aspects, reduce habitat diversity, promoting mosquito population, lowering oxygen level in water, etc. (Thullen et al., 2002). As a result, it requires proper management while using it in restoration project. In addition, there is also several details that is worth noticing while establishing the community in newly constructed wetland.

<u>Literature Review</u>:

Growth characteristics:

1. Triangular or subterete is the most distinguishing feature of California bulrush. It promises a higher survival rate of under physical disturbance like wind and wave. The stem is hollow for oxygen conductance from leaves to root. (Sloey et al., 2015)
2. It has a fairly quicker expansion rate compared to plants like *S. acutus* (common tule) and higher survival rate as well. (Sloey et al., 2015)
3. California bulrush have clonal growth with large rootstock and rhizomes. (USDA Plant Guide)
4. California bulrush is an evergreen sedge. It grows from 6-12 feet tall with brown spikelet flowers. It flowers at spring time. (CNPS)

Reproduction

1. California can reproduce both asexually and sexually. Reproduction from seed is not as successful as vegetative reproduction. Planting rootstock or rhizome pieces are recommended. (USDA)

2. In order to establish strong individual plant, 10-15cm long rhizomes with a couple of live stems are recommended. (Mallison & Thompson, 2010)
3. Adult transplant has been found to have a higher survival rate than rhizome transplants. (Sloey et al., 2015)
4. Thick non-compacted soil with short flooding duration is more ideal for expansion. (Sloey et al., 2015)

Range

1. Main habitat types are shallow freshwater, brackish marsh on the edge of lakes or ponds, estuaries, large springs and seeps, and in drainage ditches. (CNPS)
2. It can survive at elevation from – 13 to 4858 feet. In California, it mainly distributed along the coast and some areas around bay area and Sacramento area.

Habitat/Requirements

1. During the summer time, soil must be at least moist. The annual precipitation range from 3.4 to 47.1 inches. (CNPS and Mallison & Thompson, 2010)
2. It can live in temperatures from 41 degreed F to 88.7 degrees F and it requires sun for proper growth. (CNPS)
3. It can coexist with other marsh plats like Spikerush, Rush, Arrowhead, Willow, Cattail etc.. (CNPS)
4. Long flooding time lead to low survival rate if there is no stem is above water level while transplanting rhizomes. Also, flooding time limits the successful germination. (Sloey et al., 2015)
5. There should be no sulfate reduction in soil because product of sulfate reduction to considered to be harmful to *Schoenoplectus* spp.. (Sloey et al., 2015)

Tolerances

1. California bulrush can tolerate either saturated or inundated soil. (CNPS)
2. The pH range for California bulrush is from 5 to 9. (CNPS)
3. The lowest temperature it can tolerate is 20 degrees F. (CNPS)
4. It can tolerate flooding as long as there is vegetative part above water level. (Sloey et al., 2015)
5. It can tolerate high wind and wave stress due to its hollow triangular stems. (Sloey et al., 2015)

Interactions

1. The seeds of California bulrush are one important food source to ducks, marshbirds, and shorebirds. (USDA Plant guide)
2. The shoots and roots are food to Canada geese and white-fronted geese. (USDA Plant guide)
3. The stems provide habitat for endangered bird species, California black rail, and other bird species like blackbird and marsh wren. (Flores and Eddleman, 1995)
4. Nutria is problematic for establishment. It digs out plants and eat its root. (USDA Plant fact sheet).
5. Dense California bulrush community creates ideal habitat for mosquitos and reduces habitat diversity including sites for mosquito predators. (Thullen et al., 2002)
6. California bulrush is capable of removing excessive nitrogen in the waterbody, especially ammonium. (Thullen et al., 2002)

Management

1. Avoiding overtopping California bulrush is necessary for initial stage of establishment, especially when rhizomes with stems are planted. (Sloey et al., 2015)
2. Dense California bulrush communities increases the population of mosquitos. To solve the issue, open water is necessary. Hummock configuration can be one measure to control the density but still maintain the system's ability to remove excessive N in the water. (Thullen et al., 2002)
3. Another measure is to plant California bulrush in band, and each band should be no longer than 10M apart but can be 1.5m or 5m apart based on study. (Walton et al., 2012)
4. Mechanical removal, burning, thinning or rhizome thinning can also be employed as measures to control the density of California bulrush. (Thlluen et al., 2002)
5. For herbicide treatment, imazamox and penoxsulam are the ideal candidates for managing water weeds. Also, try not to use them at high dosage since it can cause dry weight loss in California bulrush. (Mudge et al., 2014)
6. To deal with nutria problem, wired cages can be used to keep out the nutria from getting to the root system of the plant and ensure the establishment. (USDA Plant fact sheet)

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Goals:

California bulrush (*Schoenoplectus californicus* (C.A. Mey.) Palla), is a dominant native aquatic plant in California wetlands. As one of the objectives of not only for Pond C project, but also for any projects which aim to restore native species in a wetland, having a coverage of the native plant as large as possible.

However, there are studies pointed out that a dense California bulrush community could lead to a high population of mosquitos (Thullen et al., 2002, Jannino and Walton 2004, and Wilson et al., 2012). Pond C is close to a residential complex and a high school, a dense population of mosquito is a potential threat to local health problem since mosquito is a vector for many disease; especially pond C was designed to be an education site which bring more teenagers and children to the site. So, having a measure on controlling mosquito population is necessary.

Open water design was one way to reduce mosquito population via creating habitat for mosquito predators. Unfortunately, there is no specific data on how much coverage is the most ideal. There is a study mention that even with 50% of open area, the reduction in mosquito population was not significant (Jannino and Walton 2004). However, it is relatively difficult and expensive to maintain the open water. It requires labor to perform the regular thinning or harvesting to reduce population density. The alternatives that scientists suggested are row arrangement (<5m wide) and hammock which were employed to reduce mosquito production in vegetation area and they were proved to be working (Jannino and Walton 2004 and Thullen et al., 2002). As a result, it is better to adjust the goal to utilizing certain planting design to control mosquito population with the cost of a full coverage of California bulrush.

The second goal of the restoring California bulrush is to reach around 47% removal of NH_4-N in the water because another objective of Pond C project is to improve water quality. One of the main water source is urban runoff which contains high nitrogen from like fertilizer used in the gardens and pesticide. If the nitrogen in the water body is high, then the eutrophication can lead to algae bloom and loss of vegetation and aquatic wildlife. 47% removal of NH_4-N is an estimated goal for based on Thullen et al.'s study (2002).

Restoration Plan

<u>Pre-restoration survey:</u>

Before planting, it is necessary to assess the environmental condition of the site for ensuring the condition is suitable or making certain changes to improve the condition for future plantation. Also, the survey provides information about the biotic condition of the site, like the vegetation composition. The survey should include: hydrology of the site, soil condition, potential biota, and local communities

The hydrology of the site refers to the water content of the soil during the summer time, salinities, and flooding regime of the site. The minimum requirements for California bulrush's survival are moist soil in summer, the concentration of salts should be no more than 5ppm, and avoiding planting transplants during the flooding time. Most California bulrush is drought intolerant; it requires the soil to be at least moist. If the site at summer time has low water content, it is necessary to consider choosing the donor plant from those drought tolerant individuals to ensure a higher survival rate. California bulrush has limited tolerance to salinity. According to data from USDA, the maximum salinity it can tolerate is 5ppm. If the salinity is higher than that, it is better to adjust the salinity before planting. Last, the flooding regime is important due to its relevance to plant survival. Flooding before maturity could lead to high mortality (USDA Plant Guide & Sloey et al. 2015), so that it helpful to know the regime for setting up the planting time.

Soil condition is also critical for planting and plant survival. There are three aspects of the soil are needed, soil texture, redox potential, and soil pH. The coarse, gravel-free soil texture is ideal for root establishment of California bulrush. The transplants need to be planted closer to each other if the soil texture is fine, like clay or silt (USDA Plant Guide). Moreover, for soil pH, it should be in a range from 5 to 9 based on the data from CNPS because if the soil pH is outside the range could to lead to nutrient deficiencies or nutrient toxicities.

Plantation:

Both the data from USDA and studies of Sloey et al. (2015) and Malison & Thompson (2011) indicate rhizome pieces with live stems gives the most promising results in a short period of time. The recommended lengths of the rhizome pieces are from 10 to 15 cm, which would lead to strong individual plants (Malison & Thompson, 2010). The rhizome pieces should be stored in a cool and moist plant to ensure the root stays moist before planting (USDA). When collecting the rhizome pieces, it is important to make sure that there is at least one growing bud on the rhizome. If the rhizome pieces are planted with soil, make sure the soil core and surrounding area are weed-free (USDA Plant Guide). Rhizome pieces need to be planted while the soil is moist, the ideal time of the year is fall according to USDA Plant Guide. In addition, the best time to plant rhizome pieces is right after the first rain when there is enough moisture for plant root establishment and low risk of flooding. To promote root growth, USDA Plant Guide also suggests that to cut the stem down to 15 to 25 cm to allow more nutrients being relocated to root production.

The transplant can be collected from any mature California bulrush from other sites. However, if the environment of the site requires plant to survive a drought condition, it is necessary to selectively choose donors which is relatively drought tolerant. Furthermore, when transplanting the plant, it is important to make sure the soil is weed-free. It is not just because a weed-free environment is important for establishment, but also it reduces the amount of effort on weed management later. The ideal planting location in Pond C project is along the bank of the wetland where there is plenty moisture for establishment and allows California bulrush to uptake the excessive N in the water body to improve the water quality.

If the condition of the site is right, the transplants should reach the maturity in a short amount of time. Depending on the size of vegetation, transplants can mature within 6 weeks. However, if the establishment is not ideal, replanting transplant is recommended because the seed of California bulrush has a low germination rate because it usually germinate in water at 86-90 degrees with continuous high lights (Lady Bird Johnson Wildflower Center, 2007). If seed is the only option, germinating the seed in the greenhouse before planting. It usually took 100-120 days to become a planting-ready plug (USDA Plant Guide).

One side effect of California bulrush community is the mosquito. High density of California bulrush tends to increase the reproduction of mosquito due to lack of predator and better habitats (Thullen et al., 2002, Jannino and Walton 2004, and Wilson et al., 2012). Open space design is useful to control the mosquito population. Building hammock for California bulrush is the most ideal design since it does not only leave enough open water to lower the mosquito population by providing habitat for predators, but also enhance the removal of NH_4-N (Thullen et al., 2002). The design of hammock could be creating small humps along the bank of the wetland. The relative deep water around the hump should be able to limit the lateral expansion of California bulrush. Each hammock should not be larger than 5 m in diameter and close to each other. The dense vegetation could physically limit the mosquitofish access and the oxygen content is relatively lower in place with dense vegetation than dispersed vegetation. (Walton et al., 2012 and Jannino and Walton 2004). Besides the hammock design, the density of California bulrush can also be controlled by mechanical removal like mowing, burning, thinning, and rhizome thinning. However, Thullen et al.'s study has shown that the ability of removing of NH_4-H decreased or lost after one year of planting.

Lastly, if the site need to use herbicide to control weed population, especially aquatic weed, Imazamox and Penoxsulam are two candidates for the job. Other herbicides have shown the chance of reducing the weight of California bulrush 49 to 97% (Mudge and Netherland, 2014). Also, it is also important to use the herbicide at the right dose because a high dose could lead to plant injury.

Monitoring:

California bulrush is a fast-growing perennial plant, it reaches maturity within 6 weeks once its root starts establishing (Mallison and Thompson, 2010). Plant height should be used as indication of maturity. A mature California bulrush can grow 1.8 to 3.8 meters high but usually 2 m is the threshold of maturity (Sagebud). In addition, California bulrush can reproduce asexually through rhizome. The lateral expansion rate of a mature California bulrush is at 1 to 2 meters per year. Assuming it is using the hammock design, the full hammock should be fully covered within 3 to 4 years. So, after the hammock is fully covered with vegetation, mosquito population should be monitored.

Mosquito population is divided into two subpopulations, adults and larvae. The adults could be captured by using the emergence trap and the larvae population data could be collected by using the dippers (Thullen et al., 2002). Mosquito population monitoring conducts at a yearly basis since mosquitos are active only during the summer time. Since the mosquito goes through its life cycle within 10 to 14 days, depending on the temperature (American Mosquito Control Association). Since the Dixon is around 70-ish on average during the summer time, so the life cycle is about 14 days. As a result, the monitoring frequency should at twice a month. Recorded data should be analyzed to see if there is an increase in population. If there is an increase, corresponding control method should be employed, like introducing natural predators or insecticide.

Similar to mosquito monitoring plan, the NH_4-N content in the water should also be monitored on a yearly basis. In site location, winter is the time the water is sufficient to keep the site as a wetland. During that period time of the year, it is functioning as a phytoremediation of NH_4-N. Water samples will be taken at inflow and outflow and the comparison between two samples indicates if the system is removing excessive nitrogen in the water body. The concentration of NH_4-N in outflow should be 47% lower than that in inflow according to Thullen et al.'s study, yet the actual may depends on the actual condition. Overall, there should be a significant decrease in NH_4-N in outflow.

Lastly, the community structure of the site need to be monitored on a yearly basis. The high growing rate of California bulrush makes it quick competitive, it could outcompete *Schoenoplectus acutus* if there is frequent high wend and wave stress (Sloey et al., 2015). Accordingly, it is necessary to monitor the population change of adjacent plant communities, it is possible that the whole area will be monoculture. In addition to plant communities, the monoculture could lead to loss of other animal species' natural habitats, which leads to low biodiversity and disobey the first goal. Also, the high abundance of California bulrush could lead to high abundance of certain animal species since there are animals depend on California bulrush as food source, like Canada geese (USDA Plant Guide). It is possible that animal species is harmful to other either animal or plant species that the project also wants to restore. As a result, it is necessary to monitor the changes in local communities along California bulrush's growth.

Overall, the whole monitoring plan can be divided into two parts. The first part is about monitoring the growth of the transplant for the first six weeks. If the mortality is high after six weeks, re-transplanting is needed. If the majority of the transplants survive, the second part is initiated. Mosquito and water quality need to be monitored during a specific season of a year, and the local community change can be monitored on a seasonal basis. The monitoring might not be necessary after the population of California bulrush is stabilized, about four years.

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Common Tule (Schoenoplectus acutus)

Megan Noonan

Background & Justification

The Common Tule, also known as Hardstem Bulrush (*Schoenoplectus acutus*), a monocot, is a perennial glasslike herb that is native to California (CalFlora). It ranges from Nova Scotia and Newfoundland west to southern British Colombia and also to North Carolina, Arkansas, Texas and California (fs.fed.us). Tule is so common in California wetlands that several places in the state were named after it. It is a key player in California wetlands because it has numerous benefits that range from habitat for wildlife to erosion control to increases in carbon storage and water filtration. It poses no threat to other native communities, has little to no problems with pests, and has large parameters as to what conditions it can grow in (Tilley 2012). Due to its high adaptability and successful growth rates seen all through California, it is a highly recommended species to consider when working on restoration projects.

Literature Review

Growth Characteristics:

- It is fairly drought tolerant and can persist through several years of dry conditions (CalFlora).
- Its blooming period begins in May and goes through August (CalFlora)
- The Common Tule reproduces sexually by seed and asexually through vegetative spread via rhizomes, which will spread more than 45cm in one growing season (Tilley 2012).
- The seeds ripen in late August to September and are not held tightly in the seed head, which leads to high winds, frost, and brushing causing the seed to fall out (Hurd 1992).
- Germination rate increases with cold stratification of 2ºC for 30-75 days (Johnson 2004).
- Seeds take 7-10 days to germinate after being propagated (Johnson 2004).

Response to External Disturbances/Disruptions:

- Fires reduce the amount of litter in Common Tule strands, this may increase its' productivity (Esser 1995).
- Common Tule is susceptible to grazing, prescribed burning, mowing and cutting, tillage

and grubbing or hand digging (DiTomaso 2013).

- Herbage production is high but forage value is low. Livestock will rarely eat hardstem bulrush but if other food becomes scarce they will utilize it (Anderson 1984).
- It is a staple food for muskrat, other small mammals, and the seeds are frequently eaten by passerines and waterfowl (Anderson 1984).
- Insects and disease are generally not problems. Aphids will feed on the stems but will generally not kill the plant (Hurd 1992).

Habitat Requirements:

- Generally found in inundated to periodically wet areas of marshes, swamps, and meadows and along lake, reservoir, and pond shorelines (Tilley 2012).
- Found in areas of standing water ranging from 10 cm to more than 1.5 m (4 in to 5 feet) in depth and will not tolerate long periods of extremely deep water (Tilley 2012)
- Hardstem bulrush grows best on sites with saturated, poorly drained soils or standing water for most of the year, either in fresh or brackish water (Anderson 1984).
- They dominate low marsh areas where more tidal flushing occurs (Leck 2009).

Soil Conditions (CalFlora):

- 4.8-8.5 pH
- Max salinity is 21.9 (strong salinity)
- Minimum Depth is 17 inches
- It grows in silt loam, clay, sandy loam, gravel, marl, and peaty soils (fs.fed.us)

Tolerances (CalFlora):

- Temperature ranges from 19-69 degrees F
- Elevation ranges 0-8430 feet
- Annual Precipitation is 6-69 inches
- It prefers full sun exposure

Response to Climate Change:

- Due to its well developed aerenchyma, an internal tissue with large, connected air spaces that allows for the passage of gases from plants roots to shoots, it is much more tolerant of increased water levels but all plants still have limits to their levels of inundation. Conclusively, this means that the Common Tule is able to withstand some level of increases in water level due to climate change but eventually it will meet its threshold(Callaway 2007).
- Due to cross-boundary ecosystem subsidies, the influence of climate change is going to be critical to ecosystems adjacent to tidal wetlands due to changes in salinity and inundation (Parker 2011).

Conclusion:

After thorough research of the Common Tule, it is apparent that it is an extremely effective restoration tool in wetlands. It has the ability to control erosion with its dense and sturdy roots, it helps retain and increase carbon storage in wetlands due to its high productivity, it helps filter water of pollutants that may have made their way into the wetlands via runoff, it serves as a habitat and food source to many species and it is highly adaptable to a fluctuating environment, whether it be a fire or something as large as climate change.

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Management Plan for Common Tule (*Schoenoplectus acutus*)

Goals:

The Common Tule is a native, perennial grass like herb that is commonly found in wetlands across California. Due to its high adaptability and successful growth rates, it is a highly recommended species to consider when working with restoration projects. Since this species is perennial once established minimal long-term maintenance is required therefore maintenance is most critical within the first week to year. The main restoration goal is to create an ideal growth environment in order to ensure the success of the planted seedlings. The restoration goals are as listed below.

- Wild transplants are commonly used with common Tule but individual seed collection is also a common method of acquiring species (Methods of how this will be done are outlined below).
- After optimal planting areas are established, either the seeds or planting plugs need to be properly planted or placed in the wetland (More details below).
- With seeds, germination begins within 7-10 days after planting therefore monitoring should be occur within two weeks of planting and then after one full growing season.
- Monitoring after a few growing seasons would be helpful to ensure that it is not dominating other species and if it is then management actions may be taken to reduce the amount of common Tule on the site.

An additional method used to ensure that the common Tule thrives in the wetland, is planting with rhizomes. Additionally, a significant amount of seedlings should be planted but information was lacking in terms of exactly how much percent cover was adequate. In order to ensure establishment without interfering with the success of surrounding species, monitoring will be key. Initially, 2 weeks to 8 months will be sufficient for short-term monitoring. Long-term would be closer 1 to 3 years.

Pre-restoration goals include:

- Soils should be saturated and open since the seedlings need sunlight in order to establish.
- Planting areas should be located near the waterline.
- The site should have some standing water year round even though once established, the common Tule is fairly drought tolerant.
- Soil should have a pH around 5.8 that is mostly sandy loam.

Restoration Plan:

The common Tule is generally found in areas of standing water ranging from 10 cm to more than 1.5 m in depth (Tilly, 2012). Although younger plants can handle deeper water, it is not for an extended period of time. Therefore, finding the optimal location for planting will further ensure the success of the plant.

If transplanting is the method of choice, either wild plant can be collected and transplanted directly on the site or planting plugs can be used (Tilley, 2012). Planting plugs should be spaced between 30 to 45 cm so that they may fill in the interspaces within the one growing season. Once planted, the soil should be kept saturated and standing water should be no deeper than 4 to 5 cm during the first growing season (Tilley, 2012). If plugs are larger, they can handle deeper standing water if stems are cut long enough so that they are not submerged. If possible, raising and lowering the water level during establishment will speed up the growth process. The fluctuation from saturated soils should reach a maximum depth of 30 cm of standing water for the establishing plants. This action can also help control weeds (Tilley, 2012).

Alternatively to transplanting, if seeds are collected they must be hand stripped from the plant or by clipping the seed head using a pair of shears. Since the seeds are not tightly help, this method of extraction is fairly simple. Seeds ripen from August to September. Once collected, the seeds must be knocked from the panicle with a hammer mill. Screens should be used to clean and capture seeds.

Once the seeds ready, germination rates have been shown to increase with cold stratification of 2ºC for 30-75 days (Hoag, 1998). Another successful method is prewashing with 10% acid solution prior to a 75 day cold stratification (Tilley, 2012). Propagation methods are with seeds or rhizomes. They must be pressed in lightly but not covered and soil must remain moist until they are transplanted. Germination is expected to begin within 7- to 10 days (Hoag, 1998).

In case of a fire, the common Tule can reestablish from seed and rhizomes. In fact, this species does extremely well in the case of fires. Fires reduce the amount of litter in strands, which can cause productivity to increase (Esser, 1995). Although, information on how long the burning period should be is unknown.

Since the growing season stretches from May to August, if plants are being transplanted, optimal planting time would be in early May (CalFlora). If seeds are being planted directly on the site, mid to late April would be the best time to plant since seeds need 7 to 10 days to germinate.

Monitoring Plan:

As previously mentioned, monitoring will need to occur before anything is planted on the site to ensure that soils are saturated, there is some standing water and there is plenty of space and sunlight available for the plants or seeds to establish (Tilley, 2012). Also, its elevation of tolerance ranges from 0 to 2570 m, and its temperature from 11 to 39° C (CalFlora). The soils it can withstand range from peat to coarse substrate with a maximum salinity of 20.6 (CalFlora). It can also go on alkaline and brackish sites. Once established, the common Tule generally grows best in areas of standing water ranging from 4 inches to 5 ft. in depth (Tilley, 2012), although it cannot handle long periods of time in very deep water. Therefore, after seeds are planted, semi-frequent monitoring needs to occur to ensure that the pre-conditions of the site were suitable and the plants or seeds take in that first growing season.

Aside from beginning monitoring before the initial planting or transplanting, the next step would be to check on the freshly planted seeds or plants within 7 to 10 days because that it how it takes for the seeds to germinate (Hoag, 1998). After this period, checking on the plants after one week or two would ensure that they are taking to the wetland. Once they have taken, monitoring would not need to occur again until after the growing season which lasts approximately 8 months (Utah State University). Since the common Tule is a very drought tolerant species, it needs little care once established. Perhaps monitoring after one year, then every other year after that, just to ensure that it isn't taking over space being occupied by other species, even though this is generally not a problem with the common Tule (Tilley, 2012). Additionally, pests have never been an issue for this species as well as the use of pesticides has never been unnecessary (Tilley, 2012).

However, if establishment of the common Tule fails completely, then switching methods between using seeds or transplanting would be the first place to start. Also, double-checking conditions before planting and right after to make sure that the plants are not drowning because they are being submerged for extended periods of time.

Some questions that came up would be, exactly how long can a young plant withstand submerged conditions? How long is a healthy amount of fire? How much common Tule is a healthy amount to plant on a site? Perhaps, using multiple methods of planting on a single site would ensure that some establish and could help us understand why some methods would versus others.

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Kat Ruesel

ENH 160 Spring Quarter

2 May 2017

Project Part 1

Common Cattail (*Typha latifolia*)

Introduction and Background

Broadleaf Cattail, *Typha latifolia* is an aggressively generalist perennial herb with a wide distribution. *T. latifolia* is an extremely robust plant able to survive not only the annual flooding which characterizes its wetland habitats, but also fluctuating salinity, a wide range of pH values, low substrate nutrients, a variety of soil types (or even no soil at all), widely ranging altitudes, extreme environmental disturbance, and quite substantial stress. For this reason, it is infamous for its out-competing of other wetland species oftentimes resulting in monocultural stands which are resilient and hardy (Stevens). *Typha latifolia* is a rhizomatous monocot averaging 1-2 meters tall and wide, and able to reproduce both asexually through rhizomatous budding and sexually. Each monoecious plant has broad green gray-green leaves for which it is named, and at maturity develops a unique inflorescence which is brown and felt-like and cylindrical in shape terminating a spike containing both staminate and pistilate flowers (NatureServe). This species is listed as of the least concern in terms of endangerment, even being characterized as a weed in many areas. Though primarily a wetland plant, it can also survive riparian ecosystems, shallow waters of eutrophic lakes, wetlands, marshes, ponds, and ditches, estuaries, and swales. Physical mowing of plants or heavy grazing is most effective to when trying to completely remove all plants, though herbicide can also be effective in reducing concentration of a stand and can therefore help to reestablish other species to attempt to restore species richness and evenness (Clements). There are advantages of having *T. latifolia* as part of the wetland ecosystem as it is very survivable and can filter out a many pollutants, both metal and chemical. For this reason, it is a common choice when implementing bioremediation in heavily stressed areas, or used for tertiary stage water treatment facilities. T. latifolia is an incredibly hardy and versatile plant, and certainly has its advantages when implemented into a wetland ecosystem.

Literature Review

Taxonomy and Classification:

Kingdom: *Plantae*, Phylum: *Tracheophyte*, Order: *Liliopsida*, Class: *Typhales*, Family:

Typhaceae, Genus: *Typha*, species: *latifolia.*

Full name: Common Cattail, *Typha latifolia* abbrv. Tyla. Linnaeus, 1753. (Clements)

Alternative names: Broadleaf cattail, Common Bulrush, Flags, Rushes, Bulrushes, Cat O'nine Tails, Cossack Asparagus, Reedmace, Baco, Cumbungi.

Relative species: Southern Cattail *T. angustifolia*, the Dominican Cattail *T. domingensis* and a hybrid of the former and *T. latifolia*, *T. xglauca* (Sojda and Solberg).

Growth characteristics:

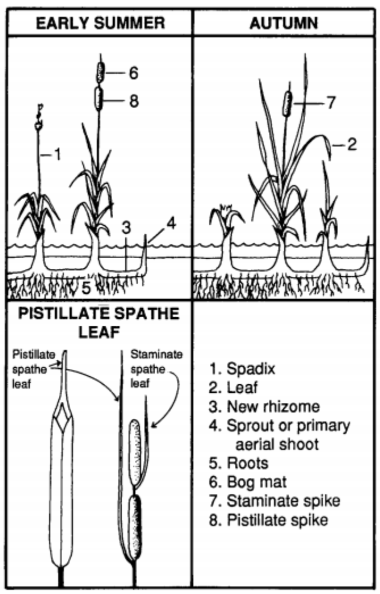

Fig. 1. **The structure of a cattail plant: 1. spadix; 2. leaf; 3. new rhizome; 4. shoot or sprout; 5. roots; 6. staminate spike; 7. pistillate spike.**

Source: Sojda, Richard S., and Kent L. Solberg. "13.4.13. Management and Control of Cattails." *Management and Control of Cattails*. Vol. 13. Washington DC: US Department of the Interior, Fish and Wildlife Service, 1993. Figure 1.

An herbaceous, rhizomatous, perennial plant, *Typha latifolia* is characterized by slender green stalks with green and later brown, cylindrical, felty, terminal inflorescences on a spike and long, wide, basal leaves with parallel linear venation.

- Large leaf surface area contributes to its spatial competitive advantage when competing with many other wetland species for light (Stevens).
- Leaves average at 15-25 mm. wide which are flat, sheathing, and pale gray-green (Clements) (different from *T. angustifolia* the Narrow Leaved Cattail which has 3-8 mm wide leaves which are solid green and somewhat convex) (NatureServe).
- Stems are stout, cylindrical and unbranched.

- Flowering spike is equal to or longer than length of leaf, six times as long as they are thick. *T. latifolia's* male and female flowers are not separated by a space, unlike that of T. *angustifolia* and *T. xglauca* (Smith).
- Plant greenery above ground dies late fall and rhizomes die over the winter (NatureServe).
- Plant height ranges from 120-180cm with maximum growth being reached within 50 cm. of water. Also exhibits 120-180cm spread (NatureServe).
- "Rhizomes are tough, stout, course, and extensive and may grow up to 70 cm. long with a .5-3cm diameter with shallow fibrous roots." There are two different types of rhizomes, the first being superficial and small and branching, the second being the deeper and thicker of the two branching only at the base and soft and spongey with internal air passages (Gucker) known as aerenchyma, which connect leaves to the subterranean rhizomes (Sojda and Solberg).
- Plant is monoecious (single house, unisexual flowers). Heterozygosity and polymorphism exhibit low genetic variation within stands, but greater variation between different communities and stands. Ramets (the clonal individuals) also exhibit similar characteristics being similar within stands.
- Rhizomes can survive up to 2 years while ramets generally die within a year, especially if flowered. Vegetation regenerates through sexual reproduction.

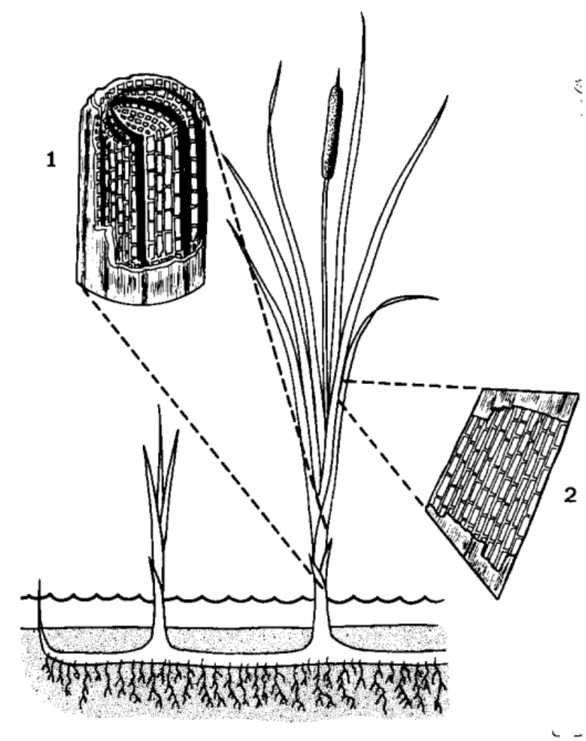

Fig. 2. Aerenchyma provides air passage from leaves to rhizomes. 1. Cross-section of a stem; 2. Longitudinal section of a leaf.

Source: Sojda, Richard S., and Kent L. Solberg. "13.4.13. Management and Control of Cattails." *Management and Control of Cattails*. Vol. 13. Washington DC: US Department of the Interior, Fish and Wildlife Service, 1993. Figure 2.

Reproduction:

- Inflorescences include staminate flowers on a club-like spadix (Smith) above pistillate flowers. The former of which will fluff out and disperse leaving the persistent female flowers a naked axis which persists.
- Post fertilization and maturation, fruits form as 1cm. long nut-like achenes which dehisce as head becomes fluffy as hair like structures scatter seed (Steven`s).
- Female flowers persist (Gucker).
- Is able to clone rapidly from a "subterranean stem and creeping rhizomes" (NatureServe).
- Seeds dispersed by wind and pollen grains can separate into "mixtures of triads, dyads and monads" when shed (Flora).
- Plant flowers in late May and June through late July, depending on soil and water temperature as well as climate and amount of litter in the stand. Fruits mature in fall from August through September (NatureServe).
- 2.54cm of standing water is required surface for germination of seeds.

Propagation:

- Can collect seeds from continuous stands by clipping below heads. Readily germinates and is very cost effective to propagate from seed.
- Seeds propagate naturally through wind, water, ice, and animals.
- Seed viability is dependent on several factors including temporality, environment, ecotype, and genotype as studies showed seeds from a 12-year-old vivacious established population failed to germinate when propagated at 2600 m. altitude.
- Rake in 1-3 cm from surface when seeding in sediment.
- Can plant from rootstock or seedlings or direct seeding. Bare root seedlings fare better with moving water. Fertilization of seedlings helps establish plants (Stevens). Seedlings can germinate on non-flooded substrates but must be submerged at early growth stages to survive.
- Plugs can be 6 x 6cm at the smallest and must include rhizomes and tops as well as 15-25 cm. of leaves and stem. Plant 1 meter apart, or closer if planting in clay or silt or along slopes or in areas of prolonged inundation. Plant late fall (late October to November) to allow rooting before flooding and winter dormancy. Drought stress of donor plant increases success for revegetation (Stevens).
- Cold stratification, salinity, light, ph, temperature, oxygen, and ash can affect germination of seeds as well, and no seeds from summer soils are viable. Seeds and plants do not require chilling hours; stratified wetland soils, less than 1atm of osmotic pressure in natural salinity, in full light, at 25-30 degrees C, with oxygen above 1.0 mg./L with full aquatic immersion provided the best results, with almost 99% germination rate.
- Three shoot emergences consist of the first being in the early spring, then the second and third being in midsummer the first with 70-80% mortality, and the last growth pulse producing 80-90 percent of reemergent shoots which will appear in the spring (Gucker).

Range and Distribution:

- Current populations are stable with a wide ecological amplitude (NatureServe).
- Has a sub cosmopolitan distribution on all continents excluding Antarctica, though was introduced to Australia.

- All three major cattail species' ranges overlap only in the east-central coastal United States and California. T. latifolia and *T. domengensis* (Southern Cattail) ranges overlap in the extreme southern US, and *T. angustifolia* (Narrow Leafed Cattail) and T. latifolia ranges overlapping in the eastern US and Canada.
- Distributions in California are widespread, some notable being the "bulrush (*Scirpus spp.)*-cattail tule marshes" in the Central Valley, "brackish hard stem bulrush (*Schoenoplectus acutus* var. *acutus*)- broadleaf cattail marshes in the San Francisco Bay" area, and "tule marshes along the Sacramento and San Joaquin rivers; marshes part of wet grasslands Forest and Range Ecosystem No. 41."
- *Typha latifolia* exhibits a wide tolerance of environments, occurring in tropical, subtropical, southern and northern temperate, humid coastal areas, and even dry continental regions.
- *Typha* grows at altitudes anywhere between sea level to 2300 meters in North America, and in California only *T. latifolia* grows above 3000m. (Gucker).

Habitat/Requirements:

- *Typha latifolia* survives in a variety of freshwater and brackish aquatic systems, often in the margins and shallow waters of eutrophic lakes, wetlands, marshes, ponds, and ditches, swales and rivers.
- Is of major importance to inland wetlands both permanent and seasonal intermittent/irregular waterways (Lansdown).
- Zones 3-10 in full sun or partial sun (Missouri).
- Can germinate and mature to reproduce in a wide gradient of substrate types including but not limited to wet pure sand, peat, clay, and loamy soils (documented) (NatureServe). Can survive with varying ph from acid (3.4) to basic (9.2) (Clements)with low or high levels of nutrients. It can even colonize a floating mat with minimal soil development.
- Colonizes early-seral areas with open access to sunlight, and will only colonize in forest post-disturbance.
- T. latifolia grows at a maximum water depth of 80cm. and dies in anything above 95 cm. The greatest bioproduction is exhibited at plants established at 22cm depth (Gucker).
- Semi-permanent marsh cycles consist of four stages: dry, generating, degenerating, or lake marsh. However, any one of these stages can be lengthened as to prevent cycle progression and thus halt the cycle completely. *T. latifolia* can survive under all circumstances except that of a completely dry habitat (Sojda and Solberg)

Tolerances:

- Can survive and reproduce through substantial water level fluctuations, and like many emergent wetland species can tolerate perennial flood drawdown cycles in wetland and riparian systems.
- Is persistent through moderate soil salinity (Stevens).
- Can store high concentrations of metals (copper and nickel tolerance mechanism) (NatureServe).

- Quantified data collected in studies measuring the removal efficiency of Methyl parathion, an extremely hazardous agricultural pesticide used in Mexico, by *Typha latifolia* to be significantly effective (Amaya-Chavez et.al).
- Can filter out many pollutants and thus is implemented in many wastewater treatment facilities (Maddison et.al).
-

Interactions:

- Is an aggressively colonizing species and will often crowd out other species in brackish and freshwater wetland ecosystems. Tends to invade when changes are introduced, often resulting in monotypic and persistent stands. To preserve heterogeneity of system, maintain water flow, reduce excess nutrients and maintain static salinity in tidal marshes (Stevens).
- Known pests are *Arzama opbliqua* and *Nonagria oblonga* (moths), aphids, and *Colandra pertinaux* (Snout Beetle). Herbivorous ungulates feed on cattails and muskrats are also a primary predator, feeding on rhizomes also using leaves for nesting. Fruits and stems provide nesting material for many bird species as well (NatureServe).
- Often associates with *Phragmites australiis, Lythrum slaicaria, Spartina sp, Acorus calamus, Scirpus sp,* and *Sagittaria latifolia* and *Carex spp*. (NatureServe)
- Can hybridize with other *Typhus spp*., one of the most common being the hybrid cross of parents *Typha latifolia* and *T. angustifolia* resulting in the "robust hybrid" *Typha x glauca* (NatureServe).

Management considerations:

- Can clone and colonize rapidly, often forming extensive monocultures and can be a serious weed.
- Flooding will kill seedlings.
- Heavy grazing can eliminate plants though *Typha spp.* is resistant to moderate grazing and is tolerant of trampling and growth is accelerated through disturbances.
- If mowing, mow after flowering heads have formed but before maturation, then again 1 month later (75% plant mortality rate) (Stevens).
- A study in Indian documented three specific scenarios preceding cattail monoculture growth: modified surface hydrology, wildfire suppression, and wetland enrichment. These three circumstances can be minimized or adjusted for to preserve wetland biodiversity and species richness and evenness (NatureServe).
- Ideal ecosystem of cattail marshes aka. a "hemi-marsh" has a ratio of 1:1 in terms of open water and vegetation.
- Roosting habitat of cattail marshes can dramatically damage nearby agricultural crops, especially sunflower seeds due to the prime habitat for blackbirds and other small seed-eating species.
- Grazing and mowing are most effective when starch reserves are at their lowest, in the spring and summer.
- Salinity above 10 ppt. will kill cattails. Unfortunately, this is extremely high and not a feasible way of eliminating cattails. Another option is to inundate cattails with sea-strength salinity for two months, which will also kill most if not all plants.

- Drought or purposeful drawdown can increase water in soil or salinity and retard growth, prevent germination and even kill some mature plants, effectively controlling cattail populations. This, again is fairly difficult to implement.
- Herbicides, especially containing glyphosate are able to interrupt metabolic pathways in cattails, and are most effective mid to late-summer when the most carbohydrates are stored in the plants. This will not likely kill all plants, but can be used to create a hemi marsh.
- Cattails can also be controlled through mechanical means such as cutting, crushing, shearing or disking. Rhizomes must also be destroyed but will die with complete removal of photosynthetic material.
- Seeds can also be persistent and can cause difficulty to extirpate cattail from a site.
- Burning can be used to weed out some plants but cannot complete kill all plants in a population. Burning is also temporally difficult as it is most effective before spring, but winter and early spring ice or precipitation can saturate soils and render burning ineffective (Sojda and Solberg).
- Landscape use recommends constraining to container or tubs as roots run deep and are hard to eradicate, plant is self-seeding and will aggressively crowd out other marginal plants (Missouri).

Miscellaneous:

- *Typha spp*. can also be used as a source of power for biomass and lights when burnt (Lansdown).
- Cattails are often a symbol of wetland ecosystems and have unique character and aesthetic appeal.
- Filters runoff and thus is sometimes planted to retain lakefront properties ("Cattail; a common…). They are also used commonly for wastewater tertiary treatment as they are particularly resilient and thus are able to filter out many different pollutants including some heavy metals (Maddison, et.al).
- Can be an obligate wetland indicator species (Stevens).
- Ethnobotanical uses historically are thatching, weaving, stuffing, or weaving into mats for furnishing or even water purification by Native Americans (Lansdown) including California and Oregon native Klamath and Modoc tribes as well as Cahuilla and Apaches. Bundled reeds can also be made into buoyant boats, or rope.
- Consumption of all parts of the cattail (at different growth stages) was common as all parts of the plant are edible and harvestable (rhizomes, shoots, stems, flower stalks, inflorescence). Even pollen is used to grind for flour (Stevens). Medicinal uses of *T. latifolia* include both ingestion and topical use. It has been utilized as an anticoagulant, diuretic, hemostatic, sterilizer, vermifuge, styptic.

<u>Management Plan for Common Cattail</u>

Goals:

The restoration goal of this project is to weigh and assess the options regarding preserving Typha latifolia populations as one of the species in the wetland restoration areas of the Sacramento and Yolo counties, or to attempt to eliminate it completely. Typha is a hardy and ecologically rich species, able to provide numerous ecosystem services including water filtration, habitat for native species of birds and mammals, food for wildlife, shelter for ground nesting birds, erosion control of riparian areas, and pollution control (Natureserve). However, there is a consistent and expected problem of *T. latifolia* outcompeting all other species of plants within its extensive habitat range, thus homogenizing the habitat areas and reducing biodiversity. It is highly resilient and also perennial, further contributing to the possibility of its possible formation of a monoculture. This monoculture is often spearheaded by an ecosystem change which allows *T.* latifolia to exhibit its adaptability and competitive advantages (Stevens). In a stable area with little to no disturbance regime or regular changes outside the standard wetland flood season fluctuations, mid-intensity management should be able to prevent the formation of a monoculture. If long term management is not possible, *T. latifolia* should be removed completely. Due to the perennial nature, visual monitoring over the course of two years should be enough to establish whether T. latifolia has been successfully eliminated. Due to rhizomic lifespan of 2 years, after the third year physical exploration of site should establish definitively whether Typha will re-colonize (Gucker).

Restoration goals should include:

- Planting of *T. latifolia* from seed in areas with pre-established wetland grasses, rushes and sedges to prevent latifolia from outcompeting other species.
- Planting of *T. latifolia* from rhizomic cuttings (no less than 6cm across and 20 cm green) in areas where T. latifolia will not outcompete other species.
- Planting of *T. latifolia* along riparian rip-rap areas can help to establish a vegetative mat to help restore lost sediment prevent further erosion of existing sediment. Tyla is able to grow with little to no sediment under poor conditions, so rhizomic cuttings should be able to root as long as area satisfies ph, salinity and water-level fluctuations as required by *T. latifolia.*
- Remove *T. latifolia* where monocultures exist, mowing and/or herbicide, the former to remove completely and the latter to thin existing populations. Mowing should be performed before inflorescence reaches maturity, pesticide should be applied in mid to late summer when carbohydrate storage is at its highest (Sojda and Solberg).
- Maintenance of hydrologic flow of riparian and wetland systems.

Pre-restoration goals should be to survey the site:

- Determine whether site is subject to disturbance and or changes which would allow *T. latifolia* to establish monoculture.
- Research historic flood patterns, precipitation, and water levels to determine cycle of inundation.
- Measure salinity of water sources.
- Take note of what species already exist in the area.
- If *T. latifolia* is already established, take note of what developmental stage plants are at.

- Check wind patterns and flow of water to determine what is downstream of *T. latifolia* populations.

Restoration Plan:

Nature of the site should determine whether *T. latifoli*a should be preserved/planted or eliminated completely.

Scenario 1: Existing monoculture

Any changes other than seasonal fluctuations in inundation should result in complete removal of *T. latifolia* through high-intensity grazing or mowing (Clements). This should be done once before flowers have matured, and then one month after again. Removal of all green material should result in an effective culling of both rhizome and above-ground plant, but maintenance and management would consist of a seasonal assessment of the site. If plants root, additional mechanical removal may be warranted (Stevens). When possible, removal of the flower heads, even when immature could further ensure that the plants will not re-establish. When possible, plant species intended to replace *T. latifolia* from seedings or adult plants in areas where rhizomes do not make replanting difficult (Sojda and Solberg). A combination of mechanical and chemical controls may be used where mowing or grazing is not possible, but it is highly unlikely anything other than intensive mechanical removal would eliminate the population completely without rendering site uninhabitable by other species (Clements).

Monitoring Plan: Return seasonally (every 4-6 months) and visually assess whether new seeds are rooting or existing plants are surviving. Additional action may be called for to remove additional vegetation. If no plants are seen within 3 years, they have been effectively eliminated from the area.

Scenario 2: Riparian monoculture establishment

The Sacramento and San Joaquin Rivers have both been extensively developed, with bank side adjustments being made to accommodate for commercial, industrial, and recreational use of the waterways. Where natural corridors exist, much of the river banks still experience intense erosion and even installation of rip rap, or degradation of the sediment along the river banks. While the fluctuation of water levels and the pathways it follows is inherent in the nature of the Bay Delta Areas, many sections of riverbank are destabilized to the point of functionless loss of land. In these situations, *T. latifolia* could be planted to stabilize the sediment or even add organic material which would eventually help to rebuild the riverbanks. Due to the hardiness and low substrate requirements of *T. latifolia*, it is a viable option in restoring rip rap and industrialized areas along the riparian corridors and due to the lack of other vegetation being able to survive the intense disturbance regimes and lack of nutrients and resources, replanting could be a viable option. However, care would have to be taken as the seeds dispersed by the *T. latifoli*a could cause problems inland or downstream, as seeds are dispersed through water or by wind (Sojda and Solberg). For this reason, this plan should only be implemented in large areas of otherwise non-suitable habitat in a large radius and away from any wind corridors. Planting from rhizomes should be most effective, after slight drought stress. Avoid planting from seed because of possible mis-distribution.

Monitoring Plan: Return seasonally and log area of established plants, if any. Once population is established, a monoculture stand is acceptable to build biomass. Eventually, culling of the *Typha* and replanting of other species may be feasible. Ensure hydrological flow is retained by thinning adult plants to a density of no more than 3-5 plants/sq. meter.

Scenario 3 Heterogeneous wetland planting

In a wetland habitat where one is hoping to establish a *Typha* population, it is necessary to determine how large the stand will be and it should be placed. *T. latifolia* is resilient and hardy and thus should only be planted if there are other resilient species which can compete effectively with the *T. latifolia* as to avoid it taking over. If already part of a wetland community it is imperative that one manage the site to make sure that the other species do not get crowded out. Places for *T. latifolia* to be planted are low sediment, poor nutrient areas with good water circulation and full sun. As it is able to withstand grazing, salinity and varied ph and substrate, areas such as ranch land and eroded riparian areas would be acceptable locations. Also areas with metal and chemical pollutants could accept plantings to work to filter water and help maintain landmass along edges of water bodies.

Monitoring Plan: Return seasonally (every 4-6 months) and heavy mow or graze at boundary of stand. Controlled burn, mowing or pesticides may be used to thin population at a 75% per instance. Ensure other species are not getting crowded out and that circulation is consistent throughout the site. Retain density of 3-5 plants per sq. meter at heart of population, thin to 2 plants/sq meter at edges. Monitor community species distribution with *Typha spp.* making up no more than 25% of total species (in terms of spatial footprint).

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<u>Common Cattail (*Typha latifolia*)</u>

Krista Ruesel

<u>Introduction and Background</u>

The Common Cattail, or *Typha latifolia* is one of four species of cattail in California, the others being the Southern Cattail *T. angustifolia*, the Dominican Cattail *T. domingensis* and a hybrid of the former two, *T. glauca* (Sojda and Solberg). Also, called the Broadleaf Cattail, *Typha latifolia* is an aggressively generalist perennial herb. It has a wide distribution and is an extremely robust plant able to survive not only the annual flooding which characterizes its wetland habitats, but also fluctuating salinity, a wide range of ph's, low substrate nutrients, a variety of soil types (or even no soil at all), widely ranging altitudes, extreme environmental disturbance, and quite substantial stress. For this reason, it is infamous for its out-competing of other wetland species oftentimes resulting in monocultural stands which are resilient and hardy. *Typha latifolia* is sometimes shortened to Tyla and is a rhizomatous monocot averaging 1-2 meters tall and wide, and able to reproduce both asexually through rhizomatous budding and sexually. Each monoecious plant has broad green gray-green leaves for which it is named, and at maturity develops a unique inflorescence which is brown and felt-like and cylindrical in shape terminating a spike. This has both staminate and pistilate flowers (the first above the second) the former which will fluff out and disperse leaving the persistent female flowers which will develop into dehiscent, nut-like achenes with seeds which disperse readily (NatureServe). This species is listed as of the least concern in terms of endangerment, even being characterized as a weed in many areas. Though primarily a wetland plant, it can also survive riparian ecosystems, shallow waters of eutrophic lakes, wetlands, marshes, ponds, and ditches, estuaries, and swales. Physical mowing of plants is most effective to when trying to completely remove all plants, though herbicide can also be effective in reducing concentration of a stand and can therefore help to reestablish other species to attempt to restore species richness and evenness. There are advantages of having Tyla as part of the wetland ecosystem as it is very survivable and can filter out a many pollutants, both metal and chemical. For this reason, it is a common choice when implementing bioremediation in heavily stressed areas, or used for tertiary stage water treatment facilities. T. latifolia is an incredibly hardy and versatile plant, and certainly has its advantages when implemented into a wetland ecosystem.

Literature Review

Taxonomy and Classification:

Kingdom: *Plantae*, Phylum: *Tracheophyte*, Order: *Liliopsida*, Class: *Typhales*, Family:

Typhaceae, Genus: *Typha*, species: *latifolia*.

Full name: Common Cattail, *Typha latifolia* abbrv. Tyla

Alternative names: Broadleaf cattail, Common Bulrush, Flags, Rushes, Bulrushes, Cat O'nine Tails, Cossack Asparagus, Reed Mace, Baco

Growth characteristics:

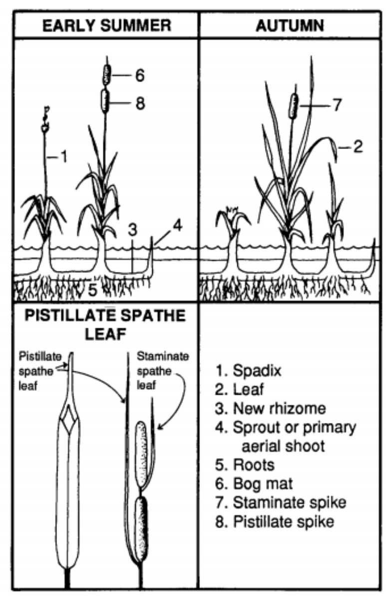

Fig. 1. The structure of a cattail plant: 1. spadix; 2. leaf; 3. new rhizome; 4. shoot or sprout; 5. roots; 6. staminate spike; 7. pistillate spike.

An herbaceous, rhizomatous, perennial plant, *Typha latifolia* is characterized by slender green stalks with green and later brown, cylindrical, felty, terminal inflorescences on a spike and long, wide, basal leaves with parallel linear venation.

- Large leaf surface area contributes to its spatial competitive advantage when competing with many other wetland species for light (Stevens).
- Leaves average at 23 cm. wide which are flat, sheathing, and pale gray-green (different from T. *angustifolia* the Narrow Leaved Cattail which has 3-8 cm wide leaves which are solid green and somewhat convex) (NatureServe).
- Stems are stout, cylindrical and unbranched.
- Flowering is equal to or longer than length of leaf.
- Spikes are six times as long as they are thick.
- Plant greenery above ground dies late fall and rhizomes die over the winter (NatureServe).

- Plant height ranges from 120-180cm with maximum growth being reached within 50 cm. of water. Also exhibits 120-180cm spread (NatureServe).
- “Rhizomes are tough, stout, course, and extensive and may grow up to 70 cm. long with a .5-3cm diameter with shallow fibrous roots.” There are two different types of rhizomes, the first being superficial and small and branching, the second being the deeper and thicker of the two branching only at the base and soft and spongey with internal air passages(Gucker) known as aerenchyma, which connect leaves to the subterranean rhizomes (Sojda and Solberg).
- Plant is monoecious.
- Rhizomes can survive up to 2 years while ramets generally die within a year, especially if flowered. Vegetation regenerates through sexual reproduction.

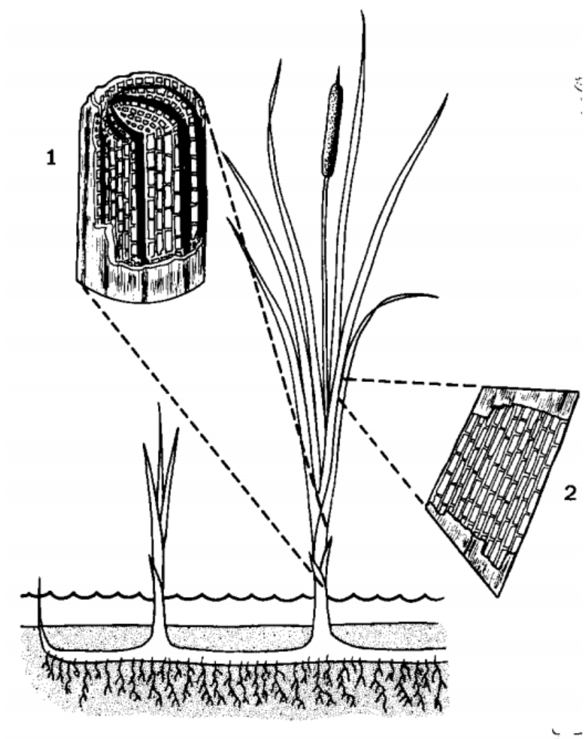

Fig. 2. Aerenchyma provides air passage from leaves to rhizomes. 1. Cross-section of a stem; 2. Longitudinal section of a leaf.

Reproduction:

- Inflorescences include staminate flowers on a club-like spadix (NatureServe) above pistillate flowers on a naked axis which persists. Post fertilization and maturation, fruits form as 1cm. long nut-like achenes which dehisce as head becomes fluffy as hair like structures scatter seed (Stevens).
- Female flowers persist (Gucker).
- Is able to clone rapidly from a “subterranean stem and creeping rhizomes” (NatureServe).
- Seeds dispersed by wind and pollen grains can separate into “mixtures of triads, dyads and monads” when shed (Flora).

- Plant flowers in late May and June through late July, depending on soil and water temperature as well as climate and amount of litter in the stand. Fruits mature in fall from August through September (NatureServe).
- 2.54cm of water is required for germination.

Propagation:

- Rake in 1-3 cm from surface when seeding in sediment.
- Can plant from rootstock or seedlings or direct seeding. Bare root seedlings fare better with moving water.
- Readily germinates and is very cost effective to propagate from seed.
- Can collect seeds from continuous stands by clipping below heads.
- Drought stress of donor plant increases success for revegetation.
- Plugs can be 6 x 6cm at the smallest and must include rhizomes and tops as well as 15-25 cm. of leaves and stem. Plant 1 meter apart, or closer if planting in clay or silt or along slopes or in areas of prolonged inundation. Plant late fall (late October to November) to allow rooting before flooding and winter dormancy.
- Fertilization of seedlings helps establish plants (Stevens).
- Heterozygosity and polymorphism exhibit low genetic variation within stands, but greater variation between different communities and stands. Ramets (the clonal individuals) also exhibit similar characteristics being similar within stands.
- Seeds propagate naturally through wind, water, ice, and animals.
- Seed viability is dependent on several factors including temporality, environment, ecotype, and genotype as studies showed seeds from a 12-year-old vivacious established population failed to germinate when propagated at 2600 m. altitude.
- Cold stratification, salinity, light, ph, temperature, oxygen, and ash can affect germination of seeds as well, and no seeds from summer soils are viable. Seeds and plants do not require chilling hours; stratified wetland soils, less than 1atm of osmotic pressure in natural salinity, in full light, at 25-30 degrees C, with oxygen above 1.0 mg./L with full aquatic immersion provided the best results, with almost 99% germination rate.
- Seedlings can germinate on non-flooded substrates but must be submerged at early growth stages to survive.
- Three shoot emergences consist of the first being in the early spring, then the second and third being in midsummer the first with 70-80% mortality, and the last growth pulse producing 80-90 percent of reemergent shoots which will appear in the spring (Gucker).

Range and Distribution:

- Current populations are stable and unfragmented.
- Has a wide ecological amplitude (NatureServe).
- Has a sub cosmopolitan distribution on all continents excluding Antarctica, though was introduced to Australia.
- Coastal and valley marshes lower than 2000 meters.
- Commonly invades pelagic zones of bogs (NatureServe).
- All three major cattail species' ranges overlap only in the east-central coastal United States and California. T. latifolia and *T. domengensis* (Southern Cattail) ranges overlap

in the extreme southern US, and *T. angustifolia* (Narrow Leafed Cattail) and T. latifolia ranges overlapping in the eastern US and Canada.

- Distributions in California are widespread, some notable being the "bulrush (*Scirpus spp.)*-cattail tule marshes" in the Central Valley, "brackish hard stem bulrush (*Schoenoplectus acutus* var. *acutus*)- broadleaf cattail marshes in the San Francisco Bay" area, and "tule marshes along the Sacramento and San Joaquin rivers; marshes part of wet grasslands Forest and Range Ecosystem No. 41."
- *Typha latifolia* exhibits a wide tolerance of environments, occurring in tropical, subtropical, southern and northern temperate, humid coastal areas, and even dry continental regions.
- *Typha spp*. grows at altitudes anywhere between sea level to 2300 meters in North America, and in California only *T. latifolia* grows above 3000m. (Gucker).

Habitat/Requirements:

- *Typha latifolia* survives in a variety of freshwater and brackish aquatic systems, often in the margins and shallow waters of eutrophic lakes, wetlands, marshes, ponds, and ditches, swales and rivers.
- Is of major importance to inland wetlands both permanent and seasonal intermittent/irregular waterways (Lansdown).
- *Typha spp*. has been reported as an invasive plant in areas of Washington (extensively), Montana, Minnesota, Michigan, Iowa, Indiana, Wisconsin, Kansas, Illinois, Kentucky, Pennsylvania, Texas, Arkansas, Louisiana, Alabama, and Florida (Swearingen).
- Zones 3-10 in full sun or partial sun (Missouri).
- Can germinate and mature to reproduce in a wide gradient of substrate types including but not limited to wet pure sand, peat, clay, and loamy soils (documented) (NatureServe). Can survive with varying ph from acid to basic with low or high levels of nutrients. It can even colonize a floating matt with minimal soil development.
- Colonizes early-seral areas with open canopy, and will only colonize in forest post-disturbance.
- Tyla grows at a maximum water depth of 80cm. and dies in anything above 95 cm. The greatest bioproduction is exhibited at plants established at 22cm depth (Gucker).
- Semi-permanent marsh cycles consist of four stages: dry, generating, degenerating, or lake marsh. However, any one of these stages can be lengthened as to prevent cycle progression and thus halt the cycle completely. *T. latifolia* can survive under all circumstances except that of a completely dry habitat (Sojda and Solberg)

Tolerances:

- Can survive and reproduce through substantial water level fluctuations, and like many emergent wetland species can tolerate perennial flood drawdown cycles in wetland and riparian systems.
- Is persistent through moderate soil salinity (Stevens).
- Can store high concentrations of metals (copper and nickel tolerance mechanism) (NatureServe).

- Quantified data collected in studies measuring the removal efficiency of Methyl parathion, an extremely hazardous agricultural pesticide used in Mexico, by *Typha latifolia* to be significantly effective (Amaya-Chavez, et.al).
- Can filter out many pollutants and thus is implemented in many wastewater treatment facilities (Maddison, et.al).

Interactions:

- Is an aggressively colonizing species and will often crowd out other species in brackish and freshwater wetland ecosystems. Tends to invade when changes are introduced, often resulting in monotypic and persistent stands. To preserve heterogeneity of system, maintain water flow, reduce excess nutrients and maintain static salinity in tidal marshes (Stevens).
- Known pests are *Arzama opbliqua* and *Nonagria oblonga* (moths), aphids, and *Colandra pertinaux* (Snout Beetle). Herbivorous ungulates feed on cattails and muskrats are also a primary predator, feeding on rhizomes also using leaves for nesting. Fruits and stems provide nesting material for many bird species as well (NatureServe).
- Often associates with *Phragmites australiis, Lythrum slaicaria, Spartina sp, Acorus calamus, Scirpus sp,* and *Sagittaria latifolia* (NatureServe) and *Carex spp*.
- Can hybridize with other *Typhus spp.*, one of the most common being the hybrid cross of parents *Typha latifolia* and *T. angustifolia* resulting in the "robust hybrid" *Typha x glauca* (NatureServe).

Management considerations:

- Can clone and colonize rapidly, often forming extensive monocultures and can be a serious weed.
- Flooding will kill seedlings.
- Heavy grazing can eliminate plants though *Typha spp.* is resistant to moderate grazing and is tolerant of trampling and growth is accelerated through disturbances.
- If mowing, mow after flowering heads have formed but before maturation, then again 1 month later (75% plant mortality rate) (Stevens).
- A study in Indian documented three specific scenarios preceding cattail monoculture growth: modified surface hydrology, wildfire suppression, and wetland enrichment. These three circumstances can be minimized or adjusted for to preserve wetland biodiversity and species richness and evenness (NatureServe).
- Ideal ecosystem of cattail marshes aka. a "hemi-marsh" has a ratio of 1:1 in terms of open water and vegetation.
- Roosting habitat of cattail marshes can dramatically damage nearby agricultural crops, especially sunflower seeds due to the prime habitat for blackbirds and other small seed-eating species.
- Grazing and mowing are most effective when starch reserves are at their lowest, in the spring and summer.
- Salinity above 10 ppt. will kill cattails. Unfortunately, this is extremely high and not a feasible way of eliminating cattails. Another option is to inundate cattails with sea-strength salinity for two months, which will also kill most if not all plants.

- Drought or purposeful drawdown can increase water in soil or salinity and retard growth, prevent germination and even kill some mature plants, effectively controlling cattail populations. This, again is fairly difficult to implement.
- Herbicides, especially containing glyphosate are able to interrupt metabolic pathways in cattails, and are most effective mid to late-summer when the most carbohydrates are stored in the plants. This will not likely kill all plants, but can be used to create a hemi marsh.
- Cattails can also be controlled through mechanical means such as cutting, crushing, shearing or disking. Rhizomes must also be destroyed but will die with complete removal of photosynthetic material.
- Seeds can also be persistent and can cause difficulty to extirpate cattail from a site.
- Burning can be used to weed out some plants but cannot complete kill all plants in a population. Burning is also temporally difficult as it is most effective before spring, but winter and early spring ice or precipitation can saturate soils and render burning ineffective (Sojda and Solberg).

Miscellaneous:

- Medicinal uses of *T. latifolia* include both ingestion and topical use. It has been utilized as an anticoagulant, diuretic, hemostatic, sterilizer, vermifuge, styptic.
- *Typha spp*. can also be used as a source of power for biomass and lights when burnt (Lansdown).
- Ethnobotanical uses historically are thatching, weaving, stuffing, or weaving into mats for furnishing or even water purification by Native Americans (Lansdown) including California and Oregon native Klamath and Modoc tribes as well as Cahuilla and Apaches. Bundled reeds can also be made into buoyant boats, or rope.
- Consumption of all parts of the cattail (at different growth stages) was common as all parts of the plant are edible and harvestable (rhizomes, shoots, stems, flower stalks, inflorescence). Even pollen is used to grind for flour (Stevens).
- Cattails are often a symbol of wetland ecosystems and have unique character and aesthetic appeal.
- They are also used commonly for wastewater tertiary treatment as they are particularly resilient and thus are able to filter out many different pollutants including some heavy metals (Maddison, et.al).
- Can be an obligate wetland indicator species (Stevens).
- Showy flowers and fruits add aesthetic appeal while wetland nature and chemical toxicity filtration also makes cattails attractive options for landscape use.
- Can be used in fresh and dried flower arrangements.
- Can be planted to naturalize in constructed wetlands and rain gardens.
- Landscape use recommends constraining to container or tubs as roots run deep and are hard to eradicate, plant is self-seeding and will aggressively crowd out other marginal plants (Missouri).
- Filters runoff and thus is sometimes planted to retain lakefront properties (“Cattail; a common…).

Management Plan for Common Cattail

Goals:

The restoration goal of this project is to weigh and assess the options regarding preserving Typha latifolia populations as one of the species in the wetland restoration areas of the Sacramento and Yolo counties, or to attempt to eliminate it completely. Typha is a hardy and ecologically rich species, able to provide numerous ecosystem services including water filtration, habitat for native species of birds and mammals, food for wildlife, shelter for ground nesting birds, erosion control of riparian areas, and pollution control. However, there is a consistent and expected problem of Tyla outcompeting all other species of plants within its extensive habitat range, thus homogenizing the habitat areas and reducing biodiversity. It is highly resilient and also perennial, further contributing to the possibility of its possible formation of a monoculture. This monoculture is often spearheaded by an ecosystem change which allows Tyla to exhibit its adaptability and competitive advantages. In a stable area with little to no disturbance regime or regular changes outside the standard wetland flood season fluctuations, mid-intensity management should be able to prevent the formation of a monoculture. If long term management is not possible, T. latifolia should be removed completely. Due to the perennial nature, visual monitoring over the course of two years should be enough to establish whether T. latifolia has been successfully eliminated. Due to rhizomic lifespan of 2 years, after the third year physical exploration of site should establish definitively whether Typha will re-colonize.

Restoration goals should include:

- Planting of T. latifolia from seed in areas with pre-established wetland grasses, rushes and sedges to prevent latifolia from outcompeting other species.
- Planting of T. latifolia from rhizomic cuttings (no less than 6cm across and 20 cm green) in areas where T. latifolia will not outcompete other species.
- Planting of T. latifolia along riparian rip-rap areas can help to establish a vegetative mat to help restore lost sediment prevent further erosion of existing sediment. Tyla is able to grow with little to no sediment under poor conditions, so rhizomic cuttings should be able to root as long as area satisfies ph, salinity and water-level fluctuations as required by Tyla sp.
- Remove T. latifolia where monocultures exist, mowing and/or herbicide, the former to remove completely and the latter to thin existing populations. Mowing should be performed before inflorescence reaches maturity, pesticide should be applied in mid to late summer when carbohydrate storage is at its highest (Sojda and Solberg).

Pre-restoration goals should be to survey the site:

- Determine whether site is subject to disturbance and or changes which would allow T. latifolia to establish monoculture.
- Research historic flood patterns, precipitation, and water levels to determine cycle of inundation.
- Measure salinity of water sources
- Take note of what species already exist in the area.

- If T. latifolia is already established, take note of what developmental stage plants are at.
- Check wind patterns and flow of water to determine what is downstream of Tyla populations.

Restoration Plan:

Nature of the site should determine whether T. latifolia should be preserved/planted or eliminated completely.

Scenario 1: Existing monoculture

Any changes other than seasonal fluctuations in inundation should result in complete removal of T. latifolia through high-intensity grazing or mowing. This should be done once before flowers have matured, and then one month after again. Removal of all green material should result in an effective culling of both rhizome and above-ground plant, but maintenance and management would consist of a seasonal assessment of the site. If plants root, additional mechanical removal may be warranted. When possible, removal of the flower heads, even when immature could further ensure that the plants will not re-establish. When possible, plant species intended to replace T. latifolia from seedings or adult plants in areas where rhizomes do not make replanting difficult. A combination of mechanical and chemical controls may be used where mowing or grazing is not possible, but it is highly unlikely anything other than intensive mechanical removal would eliminate the population completely without rendering site uninhabitable by other species.

Monitoring Plan: Return seasonally and visually assess whether new seeds are rooting or existing plants are surviving. Additional action may be called for to remove additional vegetation. If no plants are seen within 3 years, they have been effectively eliminated from the area.

Scenario 2: Riparian monoculture establishment

The Sacramento and San Joaquin Rivers have both been extensively developed, with bank side adjustments being made to accommodate for commercial, industrial, and recreational use of the waterways. Where natural corridors exist, much of the river banks still experience intense erosion and even installation of rip rap, or degradation of the sediment along the river banks. While the fluctuation of water levels and the pathways it follows is inherent in the nature of the Bay Delta Areas, many sections of riverbank are destabilized to the point of functionless loss of land. In these situations, T. latifolia could be planted to stabilize the sediment or even add organic material which would eventually help to rebuild the riverbanks. Due to the hardiness and low substrate requirements of T. latifolia, it is a viable option in restoring rip rap and industrialized areas along the riparian corridors and due to the lack of other vegetation being able to survive the intense disturbance regimes and lack of nutrients and resources, replanting could be a viable option. However, care would have to be taken as the seeds dispersed by the Tyla could cause problems inland or downstream, as seeds are dispersed through water or by wind. For this reason, this plan should only be implemented in large areas of otherwise non-suitable habitat in a large radius and away from any wind corridors. Planting from rhizomes should be most effective, after slight drought stress. Avoid planting from seed because of possible mis-distribution.

Monitoring Plan: Return seasonally and log area of established plants, if any. Once population is established, a monoculture stand is acceptable to build biomass. Eventually, culling of the Tyla and replanting of other species may be feasible.

Scenario 3 Heterogeneous wetland planting

In a wetland habitat where one is hoping to establish a Tyla population, it is necessary to determine how large the stand will be and it should be placed. Tyla is resilient and hardy and thus should only be planted if there are other resilient species which can compete effectively with the Tyla as to avoid it taking over. If already part of a wetland community it is imperative that one manage the site to make sure that the other species do not get crowded out. Places for Tyla to be planted are low sediment, poor nutrient areas with good water circulation and full sun. As it is able to withstand grazing, salinity and varied ph and substrate, areas such as ranch land and eroded riparian areas would be acceptable locations. Also areas with metal and chemical pollutants could accept plantings to work to filter water and help maintain landmass along edges of water bodies.

Monitoring Plan: Return seasonally and heavy mow or graze at boundary of stand. Ensure other species are not getting crowded out and that circulation is consistent throughout the site.

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Herbaceous Seasonal Wetland Plants:

Restoration of California seasonal wetlands

Mick Van Eck Dos Santos

PART 1

Literature list for “Restoration of California seasonal wetlands- approaches, species, methods”

The references below help in the development of a consistent and solid restoration framework. I used mainly scholar and web of science, but also EPA database, terms included: restoration, ecology, season wetlands, seasonal wetland species, seasonal wetland restoration. They provide an overview of different approaches/methods that have been used and assessed throughout the years, which contribute to a higher efficacy in restoring the seasonal wetlands. I found it difficult to find results about specific species. Also, I was wondering whether “vernal pools” are a synonym of seasonal wetlands?

Initial project design

-Upland vegetation” wild oat (*avena fatua*) Italian ryegrass (*lolium multiflorum),* yellow starthistle (*centaurea solstitalis)*, Russian thiste (*salsola kali*) and sorghum (*sorghum* sp.)

-Seasonally wet margins of drainage bed: curly dock (*Rumex crisputs)*, nutsedge (*Cyperus sp.)* and bearded sprangletop (*Leptochloa fusca)*

Benefits and uses of restoration:

Water quality improvement

Wildlife habitat

Stream mitigation for the DUSD and City Project

Recreation opportunities

Ecological field laboratory for the high school students http://www.cramwetlands.org/documents/CRAM%20application%20tech%20bulletin_FINAL

-great source of research materials, resources & documents

Calhoun, A.J.K., Arrigoni, J., Brooks, R.P. et al. Wetlands (2014) 34: 1027. doi:10.1007/s13157-014-0556-8

- Literature review on mitigation efforts to create/restore vernal pools (same as seasonal wetlands?) in northeastern and central north America
- Maybe some useful recommendations for seasonal wetland restoration approach./methods
    - Monitoring methods
    - Document outcomes
    - Adaptive management

Dennis F Whigham, Ecological issues related to wetland preservation, restoration, creation and assessment, Science of The Total Environment, Volume 240, Issues 1–3, 18 October 1999, Pages 31-40, ISSN 0048-9697, http://doi.org/10.1016/S0048-9697(99)00321-6.

(http://www.sciencedirect.com/science/article/pii/S0048969799003216)

- shows limits of wetland preservation in maintaining national biodiversity (as 46% of the nation's endangered species are influenced by wetland ecosystems)
- highlights the importance of geographic distribution/life history of species, landscape
- hydrology and biodiversity.
- California vernal pools, connectivity between habitats and boundaries between uplands and
- wetlands crucial for regional biodiversity
- Many projects unsuccessful because wetlands are parts of often neglected larger landscapes (with particular goals for a wetland)
- Invertebrate communities different in constructed/restored wetlands compared to natural reference wetlands
- Zedler's 4 principles: large systems have higher biodiversity, thus inclusion in restoration work bigger potential for sustaining regional biodiversity; linkages to adjacent ecosystems (no barriers to water/animal flow) lead to higher biodiversity; specific ecosystem types develop better near similar types; small habitats have reduced resilience and resistance to perturbations
- Restoration of soil conditions important for non-tidal wetlands
- Importance of reference wetland systems: planning restoration efforts; data comparison determines degree of success in restoring biodiversity and ecosystem functioning; in case of

failure/incomplete, data from reference useful for additional measures that enable successful restoration

- Hydrogeomorphic HGM approach: based on ecological principles and reference wetland systems – classification (riverine, depressional, slope, flats, estuarine, fringe and lacustrine fringe wetland); functions based on location, dominant water source, direction of water movement
- Clear need for policy change and more research on ecology of dry-end wetlands
- HGM's 11 ecological functions for temporary and seasonal dry-end wetlands
- HGM advantages: single framework, standardized data, comparison between sites, higher consistency and efficiency in assessment methods
- Importance of reference wetland systems for wetland management.

Dominik Kopeć, Dorota Michalska-Hejduk, Ewa Krogulec, The relationship between vegetation and groundwater levels as an indicator of spontaneous wetland restoration, Ecological Engineering, Volume 57, August 2013, Pages 242-251, ISSN 0925-8574, http://doi.org/10.1016/j.ecoleng.2013.04.028.

- Research in wetland of Poland (protected site) of the potential of spontaneous restoration:
    - relationship of groundwater table and vegetation
    - whether restoration is possible without hydrotechnical engineering

Erwin, K.L. Wetlands Ecol Manage (2009) 17: 71. doi:10.1007/s11273-008-9119-1

- Analysis of potential effects from climate change on wetland restoration
- Ecological and hydrological impacts differ with different systems
- Implications for management

J.E Grayson, M.G Chapman, A.J Underwood, The assessment of restoration of habitat in urban wetlands, Landscape and Urban Planning, Volume 43, Issue 4, 25 January 1999, Pages 227-236, ISSN 0169-2046, http://doi.org/10.1016/S0169-2046(98)00108-X.

- Describes reasons for poor assessment of wetland restoration in urban environments
    - Often no consideration of ongoing large-scale anthropogenic disturbances
    - No clear definition of restoration goals, thus nonconcrete predictive hypotheses formulated to assess success
    - Inappropriate sampling design
- Treat restoration projects as lab experiments for a more effective management in the future

Jansujwicz, J.S., Calhoun, A.J.K. & Lilieholm, R.J. Environmental Management (2013) 52: 1369. doi:10.1007/s00267-013-0168-8

- Overview on Vernal Pool Mapping and Assessment Program (VPMAP)
- Vernal pools/seasonal wetlands, crucial habitat sfor different species including endangered state-listed species (in eastern states)
- Assessment of engagement through municipal officials and private landowners in VPMAP.
- town support for proactive planning, improved awareness and understanding of vernal pools, and increased interactions between program coordinators, municipal officials, and private landowners.
- Overview of challenges for different stakeholders (e.g. inconsistency in expectations, lack of time and sufficient information for follow-up).
- Highlights importance for coordinated and integrated approaches that combine the different goals and views of different parties, leading to effective resource management
- Citizen science model
- “Lessons learned from this research can inform the design and implementation of citizen science projects on private land.”

Joy B. Zedler, Progress in wetland restoration ecology, Trends in Ecology & Evolution, Volume 15, Issue 10, 1 October 2000, Pages 402-407, ISSN 0169-5347, http://doi.org/10.1016/S0169-5347(00)01959-5.

(http://www.sciencedirect.com/science/article/pii/S0169534700019595)

- emphasis on need for habitat-specific advice, importance of landscape context and natural habitats as best reference systems
- provides a list of relevant ecologicaltheories and associated potential actions for restoration/redevelopment
- clear explanation of crucial ecological principles of restoration (**listed)**
- affirms that wetland soil restoration is complicated and perhaps wetland restoration will not match natural ecosystems
- great synthesis of promising “bolder” approaches of experimentation at different scales that help improving predictability (**listed)**

Lichko, L. & Calhoun, A. Environmental Management (2003) 32: 141. doi:10.1007/s00267-003-2967-9

- Purpose: determine whether vernal pool creation replaced key vernal pool functions
- How: assessing project goals and documentation (including mitigation plans, pool design criteria, monitoring protocols, and performance standards).
- Results: creation attempts fail in replicating lost pool functions
- Why:

  - “Pool design specifications are often based on conjecture rather than on reference wetlands or created pools that function successfully. Project monitoring lacks consistency and reliability, and record keeping by regulatory agencies is inadequate.”
- More protection of vernal pools and standardization is needed to maintain long-term landscape functions of vernal pools.

Mary E Kentula, Perspectives on setting success criteria for wetland restoration, Ecological Engineering, Volume 15, Issues 3–4, July 2000, Pages 199-209, ISSN 0925-8574, http://doi.org/10.1016/S0925-8574(00)00076-8.

- Compliance success depends on terms of contract/permit
- Functional success depends on the restoration of ecological functions
- Currently, shift from individual project (specific system/site) to landscape scale
- Landscape success measures improvement of ecological integrity of landscape/region and goals like biodiversity preservation
- Usually vegetation is measured, nut less frequently soils, fauna or hydrologic
- How to recognize and deal with uncertainty: use scientific principles of hypothesis testing and model building in adaptive management framework

State and Federal Contractors Water Agency. 2013. Final Lower Yolo Restoration Long Term Management Plan. Sacramento, CA

- -“official” report that shows a long term management approach of different habitats
- -includes wetlands, its properties (topography, soils, hydrology) and monitoring methods
- -defines site-specific management/restoration strategies

A wetland is commonly defined as a land area that is saturated with water, either permanently or seasonally. Seasonal wetlands are wetlands that are inundated part of the year, involving water cycles influenced by environmental and climatic conditions. Such hydrological cycles are mainly determined by fall flooding, drawdown during the warm spring and summer seasons, as well as irrigation applied. Usually, water is added to the system to maintain soil moisture and avoid runoff during droughts. (Climate Change Vulnerability Assessment: Seasonal Wetlands). Thus, seasonal wetlands are flooded during fall and winter, until drawdown starts in the spring. Different annual plants germinate in spring and summer (also known as “moist-soil plants”), providing waterfowl with crucial seeds, browse, tubers etc. In general, Central Valley’s wetlands are managed to improve habitat for waterfowl.

Restoration in the Central Valley is critical given that the extent of regional seasonal wetlands has been reduced to 5% of the original wetlands since the 1850s (Climate Change Vulnerability Assessment: Seasonal Wetlands). Even though some agricultural crops (e.g. rice) may have similar benefits, many other ecosystem functions/services have been lost throughout the years. Specific functions of seasonal wetlands include food production, increase in groundwater amounts, protection from floods and provision of habitat for (migratory) birds. In fact, Central Valley is home for most wintering waterfowl in North America.

Changes in hydrogeological conditions, introduction of invasive species and global warming are some of the negative anthropogenic impacts on these valuable systems (Jansujwicz et al., 2013). Seasonal wetlands are threatened by human activities such as land use change, nutrient loading, increased runoff from urban environments, the fossil-fuel economy (associated with greenhouse gas emissions) and spread of problematic species in general.

On the other hand, humans have developed key enhancements to the natural processes that support/substitute wetland functions. Regarding management of wetlands, irrigation, change in land use (e.g. by restoring original ecosystems where natural land areas were converted to farmlands), the use of disturbance regimes and mitigation strategies are some examples of practices that aim at maintaining or restoring seasonal wetlands. Besides, the development of flooded crops can also stimulate (native) biotic communities from the region. Loss of seasonal wetlands is often avoided through: prevention/protection of the ecosystems, long term standardization & monitoring (Lichko, & Calhoun, 2003).

Key climate factors: precipitation amount/timing, snowpack amount, timing of snowmelt/runoff

Core species used

(Typically) undesirable plants: Cocklebur, sweet clover, river bulrush, tuberous bulrush, Baltic rush, jointgrass, dock, salt grass..

Wildlife-Valuable Moist-soil plants in Central valley:

- watergrass (Echnochloa crus-galli – non-native)
- swamp timothy (Crypsis schoenoides, non-native)
- smartweeds (Persicaria amphibia native perennial herb (aquatic), P. punctate –native perennial, P. hydropiper –non-native)
- sprangletop (Leptochloa fusca, native annual)
- Ammannia coccinea, native annual herb
- Chufa (Cyperus esculentus,non-native)
- Burhead (Echinodorus berteroi, native perennial aquatic herb)
- Beggarticks (Bidens laevis, native perennial herb)
- Atriplex spp. (native annual herb)
- Goosefoot (Chenopodium album, non-native annual herb)
- Brass buttons (Cotula australis non-native annual herb; C. coronopifolia = invasive perennial herb)

Moderately valuable to wildlife:

- pricklegrass (Crypsis schoenoides/vaginiflora – non-native annual grass)
- alkali heath (Frankenia salina – native perennial herb)
- alkali weed (Cressa truxillensis – native perennial herb)
- Bermuda grass (Cynodon dactylon, native perennial)

Other seasonal wetlands species:

- Rushes (Eleocharis and Scirpus spp): giant, river olub, tussook, spiny, jointed,
    - bulrushes (Schoenoplectus spp.), alkali bulrush (Bolboschoenus maritimus, native perennial herb)
- Sedges (Cyperus spp., Carex spp) natives: tall, umbrella, tell flat
- Nutgrass (Cyperus rotundus, non-native perennial grasslike herb)
- Docks (Rumex spp. Perennial

    - natives: R. *crassus,dentatus, fueginus, occidentalis, salcifolius, transitorious, violascens)*
    - non-natives: R. conglomeratus, crispus, obtusifolius, pulcher
- Cattails (*Typha* spp.)
- Brooklime (native perennial herb *Veronica americana*)
- Pennywort (native perennial herb *Hydrocotyle verticillata*)
- Water buttercup (native perennial herb Ranunculus alismifolius; non-native perennial R. acris)
- Arrow head (*Sagittaria* spp., e.g. S. *montevidensis* – native perennial)

Composition of plant species along a flooding gradient is related with timing of water removal in the spring (drawdown, through evaporation or draining), (pre-existent) seed availability, succession stage and weather conditions. Moreover, given the spectrum of different management goals for seasonal wetland restoration, one can stimulate the conditions necessary to encourage desired and control undesired plant species.

A study conducted by Fredrickson and Taylor (1982) shows a simplified overview of distribution of early/late succession species along an elevation gradient (from borrow areas/deep water depth to levees or areas where soil dries faster).

This pattern is used as a recommendation for this project in the Central Valley, but is by no means intended as end-goal of the restoration process.

Increasing water depth and soil moisture

early successional (mid-late germination) species:	Late succession (early germination) species:
Berggaticks	Aster
Common Ragweed	Broosedge bluestem
Barnyardgrass	Joe-pye-weed
Chufa flatsedge	Blunt spikerush
Common cocklebur	Indigobush amorpha
Crabgrass	Sedges
Panic grass	Trumpetcreeper
Redroot amaranth	Rice cutgrass
Smartweeds	Spikerush
Arrowhead	Beakrush
Purple loosestrife	Blackwillow
Redroot flatsedge	Rushes
Toot-cup	American lotus
Bulrush	Buttonbush
Cattail	Marhspurslane
Marshpurslane	Swamp smartweed
Pondweed	

Approaches to restoration

Depending on desired species, different methods of planting/revegetation should be applied. This occurs either by seed or transplanting from a plant nursery.

-Drawdowns

early: high total seed production

late: higher stem densities and greater species diversity

slow (early in the season, 2 weeks or more): diverse vegetation cover

fast (within a few days): extensive stocks of similar vegetation, forcing of wildlife

Irrigation is another practice that is strongly recommended during Summer in Central Valley wetlands. Water in this phase of the year could have a significant impact on seed production/waterfowl supply. However, this could be a challenge given that water is an expensive resource and must be managed sustainably throughout the state of California. Please see http://www.centralvalleyjointventure.org/assets/pdf/Naylor_Final_Thesis.pdf for more info

-Summer irrigation (high financial and environmental "costs")

slows rate of drawdown (that enables soil saturation for longer periods)

production 2x higher than non-irrigated wetlands

helps mitigate drought

enable growth of native/wetland species

could promote mosquito hatches

Approaches to invasive management

A study conducted by **Naylor** on behalf of the Central Valley Joint Venture demonstrates the effectiveness of disking in enhancing seed production and controlling undesired species in the Central Valley region. This practice is mainly pertinent in the spring (to limit succession) and fall (creating water retention areas after flooding and increasing vegetation interspersion). Notwithstanding, this could have negative effects on habitat quality and food availability.

To control invasive species, the use of chemicals is often considered a more efficient measure, even though it also can have large drawbacks if not applied carefully, according to regulations and instructions on herbicide-packaging.

Careful and efficient use of permitted herbicides is required to control invasive species. The site's main weeds are annual grasses, but some native grasses are found within the plant community. These should be flagged/marked to avoid spraying them during weed control. Excessive use not only poses threats to the (ground)water system, but also means higher economical costs and risks of herbicide-resistant selection of organisms (induced or artificial selection). The herbicides applied should be selected in line with the target (invasive) species, as well as considering the chemicals that are allowed for use in such a project, according to the California Department of Pesticide Regulation (CPDR). In specific, certain materials can be used under a permit issued by the County Agricultural Commissioner (CAC). An overview of Restricted materials and permits can be found in the list available at the CPDR website (http://www.cdpr.ca.gov/docs/enforce/dpr-enf-013a.pdf)

-Soil disturbance (however, invasive species tend to grow on bare soil as well so really important to limit this to situations whereby desired species are being outcompeted/dominated by undesired species)

- Disking (leads to increased seed production)
    - Apply disking during Spring or just before the Summer, which may be a cost-efficient way of limiting succession and the spread of invasive species, but could have negative impacts on wildlife and total primary productivity as well
    - Another method is to execute multiple disking in the summer - best in case of wetlands dominated by nuisance plants.
    - (Fall), annual disking (moderate or intensively, on more than 50% of restoration site) has a strong, positive effect on moist-soil seed production. This shall also reduce the threat of potential (invasive) plants that would otherwise outcompete target vegetation. On the other hand, this method leads to increase in highly productive annuals, which require disturbance to germinate. However, the beneficial effects of this practice can

take a long time to emerge, and even seem threatening in the first year whereby stem density is reduced (depending on specific species to be restored). In the short-term, annual disking in fall can also decrease the potential of food availability and/or habitat quality.

- Mowing during late Spring, just before flowering so that spread of seeds from invasive species is prevented
- Burning should occur during late Spring as well, for the same reason as mowing; this methods has the advantage of depleting soil seedbanks, clearing of competitive vegetation and thus also releasing previously unavailable resources
- Hand weeding if time is not a constraint; however, is usually not cost-effective nor suitable for typical restoration goals
- Solarization for 3-6 weeks (kills invasive annual plants but not perennial ones)

Consideration of Zedler's (2000) ecological principles:

-*Landscape context, position and alteration* – the project should be well-placed to compensate for lost ecosystem functions

-*Natural habitat types as reference systems* – generic restored wetlands often will not support regional biodiversity unless reference systems are taken into account; shifts in habitat types and species composition are likely to occur without reference systems

-*Historical records about specific hydrological regimes and environmental factors is crucial* – flooding patterns change overtime through filling, dams, levees, water diversions and groundwater pumping; effective restoration plans should include a record of historical activities that alter the hydrology of seasonal wetland; natural recruitment of the diverse desired species equally requires history traits of environmental conditions that favor certain communities

-*Ecosystem services have different investment/time demands*

-*Biodiversity development depends on nutrient supply rates* – soil amendment using P, N, affect species' distribution (e.g. grasses required high nutrient-input, whereas fen species do not). Thus, clear delineation of target species and nutrient supply rates is crucial.

-*Specific disturbance regimes may maximize species richness* – definition of desired species enables the applicationof disturbances that increases their richness on the site.

- *Vegetation recovery depends on seed banks and dispersal* – For an efficient restoration project, knowledge on seed banks and dispersal among native and invasive species is essential.

- *Succession theory* – invasive species may dominate restored seasonal wetlands if succession patterns are neglected; ecosystems are continuously changing, especially in disturbed habitats.

By looking at eventual outcomes (from previous projects/reference sites), a pro-active plan can and should be designed for restoration.

- *Genotypes affect ecosystem composition and services*

These principles form the “hydrogeomorphic approach”, based on location and dominant water sources. First, it is important to restore soil conditions according to reference sites. It is also important to include large system to sustain regional biodiversity, providing linkages to adjacent ecosystems if these are intact.

The more commonly used restoration approaches involve species control, by introducing specific organisms on the site (thus “botanical/zoological engineering” methods). A more sustainable and perhaps efficient approach is one called “self-design”, which relies on natural processes like colonization, competition, nutrient cycles, population dynamics etc. It involves an autonomous organization of an ecosystem like a seasonal wetland, whereby environmental conditions determine the introduction and selection of species (see Mitsch et al., (1998) for more information). This leads to an optimal design and diversity of locally adapted species in the long-term. However, most restoration projects must achieve certain goals within few years or even months, while investments on such initiatives require some sort of measurable and fast outcomes.

Plants need to be protected

Irrigations are crucial in Central Valley during spring and summer (especially for waterfowl food plants, except for Swamp timothy). Well-timed irrigations enhance maximum seed production. Wilting signs can be used for plants such as smartweed and watergrass. Obviously, water necessities vary by species, which should be specified during in a restoration plan.

Regulations

One of the main regulations around wetland restoration projects is the US Clean Water Act (CWA). CWA requires compensation for materials deposited into wetlands, thus often leading to restoration or creation of wetlands. In general, permits imply monitoring to control if standards/goals are achieved

(Zedler, 2000). Thus, restoration entities are increasingly responsible for outcomes, which typically should match standards from a reference site in a short time frame (e.g. 5 years). Typical conditions of permits include high cover of native plants, data showing water quality improvement, increase in biodiversity and other ecosystem functions. However, such goals often involve complex trade-offs, excluding the option of creating simple models for all the services desired from (seasonal) wetlands. It is ineffective to generalize models for different wetland types. Therefore, habitat-specific and dynamic approaches are needed in each restoration site.

If herbicides are used, it is pertinent to consider not only the federal restrictions, but also the regulations from the CPDR which are known for being more strict and instructive. (See more in *Approaches to invasive management* section).

Approaches to follow-up management

Given that seasonal wetlands are subject to continuous change due to chemical and physical processes such as floods, droughts and fires, its management must be flexible and dynamic as well. Water management is likely to demand periodic soil and vegetation disturbances. A solid water conveyance system is crucial, developing lasting water structures such as pumps, ditches, and drainage systems. Follow-up assessment of plant populations should occur while they are still small as they are easier to control in this stage.

Applicate herbicides for specific species, and stimulate diversity for natural biological control (through natural enemies for example).

Evaluation and of success and monitoring can be made through analyzing establishment of desired species within 5 years. Moreover, education and engagement with future managers can be pertinent to enhance weed detection and reduce invasiveness likelihood in the next years.

Approaches to monitoring

This section depends strongly on the species the project aims at. One can expect a reestablishment phase of at least 2/3 years, whereby maintenance and monitoring are crucial for the success of desired species.

- Monitoring should include
  - Description of ambient conditions at existing seasonal wetland
  - Characterization of improved/degraded/unaltered state of restored wetland using data from absolute cover and relative cover analysis through time
  - Identify limits of system stressors (how much disturbance can occur without damaging quality of wetland systems
- For collection of information and statistic analysis
  - stratified random sampling
  - targeted/tiered approach, and before/after
  - control/impact (BACI)

With clear management goals, one of the monitoring targets can be performance scores for these goals/criteria. This helps to retrieve an image of the progress within the plant community of the restored seasonal wetland, which can be useful to adapt management plan/goals. For example, for transplanted, seeded and desirable (selected) herbaceous wetland species, cover can be monitored by using a 1-meter-square quadrat-transect method. Hereby, one can visually measure absolute cover and/or relative cover as soon as blooming occurs (thus between April and June, as suggested in the "2007 initial project design" document) during at least 4 years. Other methods include sampling of vegetation and/or photography to describe plant community composition (invasive and native plants) and structure, as well as to define temporal/seasonal patterns that can play a role on the restoration of the site. Also, patches dominated by unexpected (invasive or even native) species or areas where progress is not observed despite the expectations from the implementation of the proposed management plan can be mapped using GPS. If "controllable areas" are identified, these can be managed more profoundly so as to expand their desirable characteristics.

For examples of sampling design, see http:// www.epa.gov/owow/wetlands/bawwg/case.html.

There are many approaches to evaluate wetland conditions, choices should be made according to management goals.

Summary

Prior to implementing a vegetation management program for the seasonal floodplain of the site, it is crucial to develop concrete goals and targets. Hereby it is also important to determine which species can interfere with management goals, so that these can be avoided throughout the program. Then, a plan that includes methods for weed management can be designed effectively. Drawdown, disking and/or controlled burns (eventually combined with the application of herbicides if invasive species persist) are some of the techniques that can be applied, most conveniently before the Summer. Depending on the main goals of the site (bringing back wildlife, purifying water and/or flood risk mitigation) and the botanical/animal species to be reintroduced, restoration methods can vary a lot within the project boundaries. Hereafter, the management plan can be implemented (e.g. revegetation of native species) so that the set-targets can be met. To measure success - which implicitly relies on a more or less "biased" perspective - monitoring and assessment of management effects is executed. With this information, the pre-existing goals, priorities and strategies for the plant community are reviewed. Again, there are many options available - mowing, fires, solarization, herbicides, etc. – and all of these have advantages and disadvantages, perhaps becoming relevant in different phases of the restoration process. Finally, the updated management plan can be implemented, closing the cycle of restoration.

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California goldfields (Lasthenia californica)

Kathryn Canepa

Part 1

I. BACKGROUND AND JUSTIFICATION

The California goldfields (*Lasthenia californica*) are a native herbaceous annual flower found throughout most of California, with records dating back to the late 1800s in Solano County (CalScape 2014). *Lasthenia californica* subsp. *californica* are the true California goldfields, but there are two other subspecies – perennial goldfields (*Lasthenia californica* subsp. *macrantha*) and Baker's goldfields (*Lasthenia californica* subsp. *bakeri*) – that have both been designated endangered rare plants under the California Rare Plant Ranking System, meaning over the last one-hundred years they have declined within their range. There is no listing for the subspecies California goldfields (California Native Plant Society [CNPS] 2017). There are many races within the species, each specially adapted to certain conditions and soil types, thus enabling them to occupy varying habitats throughout the state (Ornduff 1966). Because of this unique phylogeny and distribution, they are valuable for studies on evolution and speciation (Rajakaruna et al. 2003). *L. californica* is versatile and produces high volumes of easily-collectible seeds, therefore it is commonly used in restoration seed mixes (Moore et al. 2011). It also provides habitat value for pollinators, attracting native bees and butterflies (CalScape 2014). Unfortunately, existing literature that specifically discusses restoration implementation and management for this species is scarce, which highlights a need for further study and documentation.

II. LITERATURE REVIEW

Plant & Reproduction Characteristics

- *L. californica* is a fast-growing annual that grows in dense patches. The size of individual plants is extremely variable depending on site conditions and amount of rainfall, but rarely exceeds six inches in height (Ornduff 1966).
- When naturally occurring in a California grassland, *L. californica* begins to germinate after fall rains, typically around November. Germination continues until December (Hobbs & Mooney 1985; Reynolds et al. 1997). The seedlings that germinate earlier tend to have lower mortality than those that germinate in December (Hobbs & Mooney 1985).
- This species begins flowering in late March, with a bloom period of March to May (Ornduff 1966; CalFlora 2017).

- Seeds fall in late May to early June (Hobbs and Mooney 1985). Most seeds germinate in the season within which they fall; seed banking has not been observed in this species (Ornduff 1966).
- Overall, the species has a low and constant (linear) mortality rate throughout the growing season until after the seeds fall (Hobbs & Mooney 1985). In inland California, the parent plants tend to die in May (Ornduff 1966).
- *L. californica* is not self-compatible and requires pollination by insects (Ornduff 1966). It is commonly pollinated by native bees and butterflies (CalScape 2014).
- It disperses through wind, attachment to animals, and gravity (Ornduff 1966). Dispersal distance is short: unaided by transport or wind, seeds rarely fall beyond a radius of 2.5 feet from the parent plant (Hobbs & Mooney 1985), and the norm is 5-50 cm (Moore et al. 2011).

<u>Habitat Tolerances</u>

- *L. californica* belongs to a plant Alliance with *Plantago erecta* and *Festuca microstachys.* This alliance is characterized by its tolerance to California's Mediterranean climate and can persist in high stress habitats, such as nutrient-poor soil (California Native Grassland Association 2016; CNPS 2017b).
- *L. californica* is unique in that it occupies an extremely wide range of habitats through California (Ornduff 1966). These include Sierra Foothills, the Coast Range, coastal prairie, meadows, flats, native grasslands, and woodland understory (CalScape 2014). It is occasionally found in wetlands (CalFlora 2017). It is part of the plant communities Northern Oak Woodland, Valley Grassland, Foothill Woodland, Coastal Prairie, Northern Coastal Scrub, and Coastal Sage Scrub (CalFlora 2017).
    - Additional resources for plant communities:
      http://geog.berkeley.edu/ProjectsResources/CalPlants/califplanttable.html
      http://www.laspilitas.com/nature-of-california/communities
- *L. californica* is a generalist at the local/site scale: it has been observed living specifically in or near vernal pools by some researchers, but occupies other habitat as well (Emery et al. 2012). In a study done in a vernal pool landscape, it generally occupied the uplands surrounding vernal pools but encroached closer to the pool boundaries than other species within the genus *Lasthenia* (Emery et al. 2012).
- It prefers soils with moderate drainage (CalScape 2014). However, studies have found that the species is more abundant in years of greater rainfall (Hobbs & Mooney 1991). Additionally, one study found a correlation between the areas where *L. californica* established and high soil water (Reynolds et al. 1997) This indicates a tolerance for wet conditions. It is also able to persist under low-water conditions (CalFlora 2017).
- *L. californica* prefers very slightly saline soil (Electrical Conductivity of 2.9 mmhos/cm) with neutral pH ranging from 6.1 to 8.1 (CalFlora 2017). The preferred minimum depth of soil is 9 inches (CalFlora 2017), but it has been found to tolerate very shallow soils of only 4 inches in depth (Reynolds et al. 1997).

- It has a wide tolerance for soils of varying textures (including heavy clay, fine sand, coarse gravel, and alluvial loam) and varying parent material (including serpentine, granite, basalt, and gypsum) (Ornduff 1966). However, races of this species are adapted to specific edaphic conditions and may have reduced fitness if removed from their ecotype (Ornduff 1966).
- Two distinct races of this species, Race A and Race C, have diverging tolerances for soil ion levels. Race A is found in stressful soil conditions where ion levels are high, e.g. serpentine soils, salt flats, and alkaline flats. Race C is found in milder habitats, such as inland pastures, roadsides, and open fields. Race C may be subject to reduced fitness in habitats characteristic of Race A (Rajakaruna et al. 2002).
- *L. californica* prefers a climate with temperature ranging between 16 and 61 degrees Fahrenheit (CalFlora 2017).
- Part-shade/part-sun conditions are ideal, though it can tolerate full-shade (Calscape 2014; CalFlora 2017).

<u>Biotic interactions</u>

- *L. californica* is pollinated by native bees and butterflies (CalScape 2014; CalFlora 2017), including the Bay Checkerspot butterfly, a federally threatened species that feeds on its nectar (Harrison et al. 1988).
- When seeded in gardens, it does well with Blue gilia, Baby blue-eyes, *Clarkia*, Lupine, and Checkerbloom (CalScape 2014). There is a lack of information on what plants it can coexist with in a natural setting, but this information indicates that it be successful in close proximity to other native forbs.
- *Plantago erecta*, the California plantain, has been shown to be a significant competitor for *L. californica* (Hobbs & Mooney 1991; Reynolds et al. 1997). Under low rainfall conditions, *P. erecta* may be able to outcompete *L. californica* for space (Hobbs & Mooney 1991). Reduced biomass and lower survivorship in *L. californica* has been observed when planted in a patch with *P. erecta* (Reynolds et al. 1997).
- Another competitor for *L. californica* is *Calycadenia pauciflora*, the smallflower western rosinweed. One study found that when supplied with more water, *L. californica* increased its aboveground biomass when competitors were absent and the soil had high water retention. However, more water did *not* result in significantly increased biomass for *L. californica* when it was grown in the presence of *C. pauciflora* (Eskelinen & Harrison 2015).
- Competition with *Aegilops triuncialis*, invasive barbed goatgrass, reduces the performance and reproductive fitness of *L. californica*, inducing later flowering and a greater allocation of resources to roots rather than aboveground biomass and flowers. Later flowering may mean that seeds drop later and thus will be more susceptible to decreasing water availability as spring moves into summer (Batten et al. 2008). The allocation of resources by *L. californica* is likely induced by nutrient stress as the invasive grass changes properties of the soil microbial community (Batten et al. 2008).

Changes in the soil microbial community happen quickly – within two months – following invasion by the grass (Batten et al. 2008). The reduction in fitness for *L. californica* likely paves the way for further invasion by the goatgrass (Batten et al. 2008).

- Gopher disturbance may have a negative effect on how successful *L. californica* is at establishing at a site, based on findings that indicated *L. californica* had difficulty establishing on gopher mounds (Hobbs & Mooney 1985; Hobbs & Mooney 1991). The researchers observed a lower abundance of the goldfields in a disturbed site compared to a control site, even five years after the initial disturbance (Hobbs & Mooney 1991).
- Herbivory of *L. californica* by *Bruchidius cisti (*a bean weevil) was observed in a California grassland in Napa County. The beetles reduced the reproductive fitness of *L. californica* by eating the flower heads (Eskelinen & Harrison 2015).

<u>Restoration and management considerations</u>

- Within this species, there are multiple races that are specially adapted to particular soils and ecotypes. One race may do poorly in conditions it is not adapted to (Ornduff 1966). Care should be taken in selecting a seed source for restoration.
- When seeded in bare soil, *L. californica* has been observed to have a 40% germination rate (Reynolds et al. 1997).
- *L. californica* grows in dense patches. Being in close proximity (within 250 meters) to an existing patch of conspecifics has proven to be the best predictor of seeding success (Moore et al. 2011).
- Because of its relatively erect structure compared to other grassland herbs, *L. californica* cannot tolerate cattle grazing. In a study done in a southern-California grassland, *L. californica* was absent from a periodically-grazed portion of the grassland and was negatively affected by clipping in a controlled experiment (Kimball & Schiffman 2003).
- This species is sensitive to organic matter mulching treatments, especially heavy mulching: under experimental conditions, *L. californica* was entirely absent from the heaviest mulch treatment patch (Heady 1956).
- Abundance of this species in a given year is positively correlated to rainfall in the previous year (Hobbs & Mooney 1991; Reynolds et al. 1997). An increased supply of water more effectively enhances its reproductive fitness when the soil has high water retention, a characteristic quality of non-serpentine soils in California grasslands (Eskelinen & Harrison 2015).
- One study found that *L. californica* became more abundant in the growing season after a wildfire. This was likely due to increased nutrients from the fire and thatch removal (York 1997).

<u>Key Knowledge Gaps</u>

- Success of distinct races in the Central Valley
- Response of California goldfields to fire

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Part 2

I. GOALS

The California goldfields are an extremely versatile native forb that can occupy a range of habitats and conditions (Ornduff 1966). For this reason, they are ideal for restoration projects. Though little information that specifically addresses management of California goldfields in restoration exists, the following goals have been developed out of a review of existing knowledge about the species. Goal 1 is likely to be the simplest to achieve, while Goal 2 and Goal 3 will be easier or harder to achieve depending on the existing climatic and spatial conditions of the proposed restoration site.

1. Establish a self-sustaining population composed of two or more patches of *Lasthenia californica.*
    a. It should be possible to establish patches at any size, so the size can be dictated according to site-specific needs and available area, but for greatest pollinator benefits (see Goal 3) the patches should be 30 square meters or larger and reach close to 100% cover.
    b. *L. californica* is a fast growing annual, so within two growing seasons (and possibly in the first after seeding) the intended area for the patch should be densely covered by the species. *L. californica* spreads a lot of seed and does not have seed banks, so in subsequent years seedlings will germinate the season in which they fall (Ornduff 1966). The seeds most commonly disperse through gravity and generally do not fall more than a few feet from the parent plant (Hobbs & Mooney 1985; Moore et al. 2011), so outward growth of the patches is likely to be minimal if it occurs. The patches should not shrink.
    c. Multiple patches should be located within at least 250 meters of each other, as *L. californica* has been found to have greater establishment success when located near other conspecifics at this spatial scale (Moore et al. 2011), which indicates there are benefits to proximity.
2. Increase the fitness of the population by siting *L. californica* patches away from disturbances and competitors that have been shown to have a negative impact on the species.
    a. Avoid grazing or mowing, which has been found to reduce the reproductive fitness of *L. californica* (Kimball & Schiffman 2003). Do not establish *L. californica* patches in places where gopher activity is prevalent, because they have trouble establishing on the mounds (Hobbs & Mooney 1985;1991). The prevalence of beetles should be monitored and controlled, as beetle herbivory has been observed on *L. californica* (Eskelinen and Harrison 2015).
    b. Control or prevent the establishment of competitors like the California plantain (native), smallflower western rosinweed (native), and barbed goatgrass (invasive) (Hobbs & Mooney 1991; Reynolds et al. 1997; Eskelinen & Harrison 2015; Batten et al. 2008). The native competitors may outcompete *L. californica* in low rainfall years (Hobbs & Mooney 1991; Eskelinen & Harrison 2015), and therefore percent

cover of these species on the site should not exceed that of *L. californica.* Invasive grasses should be kept out altogether, as they may change the soil microbial community in a way that facilitates further invasion (Batten et al. 2008).

c. *L. californica* does well with other native forbs in a garden landscape and thus can be sited near Blue gilia, Baby blue-eyes, *Clarkia* sp., Lupine, and Checkerbloom (CalScape 2014).

3. Provide habitat for pollinators such as native bees and butterflies.

a. Native bees and other pollinators are often impacted by habitat fragmentation, especially when they have a short dispersal range (Blaauw & Isaacs 2014). Therefore, patches should be near each other (250 meters or less) (Moore et al. 2011).

b. A study done in Michigan on pollinator-patch dynamics observed greater variety and density of native bees at wildflower patches that were 30 square meters and 100 square meters compared to smaller patches (Blaauw & Isaacs 2014). Though conditions in the California Central Valley might be different, there is limited information available for *L. californica* surrounding pollinator-plant interactions, and since *L. californica* are wildflowers that get pollinated by native bees (CalScape 2014), the Michigan study is likely generalizable. Therefore, 30 square meters or larger should be the patch size to aim for at the site.

c. In the Michigan study, the researchers found that pollinators were best predicted by greater wildflower diversity in patches (Blaauw & Isaacs 2014). Therefore, siting *L. californica* near other noncompetitor wildflowers it has been observed to do well with, such as Blue gilia, Baby blue-eyes, *Clarkia* sp., Lupine, and Checkerbloom (CalScape 2014) would increase the chances of attracting pollinators.

II. MANAGEMENT PLAN

1. <u>Pre-restoration</u>
    a. Gather data from the proposed restoration site. Designate boundaries for upland areas and swales (edges of wetlands). Determine soil type and texture, as well as any other information available, such as significant nutrient richness from possible outside sources. Collect pH and soil salinity data. This step is crucial, because although *L. californica* is an incredibly versatile species and can persist under a wide variety of conditions, there are multiple races of this species that are specially adapted to certain edaphic conditions (Ornduff 1966). Knowing the initial conditions of the site will inform what source to get seeds from.
        i. *L. californica* can tolerate serpentine, granitic, basaltic, or gypsum soils of varying textures, including heavy clay, fine sand, coarse gravel, and alluvial loam (Ornduff 1966).
    b. Collect seeds from appropriate natural sites that have conditions similar to the proposed restoration site or purchase from a nursery that knows the source of its seed. For example, if the proposed restoration site has nutrient poor soil, ensure that the nursery does not get their seed from plants that are fertilized, to reduce the amount of management needed. If matching the proposed restoration site conditions is not feasible, establishment of *L. californica* may not be as successful but it is unlikely to fail completely, considering the adaptability of the species.
    c. Reynolds et al. (1997) describes the number of plants needed for low density plots (4750 plants per square meter) and high density plots (9500 plants per square meter). Two-and-a-half times the desired number of seeds should be collected, based on a 40% germination rate (Reynolds et al 1997). Thus, if a proposed patch is going to be 30 square meters and low-density, 356,250 seeds are needed based on a 40% germination rate: $\frac{4750}{0.40} \times 30$.
        i. According to the S&S Seeds website (2012), there are about 1,750,000 *L. californica* seeds in one bulk pound.
    d. Take inventory of any existing plant and animal species. Check for invasive grasses (most notably, barbed goatgrass, *Aegilops triuncialis*) as their effects on the microbial composition of the soil can hinder the reproductive fitness of *L. californica* and potentially cause a positive feedback effect for further invasion (Batten et al 2008). If present, they should be killed and removed.
2. <u>Restoration</u>
    a. Choose an appropriate location on the site where the patches will be established. The area should have no invasive grasses and gopher activity (Batten et al. 2008; Hobbs & Mooney 1991) and ideally would have neutral to very slightly alkaline soil (with pH 6.1-8.1) and very slight salinity (CalScape 2014; CalFlora 2017). Upland areas with well-drained soil in full or partial sunlight are best (CalScape 2014; CalFlora 2017). However, the species may be able to establish in swale areas if they

are not always inundated, based on research that found *L. californica* to occasionally exist in and close to the edge of vernal pools (Emery et al 2012). It can also tolerate shadier conditions if necessary but sun should be a strong priority (CalFlora 2017). The patches should be located no further than 250 meters away from each other (See Goal 1).

b. Determine the desired size and density. To work towards the goal of increasing pollinator habitats, ideally the patches will eventually have a variety of wildflowers in them (Blaauw & Isaacs 2014), therefore a low density (4750 plants per square meter) might be beneficial to allow the addition of more species in subsequent years. To account for the 40% germination rate, the number of seeds used should be 2.5 times the desired number of plants (Reynolds et al 1997).

c. **Plant the seeds.** *L. californica* grows in dense carpets and has a very small seed, so planting seedlings would not be feasible because it would be too time-intensive (Ornduff 1966). Seeds should be planted in late summer or early fall before the onset of the fall rains (Late September or early October, depending on the location in the Central Valley and when the first rain is forcasted to come). Seeds can be expected to germinate following the rains, typically around late October or November (Hobbs & Mooney 1985).

- **i.** There is limited information available about seeding practices for this species in particular. However, Reynolds et al (1997) briefly describes seeding measures for *L. californica* in their field experiment that will likely work for restoration purposes, and the Tree of Life Nursery (2016) and Las Pilitas Nursery (2012) have information on seeding California wildflower mixes. Appropriate procedure for planting is as follows:
- **ii.** Kill any non-native grasses and weeds and remove from the site to reduce the chance of them interfering with *L. californica* (Las Pilitas Nursery 2012).
- **iii.** Loosen the soil in the patch area with a metal blade or tool. Distribute the seeds evenly over the area and cover them lightly with the loosened soil so they are about ¼” or ½” covered (Reynolds et al. 1997; Tree of Life Nursery 2016). Ideally, a handheld broadcast seeder would be used to get even distribution of the seed (Joey Dorrell, personal communication May 16, 2017). A substrate like sand can also be added to the seeds before broadcasting to add weight to the mix and prevent uneven distribution (Tree of Life Nursery 2016).
- **iv.** Depending on the rain patterns after the seeds are broadcast and habitat type where the patches are being established, initial watering may be needed to facilitate germination. In a low rain year, it may be difficult for the seeds to germinate as the species has been found to be more abundant in years of higher rainfall (Reynolds et al 1997). If adding supplemental water, it should be minimal and just enough to keep the soil moist during the germination period, from around October to December. Watering should not be necessary after the flowers bloom (Tree of Life Nursery 2016). *L. californica* prefers upland areas but can also be tolerant of wetter soil (CalScape 2014; CalFlora 2017); if patches are seeded in near wetland conditions supplemental water should not

be necessary unless the soil where the seeds were spread is dry for significant periods of time (Tree of Life Nursery 2016).

v. There is some uncertainty surrounding the use of mulch. In many cases, after seeding patches of wildflowers, organic mulch is used to retain moisture until germination (Tree of Life Nursery 2016). However, Heady (1956) found that *L. californica* was very sensitive to heavy organic matter mulching treatments, and Las Pilitas Nursery (2012) does not recommend mulch for wildflowers in general. Therefore, mulch should be avoided or used extremely sparingly.

III. MONITORING PLAN

1. <u>Pre-restoration</u>

a. As described above in Step 1 of the Management Plan, collect the following data:

i. pH, salinity, texture and type of soil

ii. Nutrient input to the site

iii. Habitat types

iv. Existing plant and animal species at the site

2. <u>During and after restoration</u>

a. Ideally, monitoring should happen frequently at every life stage of the goldfields during the first growing season, and the next year at germination and bloom time. *L. californica* is an annual and dies in late spring or early summer, but successful plants should disperse their seed and therefore the patch will return in late fall (Ornduff 1966). After the second growing season, if patches have not experienced significant setbacks (see "Potential Problems" below), monitoring should not be necessary beyond checking the density and size of patches every year in early spring (unless more intensive research efforts are happening).

i. Record the area of the patches that are seeded and the approximate number of seeds used at the beginning of restoration efforts.

ii. Throughout the growing season, *L. californica* should have a fairly constant mortality rate before seeding in late May and early June, according to Hobbs & Mooney (1985). Ideally, the patches should be monitored from germination until seeding to see if the mortality rate remains constant (using a quadrat method). If this degree of monitoring is not possible, the percent cover in the patches should be estimated between March to May, when the species is flowering.

iii. The patches should also be monitored during the bloom period to see if the plants are attracting pollinators, as *L. californica* is known to be beneficial for native bees and butterflies, including the federally threatened Bay Checkerspot butterfly (Harrison et al 1988). During the daytime, observe the patches and note the frequency and number of pollinators.

- Blaauw and Isaacs (2014) noted that in 30 square meter and 100 square meter patches of wildflowers, there were 4 to 5 native bees visiting per minute in a square meter area. Their study took place in Michigan, but their results provide a general target to meet.

iv. If initial establishment of the species has been successful (patches are close to 100% covered and there are no negative disturbances, invasive plants, or an excess of competitors), in the following growing season adding other native wildflowers nearby would be beneficial for pollinators, as greater wildflower patch diversity has been shown to attract a greater density and variety of wild bees (Blaauw & Isaacs 2014).

v. After the second growing season is complete, the patches should be checked yearly in springtime (the bloom period) to note the density and size of patches and any pollinator activity.

vi. Do not allow grazing on the patches, as it reduces the fitness of the species (Kimball & Schiffman 2003).

vii. **Potential Problems**

- Germination: if fewer than 40% of the seeds germinate by December, efforts should be taken to figure out why. Lack of adequate rainfall could explain the problem (Reynolds et al 1997), or the race of the seeds may not be well-adapted to those particular conditions (Ornduff 1966). Check for and carefully remove invasive grasses or weeds that may be taking up necessary soil resources, and make sure no seeds are left behind (Las Pilitas Nursery 2012).
- Bloom: If the density is far lower than expected during this period (for example, if the goldfields are not uniform across the patch but are instead infrequent with clear patches of bare soil) this may indicate a problem because goldfields characteristically grow in carpets (Ornduff 1966). Check that there are no competitors present that may be hindering the fitness of *L. californica* (competitors are described in Goal #2).
- To address the above problems, it may be necessary to seed a test patch in a different location at the site in the fall, in order to isolate and determine the factors that may be causing problems. (For example, if original patch locations were in part sun, periodically saturated and clayey soil, experimental patches could be seeded in full sun, upland areas, and soil of a different texture if present.)
- If herbivory of flower heads becomes a problem during the bloom period (as described by Eskelinen & Harrison 2015), efforts may be necessary to control the beetles.

3. Further Research

a. More accurate germination rates for this species are needed. The only one found in the literature described the germination rate in bare soil in a grassland setting (Reynolds et al 1997). If the restoration site is not an upland area, it would be useful to find out what the germination rate is for the species in wetter conditions, though this information may end up being specific to each particular race of *L. californica*.

b. There is one study on the effects of wildfire on *L. californica* that indicates it is resilient to fire and may become more abundant in the growing season after a fire due to increased nutrients and thatch removal (York 1997), but more information on the effects of this disturbance would be a valuable addition to the literature.

c. Though it is clear in the literature that *L. californica* attracts native pollinators, precise species were not detailed in most sources. A restoration site would provide an opportunity to take inventories of pollinator species. The experiment by Blaauw and Isaacs (2014) could even be replicated in a California setting, by seeding patches of different sizes and noting which ones pollinators prefer.

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Nutsedge, Cyperus difformis

Paige Moretto

Background and Justification

Nutsedge, also known commonly as the ‘smallflower umbrella sedge’ or ‘variable sedge’, is originally native to southern Europe, most of Africa, Asia, and Australia, and it is naturalized in other areas of the world (Holm, 1991). The history of introduction of *C. difformis* in the New World is not well known, however because this species behaves as an agricultural weed, it is highly probable that it was introduced as a contaminant of crop seeds.

The ability of the species to complete a vegetative and reproductive cycle within a month or so makes it especially competitive in a crop that requires at least 90 or more days to reach maturity, namely rice crops. It can impact natural wetlands and native vegetation swamps and flooded areas by heavy seed production and massive seedling densities which, combined with rapid growth, can quickly form dense colonies smothering native vegetation and hindering restoration attempts. Ultimately resulting in damaged ecosystem services, monoculture formation, impacts to agriculture, reduced native biodiversity, and the loss of native species.

Growth characteristics

- Flowering time is between July and November (Gordon, 2017).
- It is an annual sedge, sometimes behaving as a perennial (Rojas-Sandoval, 2015).
- It is a not a particularly tall, growing 6-80 cm in height, but it can have a high biomass per hectare (Rojas-Sandoval, 2015).
- Stems are smooth, triangular, slightly winged, 0.7-3.0 mm thick (Rojas-Sandoval, 2015).
- Leaves are smooth, flat, linear, 5-25 cm long or often two-thirds of plant height, 2-6 mm wide, sometimes reduced to sheaths (Rojas-Sandoval, 2015).
- The achenes are 0.6-0.8 mm long and 0.3-0.4 mm wide, triangular, obovate-elliptic, yellowish-brown or pale-brown, and minutely papillose (Rojas-Sandoval, 2015).
- The inflorescence consists of dense, globose, umbellate heads, simple or compound, 5-15 mm in diameter, with 10-60 stellately spreading spikelets (Rojas-Sandoval, 2015).

Reproduction

- Seeds sown on the surface of soil give the greatest percentage of seedling emergence (Chauhan, 2009).
- Germination of seeds is inhibited by darkness; however, when seeds are transferred to complete light they germinate readily, with the exception of two weeks of cold stratification, which can

overcome the light requirement for germination (Derakhshan, 2013).

- It propagates from seeds (achenes or nutlets), which are produced in large quantities. In Italy, Jacometi (1912) reported that one plant could produce 50,000 seeds, with about 60% germination.
- Can complete its vegetative and reproductive life cycle within 30 days (Rojas-Sandoval, 2015).
- In tropical areas, *C. difformis* can flower and produce seeds all year long if the soil moisture is sufficient (Holm, 1977).

Range

- Introduced and widespread in five of ten of the geographic floristic provinces in California as defined by the Jepson Herbarium (Gordon, 2017), namely the Sacramento Valley, San Joaquin Valley, South Coast, San Jacinto Mountains, and the Western Traverse Ranges.

Habitat/Requirements

- Eight habitat types: Bay dredged material, ditches, reservoir embayment shoreline and mud flats, rice and similar agricultural fields, river alluvium, roadsides, and shorelines (Tyndall, 1983).
- Grows best in rich, fertile soils, but can also grow in poorer sandy or clay soils (Tyndall, 1983).
- Seedlings cannot emerge when buried in soil at depths of ≥1 cm (Chauhan, 2009).
- Light is an absolute requirement for germination; darkness is an inhibitor, meaning this plant is positively photoblastic (Derakhshan, 2013).
- In a study done in the Philippines, the highest germination rates observed occurred between the range of 25 to 40 ºC and germination rates reached zero at 15 and 45 ºC, respectively. With ideal average day/night temperatures of 35/25 ºC (Derakhshan, 2013).
- Hypoxia and low rates of gaseous diffusion at deeper depths could be other reasons for the lack of emergence (Benvenuti, 2003).
- Germination is greater than 85% up to the concentration of 100 mM NaCl; 29% germination occurred at 150 mM NaCl, with germination completely inhibited at 200 mM NaCl (Derakhshan, 2013).

Tolerances

- Can tolerate fresh or brackish water (Tyndall, 1983).
- Seed germination can occur between a range of pH between 4 and 9, but the maximum germination (89%) was observed at pH=6. Suggesting that the seeds of *C. difformis* cannot survive in very alkaline conditions and that a pH below 7 was most favorable for germination (Derakhshan, 2013).
- Germination is greater than 85% up to the concentration of 100 mM NaCl; 29% germination occurred at 150 mM NaCl, *with germination completely inhibited at 200 mM NaCl* (Derakhshan, 2013).
- Insofar as soils: can tolerate seasonally waterlogged areas, acidic and neutral Ph, and all soil textures (Rojas-Sandoval, 2015).

Interactions

- There are no known natural enemies of *C. difformis* other than those pests and diseases of rice for

which it is an alternative host (Rojas-Sandoval, 2015).
- It competes with crops mostly for nutrients and water, rather than for light (Rojas-Sandoval, 2015).

Management considerations

- Duck activities, such as grazing and subsequent disturbance of the soil and water are an effective means of weed control for Nutsedge (Li, 2012).
- Flooding of rice fields to a depth of 20 cm strongly suppresses the growth of *C. difformis* (Williams et al., 1990) but with the continuous use of the more usual shallower flooding, C3 weeds, including *C. difformis*, become dominant (Ampong-Nyarko and DeDatta, 1992).
- Temperatures of 250 F for a minimum of 5 minutes are effective in inhibiting 50% of germination and decrease progressively with further increases in temperature, resulting in no germination after ≥ 320 ºF (Derakhshan, 2013), therefore fire-induced high temperatures can destroy the seeds and can also affect some allelochemicals known to inhibit seed germination (Roder et al., 1997).
- Burning vegetation can increase surface temperature to 550 ºC (Cook, 1939); however, temperature can decrease at a rate of 100 ºC cm^{-1} in the first 5 cm below the soil surface (Sanchez, 1976). Therefore, although seeds on the soil surface might be destroyed by high temperature, seeds buried below 4 cm could escape from the effect of heat, remaining dormant while buried, and then germinating when brought to the soil surface.
- As this species could not emerge from a depth of 1 cm, shallow tillage operations that bury seeds below this depth could be an option to limit the germination of *C. difformis*.
- Resistance to bensulfuron-methyl (ALS inhibitor) is widespread among C. difformis populations in California (original study done is Australia, but focuses on CA as well) (Sanders, 1994).
- A 1987 study done in Egypt found Oxadiazon at 0.5 kg and avirosan at 0.5 kg as well as the combination of Butachlor at 1.0 kg + oxadiazon at 0.5 kg or Avirosan at 0.5 kg and avirosan at 0.5 kg + bentazon at 1.44 kg/ feddan gave the best weed control against *Cyperus* difformis, post emergence (Shaban, 1987).

Management Plan for Nutsedge

Goals

Nutsedge (Cyperus Difformis) is an invasive weed species, often referred to as one of the 'worlds top ten worst weeds,' and is commonly found in riparian habitats in the Central Valley. Due to the weeds high seed load, infestations in excess of 100 plants per square foot may occur. The main restoration goal is to determine if the Nutsedge can be completely removed from the area, and if it cannot, how it can be managed. There are multiple management strategies' with varying levels of feasibility. Due to the prolific nature of Nutsedge and its ability to aggressively replace native vegetation, the ideal goal would be complete removal of the species from the restoration site. Feasibility, and the strategy to pursue, will largely depend on the duration of monitoring available at the site. Short term monitoring cannot ensure that Nutsedge will not reinvade the area.

Successful restoration would be the eradication of Nutsedge in the site by the July of the year following restoration efforts (Nutsedge would normally, if present, begin flowering in July).

Pre Restoration Goals

- Survey the extent and distribution of Nutsedge invasion, taking care to cite the location of patches.
- Measure the elevations of Nutsedge patches, taking care to cite those above the water level.
- Measure the soil temperatures and salinities of the zones in which the weed is found growing vs. not growing.

Specific Actionable Goals

- If feasible, 100% eradication should be pursued. To be accomplished by multiple iterations of controlled burns to destroy the existing seedbank, followed by an imported layer of new and uncontaminated topsoil.
- Otherwise, control of Nutsedge can be done by means of one, or a combination, of the following:
    1. Duck grazing activities
    2. Deep flooding
    3. Tilling over
    4. Herbicide application (with the exception of Group 2 [ALS] and Group 7 [propanil] herbicides, of which they are resistant to [Shaban, 1987]).
- If herbicide application is deemed a feasible option, collection and testing of Nutsedge seeds should be done in order to determine the best combination of herbicides to apply for maximum effectiveness.
- After the weeds are removed, the area should continue to be managed and monitored for as long as feasible (years due to prolific and aggressive nature of the species) in order to prevent the reestablishment of seedlings.

- Replacement of Nutsedge should be done with competing native species in the riparian habitat to prevent reestablishment of invasive Nutsedge.

Restoration Plan

Elimination of the species is very difficult as a single plant can produce thousands of seeds with multiple generations per season and possesses a high biomass per hectare (Rojas-Sandoval, 2015). Nutsedge grows most successfully in rich fertile soils, with seeds sown on the surface of soil giving the greatest percentage of seedling emergence (Chauhan, 2009), therefore, regardless of which management option is chosen, a new layer of uncontaminated topsoil should be added, as this species cannot emerge from a depth of 1 cm (Chauhan, 2009).

The preliminary controlled burn should be done in early June, before flower maturation, to temperatures of ≥ 160 ºC (320 ºF) (Derakhshan, 2013) for maximum effectiveness. However, because temperatures can decrease at a rate of 100 ºC cm^{-1} in the first 5 cm below the soil surface (Sanchez, 1976), seeds buried below 4 cm could escape from the effect of heat. Therefore, tilling over to a depth of 5 cm and facilitating a subsequent controlled burn, would result in maximum efficacy.

Flooding of rice fields to a depth of 20 cm has been shown to strongly suppress the growth of Nutsedge (Williams et al., 1990), however in riparian areas with more moderate shallow waters, Nutsedge will become dominant (Ampong-Nyarko, 1992). Therefore, the water level should be kept at or deeper than 20 cm to abate the resurgence of Nutsedge in the water zone.

In trials conducted as recently as 2014, sedge populations resistant to propanil and ALS-inhibiting herbicides were shown to be susceptible to the post-emergent herbicide Shark H2O. For control of propanil resistant sedge, Shark H2O herbicide can be applied at one of two timings (Espino, 2014):

1. Early, at the 2 to 4 leaf stage of rice, for control of submerged weeds, at a rate of 7.5 oz/a.
2. Twenty to 45 days after seeding, to the foliage of exposed weeds at a rate of 4 oz/a.

Additionally, the herbicides Bolero and Abolish used at standard rates and timings also control propanil and ALS-resistant smallflower umbrella sedge. Other herbicides will need to be used to control the whole spectrum of weeds present. For example, programs could include an early application of Shark H2O followed by Regiment or propanil; Cerano or Bolero can be followed by a later application of Shark H2O to control escapees. Alternatively, the application of Oxadiazon at 0.5 kg and Avirosan at 0.5 kg, as well as the combination of Butachlor at 1.0 kg + oxadiazon at 0.5 kg or Avirosan at 0.5 kg, and avirosan at 0.5 kg + bentazon at 1.44 kg/ feddan (Shaban, 1987).

Lastly, long-term management sans chemicals should be done by means of introducing a duck-grazing program year-round (Li, 2012), which would have the dual effect of disturbing the soil and water (eliminating the ability of Nutsedge to root in water) and any Nutsedge escapees would become duck fodder.

In order to improve the plan, it is imperative to know whether there are desired native species that could take the place of Nutsedge and that, once established, could outcompete the weed for resources, specifically water and nutrients, as Nutsedge competes with other plants mostly for the aforementioned, rather than for light (Rojas-Sandoval, 2015). Ideally, the replacement plant might possess allopathic properties that would permanently help to keep Nutsedge from reestablishing. In a 2013 study fire-induced high temperatures affected some allelochemicals in Nutsedge known to inhibit seed germination, therefore burning Nutsedge itself may help to inhibit its spread (Roder et al., 1997). There is also evidence supporting that the sees cannot survive in very alkaline conditions, therefore restoring the site with alkaline loving native plants would highly discourage the repopulation of Nutsedge in the area (Derakhshan, 2013).

Monitoring Plan

Moist environments, with a pH of 6, and temperatures between 25 to 40 ºC are most favorable for germination. There are higher occurrences of this weed in lowland fields where soil moisture is high, whereas in upland fields germination would most likely occur in the rainy season (Derakhshan, 2013).

Monitoring of the entire site should be done is feasible because Nutsedge can grow in most conditions. However, at minimum monitoring should occur where populations where first recorded, as well as in areas best adapted to support the highest germination rates. Any Nutsedge found should be treated with one of the aforementioned herbicide regimes, or if found amongst native plantings that would otherwise be harmed from the application of herbicides in their vicinity, hand weeding can be done in June, before the Nutsedge goes to seed.

The dispersal methods of Nutsedge seeds is not entirely understood, with some concern as to dispersal by birds, and obviously by contaminated water of rice crops, of which there are many such crops in the surrounding area. Due to these factors, reestablishment is possible, if not likely, in the future even if the area is made entirely free of the weed. Therefore, because the spread of Nutsedge is aggressive, monitoring should ideally occur in the weeks before the weed flowers and throughout the flowering season, between July and November (Gordon, 2017), as a single plant can complete its vegetative and reproductive life cycle within 30 days (Rojas-Sandoval, 2015) and produce 50,000 seeds with about 60% germination (Jacometi, 1912). There is no exact data available on the amount of years necessary for complete eradication of a Nutsedge seedbank; therefore frequent and long-term monitoring is necessary for restoration success.

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Perennial Pepperweed (Lepidium latifolium)

Drew Alonso Wolter

A. Background and Justification:

Why do we care about this topic? Why is this restoration topic important and interesting?

- Proper weed management is crucial for the success of the restoration of wetlands, pastures, lawn and garden, nurseries, and many other areas.
- Weeds are vigorous competitors temporally and spatially.
- Uncontrolled populations can lead to a reduction in germination percentage, vegetative growth and overall onsite success rates; and often superseding losses due to disease and insects in restoration sites (WSSA 2014).

What is your target goal's conservation value, its impact on agriculture and/or the environment?

Per the California Invasive Plant Council (Cal-IPC),

- *L. latifolium* exhibits adaptation to a wide range of ecological habitats and environmental factors. Tolerating a range of soil moisture, saline and alkaline conditions has allowed it to spread extensively through wetlands and other riparian areas in California.
- *L. latifolium* thrives in many lowland ecosystems and is extremely competitive, forming monospecific stands that can displace natives, threatened and endangered species.
- *L. latifolium* also alters the ecosystem in which it grows by acting as a 'salt pump'. It takes salt ions from deep in the soil profile and deposits them near the surface, thereby shifting plant composition and altering diversity.

What is the current state of your target topic?

According to the USDA,

- *L. latifolium* is now found throughout California, except in coastal rainforest in the northwest, and low elevation desert in the southeast.
- In the intermountain area *L. latifolium* occurs along river systems from the lower edge of coniferous forests to saline/alkaline deltas and sinks.
- Initial establishment of *L. latifolium* in the intermountain area has often occurred in association with large machinery used for diversion of irrigation water from streams.

- This type of anthropogenic disturbance usually creates bare soil, facilitating colonization of facilitator/pioneer species.
- The undercarriage of track-laying heavy construction equipment is an ideal mechanism for transporting vegetative propagules of weeds such as *L. latifolium* from site to site.

What is the history of degradation of your topic?

Per Cal-IPC,

- *L. latifolium* has a wide native range across Europe, Asia and Northern Africa but has been introduced to Australia, Asia and to the Americas.
- *L. latifolium* was first sighted in California in sugar beet seed in 1936 and was recognized as invasive in the 1980s, first in California and then in adjacent western states.
- *L. latifolium* is now listed by the California Invasive Plant Council on List A-1: a widespread, aggressive invader that displaces natives and disrupts natural habitats. These are the most invasive wildland pest plants in their classification.

B. Literature Review:

Lifecycle / Regeneration:

As the common name suggests, Perennial pepperweed exhibits a perennial lifecycle. It reproduces from seed, creeping roots, propagules and semi-woody meristematic crowns (DiTomaso et al, 2007).

Pollination:

- Perennial pepperweed is insect pollinated (DiTomaso et al, 2007).

Seed production:

Per DiTomaso and Healy (unless noted otherwise),

- Each mature perennial pepperweed plant has the capacity to produce thousands of seeds each year.
- Seed production is reported as 16 billion seeds per hectare per year from stands with 200 perennial pepperweed stems per m2.
- Flowering of perennial pepperweed is more robust in dry years, but seed set and maturity is minimal.
- In very wet years, infection of white rust (Albugo spp.) appears to largely inhibit seed production (USDA, web).

Seed dispersal:

Per the USDA (unless otherwise noted),

- Perennial pepperweed seeds have no special adaptations for long-distance dispersal, although they may be transported by wind, water, possibly waterfowl, and other animals.
- Perennial pepperweed seeds may also be transported in agricultural products and by vehicles and machinery.
- Perennial pepperweed seeds do not dehisce from the pods at maturity, but fall at irregular intervals during the winter, and some seeds may remain in pods until spring.
- New colonies may occur when seeds are transported in water from upstream sources.
- Perennial pepperweed seeds initially sink when immersed in water. A layer of mucilage then forms on the seed surface making them buoyant (DiTomaso et al, 2007).

Seed banking:

Per Buhler and Hoffman,

- Germinability of perennial pepperweed seeds, tested 1, 6, and 12 months after harvest, did not change with time. They concluded that perennial pepperweed seeds can be stored under laboratory conditions for at least a year with no special precautions. More importantly, there seems to be no inherent dormancy system (e.g. a hard seed coat) present in perennial pepperweed seeds.
- Additionally, the temperature conditions that produce optimum germination for perennial pepperweed seeds do not change within a year after harvest, as would be the case if an after ripening requirement existed.
- This evidence suggests that buried seeds of perennial pepperweed may not be a prolonged source of re-infestation once a population is controlled.

Germination:

Per Buhler and Hoffman,

- Very cold temperatures and constant temperatures between 32 and 104 °F (0-40 °C) failed to support perennial pepperweed germination.
- The highest germination rates (96% to 100%) for perennial pepperweed seed occurred under alternating temperature regimes with low night temperatures (32, 36, or 41 °F (0, 2, or 5 °C)) and high day temperatures (95 to 104 °F (35-40 °C)).
  - These fluctuating regimes represent realistic temperatures of seedbeds in the intermountain area during fall or late spring, when diurnal fluctuations are characterized by low night temperatures and high day temperatures.
  - Perennial pepperweed seeds would probably have to be on or near the soil surface to experience temperature fluctuations of this magnitude. Deep burial of perennial pepperweed seeds may greatly reduce emergence because of poor germination due to more constant and cooler temperature regimes with depth.
- No significant ($p<0.01$) differences in germination of perennial pepperweed seed were attributed to year of production, duration of storage after harvest, or seed source.

Species Ecosystem Characteristics:

Per the Cal-IPC,

- Many sites have dense infestations in one area and no plants invading into nearby locations, indicating that perennial pepperweed spread may be limited by environmental, physical, and/or geographical factors, although it is unclear what these factors are.
  - For example, in California’s intermountain region, perennial pepperweed typically grows in full sun with heavy, moist soils that are often saline or alkaline, but it also grows in drier sites and on other soil types.
  - Its precise tolerance limits for aridity, alkalinity, and salinity are unknown.

Temporal scale /Average Phenology:

Per DiTomaso and Healy (unless otherwise noted),

- As early as mid-winter in the western Intermountain Area, careful examination of perennial pepperweed root crowns reveals multiple buds that are green and slowly developing.
- Shoot growth can begin at varying periods, depending on timing of the last frost, but generally shoots emerge in late winter to early spring before those of most native species.
- Observations of perennial pepperweed seedlings are rare in the field, "but germination appears to occur late winter/early spring" (Cal-IPC, web).
- Flowering May- August

Spatial scale / Distribution (W/I CA Intermountain Region):

According to the Cal-IPC,

- Perennial pepperweed seems to be most problematic in riparian areas, marshes, estuaries, irrigation channels, wetlands, and floodplains, but is not exclusive to these areas.
- Perennial Pepperweed is a facultative plant; i.e. it has about equal probability of occurring in wetland or non-wetland sites.

Environmental / Management Response:

Per the Weed Science Society of America (WSSA),

- Fire:
  - On its **own**, the efficacy of controlled burns on perennial pepperweed is poor.
    - The deep, extensive root system has a high reproductive potential that allows it to sprout repeatedly following removal of aboveground growth due to fire.
    - Limited information in studies regarding the response of perennial pepperweed seed to heat, smoke or fire is available.

- Physical and mechanical control:

According to the WSSA,

  - Methods such as disking and tilling:
    - <u>Poorly controls perennial pepperweed</u> results in new plants quickly regenerating from roots, root crown, and propagules dislodged by machinery.

  - Methods such as Mowing and Grazing:

- These methods on their **own** still proves to have low efficacy on a short-term scale, due to large carbon storage in its extensive below ground rooting system.
- Long-term mowing/grazing plans can gradually deplete the carbon storage.

Environmental and Ecological Impacts:

Per the Cal-IPC,

Impact mechanisms:

- Competition - monopolizing resources
- Competition – shading
- Ecosystem Engineer

Impact outcomes:

- Altered trophic levels
- Modification of nutrient regime
- Modification of successional patterns
- Modification to biogeochemical cycles
- Ecosystem state change/shift
- Monoculture formation
- Threat to/ loss of endangered species
- Threat to/ loss of native species

Management options:

The California Invasive Plant Council states that a dynamic integrated approach has shown to be most successful when managing *L. latifolium.*

Example:

Mowing, Burning or Grazing

+

*Annual application of systemic herbicide (*Glyphosate or 2-4D)*

=

Greatest Control of Perennial Pepperweed

Burning, Mowing and/or Grazing:

Per UC-IPM,

- These management methods should be applied in the Spring (May-Aug), before perennial pepperweed has a chance to set seed.
- Acts as early depletion of carbohydrates stored in root systems.

Glyphosate (*Recommended*):

Per the WSSA Herbicide Handbook,

- Fall application of herbicides in perennial weeds insures translocation to root system.
- Glyphosate is a <u>non-selective</u>, post-emergent, and systemic herbicide used on agricultural and nonagricultural areas around the world.
- Due to <u>non-selective</u> nature, WICK or spot application is recommended.
- It works by inhibiting the synthesis of the enzyme 5-enolpyruvylshikimic acid-3-phosphate synthase (EPSP), which is needed for production of aromatic amino acids: tyrosine, tryptophan, and phenylalanine. These amino acids aid in synthesis of proteins that link primary and secondary metabolism
- Glyphosate is <u>not effective on submerged</u> or mostly submerged foliage and therefore is only applied to control emergent foliage. Glyphosate is commonly sold as Round Up, Rodeo or AquaMaster in the formulation of isopropyl ammonium.
- Glyphosate is <u>relatively nontoxic to animals</u> because it acts on plant enzymes that are not present in animals.

2,4-D (Alternative):

Per the WSSA Herbicide Handbook,

- There are many forms of 2,4-D, including acid, salt (mostly amine), and ester formulations. Ester formulations are particularly <u>toxic</u> to fish and other aquatic life.
- 2,4- D is a <u>selective</u> herbicide that kills dicots by mimicking the growth hormone auxin, causing uncontrolled growth and eventual death (Tu et al. 2001).
- It is used for cultivated agriculture, pasture, rangeland, forest, home, and garden applications and to <u>control aquatic vegetation</u>.

Goals, Management and Monitoring Plans

Lepidium latifolium

Identification

Family: Brassicaceae

Per the Weed Society of America, mature plants have numerous erect, semi-woody stems that originate from one large or interconnected root system.

Roots are long, minimally branched, and enlarged at the soil surface forming a semi-woody crown.

Foliage is smooth and green to gray-green in color. Rosette leaves are ovate to oblong with smooth to slightly toothed margins on long stalks. Rosette leaves are about 4 to 11 inches long and 1 to 3 inches wide.

Umbel **inflorescence** with small, white flowers form dense clusters arranged in panicles at the tip of each stem.

Figure 1 Left: Young Basal Rosette, Right Mature Plant

Acting as vigorous ecosystem engineers, populations form dense monocultures alter environmental conditions. Invasion by perennial pepperweed has the potential to alter soil properties and processes relative to uninvaded sites to favor its own growth and survival, and can also alter the trajectory of ecological community. Research has shown that these plants can act as "salt pumps" taking salt ions from deep in the soil profile, transport them up through their roots and deposit them near the surface. This can favor halophytes and other species are at a disadvantage, thereby shifting plant composition and diversity. As a strong competitor, spreading by root fragments and seed. Perennial pepperweed has many common names including tall white top, perennial peppercress, ironweed, perennial peppergrass, and broad-leaved pepperweed.

A. Goals:

The overriding goal for managing Lepidium latifolium in Dixons C-Pond site is to gradually reduce and eradicate the impacts on environmental resources posed by this species, this will ideally open niche space for desired species, allowing them to compete with a higher efficacy level. To accomplish this, I believe that a site wide integrated pest management program should be implemented in the following order of priority:

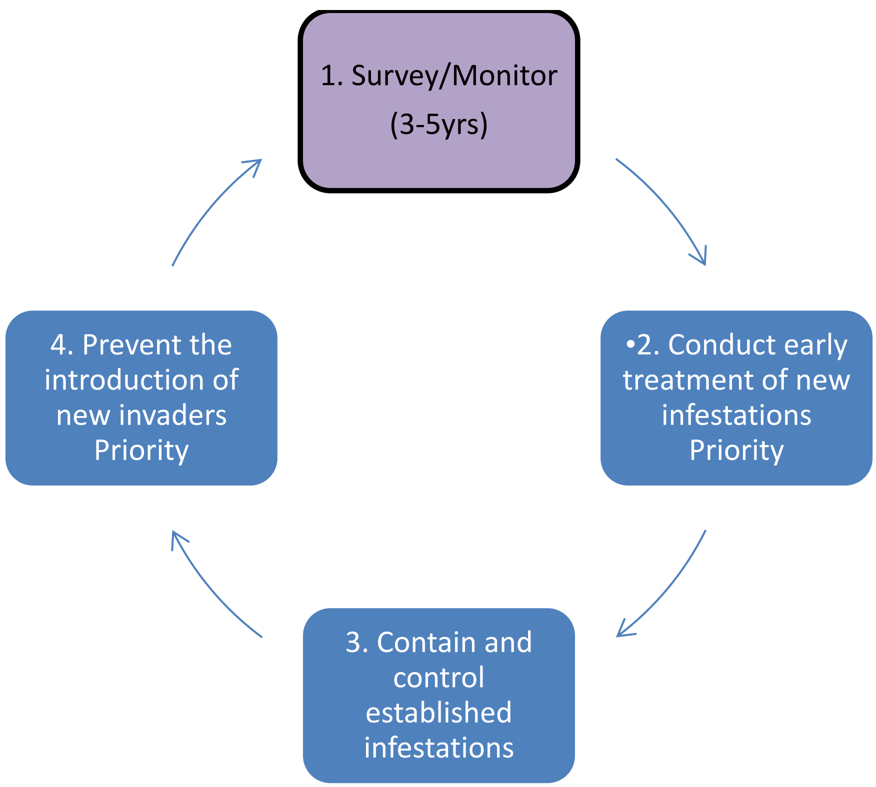

Figure 2 Goals: Order of Priority

As shown in figure 2, this management plan requires a minimum of three years. Established perennial pepperweed populations are difficult to control and require multiple years of intensive management. Suppressing the extensive root system is critical for successful control. After the initial surveying of the site, A management program should include prevention, monitoring, and treatment of <u>small satellite populations</u> before plants develop extensive roots. If <u>large populations exist</u>, focus management on containing the infestation and preventing further spread to surrounding areas.

1. **Initial Survey**

- Quantify the approximate number of individual Lepidium latifolium with assumed reproductive viability (Full grown and seedlings)
- From population size, estimate site **seedbank**
  - Each mature plant has the capacity to produce approximately 1000 seeds each year (greater for well-established "founder").
    Seeds typically germinate in spring in wet sand or mud. Seedlings grow rapidly and can produce flowering stems the first year. Seed viabilities is high, lacking a hard seed coat allows for high germination rates and rapid growth. Lacking the hard seed coat is a double edge sword for this species, viability can be rapidly lost, suggesting that resurgence of a treated infestation from the seed bank would be low.

Record temporal phenology of population on site.

- Restoration sites can pose environmental condition that can alter a species "historical" phenology. Targeting invasive species prior to setting seed insures that the seed bank is reduced and restricted.
- Quantify spatial distribution (distance form and elevations above the water table).Measure soil salinity near established Lepidium latifolium populations (addressing legacy effect concerns). According to the WSSA,Acting as a salt pump, L. latifolium create saline conditions harmful to desired species
- Salinity concentrations The majority of plants on the proposed planting list have: sensitive (0 – 3 dS m-1), moderately sensitive (3 –. 6 dS m-1)

2. **Conduct early treatment of new infestations:**

Emphasis on treating/eradication of satellite populations. The California Invasive Plant Council states that an integrated approach has shown to be most successful when managing *L. latifolium.* Initiating a management plant that controls L. *Latifolium* throughout its various growth stages. Targeting the carbohydrate reserves of established plants, depleting seed bank and eradication of seedlings.

Targeting new invaders and satellite populations first, will minimize the spatial distribution of impacts *L. latifolium* may have on high value resources throughout the site.

3. Contain and control established infestations

Emphasis on treating/eradication of established populations:

Criteria for "established" populations: Large patch, often site of founder. Slow growing with heavy thatch.

Criteria for "satellite" populations: Small patches of rapid growing population (due to greater resource availability). Low levels of thatch.

The California Invasive Plant Council states that control methods with the highest efficacy include: chemical, grazing (cattle, goats, sheep), prescribed burning. Integrated approaches, where two or more methods are used in combination will typically lead to more effective long-term control. (This process is elaborated on in the restoration section (B) of this document).

4. Prevent the introduction of new invaders:

Prevention is the foundation of any weed management program, this especially the case with a vigorously competitive invader such as *L. latifolium.* The following are prevention efforts that may be made:

- Perennial pepperweed root fragments and seed have been found in straw, hay bales, mulch; be sure that these items are free of weed seed and propagules before applying them to an area.
- Periodic surveys of property lines, roadsides, waterways, wetland and riparian corridors, help detect new infestations before they become well established.
- If construction or soil disturbance occurs in infested areas, make sure root fragments and seed are not transported to other sites.
- Always clean vehicles, machinery, and clothing after visiting infested areas.
- If livestock graze perennial pepperweed, hold the animals in closely monitored paddocks for several days to allow seed to pass through their digestive system before transporting them to new areas.

5. Monitoring (cyclical):

For effective, long-term site management of L. latifolium, funding for monitoring on an annually repeating cycle for three through five years should be sought. During annual monitoring, all roadsides, waterways, wetland and riparian corridors must be re-surveyed. Some L. latifolium cultivar and/or unique populations may require more frequent monitoring if near highly functional dispersal vectors.

B. Restoration Plan

The California Invasive Plant Council suggests that a dynamic and integrated approach has shown to be most successful when managing *L. latifolium* control types.

Control Types:

1. Satellite population management program should include prevention, monitoring, and treatment of small satellite populations before plants develop extensive roots. Seedlings can develop an extensive tap root with in the first year. Removals should be made in summer prior to development of seeds and taproot.
2. Established perennial pepperweed populations are difficult to control and require multiple years of intensive management. Suppressing the extensive root system is critical for successful control. Large population management should be focused on containing the infestation and preventing further spread to surrounding areas.

Suggested Integrated Pest Management Plan:

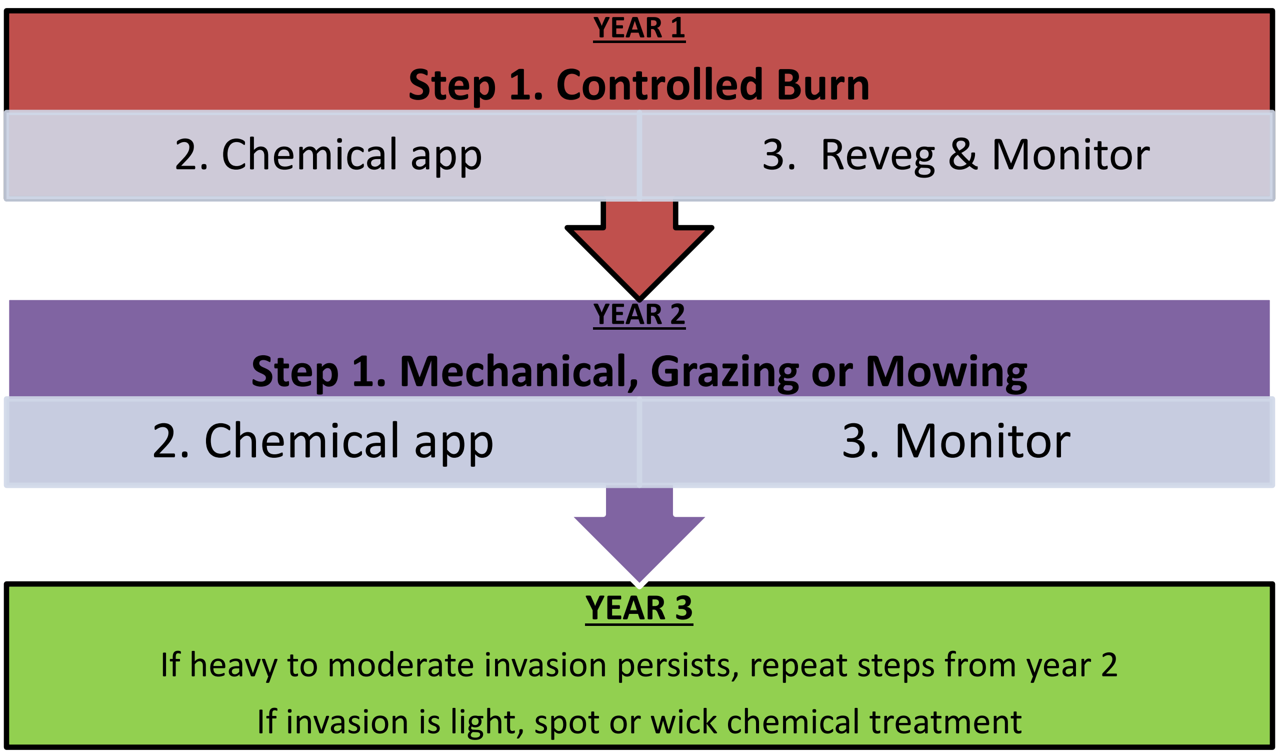

Figure 3 Flowchart for suggested Integrated Pest Management Plan

Outline for 3-year plan:

Year one:

Step 1: Controlled burn should be made in spring well before plants begins to flower. This acts as a form of carbohydrate depletion. This allows for same season revegetation).

Step 2: Follow controlled burn with a chemical application of Glyphosate during fall. This insures that systemic herbicide is properly translocated to the taproot (carb storage).

Expected Results: Dropping the Carbohydrate storage twice in one season along with the depletion of the sensitive seed bank and eradication of seedlings, expect a population reduction of ~ 40-80%, per UC-IPM.

Step 3: Monitoring should be done frequently throughout the first year. Any survey information should be used to ask the question of how effective our treatments were (in terms of treatment. efficacy, target population size, and establishment). This information should be used to tailor the following years management plan to population structure needs. Allowing for the opportunity to use less hazardous methods if possible.

Year two, first make post survey adjustments to management plan. Adjudgments should be made regarding the selection and intensity of grazing or moving and the application method of chemical treatments that should be applied to remaining populations. Expected reduction of population should bring the sites infestation to a manageable and controlled state, with no remaining satellite populations and a reduced founder patch. Monitoring is most important now.

Year three, further adjustments should be made to management plan. Spot and wick applications of remaining populations. Spot and Wick applications in contrast with broadcast applications, directed applications target individual plants. This makes it possible to apply less-selective herbicides such as glyphosate, precisely on individual plants without the risk of injuring nontarget vegetation. However, directed treatments are only possible when target plants are discrete enough to be treated individually prior to setting seed in summer.

Hand Pulling and Tillage Disclaimer

Seedlings are easily controlled by hand-pulling or tillage, but these techniques do not control established plants over a year old, because shoots quickly resprout from vast root reserves. Root segments as small as 1 inch are capable of producing new shoots.

Burning, Mowing and Grazing

Mowing, grazing or burning on their own are not effective at reducing perennial pepperweed stands, but they are helpful in removing accumulated thatch and performs early depletion of carbohydrates stored in root systems. Per UC-IPM, these management methods should be applied in the Spring (May-Aug), before perennial pepperweed has a chance to set seed.

Burning: Perennial pepperweed thatch burns best in winter or spring under dry conditions during the initiation of spring growth. For best results, apply herbicides to resprouting shoots once they have reached the flower bud stage. Burning is key to diminishing the seedbank of L. latifolium, seeds are short lived and sensitive to fire. The fires intensity (high), rate of travel (slow) and spatial distribution (even) can influence efficacy of burn.

Mowing and Grazing: Breaks old stems into small fragments and helps slow resource acquisition, opening space for favorable species. For best results, mow plants at the flower bud stage and apply herbicides to resprouting shoots once they have reached the flower bud stage.

Chemical Applications:

There are several post-emergent herbicides shown moderately control perennial pepperweed; however, it is recommended that repeat applications are necessary for several years to treat re-spouting shoots and seedlings emerging from the seedbank.

Herbicide choice is limited at the Dixon C-Pond restoration site due to its riparian nature. Thus, aquatic herbicide formulations Glyphosate (primary option) and 2-4D which are both EPA-registered for application in and around bodies of water. These formulations were chosen to provide enhanced protection to aquatic resources.

The timing of herbicide application is critical. Herbicides work best on perennial plants when applied late in the season before the plant starts to senesce and is least effective at the rosette or early bolting stage. Plant phenology differs between location and year.Thus, infested areas should observed once in the early spring for seedling count/management. With seedlings, grazing or mowing should be applied first. Observed a second-time early summer for herbicide application. Herbicides applications should be made prior to senescence to insure translocation to carb storing root system.

Glyphosate (*Recommended*):

Per the WSSA Herbicide Handbook,

- Fall application of herbicides in perennial weeds insures translocation to root system.
- Glyphosate is a non-selective, post-emergent, and systemic herbicide used on agricultural and nonagricultural areas around the world.
- It works by inhibiting the synthesis of the enzyme 5-enolpyruvylshikimic acid-3-phosphate synthase (EPSP), which is needed for production of aromatic amino acids: tyrosine, tryptophan, and phenylalanine. These amino acids aid in synthesis of proteins that link primary and secondary metabolism
- Glyphosate is not effective on submerged or mostly submerged foliage and therefore is only applied to control emergent foliage.
- Glyphosate is commonly sold as Round Up, Rodeo or AquaMaster in the formulation of isopropyl ammonium.
- Glyphosate is relatively nontoxic to animals because it acts on plant enzymes that are not present in animals.

2,4-D (Alternative):

Per the WSSA Herbicide Handbook,

- There are many forms of 2,4-D, including acid, salt (mostly amine), and ester formulations. Ester formulations are particularly toxic to fish and other aquatic life.
- 2,4- D is a selective herbicide that kills dicots by mimicking the growth hormone auxin, causing uncontrolled growth and eventual death (WSSA. 2017).
- It is used for cultivated agriculture, pasture, rangeland, forest, home, and garden applications and to control aquatic vegetation.
-

Site Revegetation

Revegetating the site post burn is important for nutrient retention and it provides a narrow window for desired plants to compete with maximum resource acquisition. Immediate establishment of desirable vegetation at the restoration site is crucial to managing perennial pepperweed and preventing future invasive weed infestations. Due to the competitive edge of *L. latifolium*, seed or transplant desirable vegetation after dense perennial pepperweed stands are controlled. Choose vigorous, fast growing plant species that are adapted to the site such as existing native grass populations and perhaps a strong competitor such as Muhlenbergia. Perennial grasses are a good choice for natural areas and pastures. Grasses are used to compete with perennial pepperweed, gradually controlling population and over time grasses can form a thick thatch that prevents future weed establishment.

Survey / Monitoring Plan:

Surveying or Ecological Monitoring should include the direct objective of identifying persistent populations, sprouting seedlings and key indicators of ecosystem community composition shift to evaluate the success of restoration goal. As mentioned above, for effective site management of L. latifolium, monitoring should be made on an annually or biannual cycle for a minimum three year. During annual monitoring, all roadsides, waterways, wetland and riparian corridors must be re-surveyed. Some L. latifolium unique cultivar and/or populations may require more frequent monitoring if near highly functional dispersal vectors/features (riparian zones, streams).

Findings from annual monitoring's can be used to answers the question of how well (or accurately) treatments were carried out (in terms of treatment efficacy, target population size, and establishment), relative to a restoration prescription. These answers should be used to adjust dynamic pest management plan accordingly to site/population needs or environmental stochasstisity.

Regardless, the findings from ecological monitoring's may be difficult to interpret or apply within an adaptive management context if funding for annual concurrent monitoring is not available.

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Lower Riparian/Seasonal Wetland to Upland Herbaceous Plants

California Mugwort (Artemisia douglasiana)

Ann Le

Artemisia douglasiana is a perennial herb in the family Asteraceae native to western United States. Distributed widely throughout California, the species is most often found in areas with moist soil, such as drainages and riparian habitats (Schultz, 2006). Additionally, *A. douglasiana* has been documented to occur in woodland, grassland, and the chaparral (California Native Plant Society, 2014). *A. douglasiana* characteristically has many narrow, 3-5ft. tall stems which, along with the dorsal side of the leaf, are grey-green in color (Schultz, 2006). The flowers of *A. douglasiana* are white and are arranged in disciform heads 0.1 to 02 inch in diameter (Tutka, 2015).

A. Background & Justification

Artemisia douglasiana is valuable for a variety of purposes. The species provide seed forage for wildlife, vegetative cover for nesting birds, nesting equipment for bees, and perching spots for a variety of organisms (Tutka, 2015). In addition to ecological benefits, *A. douglasiana* is valued in many Californian tribe cultures for its medicinal uses and role in traditional ceremonial processions (McCarthy et al 2012). While it has an abundance of uses, outside of natural areas *A. douglasiana* may become invasive or weedy and consequently displace other desired cultivated plant species if not appropriately managed (Tutka, 2015). This is especially a problem in agricultural drainage ditches and low areas on pastures (DiTomaso and Healy, 2007).

B. Literature Review________________________________

For species/community types:

- Generally, *A. douglasiana* flowers bloom from mid-season spring through the late fall period. *A. douglasiana* seeds germinate with colder temperatures in order to take advantage of fall rains. Direct seeding is achievable from late fall through winter on well prepped sites at a seeding rate of 2.2 lb/ acre at a depth of ¼ of an inch. The plant is highly tolerant of a wide range of soils types and moisture availability, especially at sites with abundance shade availability. The roots of the plants themselves also spread through rhizomes, which die back in the winter as well as summer drought periods and sprout when optimal moisture and temperature levels are present. For this reason, only a few plants are needed to establish the population at a specific site. (Tutka, 2015).
- In terms of co-occurring and mutualistic species, *A. douglasiana* is often found with co-occurring plants in moist areas, such as the Currant/Gooseberry (*Ribes sp.*), Wild Rose (*Rosa sp.),* willow (*Salix sp.),* and wild grape (*Vitis sp.).* (California Native Plant Society, 2014).
- Specifics needed from ecosystem
    - For animals: habitat structure, food, shelter
        - A well-documented service of *A. douglasiana* comes from its association with birds. For example, the Least Bell's Vireos (*Vireo bellii pusillus*), a bird species of special concern, may have a close association with *A. douglasiana*. In a USFW report in 2005 the species was documented to have been found nesting in a plot at the San Joaquin National Wildlife Refuge. The nest itself was hidden amongst dense patches of A. douglasiana, suggesting of a possible wildlife association with the plant. (Wood, Howelland Geupel, 2005). In addition, analyses of restored sites in the Central Valley have suggested that *A. douglasiana* plays an important role in providing understory cover many additional native birds. (Golet et al. 2008). Following its seeding period during the fall season, when temperatures start to fall, *A. douglasiana* is also an important food source for these bird species (Tutka, 2015).
    - Species tolerance to moisture, temperature, pH, etc.
        - *A. douglasiana* seeds and rhizomes need 4.11 to 119.3 inches of rain annually to sprout. During the summer months, where precipitation is below 4.10 inches, seeds are not able to germinate and the plant cannot spread through rhizomes. With adequate rainfall, *A. douglasiana* can tolerate cold up to zero degrees Fahrenheit. The species also require a soil pH ranging from 5 to 8 to thrive. (California Native Plant Society, 2014).
- Spatial scale needed (home range, dispersal distance, etc.)
    - In its native range in western North America *A. douglasiana* can be found from Washington and Idaho, through Oregon, in Nevada, to California and Baja Mexico.

Along the Pacific Coast, the species is also found in riparian corridors from 7,200 feet in elevation to sea level (Tutka, 2015).

- Temporal scale needed (time to maturity, generation time, time period when most vulnerable to disturbance, etc.)
    - Depending on precipitation availability *A. douglasiana* has a very fast growth rate. It is winter deciduous and has flowering seasons in the spring, summer, and fall if rainfall conditions are met (California Native Plant Society, 2014). During especially hot summers when soil moisture is limited, *A. douglasiana* is most vulnerable to disturbance as rhizomes start to dieback rather than spread, leading to reduced plant population establishment (Tutka, 2015).
- How does your topic respond to: climate change, other management actions?
    - Monitoring data provided by the report indicates that factors associated with climate change, including tropospheric ozone and certain air pollutants, have inflicted injury to understory plants such as the *A. douglasiana*. The report also provides a geographic map delineating different risk levels to injury from ozone exposure in California, with certain areas in Fresno having moderate to high risk. In these regions, the establishment of future *A. douglasiana* populations may in the future prove to be more difficult, as ozone pollution can have to potential to alter soil moisture levels, which *A. douglasiana* is sensitive to (Campbell, Wanek and Coulton, 2007).
    - Previous restoration efforts focused on increasing understory vegetation have found that a "passive relay" floristics (RF) approach, where several common trees and shrubs well tolerant of disturbed early successional conditions are planted in order to facilitate the establishment of other understory and woody plants, does work with *A. douglasiana.* In fact, *A. douglasiana* is one of the few understory plants which are able to become established at a disturbed site using this RF approach (McClain et al., 2011). This may be due to the ability of *A. douglasiana* to spread rhizomatously in addition to the species being tolerant of both open and canopy conditions (Moore, Holl and Wood, 2011). The plant's ability to tolerate shade is critical to its establishment at restored riparian forests in north to central California as cover of non-native, unplanted understory vegetation is generally much lower under the canopy compared to open areas treated with grass-specific herbicide (Moore, Holl and Wood, 2011). This would allow *A. douglasiana* to be an ideal candidate for native establishment during the earlier successional stages of the restoration process (Moore, Holl and Wood, 2011).
- For invasive species, etc.- need to include how it may negatively impact the system.
    - Though it is considered native in its range, *A. douglasiana* may become weedy and invasive especially on private property. This is especially the case in irrigated areas where the soil is moist, such as in irrigated pastures. As *A. douglasiana* has the ability to spread rhizomatously when soil moisture conditions are good, the speacies may displace any desirable forage species in the pasture or other human cultivated habitats (DiTomaso and Healy, 2007).

C. Restoration Goals

- Restore *A. douglasiana* at riparian sites which have been used previously for agricultural purposes in California's Central Valley; specifically, where *A. douglasiana* and other such riparian species have been eliminated in order to make space for crop rows over the past several decades. The selection of sites will prioritize areas where the presence of *A. douglasiana* has been documented to serve a historical role in Californian tribe cultures, which, in terms of geographic location, range all across California (McCarthy et al 2012).
- Establish a dense early successional understory layer of *A. douglasiana* at a level that is suitable for the necessary concealment of nests for native bird species, such as the Least Bell's Vireo. Based on existing data on the Least Bell's Vireo Breeds in restored riparian habitats at the San Joaquin River National Wildlife Refuge, a sufficiently dense understory layer would entail a substrate height of 450 cm. In addition, the density of *A. douglasiana,* in order to be sufficient, would have to provide at least 40 percent concealment one meter distance above the nest, 30 percent concealment one meter south of the nest, and 90 percent concealment one meter west of an existing nest (Wood, Howell and Geupel, 2005). The height of *A. douglasiana,* however, may be highly dependent on availability of soil moisture, shade, and rainfall conditions at each specific site (California Native Plant Society, 2014). Knowing the degree to which each of these variables influences the developmental process of *A. douglasiana* could aid in the assessment of whether or not additional plants would be needed alongside existing vegetation in order to provide adequate cover for numerous species of concern over the full nesting season.
- Establish a dense early successional understory of *A. douglasiana* which will serve to facilitate the established of other understory and woody plants commonly found to co-occur with the species (McClain et al., 2011). These co-occurring plants will include Currant/Gooseberry (Ribes sp.), Wild Rose (Rosa sp.), willow (Salix sp.), and wild grape (Vitis sp.). (California Native Plant Society, 2014).
- Assure that *A. douglasiana* individuals do not proliferate pass desirable conditions outlined in bullet point 1 in established agricultural areas. As *A. douglasiana* has the ability to spread rhizomatously when soil moisture conditions are good, the species may displace any desirable forage species in pastures or other human cultivated habitats (DiTomaso and Healy, 2007). Restoration projects in or near human cultivated habitats will curtail about 80 percent of this rhizomatous growth from going out of control following restoration planting, which is of special concern at sites where there is good soil moisture as well as shade availability (DiTomaso and Healy, (2007).

D. Restoration Plan

- Previous restoration efforts focused on increasing understory vegetation have found that a "passive relay" floristics (RF) approach, where several common trees and shrubs highly tolerant of disturbed early successional conditions are planted in order to facilitate the establishment of other understory and woody plants, does work with *A. douglasiana*. In fact, *A. douglasiana* is one of the few understory plants which are able to become established at a disturbed site using this RF approach (McClain et al., 2011). This may be due to the ability of A. douglasiana to spread rhizomatously in addition to the species being tolerant of both open and canopy conditions (Moore, Holl and Wood, 2011). The plant's ability to tolerate shade is critical to its establishment at restored riparian forests in north to central California as cover of non-native, unplanted understory vegetation is generally much lower under the canopy compared to open areas treated with grass-specific herbicide (Moore, Holl and Wood, 2011). This would allow *A. douglasiana* to be an ideal candidate for native establishment during the earlier successional stages of the restoration process (Moore, Holl and Wood, 2011). With this consideration, restoration at each specific 5 to 60 hectares site will first focus on establishing a vibrant *A. douglasiana* population. The establishment of *A. douglasiana* will occur over a 3 to 4-year period, depending on optimality of conditions over the first 2 years. Planting will be monitored to ensure a minimum of 75 percent survival over the first 2 years with plant densities ranging from 1000 to 1300 plants per hectare.
- Direct seeding will occur from late fall through winter on well prepped sites at a seeding rate of 2.2 lb/ acre at a depth of ¼ of an inch (Tutka, 2015). Seeds will be collected from naturally occurring populations of *A. douglasiana* located within California's Central Valley. However, as *A. douglasiana* has insufficient published seed collection information and data, more information will be needed to determine the ideal window for seed collection (Barton et. al, 2016). The plant is highly tolerant of a wide range of soils types and moisture availability, especially at sites with abundance shade availability, so planting along riparian sites can be dispersed evenly throughout the specified acreage of each area. During the first two initial years, irrigation will be used to secure the establishment of *A. douglasiana*. The roots of the plants themselves also spread through rhizomes, which die back in the winter as well as summer drought periods and sprout when optimal moisture and temperature levels are present. For this reason, even at a 50 percent survival rate, enough plants will be present to establish the population at a specific site in the following season. (Tutka, 2015).
- There is reason for concern that *A. douglasiana* may become an invasive as a result of restoration efforts close to human manipulated habitats, including pastures and farmland where irrigation could provide year round optimal moisture conditions for the

establishment of the species (DiTomaso and Healy, (2007). Removal will take place to remove the rhizomatous roots of *A. douglasiana* once they die back in the winter in order to prevent sprouting from taking place in the fall and spring when moisture and sunlight conditions are optimal. Removal itself can come in the form of targeted hand weeding so as to limit the removal of desirable plant species. There is, however, limited information on the specific threshold at where *A. douglasiana* could secure dominance over the landscape. When specifically to initiate the removal of rhizomatous roots is a matter which further scientific research is necessary (DiTomaso and Healy, (2007).

E. Monitoring Plan

- Pre-restoration monitoring will take place one year prior to restoration efforts for every month over a period of 12 months. For each month, eighty vegetation measurements will be taken per site with 1 x 1m quadrats on a grid of sampling points spaced 80m apart. For each quadrat, total live cover, litter cover, woody seedlings, and bare ground will be recorded. Average rainfall per month, soil nutrient richness, and existing animal communities in the area will also be recorded on a month by month basis for the duration of the 12 months monitoring effort. This is done to determine whether *A. douglasiana* is already present at the current site, whether specific species of concern with different vegetation needs are present, and if *A. douglasiana* could thrive in restored areas in the long term in consideration to present environmental conditions.
- Post-restoration monitoring will take place for 10 years after the restoration effort wraps-up. It will take about 2 years for *A. douglasiana* to be fully established on the site, and it will take an additional decade before the habitat could progress onto the next successional stage (Tutka, 2015). Monitoring will be less frequent than pre-restoration monitoring but follow the same procedures. Measurements and samples will be taken once every 2 months in order to ensure that *A. douglasiana* is thriving at each restored site.
- If complete failure of establishment is recorded over the first 2 years of restoration work, a full reassessment of planting techniques will be taken into account. Plants will subsequently be transplanted rather than seeded. One and 2-year old seedlings will be grown at a nursery, rather than directly onsite, and subsequently transplanted onsite during early spring. Irrigation for these transplanted plants will be heightened to ensure optimal soil moisture levels are being maintained during the plants' initial readjustment period to new environmental conditions (Tutka, 2015). If establishment is sporadic, transplanted plants will be used in pockets where *A. douglasiana* was unable to grow with direct seeding. Data will be recorded to determine whether soil moisture conditions and shade levels are different in these regions in order to garner additional data as to which conditions *A. douglasiana* prefers at each specific site.
- Monitoring data pertinent to bird species of concern will be investigated carefully. During the nesting season, the areas around each nest will be carefully measured for percent cover by vegetation to determine whether a greater density of understory plants will be needed. This could be done through monitoring the percentage of nests harmed by predation. If a significant portion of nests are reported to suffer damage from predators, a greater density of *A. douglasiana* plant will be assessed and planted in order to ensure adequate protection for future nesting seasons.
- In restored areas near human settlement and farmland, percent cover of vegetation will be monitored at random points established within half a mile of the agricultural enterprise. If

a significant percentage of the vegetation at these random points are reported to be of *A. douglasiana*, weeding will be applied in order to prevent the invasion of the species onto human landscapes. The determination of 'significant', however, requires a more in depth understanding of the speed and vigor of *A. douglasiana* in dominating the landscape.

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Deergrass (Muhlenbergia rigens)

Emma Liffick

Part I: Species Background and Justification

Deergrass (*Muhlenbergia rigens*) is an evergreen perennial bunchgrass native to California. It is an adaptable, fast-growing plant with an extensive root system, making it a valuable for streambank stabilization and erosion control**Invalid source specified.Invalid source specified.**. It can also suppress weed growth when it grows in dense colonies. Deergrass can tolerate varying levels on water inundation, poor soil conditions, drought, grazing, and fire **Invalid source specified.Invalid source specified.**. It can occupy wetland and riparian habitats, but also thrives in upland communities like valley grasslands, yellow pine forests, and central oak woodlands **Invalid source specified.**.

Growth and Reproductive Characteristics:

- Grows in large, dense clumps with mature plants reaching 3-5 feet tall and 3-6 wide **Invalid source specified.Invalid source specified.**
- Flowering period occurs from May to September **Invalid source specified.Invalid source specified.**
- Seeds are very small, requiring 2.5 million to make one pound **Invalid source specified.**
- This is a fast-growing plant that reaches maturity from seed in one to two seasons **Invalid source specified.Invalid source specified.**

Range:

- *Muhlenbergia rigens* is native to California, but is also currently found in Nevada, New Mexico, Arizona, Texas, and Mexico. Its range is restricted to North America **Invalid source specified.Invalid source specified.**

- Occurs naturally in valley grasslands, chaparral, yellow pine forests, central oak woodland, and wetland-riparian areas, and is used as an ornamental plant in private and commercial landscaping **Invalid source specified.Invalid source specified.Invalid source specified.**
- Grows below 2150 m elevation **Invalid source specified.**
- Found in sandy or gravelly soils, well-drained soils **Invalid source specified.**

Habitat/Conditions:

- In Solano County, *Muhlenbergia rigens* can successfully exist in riparian areas that are submerged/very wet for most of the year, lower floodplain areas that flood when streamflow exceeds capacity of channel, and upper floodplain areas that flood when streamflow exceeds the capacity of the stream channel**Invalid source specified.**
- Can tolerate sand, clay, gravel soils, but cannot tolerate poorly-drained soils **Invalid source specified.Invalid source specified.**
- Grows best in soils with a pH of 5.0 – 8.0 **Invalid source specified.**
- Grows in USDA zones 6 – 10 with a minimum average annual low temperature of -10°F**Invalid source specified.**
- Tolerant of shade, and often occurs naturally in openings within chaparral and mixed forests **Invalid source specified.**
- Tolerant of moderately saline water. One study found *Muhlenbergia rigens* maintained good growth when receiving irrigation water with a salt concentration up to 1500 mgL^{-1} NaCl**Invalid source specified.**

Restoration and Management Considerations:

- Once established, deergrass is drought-tolerant **Invalid source specified.**
- Burning or mowing every 2 to 5 years helps to maintain vigor, reduce accumulated dead material, and promotes seedling production. Burning or mowing should be done in the fall after the plants have gone to seed **Invalid source specified.**
- The seeds of deergrass germinate slowly, varying from two weeks up to two months. Repeated tillage and burning are recommended to prepare the site for planting to reduce the weed seed bank and give the slowly-germinating deergrass seeds time to establish **Invalid source specified.**
- Deergrass can be planted by broadcast seeding or using plugs. Broadcast seeding should be done in late spring or summer, with irrigation. Seed can also be sown into flats or cells in May and planted out in the Fall of the same year, or during the summer or fall of the next year **Invalid source specified.**
- One study done in Arizona demonstrated that broadcast seeding of *Muhlenbergia rigens* at a riparian restoration site was unsuccessful, resulting in all germinated plants not persisting past one or two years. The authors of this study and the USDA recommend planting with plugs as a more successful alternative to broadcast seeding for *Muhlenbergia rigens* ***Invalid source specified.Invalid source specified.***

Interactions

- If grown in dense colonies, deergrass has the ability to crowd out other potentially invasive plants and act as a weed suppressor **Invalid source specified.**
- Young tufts of *Muhlenbergia rigens* are grazed deer, cattle, ground squirrels, and rabbits. The seeds provide food for songbirds **Invalid source specified.Invalid source specified.**
- Deergrass serves as an insectary plant for the California ringlet (*Coenonympha California*) and umber skipper (*Poanes melane*) butterflies as well as ladybugs that overwinter in clumps of deergrass. Supporting beneficial insects may benefit other plants in the community with insect herbivory problems**Invalid source specified.Invalid source specified.**
- Several fungi are known to infect the leaves of deergrass, including tar spot (*Phyllachora epicampis*), rusts (*Puccinia schedonnardi* and *Uromyces epicampis*), and stripe smut (*Ustilago striiformis*). These infections are debilitating, though not typically deadly, and can be eliminated using fire **Invalid source specified.**

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<u>Part II: Goals, Restoration, and Monitoring</u>

A. Goals

Deergrass (*Muhlenbergia rigens*) is a highly adaptable, native, perennial grass. Once established, deergrass can tolerate periodic water inundation, drought, poor soil conditions, and a wide variety of other disturbances. Because the species is so adaptable, the main challenges in restoration will be to plant and establish a self-sustaining population, and to control invasive weeds that can outcompete and displace the native grasses.

The restoration goals should include:

a. Prepare site by removing existing vegetation and exhausting weed seed bank using burning, tilling, or a combination of those treatments (methods outlined in restoration plan). Non-native annuals present in the seedbank grow quickly and may outcompete the slower growing native perennials. Site preparation is critical to the success and long-term establishment of native deergrass **Invalid source specified.**.

b. Establish a population of deergrass either by broadcast seeding on site or by sowing seed in containers and out planting young plants (methods outlined in restoration plan). It's suspected that once established, native perennial grasses persist at relatively low densities (5-10 individuals per square meter), but can reach higher densities under favorable conditions. 5-10 individuals per square meter should be considered the minimum density threshold for successful stand establishment. If possible, higher densities (up to 100% cover) may increase species benefits such as weed suppression (USDA NRCS National Plant Data Center 2003); **Invalid source specified.**.

   i. If broadcasting, sow between 50-500 seeds per m^2 (Stromberg and Wolden 1997); **Invalid source specified.**; (USDA NRCS National Plant Data Center 2003).
   ii. If planting from containers, plants should be spaced at a minimum width of 24 inches (USDA NRCS National Plant Data Center 2003).

c. After the plants are established, continue monitoring and weed control efforts for at least 4-5 years when possible **Invalid source specified.**.
   i. Burning or mowing every 2-5 years in the fall after the plants have gone to seed may increase vigor and help suppress other invasive grasses **Invalid source specified.**. If regular burnings are not possible, burning in the fall for the first two years after planting is recommended **Invalid source specified.**.
   ii. Application of broad-leaf or pre-emergent herbicide can be important during the first growing season when particularly troublesome species are present in the seed bank. On productive sites, most native perennial grasses grow large enough to shade out annual weeds within 2-3 years, and should not require additional herbicide treatments **Invalid source specified.**.

These goals are feasible, assuming resources are sufficient and long-term monitoring is possible. If resources are limited, the most important task is limiting invasive annual growth through site preparation and continued weed management through establishment (at least through the first 2 years if possible)

(Stromberg and Kephart 1996). In the absence of monitoring and addressing weedy plant invasion, those plants will easily take over the site and out-compete deergrass before it is able to out shade them.

B. Restoration Plan

a. Preparing Site

   i. Deergrass is very adaptable and can grow in a wide variety of conditions and habitat types (USDA NRCS Plant Materials Program 2002). Consequently, specific site selection is not as important when planting deergrass as it is for other species. Generally, deergrass can tolerate clay, sand, and gravel soils; but it does best when soils are not poorly-drained (USDA NRCS National Plant Data Center 2003). Deergrass also does well in soils with a pH of 5.0 – 8.0. Soil tests can be done to determine soil composition and pH; however, this should not be the primary focus of site preparation.

   ii. Repetitive tillage involves loosening the soil, irrigating, and cultivating the area with disc harrow. A flush of weeds will grow and can be burned or passed over with a ring roller. This should be done several times before seeding to exhaust the seed bank (USDA NRCS National Plant Data Center 2003).

b. Establishing a population of *Muhlenbergia rigens*

Ideally, seeds should be gathered from a local source to maintain genetic diversity. When seeds are mature, flower stalks can be cut, bundled, and beat over a tarp or bucket to release seeds (USDA NRCS National Plant Data Center 2003). Seeds can then be broadcasted or planted into containers for future transplant. For establishing plants, planting from containers may be more successful (Stromberg and Kephart 1996; USDA NRCS Plant Materials Program 2002), but is more expensive than seeding. Site preparation is the same for both broadcasting or container transplants. Fertilizers or soil amendments should not be used as they can give the upper hand to invasive weeds (USDA NRCS Plant Materials Program 2002).

i. If using seeds, they should be planted in late spring to summer in May, June, July, or August. The seeds are very small—just 0.2mg each—so making sure the seeds are in contact with the soil is of upmost importance. After broadcasting seeds at a rate of about 150 seeds per square foot, seeds must be run over with a ring roller or culti-packer to press them into the soil. If machinery is not suitable for the site or is too expensive, driving cattle or other livestock over the seeds is a low-budget method for incorporating the seeds into the soil. Germination rates can vary from 2 weeks to 2 months (USDA NRCS Plant Materials Program 2002; Stromberg and Kephart 1996)

ii. Container planting is a more effective and less time-consuming method for establishing deergrass plants, but is more costly than seeding on a large scale. If planting from containers, sow seeds into flats, D-pots, stubby cells, or reforestation tubes in May. Plants can be planted out from containers the same fall after the first rains. When transplanting young plants at the site, space plants at a minimum of 2 feet apart. Irrigation is not necessary in normal rainfall years. Larger bunches of deergrass can also be divided in winter or early spring and transplanted. When using container planting, a stand of deergrass can be established in just 1 ½ years (USDA NRCS Plant Materials Program 2002).

c. Control weed competition

Whatever techniques are used, a long-term weed control program must be followed for several years after planting to prevent the site from reverting to invasive plant communities. Ideally, sites should be monitored (see monitoring plan) and weeds controlled for 4-5 years after planting (Stromberg and Kephart 1996).

i. After seeding when the plants are still young and not very competitive, several weed control options are possible. If annual invasive grasses are a problem, mowing or intensive short-duration grazing by cattle or sheep before the annual grass seeds have matured can be very effective. Doing so increases the sunlight reaching the young, slower growing deergrass plants (Stromberg and Kephart 1996).
ii. Applying broad-leaf or pre-emergent herbicides can benefit young deergrass plants, particularly in the first growing season and when the site has a seedbank with particularly troublesome species (Stromberg and Kephart 1996).
iii. Mowing or burning in the fall after the plants have gone to seed for at least the first two years of establishment can be beneficial in keeping other unwanted plants at bay. If there is not enough fine fuel on the site to carry a fire, propane-fired burners can be used to destroy germinating exotic seedling grasses and broadleaf plants in the early winter growing season. There is also ethnobotanical evidence that manmade fire increases vigor of deergrass and allowed it to grow in denser stands than under normal conditions. Fire also eliminates fungal pathogens that can afflict deergrass (Stromberg and Kephart 1996; USDA NRCS Plant Materials Program 2002).

C. Monitoring Plan

When first planting the deergrass, if the entire stand should fail, another method of cultivation should be tried (for example, if broadcasting seeds failed, try planting from containers). If only parts of the stand fail, try replanting using the same planting method during the next planting season; or try a different method. Studies suggest that adding irrigation for new plants may also beneficial; however, research has not yet been done to determine appropriate timing or amount (Stromberg and Wolden 1997).

Most studies involving planting and restoring deergrass populations have not followed through with monitoring beyond the first year after planting, so little is known about when and how to monitor the success of these plantings. However, it is suggested that consistent, long-term weed control be followed for several years after planting to avoid weeds reclaiming the site (Stromberg and Kephart 1996). After the plants are planted, most of the monitoring should be focused on watching the balance between deergrass establishment and weed populations. As the deergrass plants become larger and more established, weed control will be less important as they should be able to grow above and shade out most of the annual weeds (Stromberg and Kephart 1996). Monitoring should be most thorough during the first 2-3 years after the plants are planted since this is when the plants are most susceptible to invasion by invasive annual grasses and other weeds (Stromberg and Kephart 1996). If the plants are becoming established and the weed populations are under control, monitoring can be eased off over the next 1-2 years, watching mainly for weeds tipping the balance in their favor and beginning to outcompete deergrass.

D. Research Needs

More research needs to be done on how the different factors (i.e. planting method, types of weed suppression, etc.) affect long-term viability and success of the planted populations. Other studies using deergrass and other perennial native grasses in restoration have success following the first year or so, but monitoring ends before the plants take hold, and the sites often revert to invasive annual weeds (Stromberg and Kephart 1996). This restoration project could improve the body of research surrounding the restoration of deergrass and other native grasses by experimenting with types and frequencies of weed control following planting and monitoring the success of the stands over several years.

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California Aster (*Aster chilensis*)

Steffi Sin

Background and Justification:

The California Aster (*Aster chilensis*) is a California native species. It is currently not listed as endangered (CNPD 2010). It is an understory plant used in hedgerows and tailwater pond planting, especially in the Sacramento Valley region (Pickett, 1998). There have not been many comprehensive studies done, focusing on the California Aster in wetland-riparian zones. Though its host butterfly, *Phyciodes campestris,* is extensively researched. Reports have shown that the coverage of this butterfly has reduced along with California Aster numbers, and the most likely cause of this is successional vegetation change (O'Brien et al., 2011). Introduciton of invasive plants into wetland-riparian areas have also displaced the resources of these butterflies (O'Brien et al., 2011).

Literature Review:

Growth Characteristics:

- It is a low, spreading, evergreen groundcover (CNPD 2010).
- The California Aster is a perennial forb (Reed et al., 2011).
- It has a relatively fast growth rate (CNPD 2010).
- The California Aster grows to a height of 6-12 inches and about 5 feet in width (CNPD 2010).
- It flowers from year round (CNPD 2010).
- Flower color is violet. Several stems group upwards from the base into large panicles of flowers that are characteristic of the Asteraceae family (CNPD 2010).

Reproduction:

- It spreads by runners (CNPD 2010) and seeds.
- There is a chance of delayed germination of up to two months when growing the California Aster to plant in a site (Adams, 2012), which could be due to low seedling vigor (Pickett, 1998).

Range:

- The California Aster is widely distributed in the west and central northwest, Central west, the north south coast, and the North Channel Islands (CNPD 2010).
- Its natural habitat is in the grasslands, and disturbed places below 2000’ (CNPD 2010).
- According to historical ecology, scientists hypothesize that *Phyciodes campestris* was probably common in the California Delta region and in the tules with California Aster before the Europeans had colonized (Shapiro 2009).

Habitat/ Requirements:

- Water requirements are moderate to regular (CNPD 2010).
- The California Aster is highly adaptable in terms of soils (CNPD 2010).
- It is an understory plant, which means that it requires some amount of shade to thrive (Pickett, 1998).

Tolerances:

- The California Aster is cold hardy to 25 degrees Fahrenheit (CNPD 2010).
- It grows in full to part sun exposure (CNPD 2010).
- It is adaptable to a wide range of soil types (CNPD 2010).

Interactions:

- Competition from non-native plants may outcompete the natives for water resources (Ho, 2015).
- The butterfly *Phyciodes campestris*, Field Crescent, is an endemic native to the Sacramento region. It uses the California Aster as its host plant. They have been reported to be located in large colonies alone Willow Slough from northwest of Davis to the Yolo Bypass. There are also smaller colonies reported at north Woodland, Stone Lake-Beach Lake, and North Sacramento. Colonies found in Davis, Willowbank, and West Sacramento are noted to be strays and are mostly seen in the fall season (Shapiro, 1974).
- The California Aster is used for grazing by sheep and deer though it is not a large percentage of their diet (Smith, 1965). It is mostly part of mule deer diet from summer to early fall (Dietz & Nagy, 1976).

Management Considerations:

- While the California Aster is native to the state, it can be invasive since it spreads by runners (CNPD 2010).

- The California Aster has a FAC wetland indicator status (Reed et al. 2011).
- The planting of the California Aster is considered appropriate for the purpose of restoring a site when reference sites carry many similarities (Reed et al., 2011).
- Soil moisture effect the growth and the chances of success of revegetation in riparian areas. Studies have shown that seedlings grown on sloped plots rather than more even terrain have a lower mean growth rate. This means that restoration efforts on flat terrain have a higher chance of success (Ho, 2015).
- Soil moisture at a site differs depending on the evapotranspiration rate between invasive and native species (Ho, 2015).

Management Plan for the California Aster

Introduction:

The California Aster (*Aster chilensis*) is a California native species, and it is not listed as endangered (CNPD 2010) though its numbers have been reported to be in decline due to successional vegetation change (O'Brien et al., 2011). It is an understory plant used in hedgerows and tailwater pond plantings, especially in the Sacramento Valley region (Pickett, 1998). There have not been many comprehensive studies done on the California Aster in wetland-riparian zones. It grows at a relatively fast rate and is highly adaptable in terms of soils (CNPD 2010), though it requires some amount of shade to thrive (Pickett, 1998). It is the sole host plant of the butterfly *Phyciodes campestris* (Shapiro, 1974). The California Aster has a tendency to spread invasively since it spreads by rhizomes (CNPD 2010). When planting, it is important to group them with other fast-growing plants that have the ability to compete with the aster and after less competitive species have been well established on the site. The monitoring plan, spanning 2 years, will ensure it does not out-compete other plants in the area.

Key Restoration Goals:

1. Establish site suitability for the planting of California Aster seedlings with necessary conditions. Implementation of this goal is outlined below.
2. Plant and monitor the growth of the California Aster for 2 years after it is planted to ensure success. A monitoring and maintenance plan is outlined below.
3. Manage for species interactions by attracting the California Aster's host butterfly, the *Phyciodes campestris* (Shapiro, 1974) and establishing a small population in the area.

Restoration Plan:

Establish Site Suitability:

- Eliminate/ combat invasive species where planting to ensure the success of the California Aster along with its host butterfly (O'Brien et al., 2011).
- Establish dense plantings of trees or large shrubs to create shaded areas. The California Aster requires part shade and part sun to thrive (CNPD, 2010).
- Measure the amount of water the site receives throughout the year. When first planted, the California Aster requires regular water (CNPD, 2010), so depending on the site, it might be necessary to put in irrigation.
- Measure the temperature variability of the site in all seasons. The California Aster is only cold hardy to 25 degrees Fahrenheit (CNPD, 2010).
- Measure the elevation of the site. The California Aster is to be planted in areas below 2000' (CNPD, 2010).
- Seedlings have a higher success on flatter slopes.
- The California Aster is adaptable to a wide range of soil types and salinity (CNPD, 2010).

Planting:

- Plant the California Aster after site suitability is established.
- When planting California Asters, acquire seedlings through nurseries (Bickart, 2013).
- The ideal planting time is in the spring, around March-April (Calflora).

- There have been reported cases of delayed germination in nursery seedlings of up to two months (Adams 2012), which might be the result of low seedling vigor (Pickett, 1998).
- Seedlings have a higher chance of success on flat terrain, so avoid planting on steep slopes.
- The California Aster requires part sun and part shade in order to thrive (Pickett, 1998), so plant them in locations with sufficient shading and sunlight, such as under established trees or large shrubs.
- The California Aster is best suited for upland/ riparian habitats and grasslands below 2000’ in elevation (CNPD, 2010).
- Due to its rhizomous habit, the California Aster requires ample room for growth and establishment. It is recommended that each seedling be planted 4-5 feet apart (CNPD, 2010).
- Plant the California Aster after less competitive species have been established for 1-2 years since the California Aster has a tendency to spread invasively (CNPD, 2010).

Monitoring Plan: (2 Years)

- Due to the California Aster's spreading habit, it is a good competitor against reinvasion of invasive species (CNPD, 2010).
- Monitoring should begin for 6 months after first planting the seedlings to ensure they are receiving an adequate amount of water, and if there is an irrigation system, check that it is working properly. Make sure the California Aster seedlings are receiving enough shade and sunlight.
- After the first six months, monitoring can be less frequent, to about every other month. At this stage, it is important to monitor for growth and whether the California Aster begun to flower. It flowers year-round.
- Once the California Aster flowers, monitoring can be lessened to every two or three months. After having been established for a year, the California Aster will have a high chance of attracting its host butterfly, the *Phyciodes campestris* (Shapiro, 1974). When mnonitoring the growth and establishment of the California Aster, be aware of pollinators and such as bees and butterflies and their abundance in the area. A well-established California Aster population should attract a population of *Phyciodes campestris*.
- After 2 years, the long-term monitoring plan is to ensure the California Aster does not spread to become a competitor for native species that have been planted as part of the restoration plan. If feasible, there should be continued monitoring of the host butterfly in conjunction with the growth success of the California Aster.

<u>Species Interactions:</u>

- The California Aster is a small percentage of sheep and deer diet (Smith, 1965). This means that its presence will not solely attract grazers, but if grazing animals are present, they will graze on a small portion of California Asters.
- It is important to manage for species interactions. Dips in the *Phyciodes campestris* population could mean a decrease in California Aster population, and vice versa. Promoting species interactions between plants and pollinators ensures a healthy ecosystem in the long-term.

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Narrow leaf milkweed (*Asclepias fascicularis*)

Emma Steer

Background and Justification

The narrow leaf milkweed (*Asclepias fascicularis*) is a drought tolerant native perennial forb to California. It is an important species for pollinators, especially monarch butterflies which depend on it as a larval host, and use the foliage for food and the flowers for nectar (Luna and Dumroese, 2013). Conservation of pollinators is essential for agriculture and the environment and narrow leaf milkweed is important for creating critical habitat for pollinators which are in extreme decline. Annual surveys have shown a nearly 90% loss of monarchs on the California coast over the last decade (Landis et al. 2015). A major factor contributing to this loss is the decline of native milkweeds caused by urban and agricultural development as well as the application of post-emergent herbicides in croplands, pastures, and roadsides (Landis, 2014). Narrow leaf milkweed also attracts beneficial insects that are predators of many crop pests (James et al. 2016). As the most widespread milkweed species in California, it can be found in a variety of habitats including lower riparian, seasonal floodplain, foothill woodland, chaparral, valley grasslands, as well as drier upland areas as it is tolerant of drought (CNPS, 2017). It can be found in every region of the state except the Sonoran Desert and the upper montane, subalpine, and alpine zones of the Sierra Nevada (Xerces, 2011).

Literature Review

Growth Characteristics:

- Narrow leaf milkweed is a flowering perennial with many thin, erect stems that bear narrow, long, pointed leaves that are in whorls of 3-5 (CNPS, 2017, USDA, 2017).
- The bloom period is from May to October and the white or lavender tinted flowers are in clusters that look like crowns with reflexed corolla (Calfora, 2017, USDA, 2017, Xerces, 2011).
- Narrow leaf milkweed is deciduous meaning it loses its leaves in the winter and sometimes dies back to the ground (CNPS, 2017).
- The active growth phase occurs for 6-8 months, from later winter to mid-summer (Leigh et al. 2006).
- It grows up to 3 ft tall and 1 ft in width (CNPS, 2017).
- It is generally glabrous, meaning they are smooth without any hairs or appendages (Rosatti and Hoffman, 2017).

Reproduction:

- It is pollinated by a diverse array of native bees, wasps, flies, moths, and butterflies, and augmented by wind dispersal of comose seeds, or having tufts of hair (Wyatt and Broyles, 1994).
- It is self-incompatible, meaning it must receive pollen from another plant of the same species to produce viable seeds (Luna and Dumroese, 2013). It can occasionally hybridize with other milkweeds (Wyatt and Broyles, 1994).
- The pollen is stored as pollen masses (pollinium) rather than individual pollen grains, which attach to pollinators and are carried to other individual milkweeds (Luna and Dumroese, 2013).
- Flowers develop into follicle fruits that mature from late summer to fall, which open on one side and release flat brown seeds with long white hairs to aide with wind dispersal (Luna and Dumroese, 2013).
- Plants will likely reach maturity, flower and seed within the first year (Borders and Mader, 2014).
- Reports have shown that peak seed production occurs in the third or fourth year however it is unclear exactly how long milkweed stands can persist in the wild, as some have shown peak seed production in the 10^{th} year (Borders and Mader, 2014).

Propagation:

- Seeds should be collected right before or when the fruit is completely ripe and dried during mid spring to mid-summer (Leigh et al 2006).
- Stratification of seeds at a temperature of 5 degrees C over winter has shown to significantly improve germination success and uniformity (Borders and Mader, 2014).
- It does best when seeded in the ground as opposed to a pot during the first fall after collection (USDA, 2017).

- It can be propagated by cuttings of the tuberous rhizomes collected during dormancy and planted during the fall at the beginning of the rainy season (USDA, 2017).
- Initial germination occurs within 6 weeks and establishment of rooted sprouts takes at least 7-8 weeks (Leigh et al. 2006).
- Optimal germination occurs at temperatures between 35 and 40 degrees C, with better results when treated with gibberellin and potassium nitrate (Harmon et al. 2005).
- Both seedlings and cuttings will bloom in the second year however cuttings may bloom during the first year (USDA, 2017).

Range:

- Narrow leaf milkweed is found throughout California except in except the Sonoran Desert and the upper montane, subalpine, and alpine zones of the Sierra Nevada (Xerces, 2011)
- The range extends beyond California into Washington, Utah, and Baja California (USDA, 2017).

Habitat/Requirements:

- Narrow leaf milkweed is found in a wide array of settings including valleys, foothills, canyons, mountains, often found in dry areas, and occasionally in wetlands (CNPS, 2017).
- Narrow leaf milkweed grows on dry ground and in full sun areas, usually in clumps on roadsides and open areas, valleys and foothills (USDA, 2017).
- It requires an annual precipitation of anywhere from 3.5 inches to 117 inches, with summer precipitation between 0.13 and 3.6 inches (CNPS, 2017).
- The rainy season can be anywhere from 0 to 8 months (Calflora, 2017).
- The average temperature range is between 24 and 69 degrees F (Calflora, 2017).
- It can tolerate a variety of soils including sandy, clay, and saline, with soil pH ranging from 6-8 (Calflora, 2017, CNPS, 2017).
- It can grow at elevations of 0 to 3050 meters (Calflora, 2017).
- It requires a minimum soil depth of 17cm (Calflora, 2017).

Tolerances:

- Narrow leaf milkweed is a hardy plant that can tolerate slightly saline soils (Calflora, 2017).
- It tolerates drought and well-drained soil, as well as seasonal flooding and some shade (CNPS, 2017).
- It can survive colder conditions since it is deciduous and usually dies back during the winter (Calflora, 2017).
- It can withstand temperature in the coldest month as low as 18 degrees F, and in the hottest month up to 98 degrees F (Calflora, 2017).

Interactions:

- It grows well in clumps of other milkweeds as well as a wide variety of other plants, however it should be planted around other plants that will attract monarchs, such as mallow, California lilac, western thistle, California aster, California fuchsia, buckwheat, mint, monkeyflower, and sages (CNPS, 2017).
- Due to a toxicity (cardenolides) in the milky sap, it is bitter to range animals which will usually avoid eating them (Xerces, 2011). Poisoning can occur in livestock if large amounts are consumed (Xerces, 2011).
- Narrow leaf milkweed is attractive to butterflies, bees, and other beneficial insects and it is generally pest resistant (USDA, 2017, Calflora, 2017).
- It may be vulnerable to leafhoppers, specifically the glassy winged sharpshooter and oleander aphids (Calflora, 2017, James et al 2016).
- Milkweed bugs are commonly found on milkweeds and suck the content out of the seeds making them inviable. If populations become dense, they can be controlled using neem oil which is non toxic to pollinators (Borders and Mader, 2014).
- Narrowleaf milkweed has been heavily browsed by black-tailed jackrabbits in California, which is more likely to occur during drought conditions when other food resources are limited (Borders and Mader, 2014).

Management Considerations:

- It grows best if started in a nursery and grown in large containers, and then transplanted into the field rather than directly seeded (Brown and Bugg, 2001).
- Since milkweeds are a main food source for monarch caterpillars, it is best to plant in small, scattered clumps to provide abundance of food and reduce stress in any one given plant (CNPS, 2017, Landis, 2014).
- It is critical to avoid using any pesticides around narrow leaf milkweed which can be fatal to monarch caterpillars (CNPS, 2017).
- If herbicides must be used, avoid broadcast applications and go for spot treatment of individual invasive plants to minimize the impact on larval host plants and adult forage plants like narrow leaf milkweed (Hopwood, 2013).
- It may be particularly sensitive to existing grasses after emergence, so till treatment is recommended (Brown and Bugg, 2001).
- Mowing during the first growing season will help native forbs to establish and keep invasive grasses under control, but it is best to mow when pollinators are least active during the early spring or late fall (Hopwood, 2013).
- Any mowing done after the first year will hinder the milkweed's ability to establish and compete with invasive grasses (Hopwood, 2013).
- Burning in the fall can help to stimulate new growth with taller and stronger stems, as well as stimulating flower and seed production (USDA, 2017).

<u>Management Plan for Narrow Leaf Milkweed (*Asclepias fascicularis*)</u>

<u>Goals:</u>

Narrow leaf milkweed is a hardy plant that can handle a variety of soils, salinity, some shade and flooding and drought, therefore once it is established it will be able to survive and reproduce for an extended period without human intervention or management (Calflora, 2017). It will be important to plant narrow leaf milkweed in clusters alongside other native forbs, grasses, and nectar plants to provide habitat and food for pollinators (Borders and Mader, 2014). The critical management and monitoring period will be during the first two years at the site while it's still being established. To ensure success of narrow leaf milkweed establishment at a given restoration site, it must first fit favorable environmental conditions.

- Establish narrow leaf milkweed within a native community that covers 85% of soil, with a species presence of about 10% cover to ensure sufficient habitat and resources for pollinators without overcrowding or encroachment into croplands and residential areas
- Establish narrow leaf milkweed in mostly dry, sunny areas of the site in linear hedgerows along perimeter to draw in pollinators, avoid encroachment on surrounding croplands, and increase positive edge effects such as erosion control and in clusters within the core of the site to further support the pollinator populations and decrease stress on any one individual plant
- Prevalence in seed bank should be 2-20 live seeds per linear foot based upon an estimated seed viability of 85% and at least 1-2 feet in between plants to ensure continuous coverage and avoid overcrowding once established

- Monitoring of plants for flowering, plant growth and vigor, pests, weed encroachment and any signs of herbivory during the first two years of establishment at the site at least once per month during the growing season from May until October
- Management should include shallow till or mow treatment (preferably early spring/late fall when pollinators are least active) if weed stress is high, potentially drip irrigation maintenance during establishment for the first year if water stress is high, and controlled burns in the fall during the first two years to help stimulate new growth with taller and stronger stems and flower and seed production if plants are not establishing well at the site

Pre-restoration Goals:

- Obtain viable plant material (seeds or cuttings) adapted to local environment and free of herbicides and pesticides to avoid any detrimental effects on pollinators and ensure that plants will be well suited for the environmental conditions at the site
- Survey the area for species currently existing at the site, in what amounts and where, hydrology and depth to the water table, soil characteristics, and wildlife to determine an appropriate weed management strategy and planting scheme
- Control spread of invasive plants using controlled burn, smothering, solarization, pre-emergent herbicide spot treatment (to minimize impact on pollinators and milkweeds), or a shallow till treatment (to avoid bringing up buried seeds in the deep bank)
- Continue weed control for at least 1-2 years (especially if direct sowing seeds) to deplete seed bank and control for emerging weeds that result from cultivation to assist in milkweed establishment

Restoration Plan

Weed Management

Before bringing in narrow leaf milkweed to the restoration site, it is critical to assure that it a suitable environment. The most common hindrance for milkweeds will be invasive grasses at the site. The area should first be surveyed to assess what species are present at the site and in what abundances and where. From there it can be determined what the best method for controlling invasive will be. If the invasive at the site are abundant and widespread, the best options would be a controlled burn (if in a safe location away from structures) or shallow till treatment. The till treatment should be shallow to avoid bringing up weed seeds buried deep in the seed bank (Borders and Mader, 2014). Only use herbicides at the site if the invasive weeds are isolated and scarce, and use spot treatment instead of broad application to minimize impact on pollinators (Hopwood, 2013). Post-emergent herbicides should be avoided as they are a major factor contributing to the decline of native milkweeds; use pre-emergent herbicides whenever possible (Landis, 2014). If a controlled burn or till treatment are not feasible, solarization or smothering can also be used to control the weeds (Borders and Mader, 2014). The weed control should continue for at least 1 year prior to introducing narrow leaf milkweed to the site to deplete the weed seed bank and control for the emerging weeds that may have resulted from cultivation (Borders and Mader, 2014). This is especially important if direct seeding of milkweed is done instead of transplanting.

Propagation

It is necessary to find viable, locally adapted seeds or plant material free of insecticides and herbicides. If there is not a local seed distributor for narrow leaf milkweed, it will be necessary to collect seeds from a local community. Narrow leaf milkweed will best compete with invasive species and establish in the field if started in a nursery from seeds or cuttings and then transplanted (Brown and Bugg, 2001). Additionally, if transplanted the plants may flower and produce seed within the first growing season (Borders and Mader, 2014). Transplanting requires less seed if supplies are limited and it is feasible for a small or large scale project (Borders and Mader, 2014).

Seedlings

Seeds should be collected right before or when the fruit is completely ripe and dried during spring to mid summer from a similar native community (Leigh et al., 2006). Seeds can also be outsourced; however, it is important that thy are locally adapted and free of herbicides and pesticides. If starting seeds in a nursery, sow seeds in prepared trays and stratify over winter at 5 degrees C for one week to one month or longer for optimum germination (Borders and Mader, 2014). To ensure success, begin stratification at least 3 months prior to desired transplant date (Borders and Mader, 2014). After stratification, sow seeds in a potting medium two months before the last frost and store in a greenhouse (Borders and Mader, 2014). Optimal germination occurs in soil temperature between 35 and 40 degrees C, with better results when treated with gibberellin and potassium nitrate (Harmon et al., 2005). Germination will occur within one week and may be ready for transplanting within 8 week to 5 months (Borders and Mader, 2014).

Cuttings

Using cuttings may be advantageous because they may reach maturity and flower within the first year while both seedlings and cuttings will bloom in the second year (USDA, 2017). Cuttings should be taken from the tuberous rhizomes during dormancy from a local native community or nursery. The rhizomes should be planted during the fall at the beginning of the rainy season (USDA, 2017). The soil from the roots should be removed and the rhizome planted horizontally; the new shoots that emerge can be removed and used as stem cuttings. Establishment of rooted sprouts takes at least 7-8 weeks (USDA, 2017). Plants should be kept in a deep pot to ensure a strong tap root which will increase survival and establishment when transplanted to the field (Borders and Mader, 2014). Move plants from the greenhouse to an outdoor shade house a week before transplanting to allow them to acclimate to the environment (Borders and Mader, 2014). Pruning the transplants down to the juvenile growth just before planting in the field will allow growth of new shoots that are acclimated to the site conditions and promote establishment (Borders and Mader, 2014).

Field Establishment

The milkweeds should be planted in sunny, mostly dry areas in uplands and seasonal floodplains, either in hedgerows or clusters. Planting in hedgerows along the perimeter of the site will attract pollinators into the site, create positive edge effects such as erosion control, and the linear growth will not encroach upon surrounding crop lands (Borders and Mader, 2014). Planting in small, scattered clumps will provide abundance of food and reduce stress in any one given plant, since milkweeds are the main source of food for monarchs (CNPS, 2017, Landis, 2014).

Transplants

Transplants should be planted in the fall in 2ft centers (1 plant per 4ft) in linear hedgerows or 1 plant per 2sq.ft. in clusters (Borders and Mader, 2014). If the weed pressure is high, a thin layer of mulch should be added to further assist establishment and retain moisture (Borders and Mader, 2014). Narrow leaf milkweed is well-adapted to non-irrigated conditions; once established they require a minimum of 3.5 inches of annual rainfall (CNPS, 2017). However, milkweeds need about 1 inch of water per week during the establishment phase, excluding natural rainfall events (Borders and Mader, 2014). Drip irrigation should only be installed if water stress is high during a drought period when seasonal rainfall is limited during establishment (Borders and Mader, 2014). Milkweeds will strongly benefit from sufficient moisture during the first two years, as it is unlikely that they will establish in dry conditions especially when planted from seed (Borders and Mader, 2014). An appropriate labor force will be needed for planting transplants and managing drip irrigation. Transplants are be advantageous because they may seed during the first growing season, they have a competitive advantage over weeds, and requires lower quantity of seed (Borders and Mader, 2014). However, it does require a sufficient labor force to plant the transplants as well as nursery space and time to grow the transplants (Borders and Mader, 2014).

Direct Seeding

If nursery access or labor force is unavailable, direct seeding into the field can also be used. The use of a specialty seed drill designed for wildflowers will be helpful at sites that exceed ¼ acre (Borders and Mader, 2014). If smaller scale, hand sowing can also be used and requires no equipment (Borders and Mader, 2014). For hedgerows, an average of 12 live seeds should be sown per linear foot. For clusters, an average of 8 seeds should be sown per square foot. A planting depth of ¼ to ¾ inch is optimal (Borders and Mader, 2014). If the seed source is limited, be more conservative, if not, it is better to seed at a high rate to promote vigorous germination and establishment. Seeding should be done in the fall as it mimics the natural germination time and winter conditions will stimulate growth in the spring (Borders and Mader, 2014). If direct seeding, it is very important to keep the site free of weeds so that the milkweeds can establish. It is critical that the soil is moist to stimulate germination; seeds should be sown in fall when the rainy season starts (Borders and Mader, 2014). If rainfall is scarce, drip irrigation should be installed to supplement water supply in between rains (Borders and Mader, 2014). Direct seeding may advantageous as it requires little time, labor and equipment (Borders and Mader 2014). However, it requires a much higher quantity of seeds and the plants will likely take longer to establish and reproduce in the field and initially will not be as competitive as transplants with invasive grasses (Borders and Mader, 2014).

Native Communities

Narrow leaf milkweed should be planted alongside a diverse native community of forbs, legumes, small statured native grasses, and other nectar plants to support pollinators and resist pests and pathogens, including weed encroachment (Borders and Mader, 2014). Consider planting Indian mallow (*Abutilon palmeri)*, California lilac (*Ceanothus sp.)*, western thistle (*Cersium occidentale*), California aster (*Corethrogyne filaginifolia*), California fuchsia (*Epilobium canum*), buckwheat (*Eriogonum sp.*), mint (*Monardella sp.*), monkeyflower (*Mimulus sp.*), and sages (*Salvia sp.*) alongside the narrow leaf milkweed (CNPS, 2017). They should not be planted next to taller trees because the shade will hinder their ability to thrive (Borders and Mader, 2014).

Continued Management

Narrow leaf milkweed may be particularly sensitive to any invasive annual grasses after emergence, so till treatment is recommended to control weeds (Brown and Bugg, 2001). Shallow cultivation or mowing should be performed at the site periodically during the first year to control for invasive weeds and allow the plants to establish. Mowing during the first growing season will help native forbs to establish and keep invasive grasses under control (Hopwood, 2013). Mowing and tilling should be done during the early spring or late fall, when pollinators and other wildlife are least active at the site (Hopwood, 2013). Any disturbance beyond the first year can hinder the milkweeds ability to compete with invasive grasses (Hopwood, 2013). The use of herbicides at the site should be extremely limited and only used as spot treatment, preferably pre-emergent, during the early spring or late fall when pollinators are least active to avoid any detrimental effects on the milkweeds and pollinators (Hopwood, 2013). If weed pressure is particularly high and the plants are not establishing well, a controlled burn should be done in the late fall when pollinators are least active to help stimulate new growth with taller and stronger stems and flower and seed production in the milkweeds (USDA, 2017).

Monitoring Plan

Narrow leaf milkweed may be particularly sensitive to existing grasses after emergence, so the critical monitoring period is during establishment, or the first two years after being planted at the site (Brown and Bugg, 2001). Monitoring should be done mainly during the growing season, May to October, since narrow leaf milkweed is deciduous and tends to die back during the winter (CNPS, 2017). The plants should be monitored for flowering and fruit production during the first two growing seasons. Characteristics such as plant height, growth vigor, stem strength, leaf size should be noted as an overall assessment of how the plant is establishing. If weed encroachment is particularly high, considerer some of the management practices outlined above. The plants should also be monitored for any pests, including milkweed bugs, glass winged sharp shooter, and oleander aphids (Calflora, 2017, James et al. 2016, Borders and Mader 2014). If populations of pests are dense, they can be controlled using neem oil which is non-toxic to pollinators (Borders and Mader, 2017). The use of pesticides at the site should be avoided at all costs, as they can be detrimental to pollinator populations (CNPS, 2017). The plants should be monitored for any evidence of herbivory, as narrow leaf milkweed has been heavily browsed by black-tailed jackrabbits in California, which is more likely to occur during drought conditions when other food resources are limited (Borders and Mader, 2014).

<u>Potential Problems/Solutions:</u>

- Herbicide/pesticide drift from neighboring crop lands: This is mainly out of the control of the restoration managers and should be addressed to surrounding farmers who can adopt practices that minimize drift. Woody species may be established along the perimeter of the site to act as a filter for herbicide/pesticide drift and create positive edge effects.
- Narrow leaf milkweed may be particularly sensitive to invasive grasses, and may not establish on its own if mowing/tilling treatment is not an option: Weeding by hand and using mulch are viable options for controlling invasive weeds on smaller scale, lower budget sites. A controlled burn may be an option if the site is in a suitable location and the burn is done at the correct time.

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California Bee Plant (Scrophularia californica)

Megan Stover

Background and Justification

The California Bee Plant (*Scrophularia californica*), also commonly referred to as The California Figwort, is a perennial herbaceous plant native to California. The species has been observed in 52 counties spanning much of the state. Its communities are concentrated in Northern Coastal Scrub, Closed-cone Pine Forest, Redwood Forest, Chaparral, Coastal Sage Scrub, and wetland-riparian areas (Calflora, 2017). It is a fast growing, evergreen plant, with red flowers blooming from winter to summer. It ranges in size from 2-4 feet in height, and 6-12 inches in width. It is best suited to areas that receive 11-85 inches of rain per year, needing little to no water in the summer months. It is frost tolerant to 20 degrees Fahrenheit, and endures heat levels into the upper 80's. With its deep red flowers and nectar producing capabilities, it is attractive to bees as well as other pollinators like hummingbirds and wasps. The California Bee Plant also serves as a food source for the larvae of the Common Buckeye butterfly (Calscape, 2017). Pollinators are vital to the health of plant and agriculture communities, and therefore, plants that support these pollinators are essential. The California Bee Plant is not currently listed on the California Nature Plant Society's Inventory of Rare and Endangered Plants list, and populations do not appear to be in decline (CNPS, 2017).

Growth Characteristics

- Mature plant size ranges from 2-4 feet in height, and 6-12 inches in width (Calscape, 2017).
- Stem length ranges from 80-120 centimeters, with leaf blades measuring from 8-17 centimeters (Jepson, 2017).
- Leaves of the California Bee Plant are blue-green, triangular-ovate, and opposite from one another, on a square shaped stem (Nathistoc, 2017).
- The flower's corolla is red, and measures 8-12 millimeters in length (Jepson, 2017).
- The plant is categorized as "fast growing" (Calscape, 2017).
- It is an evergreen, herbaceous perennial (Calscape, 2017).
- While the California Bee Plant is commonly found, the plant is not considered to be invasive (Young, 2002).
- Average flowering time for the California Bee Plant dates from February thru May (Calflora, 2017).

Reproduction

- As with many chaparral species, the California Bee Plant's germination rates are elevated following fire, making the plant more abundant in post-fire territories (Keely, 1987).
- The plant's fruit at maturity is dry and dehiscent (Nathistoc, 2017).
- Each fruit capsule produces multiple seeds, released by the splitting open of the fruit at maturity (Nathistoc, 2017).

Range

- The California Bee Plant is found in 52 counties throughout the state of CA, reaching north, south, east, and west borders (Calflora, 2017).
- It is most abundant in San Diego, Riverside, Los Angeles, San Francisco, and Santa Barbara counties (Calflora, 2017).
- The plant is found in elevations ranging from negative 40 feet, all the way up to 10,537 feet (Calscape, 2017).
- It is located primarily in Northern Coastal Scrub, Closed-cone Pine Forest, Redwood Forest, Chaparral, Coastal Sage Scrub, and wetland-riparian areas, preferring cooler summer temperatures (Calflora, 2017).

Habitat/Requirements

- The California Bee Plant grows in clay, sand, and silt soil; needing fast to medium drainage. It is also cooperative to garden soils (Calscape, 2017).
- Soil pH requirements are somewhat widely ranged, growing in environments extending from 5.2 (mildly acidic) to 8.2 (mildly basic) (Calscape, 2017).
- Part shade is preferable, but the California Bee Plant will tolerate cool full sun conditions (Calscape, 2017).
- Temperatures should not regularly exceed 83.5 degrees Fahrenheit in summer months (Calscape, 2017).
- The California Bee Plant is naturally found in, as well as recommended for planting in hardiness zones 6b-10b (Calflora, 2017).

- The plant requires 11-85 inches of rainfall per year, requiring little to no rainfall in summer months (Calscape, 2017).
- It is commonly detected at slope bottoms and on north-facing slopes where partial shade can be provided (Calflora, 2017).

Tolerances

- The plant is deer resistant, likely due to the iridoid glucosides it produces, making the plant poisonous if ingested (Calscape, 2017) (Nathistoc, 2017).
- The California Bee Plant can tolerate winter temperatures down to 20-degree Fahrenheit lows (Calscape, 2017).
- It has a moderate tolerance for salinity in soil, with a maximum tolerance of 10 (Calflora, 2017).
- A minimum soil depth requirement of 13cm is required for proper support of root system (Calflora, 2017).
- The California Bee Plant has a very low immunity for $CaCO_3$, tolerating only 3% (Calflora, 2017).
- *Scrophularia californica* is listed as a drought tolerant species (Sfpublicworks, 2017).

Interactions

- Pollinators including bees, hummingbirds, and wasps are attracted to the nectar of the California Bee Plant (Calscape, 2017).
- The California Bee Plant serves as a host to Common Buckeye butterfly larvae, to which the leaves of the plant are fed upon (Calscape, 2017).

Management Considerations

- Requiring no outside human intervention for growth, the ease of care for the California Bee plant is considered to be “very easy” (Calscape, 2017).
- The larvae of the Common Buckeye butterfly (*Euphydryas chaldeona*) feed upon the leaves of the California Bee Plant from January through July, and therefore, disturbances to the plant during this time would negatively affect Common Buckeye populations (Williams, 1983).
- While the California Bee Plant is in bloom, from February through May, bees and other pollinators are reliant on the plant for its nectar. Disturbances to the plant during this time would negatively impact these pollinators (Calflora, 2017).
- The California Bee Plant prefers cooler summer months and 11-85 inches of rainfall per year, and therefore, it is important to consider climate change and warming temperature trends when choosing this plant (Calscape, 2017).

Management Plan for California Bee Plant (*Scrophularia californica*)

Goals:

The California Bee Plant is a perennial herbaceous plant native to California. It is found in Northern Coastal Scrub, Closed-cone Pine Forest, Redwood Forest, Chaparral, Coastal Sage Scrub, and Wetland-riparian areas. It is not typically found in California's Central Valley (Calflora, 2017). The primary restoration goal is to determine if the California Bee Plant can survive and thrive in a wetland-riparian like area located in the Central Valley. The California Bee Plant does not tolerate summer temperatures that routinely reach above 83.5 degrees Fahrenheit (Calscape, 2017). Therefore, a main factor in determining the likelihood of success for the implementation of *Scrophularia californica* to a site in the Central Valley will depend on its access to shade. Shade is well tolerated by the Bee Plant, and not detrimental to the insects who depend on it. The California Bee Plant is a host to the Common Buckeye butterfly larvae, and provides nectar to important pollinators that have decreased in numbers in recent years. A full representation of site considerations should include:

- Site Survey**:** The ideal site has slopes, particularly north facing, as well as other shade providers such as trees, structures, large shrubs, etcetera.
- Soil testing: The soil must be tested at these shaded sites. The soil cannot consist strictly of slow draining clay.
- Annual precipitation: The site must receive 11-85 inches of rainfall per year during the rainy months.

- Monitoring: The site should be monitored annually for the first 3 years.

If these requirements are met, and satisfactory conditions are present, the California Bee Plant is said to be easy to grow, requiring no outside human intervention for success (Calscape, 2017). If the plant can be successfully implemented, it will provide habitat for Common Buckeye butterfly larvae, and support communities of important pollinators by providing them nectar.

Restoration Plan:

Land Survey

- The survey of the site must pay particular attention to presence of slopes, as well as other shade providers such as trees, structures, and large shrubs. Part shade protection for the plant from high summer temperatures is imperative (Calflora, 2017). If these shade providers do not already exist, introduction of the California Bee Plant to the site should be postponed until partial protection from sun can be provided.
- The plants should be placed at north facing slope bottoms, as well as on the north end of trees, large shrubs, or structures in an effort to shield them from long periods of direct sunlight.
- The soil must be tested at the shaded sites. The California Bee Plant requires fast to medium drainage, so planting in strictly clay soil is inadvisable. A mixture of clay, sand, and silt is ideal. The plant is adaptable to garden soil as well. Soil pH should not read below 5.2, and should not exceed 8.2 (Calscape, 2017). Salinity levels should not test beyond 10, and $CaCO_3$ levels cannot exceed 3% (Calflora, 2017).
- The California Bee Plant requires 11-85 inches of rainfall during the rainy months, requiring little to no watering in the dry months (Calflora, 2017). It is not necessary, nor is it detrimental to the plant to have access to a water table. It does, however, require a minimum soil depth of 13 centimeters to support the anchoring root system (Calscape, 2017).

Seed and Transplant Collection

- There is little to no information available on the California Bee Plant's success rates when comparing seed spreading, planting of propagules, or the introduction of full sized plants. It is my recommendation, that due to cost restraints and likelihood of hardy establishment and survival, that transplants should be utilized. Transplants can be purchased from nearby nurseries, such as Morningsun Herb Farm in Vacaville, CA, where they are surface sown from seed, and sold for $7.95 per 4" pot. Common Buckeye butterfly larvae can be supported immediately upon instillation when choosing transplants of this size.
- As with all transplants, plants should be inspected for pests and disease prior to introduction to site. Presence of disease and/or pests will not only negatively affect the individual, it may spread to surrounding vegetation, and negatively impact the area as a whole.

Planting

- The transplants should be introduced early in (a wet) spring season. The California Bee Plant can tolerate temperatures as low 20 degrees Fahrenheit at maturity, therefore, younger transplants can likely tolerate temperatures typical of the Central Valley's early spring lows (Calscape, 2017).
- Because the California Bee Plant can reach widths of up to 1 foot in diameter, the spacing of these transplants should range no less than 2 feet apart.

- Each fruit capsule is dry and dehiscent, releasing many seeds (Nathistoc, 2017). These seeds are extremely lightweight, and wind carried. The plant spreads by rhizomes as well, so 2-3 plantings per “moist bench” zone will likely suffice (Friendsofthewildflowergarden, 2014). However, the total number of transplants ordered will depend greatly on how many areas of the site comply with the plant’s shade and soil needs.
- Drip irrigation is only necessary if the area is experiencing drought.
- The plant should be introduced to the site after sufficient shade can be administered. Trees and shrubs should be full-grown, and able to provide the Bee Plant with more than 4 hours of afternoon shade per day, in summer months.

<u>Additional Considerations</u>

- The California Bee Plant is not considered to be invasive, and due to the plant’s requirement for shade, it is likely that it will be contained only to the areas that provide the necessary shade cover (Young, 2002).
- Fires are not mandatory for the success of the plant, nor are they detrimental. Though, as with many chaparral species, the plant’s germination rates are elevated following fire (Keeley, 1987). Because the California Bee Plant will require more shading from summer heat levels in the Central Valley, it is important to consider the impact that fire will have on the plant’s shade providers, should those providers be trees, large shrubs, or structures. Fires should to be avoided from January through July, because the plant serves as a host to

Common Buckeye butterfly larvae, as well as a nectar source for pollinators during this time.

- The Common Buckeye butterfly larvae and pollinators of the California Bee plant are negatively impacted by exposure to pesticides, so it is advised that the California Bee Plant not be exposed at close range to pesticides or herbicides, as this would negate the benefits of adding the plant to the site (EPA, 2017). No information was found on the California Bee Plant's individual aversion to these chemicals.
- Common Buckeye butterflies *may* need to be introduced to the area if they are not already present.

Monitoring Plan:

- While there is no information available pertaining to the timeline to full maturation for the California Bee Plant, the plants should likely be monitored annually for the first 3 years, or until the transplants reach their full size (or near) at 2-4 feet in height, and 6-12 inches in diameter (Calscape, 2017). The initial monitoring should take place in spring or summer months while the plants are in bloom. The activity on and around the plant (flowers/pollinators present) will provide the easiest path to accessing its health. Monitoring thereafter need only occur following disturbances such as fire, insect or pathogen infestation to the site (affecting either the plant itself or the plant's shade providers), or at times of extreme drought.
- Success of the Bee Plant should be measured by its size (2-4' in height, 0.5-1' in width), healthful appearance (blooming, green), and presence at the site. This assessment should take place 2-3 seasons post instillation. Presence of the Bee Plant at the site is considered sufficient when at least 1 healthy plant is accounted for at 2 or more "moist bench" zones.
- Common Buckeye butterflies lay their eggs singly. Camouflaging color accompanied with their small size make the eggs especially difficult to see (Raisingbutterflies, 2017). Therefore, the success of the Bee Plant should not be rated based on butterfly larvae populations.
- If the California Bee Plant is implemented at the site, and complete species loss is experienced, I would recommend introducing an herbaceous species more adapted to the high summer temperatures that are experienced in the Central

Valley, such as fiddleneck, lupine, or salvia (Pollinator, 2017). *Antirrhinum vexillocalyculatum*, or Wiry Snapdragon, is an annual herb native to California that also supports Common Buckeye butterfly larvae (Calflora, 2017) (Raisingbutterflies, 2017). It has a shorter bloom period than the Bee Plant, only blooming from June through July, but can tolerate temperatures upwards of 96 degrees Fahrenheit, is drought tolerant, and is found in nearby Solano County (Calflora, 2017). All options listed would provide nectar to pollinators.

- If partial species loss is experienced, I would also recommend replacing the species with a more heat tolerant native herb, as I am concerned that the California Bee Plant is not well-suited for Central Valley climate. If replacement is not an option, conditions should be assessed (e.g. shade cover, access to water) and adjustments made accordingly. Supporting the plant with drip irrigation will relieve any water stress, and may ease heat stress as well. The plant's yearly rainwater needs (11-85") should be considered when administering water treatment. Care should be taken not to flood the plant continuously, which may lead to root diseases.

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Upper Riparian/Upland Herbaceous Plants

Summer Lupin (Lupinus formosus)

Laura Breidenthal

Background and Justification

Summer lupine (*Lupinus formosus*) is a California native species of the *Lupinus* genus in the legume (Fabaceae) family. *Lupinus formosus* attracts native bees, bumble bees, Arrowhead blue butterflies, and hummingbirds (Calflora). These associated organisms are important pollinators. It is also a food source for the endangered Mission blue butterfly (Species Account, USFWS, Sacramento Office). It is cited as a poisonous plant, and while it is not endangered, it faces threat of eradication from farmers with livestock due to its implications in crooked calf disease. It is poisonous from when it begins growing until its pods shatter, being the most toxic at its youngest (Jepson eFlora). *Lupinus formosus* is one of only three piperidine alkaloid containing plants along with poison hemlock and tree tobacco. These plants have induced skeletal abnormalities in young livestock in species such as sheep, cattle, and pigs which is why it is targeted by cattle farmers to eradicate (Keeler 1992). So, while Summer lupine attracts beneficial pollinators and acts as a food source for the Mission blue butterfly, the proximity of livestock is an important consideration when restoring this species. It can tolerate heavier, clay soils with low water tables, grassy places, open spaces, and valleys. It is often found in areas of dry slopes beneath pine trees, on clay soils, in grasslands, and in coniferous forests (CNPS).

Literature Review

Growth Characteristics:

- Summer lupine grows well on dry slopes under pines, and in grasslands (Calflora 2016)
- Its height ranges from 1 to 3 feet and has clustered flowers with inflorescences < 5 inches ranging in color from blue to purple (S&S Seeds)
- It's foliage type is stress deciduous meaning they will lose their leaves under stress (Las Pilitas Nursery 2012)

Reproduction:

- Summer lupin blooms from June to October and has a perennial life cycle (USDA 2017)
- It is a member of the legume family which have dry dehiscent fruits with seeds in pods that split on 2 opposite sides at maturity (Las Pilitas Nursery 2012)
- Reproduction is by seeds or rhizomes, with each adult plant capable of producing dozens of pods with several hundred seeds each (Las Pilitas Nursery 2012)
- It develops a long taproot and prefers moist, cool soils.
- Germination can be increased by 7-day cold treatment, or by soaking seeds in warm water for 24 hours before planting. Treated seeds can be sown in Spring or Summer through early August. Untreated seeds, however, will do well sown outdoors September-November. Plants that are grown from seed will bloom in their first year (Planet Natural Research Center 2012)

Range:

- Summer lupine has a wide range in California spanning mostly from central to Southern California (Calflora 2016). It can be found in coast, desert, inland, and mountain regions (S&S Seeds 2012)
- It can be found in the Sacramento region (Calflora 2016)
- It extends only slightly beyond CA borders (S&S Seeds 2012)

Habitat/ Requirements:

- It prefers cooler regions with full sun to light shade. Because of its long taproot, it grows well in medium soils that are moist and cool. It does not grow as well in clayey soils but can tolerate clay and dry, sandy soils (Las Pilitas Nursery 2012)
- It is mostly found in the montane coniferous forest, San Jacinto, Santa Rosa, and San Gabriel Mountains (Calflora 2016)
- It can also be found in the openings between oaks and chaparral (The Watershed Nursery 2017)

Tolerances:

- Summer lupin can grow easily in a wide variety of conditions which is why it is so widespread in California. It is a nitrogen fixing legume and can grown in nutrient enriched or unenriched soils (Planet Natural Research Center 2012)
- It has an elevation range of 7 to 3000 meters, precipitation range of 13 to 53 inches, soil type of medium to clayey and texture medium, soil pH of 5.4 to 7 and soil minimum depth of 40 cm, it tolerates non-saline and low calcium carbonates present in soil (Calflora 2016)
- It cannot survive in frigid or highly arid areas with a temperature range of 30 to 63 degrees F. (Calflora 2016)

Interactions:

- Summer lupin has been investigated in ranches in pasture in Oregon and California for its implications in “crooked calf disease” amongst livestock. A study conducted in Oregon revealed that levels of anagyrine, a toxic alkaloid found in the developing seeds of lupin, causes harmful defects in calves that were grazing in the area. This disease results in congenital skeletal malformations mostly in the front limbs, neck, and spine. Thus, lupine is targeted by ranchers to eradicate from and around ranches and grazing pastures (Keeler 1989)
- It attracts butterflies (in particular the Mission blue butterfly, an endangered species), bees, and is deer resistant (The Watershed Nursery 2017)
- This species has very few pests, but is susceptible to aphids (The Watershed Nursery 2017)

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Management Plan for *Lupinus formosus*

Goals:

Summer Lupin (*Lupinus formosus*) is a native perennial herb that has a wide tolerance of growing conditions. It is found all over California, particularly in dry, grassy, open areas. It is an early successional species that thrives at a variety of elevations, and can tolerate clayey, sandy, and loamy soils, especially in disturbed areas. It is very easy to grow, and seeds need little to no treatment. Our main restoration goal is to ensure that we have an established population of *Lupinus formosus* that is self-sustaining. Because it is a beneficial nitrogen fixer and an important pollinator habitat, we might consider having a large percent cover of Lupinus. For this plan, we will work with a one acre plot. Adjustments may need to be made according to the site's allocated area for this species. *Lupinus formosus* also grows well with a variety of companion plants. We may want to consider testing small plots with various companion plants to see what mix leads to the most pollinator visitation.

1. Establish self-sustaining population within the first 3 years: *Lupinus formosus* does well in a healthy site with well-drained soil and dry conditions. It blooms in its first year can drop up to thousands of seeds per plant (Las Pilitas Nursery, 2012). It is typically grown as a monoculture in meadows, but is also widely grown in patches with other native forbs and grasses. We should test mixes of native forbs that grow well together and attract the most pollinators. My goal of 20 to 30 % cover takes into account other native forbs and grasses that will occupy the upland region. To achieve 20 to 30 % cover we will need to adjust the seed use as necessary. For 25 % cover, we will need to broadcast approximately 4000 seeds (about 2 pounds) onto the site. *Lupinus formosus* often blooms the first year after planting, and once a population is established, there will be abundant seeds in the seed bank. While seed banking information on the species *Lupinus formosus* is scarce and needs further research, wild lupine seeds may germinate the summer that they mature or remain dormant in the seed bank for at least 3 years (Halpern, 2005).

2. Clear understory competition and invasive species with moderate burns: Provide beneficial, moderate burns to promote germination. Although no research on the specific species *Lupinus*

formosus has been found, research on other *Lupinus* species has found a generally positive response to moderate fires. *Lupinus* has several post-fire regeneration strategies, usually sprouting from rhizomes. Studies show that seeds of wild lupine exposed to a moderate fire can increase germination and decrease seedling mortality. It has also been suggested that its nitrogen-fixing ability provides an advantage over other species on burned sites because of nitrogen volatilization during the burn, and nitrogen loss from above ground burn-off (Leach 1993). However, a hot fire can result in no germination and an increase in seedling mortality (Grigore, 1996).

3. Protect from common pests and prevent/control disease especially in the 1st year. *Lupinus formosus* is susceptible to powdery mildew, especially in hot and humid conditions. It should not be a big issue in the central valley due to the dry climate, however, in the event of a powdery mildew infestation further research on a fungicide to apply will be necessary. Pill bugs often eat the seeds and seedlings, so we may have to monitor the site for damage and control them with a pesticide if persistent. When broadcasting seeds, some birds like to eat the seeds if they are not lightly covered when planted. Fires can also help to eradicate diseases and pathogens like powdery mildew. If an infestation becomes rampant, we may want to implement a prescribed, moderate burn.
   Feasibility: The establishment of a 20 to 30% cover of *Lupinus formosus* is very feasible if we don't have any extreme or unusual climatic events, hot burns, or disease outbreak. It often grows easily and does well with companion plants. Overall it will increase the fertility of the soil, and is known for returning in a strong bloom every year or at least every other year.

Restoration Plan:

Pre-Restoration goals:

1. Site Characteristics: Because *Lupinus formosus* has a wide range of tolerances, there is flexibility with the spatial aspects of the site. In general, we should clear a patch at a higher elevation on the site, with disturbed soil, that is moderately dry with adequate water access. It will be important to get a high rate of pollinators visiting the site. We will need to test for the best forb mix to attract the most pollinators. To test for the best forb mix for pollinators, we can have sections of *Lupinus formosus* growing with various companion plants. In the Spring, we can measure the frequency and type of pollinators to visit the site. *Lupinus formosus* has a long taproot and deep rooting system. This quality in combination with its perennial life cycle and extensive seed bank makes it resistant to disturbance.

2. Temporal & Spatial Conditions: Provide adequate site conditions for life history and habitat needs. *Lupinus formosus* has a perennial life history, so will live multiple years and grow up to 3 feet over the course of its lifetime. They reach reproductive maturity within one year, so we can expect full cover within 1-2 years. It does well with a variety of elevations, on slopes as well as valleys. For our site, slopes at slightly higher elevations away from the water are preferred, so we will need to survey the site and give priority to drier slopes to flat regions away from the water's edge at slightly higher elevations for *Lupinus formosus.* Its pollen is dispersed via butterfly and bee populations, and it has bisexual flowers so there isn't a need to consider different growing conditions for the male and female plants. *Lupinus formosus* does not spread rapidly, but monitoring of dispersal and the amounts of pollinators to visit the site should be considered to measure dispersal (to be elaborated on in management plan). It does not grow well in wet or inundated soils, flooding, especially during the winter, will result in increased mortality.

Restoration goals:

1. Survey the area for soil quality, water access, and note what species are already present.

a. Measure soil pH, texture, and drainage. Remove weeds, invasive grasses and strong competitors from the site. This may require a targeted application of an herbicide in combination with hand picking or mowing. Further research must be done to choose an appropriate herbicide.

b. The water flow into the area should be moderate. If flooded, *Lupinus formosus* will not grow well. We will need to adjust the area for this species depending on moderate water access.
c. Timing is important, checking soil drainage in the winter as well as spring and summer will be critical to predict inundation and the probability of powdery mildew outbreak.
2. Prevent harmful insect herbivory by removing herbivores and predators, and controlling competition by removing by hand or with a targeted herbicide. While more research must be done for this specific species, in general, herbivory has negative impacts on lupine seedlings. Plowing, frequent mowing, and continuous close-cropped grazing all have negative impacts on many lupine species and should be avoided (Swengel, 1993).

<u>Growing method:</u>

a. Seed in, with no treatment needed if sown in September through November (Planet Natural Research Center, 2012). If there is a need to grow earlier, we may want to consider soaking the seeds in warm water for 24 hours before broadcasting to soften the tough seed coat and ensure germination. Treated seeds can be sown as early as spring, summer, or early August. Germination can take up to 10 days. It is recommended to sow 1 pound (about 2000 seeds) per 1000 feet for total coverage (S&S Seeds).

b. Water and temperature heavily affect germination, with studies showing that lupine ssp. seeds that received 11 to 14 inches over 3 months had a 92% germination, while seeds that received 2 inches over 3 months had 62% germination. The seed mass was also affected by water availability and temperature (Halpern, 1995). Lupine plants do not always sprout every year, and addressing this will be discussed further in the monitoring plan.

Monitoring Plan: Once the invasive species have been burned and controlled with herbicide, the site may be ready for the introduction of native forbs and grasses, depending on the success of the removal.

Year 1: Broadcast seed in September/ November, watch closely in winter months (December through February) for powdery mildew or frost bite on the saplings. Return to the site to monitor in Spring (March through May) to ensure the lupine blooms. Continue to remove invasive species by hand or with targeted herbicide to prevent competition. Monitor for pollinator visitation to the site.

Year 3: Monitor again in Spring and Winter to watch for blooms and disease outbreak. If competition from invasive grasses threatens the population, implement a prescribed understory burn onto the site. This will promote growth and germination of *Lupinus formosus* and rid the site of invasive competition. Invasion is likely, due to the long seedbank length of invasive grasses and the increases nitrogen levels in the soil because of the lupine. Implement the fire in late fall to early winter. This timing is necessary to avoid the winter rains and the summer heat and thatch. If burning is successful, less than 10% of invasive grasses will survive, and the population of *Lupinus formosus* will survive.

Year 5: Check back in Spring to ensure a successful bloom. Continue to watch and remove invasive grasses through targeted herbicide and hand removal, they will likely emerge each Spring and Summer due to their long-lived seed bank.

Research Needs:

A clear understanding of the interactions between the Nitrogen fixing impacts on the soil and how this will affect surrounding communities, how herbivory will impact wildlife due to the toxicity of lupine seeds, the best mix of companion plants to support a diverse and abundant pollinator population.

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California Onion Grass (Melica californica)

Jaquelyn Gomez

PART 1

Background and Justification

The Melica californica (M. californica) is a perennial bunchgrass that is native to California (Calflora). The grass, also known as California Onion Grass is extant. It is found in a wide range of communities, but most commonly in foothill woodland, mixed evergreen forest and yellow pine forest communities along slopes and ridges (Calfora). Once grown, M. californica, sturdy and compete well with weeds. Deep roots makes M. californica useful in erosion control which allows this grass to be a good grass stabilizing slopes (The Watershed Nursery). Thus, it can be used as a good mitigation measure. Since the M. californica is a drought tolerant grass its use can be vital in restoration projects taking place across California (USDA). Because of the recent drought in California, knowing how to use this grass in management and restoration efforts is very important.

Literature Review

Growth Characteristics

- M. californica will grow well in coarse and medium textured soils since they are well adapted to these soils. However, it will not do well in fine textured soils because they are not adapted to this soil type (USDA).
- The pH of M. californica ranges from 5.5 to 7.5 (Calscape, USDA).
- The precipitation needed for M. californica to grow and prosper is in the range of 14-24 inches (USDA).
- Its minimum root depth is 10 inches. The maximum width of a single M. californica is one foot. In terms of height, it can grow to be in the 1-4ft range (Calscape, USDA).
- M. californica is suited best in environments with one soil phase, seasonal creek banks, and partial shade (although it can tolerate full sun) (Linden).
- M. californica and Nassella have similar habitat requirements but they are not competitors because they have different shade requirements (Linden).

Range

- M. californica is found in elevation that ranges from sea level to 7,000 ft (Forero 2016, USDA).
- Grown in many habitats in California; from mountain forests and open grasslands (Calscape).
- Most commonly found in foothill woodland, mixed evergreen forest and yellow pine forest communities along slopes and ridges (Calflora).

Tolerance

- M. californica has a low anaerobic tolerance and a low $CaCO_3$ tolerance. It also has no tolerances salinity and hedges (USDA).
- M. californica has high tolerances to fire and drought and a moderate tolerance to shade (USDA).
- Tolerate a wide variety of soils, however the drainage needs to be good. Serpentine soils tolerated in M. californica grasses (Calscape).
- Tolerates temperatures as colds as -10°F (frost tolerant) (Calscape, USDA) and is deer resistant (The Watershed Nursery).

Reproduction

- The bloom period of M. californica occurs in the summer months: June, July, and August (Calflora).
- The fruit/seed period begins in the summer and ends in the fall (Calscape).
- Has a slow seed spread rate and slow vegetative spread rate. It also has a slow regrowth rate after harvest (Calscape).
- Has a low seedling vigor and can be propagated by seed but not by tubers (Calscape).

Management Considerations

- Most resistant to non-grass invasion compared to other 5 grasses that were observed and measured. Able to withstand non-native invasion because it forms short rhizomes (Lulow 2006).
- Melica californica died during the first growing season when competing with native clovers and non-native clovers (Lulow 2008).
- Low-salt treatment did not influence salt stress symptoms in melica californica, but high-salt treatments did. High-salt treatments increase the percent of chlorotic symptoms in M. califonica. Thus, M. californica would be better suited under irrigation with recycled water, rather than sprinklers (Hunter 2007).
- Using recycled water irrigation will affect the salt tolerance of M. californica depending on how many times it was treated. M. californica is more vulnerable the concentration of salt stress from sprinkler irrigation than from drip irrigation (Wu 2010).
- Used as a fodder product—platable to graze and browse animals. However, it is low in protein potential for these animals (Calscape).
- M. californica increased in abundance as grazing intensities decreased. Grazing intensity was decreased by gradually removing cattle from the grasslands (D'Antonio).
- During a single fire where grazing took place, results show that the frequency of the grass of M. californica after the burn was not affected (D'Antonio).
- It was found that M. californica has low drought tolerance, but plants 90% of the plants were able to recover in a study (Balachowski 2016).
- In one-year-old M. californica there was larger reduction in grass vigor than in the M. californica that was two years. This may be due to the fact that the two-year-old grasses were in a location where there were less weeds present. Also, since the two-year-old plants are larger in size and have a deeper root system they may have been better at competing with the weeds. Since there were less weeds in this area there was a reduction in preermergence herbicides used. It was

concluded that herbicides used for weeds play a role in the reduction of the M. californica (Lanini).

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PART II

Goals

Melica californica is found all throughout many habitats in California including the Central Valley. This grass can be very beneficial to the Central Valley region because it is drought tolerant and controls erosion (USDA, The Watershed Nursery). Because of these advantageous characteristics the main restorations goal it to determine how prevalent this species should be in a particular central valley region. This goal depends how much the environmental conditions can be altered to suit M. californica. depending on the range of tolerance of the other plants in the area. Since M. californica can tolerate a wide variety of conditions, ideally, our goal is to reach 60% cover. These restoration goals include:

- Alter surrounding region that will allow M. californica to can to thrive and prosper well in
- Sow seeds during the seeding months, fall and winter
- Sow seeds where dispersal would aid in creating a prevalent M. californica environment
- After a year, dispersion should be observed to more seeding is necessary
- Repeat for another year and add other vegetation

These goals are feasible if seeding is consistent in the fall and winter months (Kent 2017). Also, flowering that takes place midwinter and early spring must be monitored to measure the success rate of seedlings planted.

Restoration Plan

In order for M. californica to reach at least 60% of the total cover of the region, the environment must be altered so that it can support a widespread cover of the grass. Species that will be a detriment to the growth of M. californica, such as invasives and weeds, should be removed completely (Lulow 2006, Lanini). This is because it will take a couple of years for M. californica to develop roots and short rhizomes (Lanini). This is an important symbiosis that must be developed and matured in order for these grasses to outcompete invasives and weeds.

After this has been done, seeds should be sown starting from fall through the winter (Kent 2017). After a month of growth, more seeds should be sown since there is a strong likelihood that the majority of the grasses may not have grown since M. californica has a low seedling vigor (Calscape). Seeds should be added every month until the end of the sowing seed period (fall-winter) to increase the chances that M. californica will be prevalent in the region.

Is it also important to consider the best possible location in the region to plant the seedlings of M. californica. M. californica is able to disperse by means of gravity, meaning its seeds can travel farther from its original location by wind and animals (Porensky 2012). It would be best to plant the seeds of M. californica alongside slopes and higher elevations so that that when seeds are later dispersed they will be able to reach wider and longer distances.

It is very important to not sow any seeds in places that can or will hold standing water since M. californica cannot survive in such places for long (Kent 2017). Since M. californica has low tolerance to salinity using recycled water to irrigate the grass or the whole region itself will be more beneficial instead of using a sprinkler irrigation system (Hunter 2007, Wu 2010). It is important to note not to allow grazing to take place early on in the growing period of M. californica because the grasses will decrease in abundance if cattle do graze on it (D'Antonio).

Monitoring Plan

The amount of seedlings of M. californica that that do survive and do not survive should be monitored. This should be monitored every month during the seeding period which takes place in the fall and winter months. It should be monitored so that it is known how much seedling should be planted for the next seeding period. This should take place for two years to ensure that a prosperous and thriving M. californica region will be established. At two years of age there should be an abundance of M. californica that are able to withstand weeds and invaisves that may appear later (Lanini).

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<u>Purple Needle Grass (Stipa/Nassella pulchra)</u>

Ally Overbay

Background and Justification:

California Purple Needlegrass (otherwise known as *stipa pulchra* or *nassella pulchra*) is not only the California State Grass, but also a dominant species of California grasslands. The species can be found as far south as Baja California and as far north as the Oregon border, though it also resides inland within the Sierra Nevada and the Central Valley (Dyer, 2005). Purple Needlegrass, a perennial grass, is primarily threatened by competition with exotic annual grasses. As Purple Needlegrass is outcompeted by the more aggressive, fast-growing annuals, native California grassland habitat is lost (Bartolome, 1981). And, because management solutions like limited watering or nutrient input benefit both the at-risk native grass and its competitors, management is challenging. As of a 2014 study, Purple Needlegrass is more at risk today than it was 30 years ago, with annual grassland competitors as its primary threat

(Stahlheber, 2014). However, studies have proven that grazing and prescribed burns are plausible solutions as they may give the native *stipa pulchra* an advantage over its competitors (Stahlheber, 2014). Lastly, because of its drought tolerance and ability to withstand physical disturbances, Purple Needlegrass is well equipped for restoration (Buss, 1997).

Literature Review:

<u>Natural History</u>

- *Stipa pulchra* (further referred to as *stipa*) has been long considered the most common CA grass for its ability to withstand disturbances. However, studies suggest that exotic annual grasses pose a competitive threat to this perennial grass (Bartolome, 1981).
- *Stipa* ranges from the northern part of Baja, California up the Oregon border. It can also be found as far inland as the Central Valley and the Sierra Nevada (Dyer, 2005).
- It can survive in oak woodlands chaparral, and grassland environments (Dyer, 2005).
- The grass must receive 20-76 cm of annual precipitation in order to survive (Dyer, 2005).

- Like most native perennials, *stipa* dedicates much of its biomass to its root system (has a high root to shoot ratio), which allows them to better utilize soil-water in the dry season (Holmes 1996).
- *Stipa* is typically found in clay soils, either partial or full sun, and is typically drought tolerant (Dyer, 2005).

<u>Growth/Reproduction</u>

- *Stipa* germinates more slowly than annual grasses, and has difficulty competing with non-native annual grasses, especially during rapid springtime growth (Bartolome, 1981).
- It can germinate easily under most stresses except severe moisture stress. Growth on bare ground is preferable to mulch (Bartolome, 1981).
- The grass survives better on "intermound" regions (defined as shallow soil areas) (Dyer, 2003).

<u>Nutrient and Fungal Interactions</u>

- *Stipa* typically depresses N cycling rates, and the effects are stronger in shallow soil as opposed to deeper soil (Hoskinson, 2013).
- The grass' effect on soil is limited to directly beneath and adjacent to the rooted basal area of the plant (Hoskinson, 2013).
- *Stipa* is little affected by the fungal mutualist, mycorrhizae, and even less so in moderate to high levels of Phosphorus. Inoculating *Stipa* with mycorrhizae did not help to reduce its competitive interactions with annual grasses (Nelson, 1993).

Competition/Management

- California native perennial grasses like *Stipa* border on coexistence and exclusion with exotic annual grasses (Stahlheber, 2014).
- The root composition of Blue Oak (*Quercus douglassi)* trees influences *Stipa*'s competitive abilities. In shallow tree roots, *Stipa* is relieved of competition by annual grasses, and vice versa (*Stipa* and is threatened in areas of deeper tree roots) (Aschehoug, 2014).
- This study suggested that reducing soil disturbance and adding late-season water may improve *Stipa*'s stability as a competitor. Specifically, watering during the growing season may alleviate competitive interactions (Stahlheber, 2014).
- Grazing and prescribed burns have historically benefitted *Stipa*, but in order to be successful this study suggests it must occur at high intensity (32% density loss) (Stahlheber, 2014).
- By contrast, methods like biomass and seed reduction of competitors must reduce density by 87% to be successful (Stahlheber, 2014).
- Though overall growth of *Stipa* is influenced by topography (mound versus intermound areas), the success of prescribed burns and grazing was not influenced by topography (Dyer, 2003).
- This study in Jepson Prairie, CA measured *Stipa* density after the occurrence of 3 prescribed burns over 7 years. Burned plots had a density decrease of only 10%, whereas unburned plots decreased density by 45%. This suggests prescribed burns may have a positive effect on overall *Stipa* growth (Dyer, 2003).
- *Stipa* is listed by this study as being a successful roadside grass and/or hedgerow plant for its ability to produce a moderate biomass and its drought tolerance (Buss, 1997).

Management Plan Overview:

California Purple Needlegrass (otherwise known as *stipa pulchra* or *nassella pulchra*) is not only the California State Grass, but also a dominant species of California grasslands. This perennial grass is primarily threatened by competition with more aggressive and fast-growing exotic annual grasses, leading to a loss of California grassland habitat (Bartolome, 1981). And, because management solutions like limited watering or nutrient input benefit both the at-risk native grass and its competitors, management is challenging. For this reason, our primary management goal is to ensure *S. pulchra* is not outcompeted. Studies have proven that grazing and prescribed burns are plausible solutions for giving this native the advantage it needs over its competitors (Stahlheber, 2014).

Specific Goals:

- For healthy, predominantly native, inland grasslands, there should be 5 to 10 species per square meter. By contrast, coastal regions should have 20 native grass species per square meter (Stromberg, 2007). Therefore, achieving this approximate cover is a good estimate for a complete and final goal of a natural, non-grassland landscape.
- For a restoration site in Solano County, the successfully restored grassland had 75% native grass cover with minimal weeds. This was achieved by drilling seeds over a 50 acre span, in November, at a quantity of 21 lbs/acre (Stromberg, 2007). This was measured after a 2 year period. Therefore, a similar goal of 75% native cover is realistic for any site looking to restore itself to a primarily grassland site.
- According to a study in Jepson Prairie, CA, native grasses like *S. pulchra* were successfully managed against non-native annuals when prescribed burns occurred 3 times over a 7 year period (Dyer, 2003). By the success of this management, a primary goal is to prescribe burns at a similar rate (approximately once every 2.5 years).
- The prescribed burns, in order to ensure effectiveness, should reduce grassland density by about 32% (Stahlheber, 2014).
- Though *S. pulchra* is a drought tolerant species, providing the grass with water during key growth periods may significantly alleviate competitive pressures (Stahlheber, 2014). Therefore, for the first two to three years of management, *S. pulchra* should receive additional water (additional meaning above what natural water it receives), before the grass flowers in the spring (Bartolome, 1981). Doing so will allow the grass to outcompete its competitors at a vital point in its life cycle.

Restoration Plan:

Stipa pulchra is generally a durable species in terms of soil conditions, drought, and nutrient deficiencies. Its primary threat, therefore, is competition with non-native annual grasses.

However, because improving environmental conditions related soil, water, and nutrients benefits *S. Pulchra*'s competitors in addition to itself, management is challenging. Furthermore, reestablishing *S. pulchra* is less challenging during colonization, but becomes increasingly more difficult as other non-native grasses begin to dominate the landscape.

S. pulchra is actually a vigorous colonizer. Its ability to reproduce and re-seed rapidly and under poor conditions makes it an excellent species for restoration efforts. In fact, seed output may exceed 20 kg/hectare under normal conditions (Bartolome 1981). The species' life stage cycle similarly has a fast turnover rate; under proper conditions, juveniles may begin flowering and reproducing after 2 years (Bartolome 1981). If seeds are disked/plugs are planted on a slope, it's preferable that there is a higher density of seed on higher slopes, by which wind and gravity will naturally carry seeds down (Hoskinson, 2013). For smaller projects, however, planting plugs may be preferred to disking seeds, as the survival rate is higher for plugs than seed (though more expensive) (Stromberg, 2007). In terms of location, *S. Pulchra* grows best in shallow soils, often beneath canopies of blue oak trees (Aschehoug, 2014), and in areas of barren soil as opposed to mulch (Stromberg, 2007).

However, because non-native competition doesn't pose a threat to *S. pulchra* until two to three years into restoration (and because the species has proved itself a vigorous colonizer), restoration efforts are most important at later stages (Stromberg, 2007). At the two year mark, additional water should be added to areas of high density *S. Pulchra* to give the species a growth advantage over its annual competitors (Stahlheber, 2014). Preferably, water will be added in the spring, before the grasses begin flowering, to aid with the energy expenditures associated with reproduction.

Prescribed burns and grazing have similarly proven beneficial for the species. A study in Jepson Prairie, CA successfully managed a native grassland by prescribing 3 burns over a period of 7 years (Dyer, 2003). This approximately comes to one burn every 2.5 years, a timing that coincides with the aforementioned management tactics like excess watering. When performing a prescribed burn, it's preferable to be done in the summer, to replicate incidences of natural fires (Bartolome 1981). This way, the native grass will have already flowered and dispersed its seeds, and the fire will not prevent any further reproduction.

Edge effects are something to be considered, but do not present a predominant threat to *S. Pulchra*. Because of the grass' durability, it is often used in areas bordering a site, such as in a hedgerow or as a roadside plant (Buss, 1997). It is more likely that neighboring pesticides/herbicides will pose a threat to the species.

Monitoring Plan:

For areas with already existent *S. pulchra*, management should primarily consist of regulating prescribed burns, excess watering, and potentially the weeding out of invasives. As previously mentioned, such management should occur dependant on both season and life stage history. Specifically, intensive management like prescribed burns, grazing, or weeding should take place around the two-year mark. Subsequent management will depend on season and circumstance: burns/intensive grazing should average once every 2.5 years and only after the grass has flowered, whereas weeding and watering should be on an as-need basis, with watering being most effective during springtime growth.

For areas with no *S. pulchra*, management will include seeding/plugging the grass in the appropriate time and space scales: about 21 lbs of seed per acre via drilling, or 15 plugs per square meter (based on a survivorship of 30%) (Stromberg, 2007). Management against invasives may be more or less intensive than areas with already established *S. Pulchra*, depending on the survivorship of non-native annuals.

Though the above information is well-supported by research, there is information still missing in the following areas (Stromberg, 2007):

- Though *S. Pulchra* is frequently used in restoration, there is a surprising lack of records of its dominance in restoration projects. Gaining better access to these projects — in regards to both the subsequent successes and failures — would significantly improve our ability to manage grasslands.
- There is insufficient data regarding the genetic variation associated with seed collection. Access to this information would improve micro-management based on geographic discrepancies.
- There was very little information given on the cost-effectiveness of each management solution. Because restoration is often heavily reliant on funding, such information would aid in the evaluating the cost and benefit of a specific restoration project.
- The relationship between *S. Pulchra* and soil is minimally studied. There is evidence that *S. Pulchra* thrives in a range of low-high nutrient regions, but the effects of the species on soil is less evident. More information on this subject would improve our understanding of the potential downfalls associated with using *S. Pulchra* in restoration.

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Centaurea solstitialis

Asa Holland

Background and Justification

Yellow starthistle (*Centaurea solstitialis*) has been called one of the most invasive plant species in the western United States region (Kyser et al. 2013). This species derives from a source population in Eurasia (Barker et al., 2017), most likely in the Mediterranean near Turkey (Eriksen et al., 2014). Later, a single source population was introduced to California (Barker et al., 2017) from a Spanish subpopulation, and subsequently invaded the Californian interior. As its distribution widened, both the individual population and individual size until *C. solstitialis* became a significant competitor in native ecosystems. In current times, California and the western US are highly affected by the presence of this species (CalFlora, 2017), which impacts soil water dynamics within Central Valley rangeland plant communities (Enloe et al., 2004) and largely outcompetes native species. As with any invasive, *C. solstitialis* is unlikely to be in decline, and will continue to impact native communities unless adequate methods of control can be developed and/or implemented. There is a long history of involved management strategy which has incorporated an integrated approach to removal of *C. solstitialis* by prescribed burning, planting of competitive vegetation, and herbicide application (Kyser et al., 2013), but continued efforts against this species are ongoing.

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Literature Review

Growth Characteristics

- Seedlings germinate quickly after initial rains in early fall, form rosettes during winter and a taproot by early spring. Plants then bolt in late spring with flowering and seed production occurring in summer / early fall. One of longest lifecycles of any annual plant in California due to a long annual phenology and its deep taproot (Stephen. 2004).
- This can produce roots that can extend over three feet down into the soil profile, even with a rather small basal rosette (DiTomaso et al, 2007).

- The rosette grows near the ground, producing 6 to 28 leaves that are deeply lobed. Stems are rigid and branched, averaging ~2 feet tall but can reach 5 feet tall in certain conditions. Solitary flowers are yellow with stout spiny bracts 1-2 inches in length (Jacobs et al., 2011)

Reproduction

- Plumed achenes represent 90% of an adult plant's seedbank, and disperse at maturity for fall germination during the current year. The remaining 10% are plumeless, disperse during winter, and tend to remain dormant for several years before germinating (Jacobs et al., 2011).
- Average seed longevity was 6 years for plumeless achenes and 10 years for plumed achenes. Soil depths ranging from 2.5 to 15 cm do not appear to affect longevity or viability of seeds (Callihan, Prather, and Northam, 1993).
- Most seeds germinate in the period between fall and spring (the California rainy season) (DiTomaso et al, 2007)
- Some estimates state roughly 60 to 75% of seedling rosettes die from moisture stress and self thinning, before survivors even develop a taproot and can bolt to produce flowers (Jacobs et al., 2011)
- Plants normally each produce 20 to 120 seeds. Seedling densities have been reported as high as 2,500 per square foot (Jacobs et al., 2011)

Range

- This species is found below 7,000 feet in elevation in areas that are dry (between 10 and 60 inches average annual rainfall) and light intensity is high (DiTomaso et al, 2007)
- *C. solstitialis* is commonly found in open areas, particularly in rangelands, wild spaces, pastures and hay fields, and along roadsides and waste areas. Infestation area is estimated at 10 to 15 million acres within California alone (DiTomaso et al, 2007).
- This species is highly prevalent in the Central Valley and the surrounding foothills (Jacobs et al., 2011)

Tolerance

- The range of this species is likely to expand with climate change (Bradley, B. A., et al. 2009).
- This plant was documented to grow more than six times larger with added CO2 and triple in growth in response to elevated nitrate levels, suggest large increases in prevalence in western North America (Dukes, Chiariello, Loarie, and Field, 2016).
- No single temperature provides optimum germination, but germination is successful for most temperature profiles from 0 to 40 degrees C, but the most optimal germination in Davis, CA were for 5 and 10 degree C cold periods that were alternated with 15 to 25 degree C warm periods (Young, et al, 2005).
- This plant does much more poorly in areas of low light than high light intensity (DiTomaso et al, 2007)
- *C. solstitialis* performs well in areas that have been disturbed, such as cultivated regions, road building spaces, pastures or fields subjected to overgrazing, or areas with mowing that has been poorly timed (DiTomaso et al, 2007).
- As little as one quarter to one half inch (0.6 - 1.3 cm) of rain is enough germination to occur (Jacobs et al., 2011).

Interactions

- Four biological control agents (two weevils and two flies) attack the flowerhead and seedhead and help provide ~50% of the seed suppression in the State (DiTomaso et al, 2007)
- Goats will eat *C. solstitialis)* during seed production, and notably even in the spiny storms. This is in comparison with sheep and cattle. Which only eat yellow starthistle before the spined show up (DiTomaso et al, 2007)
- Although annual legumes make for good restoration replacements for *C. solstitialis,* follow-up herbicides to select for only the legumes are tricky. Thus, overseeding with grasses is the most useful method to control by revegetation. Grasses (particularly perennial, although these take longer time) , are more effective at competing with *C. solstitialis* than herbs, and can be paired with targeted herbicides (DiTomaso et al, 2007)

- Tends to crowd out native species, and can be toxic to horses (USDA, 2017).
- A rust fungus exists that reduces vigor of *C. solstitialis* plants (Jacobs et al., 2011).

Management Considerations

- Biologic control using weevils and flies may need to be complete to overcome plant's increased compensation of per-plant seed production in response to lower plant densities (Gutierrez et al, 2005).
- Mowing and bud damage can reduce seed number by 76% and 21% respectively, but results in shorter plants that weighed less. This also caused a decrease in root abundance, but has no effect on Yellow Starthistle's soil water requirements. Mowing combined with bud damage results in more reduction than just bud damage alone. Spencer, D. F., et al. (2014).
- A 40% concentration of a 50/50 mixture of mustard oil and water was applied as a pre-emergence spray in greenhouse conditions. This had no effect on seedling emergence, but reduced plant height and dry mass of the plants. This treatment is based on the allelopathic effects of mustard oil and water on *Centaurea solstitialis* (Uygur, 2011).
- Burning reduces seedbank during the first year after burning, and decreases number of seedlings the following year. Consecutive burning can be an effective management tool. (DiTomaso et al, 1999).
- Yellow Starthistle displays no significant response to 70 and 140 g/ha of the herbicide Imazapic. However, it displayed a 93% density and biomass decrease 60 days after treatment with 280 and 420 g ae/ha of the herbicide Picloram (Shinn and Thill, 2002)
- The herbicide Aminopyralid was used along with prescribed burning and reseeding of native grasses, and in this case was recorded to provide almost complete control of Yellow Starthistle when applied from January to March (Kyser et al., 2013).
- Tillage or plowing will control *C. solstitialis* in systems that are annually maintained for crops. However, because this creates disturbance, tillage should be paired with revegetation planting of desirable vegetation to prevent further invasion by *C. solstitialis* (Jacobs et al., 2011).

Management Suggestions

I. Goals

Yellow starthistle (*Centaurea solstitialis*) is an invasive, annual herb that can commonly spread to disturbed habitats within the Central Valley. The primary restoration goal at any Central Valley site will be to ultimately remove the presence *C. solstitialis* from the site. Feasibility of this removal will vary from site to site, but in the ideal case the aim of any restoration effort should include complete removal of this species and replacement with native vegetation. Thus, for any restoration project within the Central Valley, the goals of managing *C. solstitialis* should include:

- Entirely eradicate *C. solstitialis* from the restoration site when possible, although this may not be feasible in cases where the plant is well-developed in the area. Specific eradication methods will be summarized later in the restoration plan.
- Continued management and monitoring should be implemented to document restoration plan effectiveness, notably with regards to *C. solstitialis* removal. On average, sites should be monitored for six years to ensure that the *C. solstitialis* seed bank is sufficiently damaged to prevent re-invasion. Again, specifics of monitoring techniques will be summarized later in the restoration plan.
- In the more likely case of incomplete removal of *C. solstitialis* from the site, preventative management can assist in keeping populations small, or at least limiting spread of the plants. Again, specifics of monitoring techniques will be summarized later in the restoration plan.
- Once *C. solstitialis* can be removed from a site, native vegetation should be planted in its place, both to combat erosion and re-establish a non-invasive community at the restoration site.

These general restoration goals can be feasible, but again they vary situation by situation. In many cases, complete removal of *C. solstitialis* may not be possible despite intensive management efforts, so a monitoring period longer than 6 years may be required.

II. Restoration Plan

The *C. solstitialis* growth form makes it a highly successful invader, and also a challenge to remove from a site. Seedlings germinate quickly after initial rains in early fall (Stephen. 2004). Young plants form rosettes during winter months, and develop a taproot by early spring. Plants then bolt in late spring with flowering and seed production occurring in summer / early fall. Throughout this time, the long taproot can produce roots that can extend over three feet down into the soil profile, even with a rather small basal rosette (DiTomaso et al, 2007).

Complete elimination of *C. solstitialis*, while ideal, is challenging due to the propensity of the adult plant's seedbank. *C. solstitialis* produces two types of seeds, which are respectively adapted to germination during the current year and adapted to remaining dormant for several years before germinating (Jacobs et al., 2011). Seed longevity, on average, can last for 6 to 10 years depending on the seed type (Callihan, Prather, and Northam, 1993), so re-invasion of the plant from a dormant seed bank is a real possibility. Prescribed burning represents an effective way to decrease the success of the *C. solstitialis* seedbank, both during the first year after burning and in subsequent years (DiTomaso et al, 1999). Consecutive seasons of prescribed burns can be an effective management tool. Likely, the optimal timing for burns would be to remove adult plants before flowers transition to seed, purely to reduce the risks of a new year's seedbank to be deposited. The clear downside to prescribed burning is that some native plants may also die off as a result of the burns, but burning can be compared with other methods to lessen the impact of native loss.

Following a successful prescribed burn, the adult plants should be removed from a site, leaving the seedbank in the ground accessible for herbicide. Many herbicides represent options at this stage, as long as the application reduces the survival of newly emerged seedlings. For example, the herbicide Picloram reduced *C. solstitialis* density by 93% sixty days after treatment (Shinn and Thill, 2002). In an additional case, the herbicide Aminopyralid was used along with prescribed burning and reseeding of native grasses, and in this case was recorded to provide almost complete control of *C. solstitialis* when applied from January to March (Kyser et al., 2013).

In cases where herbicide is not desirable, grazing represents an additional method of control. Horses should not be used for grazing practices on this species, as *C. solstitialis* can be toxic for them (USDA, 2017). Sheep and cattle will consume *C. solstitialis* during the seedling and rosette stage, up until initial spines begin to form on the bolting stalks (DiTomaso et al, 2007). Goats represent the optimal grazer for *C. solstitialis*, as they will target the plants throughout seed production and notably even into the stages where the stems develop spines. However, it is important to remember that grazing may not guarantee complete control of the species, and that *C. solstitialis* may persist if grazing does not fully remove all individuals.

Mowing and plowing are additional actions that can be taken against this species. Mowing and bud damage can reduce seed number and reduce root density, but tend to not entirely remove the plants (Spencer, D. F., et al. 2014). Similarly, tillage or plowing will control *C. solstitialis* in systems that are annually maintained for crops. However, because this creates disturbance, tillage should be paired with revegetation planting of desirable vegetation to prevent further invasion by *C. solstitialis* (Jacobs et al., 2011). Generally, these actions should not be used alone, but instead should be incorporated into an integrated management plan if herbicides or grazing practices are not feasible.

Furthermore, once *C. solstitialis* adults have been removed via burning or plowing, and the seedbank has been reduced through further management efforts, it is important to return native plants in the area. *C. solstitialis* thrives in disturbed habitats such as cultivated regions, road building spaces, pastures or fields subjected to overgrazing, or areas with mowing that has been poorly timed (DiTomaso et al, 2007). Following burning and herbicide use in a site, open areas will remain, and these are locations where re-establishment of natives can help avoid continued restoration issues with *C. solstitialis.* Fill in disturbed areas with long-term, more sustainable, native plants. Although annual legumes make for good restoration replacements for *C. solstitialis* and can take advantage of nitrogen released from prescribed burnings, follow-up herbicides to select for only the legumes are tricky. Thus, overseeding with grasses is perhaps the most useful method to control by revegetation. Grasses (particularly perennial, although these take longer time) , are more effective at competing with *C. solstitialis* than herbs, and can be paired with targeted herbicides (DiTomaso et al, 2007)

III. Monitoring Plan

Overall, *C. solstitialis* is found below 7,000 feet in elevation in areas that are dry (between 10 and 60 inches average annual rainfall) and light intensity is high (DiTomaso et al, 2007). It is commonly found in open areas, particularly in rangelands, wild spaces, pastures and hay fields, and along roadsides and waste areas (DiTomaso et al, 2007). Thus, open, well-lit areas within the California Central Valley and the surrounding foothills should be examined for the presence of this species, and closely monitored for long-term trends in invasion.

Monitoring efforts should begin in fall and early spring (the California rainy season), as this is when most seeds begin germination (DiTomaso et al, 2007). As little as one quarter to one half inch (0.6 - 1.3 cm) of rain is enough germination to occur (Jacobs et al., 2011), so proactive monitoring should occur after the first rains of early spring. Preventative monitoring efforts should be focused at looking for nondescript rosettes producing 6-28 leaves that are deeply lobed (Jacobs et al., 2011). Catching early germinating seedlings and hand-removing them should be effective in preventing invasion. This is particularly relevant in new locations within the Central Valley where *C. solstitialis* has not yet been established. The range of this species is predicted to expand as climate changes (Bradley, B. A., et al. 2009), as well as grow larger with added CO2 in the air (Dukes, Chiariello, Loarie, and Field, 2016). However, individual removal becomes more prohibitively labor-intensive if the initial spread has not been caught, so other management actions should be taken if *C. solstitialis* is already established.

Continued long-term monitoring is important to track the effects of management efforts. After a control burn has been implemented, it is important to do follow-up monitoring each of the next three following springs ensure seedlings do not develop. Monitoring must also be repeated alongside efforts until the seed bank appears to be cleared. Burning can be an effective management tool for *C. solstitialis* but it must be repeated to ensure complete control (DiTomaso et al, 1999). Once annual monitoring following a burn season has determined significant reductions in *C. solstitialis* presence, continued monitoring should be repeatedly annually during the spring. These efforts should be focused on looking for more seedlings, removing them if their numbers are few, and estimating a total count of spread of *C. solstitialis* within the area of interest. These efforts can help prescribe additional methods.

Improving this recovery plan requires a better knowledge of each individual restoration site. Each location has a different community of natives that would be most suited to replacing *C. solstitialis* plants if they can be successfully removed. The roles of controlled burns, herbicide use, plowing and grazing will vary at each given site, so it is important to perform proactive monitoring for at least a season before beginning restoration efforts. This will help catalog the specific characteristics of a particular site, and determine which management efforts are applicable.

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<u>Black Mustard (Brassica nigra)</u>

Joaquin Meckler

PART ONE:

Background and Justification:

Black Mustard (*Brassica nigra*) is a wide-spread, invasive herb that is commonly recognized across California by its bright, yellow flowers. *B. nigra* can be harvested for its seeds, which are commonly used in the condiment sauce, table mustard. However, the ability of *B. nigra* to inhabit a variety of environmental conditions, ranging from weedy meadows to vacant lots, have allowed it to escape cultivation and overtake fields of crops (Koch 2016). Some farmers have found its ability to quickly establish in an area an appealing quality for a winter cover crop and have used it as such. Planted in fall, *B. nigra* will cover the fields when no crops are present and add organic matter while suppressing weeds from growing in the following year (Björkman 2014). *B. nigra* was given a "moderate" invasive potential rating by the CAL-IPC, meaning it can establish it both undisturbed and disturbed areas with little help. It is especially difficult to control as it displays high levels of herbivore resistance (Oduor 2011) and the ability to tolerate a wild range of pH levels in soil and climatic conditions (Moore 2016). There are various means of control that can be used, ranging from chemical pesticides to tilling fields, but the ability of *B. nigra* to have seedbanks that can remain viable for up to 50 years has proved difficult to manage (Koch 2016). Currently, there are 35 distinct populations of *B. nigra* in Solano County (Calflora 2017).

Literature Review:

Control and Management:

- Non-chemical control methods are mechanical and cultural. Mechanical, such as pulling or cutting the plant, can be effective but tilling the ground can bury seeds to deeper depths and allow them to remain dormant and germinate at later time. Cultural methods include grazing and burning. Burning is likely to increase the abundance of *B.nigra* in an area as they can successfully invade disturbed areas and can survive periodic burns (Koch 2016).
- It is difficult to control *B. nigra* as seeds buried deep in soil can remain viable for up to 50 years. Those near the surface do not have as long of a viability period, often only remaining viable for 10 to 20 years (Koch 2016).
- Chemical control methods can be implemented through various pesticides applied during the vegetative rosette stage that can limit the emergence of the *B. nigra* (Koch 2016).
- It has an invasiveness grade of "B" according to CA IPC due to its has high innate reproductive potential and high rate of spread when no management is occurring (Cal-IPC 2016).
- Areas at most risk for invasion by *B. nigra* are recently disturbed areas as it preferentially invades habitats caused by natural disturbances or urban developments. It is especially important in restoration ecology as it is one of the first plants that will colonize a recently disturbed area and can strongly effect the soil conditions present (Palenscar 2013)

Reproduction and dispersal:

- *B. nigra* is an annual dicot that reproduces once a year and produces an average of 13,400 seeds per plant. The seeds are dispersed via seed pods that dehisce in June and July and will spread several meters from the adult plant that released them (Moore 2016).
- When released, the seeds are wet, which can help with dispersal as they can stick to moving animals or crops that are being transported (Palenscar 2013).

Tolerances:

- It was found that invasive populations of *B. nigra* had a higher resistance to herbivore damage. However, they did have lower tolerance to herbivore damage than did the native populations. This could suggest that that certain traits were rapidly evolved after the plant was introduced to an area (Oduor 2011).
- A study compared how a species similar to *B. nigra* could overcome droughts through a changing flowering time. Seeds collected before and after a drought and then planted in high water and low water areas were grown in a greenhouse. It was found that post-drought plants flower earlier, hinting that *B. rapa* can overcome periods of drought through early flower instead of efficient water usage (Franks 2011).
- A study found that there was a certain time required for solarization that would inactivate the ability of a *B. nigra* to propagate, effectively killing it. Seeds held at a constant temperature of 54 °C for 3 hours had 100% mortality. Lower temperatures, such as 50 °C or 42 °C, required more time to successfully kill the seeds.

- *B. nigra* can survive in soil with pH ranging from acidic levels of 4.9 up to a more basic value of 8.2, a much larger range than many other invasive plants (Moore 2016).
- *B. nigra* can be effected by both bacteria and viruses and natural predators, such as insects and birds. Black leaf rot and stem rot can be detrimental to crops of black mustard for cultivation. Aphids and seed-pod weevils also can have a damaging effect on drops. (Palenscar 2013).
- Being an invasive annual, it is believed that *B. nigra* will increase in range as temperatures rise and native plants are unable to adapt to shifting environmental baselines. It is thought that a spread to previously cooler areas will take place as *B. nigra* will have a higher chance of overcoming biotic constraints in those areas (Hellmann 2008).

Habitat characteristics and qualities:

- *B. nigra is* found along roadsides and in waste places, fallow fields, and vacant lots. It has a strong presence in coastal areas but has a widespread presence across the U.S (Palenscar 2013).
- It prefers a warm, temperate climate with dry summers but can tolerate environments that are wet all year long. It can live in a temperature range between 6 and 27 °C as well as between 300-1700 mm of rain per year (Palenscar 2013).
- *B. nigra* grows best on light, sand soil or rich, fertile soil and prefers full sun and a well-drained area that does not experience flooding (Koch 2016).

- *B. nigra* strongly prefers coastal scrub habitats, invading more than 50% of those habitats in California. It does slightly better in grasslands and vernal pools and only has invaded less than 5% of riparian areas (Cal-IPC 2016).
- It is characterized as a disturbance-following weed as it occurs in habitat openings that are caused by fires, human development, or other disruptions (Palenscar 2013).
- It can successfully invade grasslands, shrublands, and riparian areas, displaying a range across most of California (Koch 2016).

Uses:

- *B. nigra* is used as a spice and medicinal herb and when mixed with vinegar, produces the condiment known as table mustard. Tea from the seeds are believed to help with a variety of ailments, ranging from a sore throat to arthritis (Palenscar 2013).
- *B. nigra* can be planted as a winter cover crop and help add organic material while reducing the chance that other invasive weeds will occur in the following crop (Björkman 2014).
- It was found that certain allelochemicals found in *B. nigra* can be used as a form of weed management. When planted alongside wild barley, the growth rate, measured by both height and weight, was significantly lower in the wild barley than when it was planted in an area free of *B. nigra.* Thus, it inhibits the germination of other species through allelopathy (Tawaha 2003).
- *B. nigra* is also used as a trap crop where it is planted to attract certain species of pests and then treated with pesticides before the actual crop a farmer is preparing to cultivate is planted in a field (Franks 2016).

- In 2010, total commercial production of the seed of *B. nigra* was over 59 million tons, with the main producers being Canada and Nepal (Koch 2016).

Interactions with habitat and biodiversity:

- It contains glucosinolates, which can irritate the digestive track of livestock and cause toxicity problems if exclusively by livestock (Koch 2016).
- *B. nigra* is an early-successional species and will decline in abundance once native grasses are reintroduced into a disturbed area. It can persist in disturbed areas and has invaded over 50 of coastal communities currently (Palenscar 2013).
- By producing large amounts of biomass and maturing early in the year, it can displace other native plants by using up soil water before native plants reach peak maturity (Cal-IPC 2004).
- While the study was not done specifically with *B. nigra*, a study completed in 2014 found that invasive plants had lower herbivore densities and were visited more frequently than native plants, highlighting their ability to quickly invade and area and become well-integrated into pollinator webs (Bezemer 2014).

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PART TWO:

Restoration Plan for Brassica Nigra

Goals:

Brassica Nigra, commonly known as black mustard, is an invasive herb with a range that spreads across California through a variety of different environments. Its ability to tolerate and inhabit various environmental conditions, ranging from meadows and fields to parking lots and urban areas, cause the main goal of this restoration plan to center around control, as opposed to complete eradication. Another complication for the restoration plan is the beneficial use of *B. nigra* in agricultural fields. It is used both as a commercial crop to produce mustard sauce and as a trap crop or cover crop. The restoration plan has two main tracts: to decrease the abundance of invasive populations of *B. nigra* and to actively manage its use in agriculture to ensure spreading does not occur. Thus, the goals of this restoration plan will center on keeping *B. nigra* below a certain threshold of abundance, require agricultural use to follow strict regulations to limit spread, and determine areas of high importance for control. The restoration goals are as follows:

- Limit the 35 invasive populations of *B. nigra* in Solano County (Calflora 2017) to a 30% population abundance through aggressive culling measures carried out in March and April (will be expanded on in restoration plan).
- Require farms that grow *B. nigra* as a commercial or cover crop to have a .25 mile boundary of barren land around the edge of the field where *B. nigra* is grown (specifics of this will be elaborated on in restoration plan.)

- Replace invasive populations of *B. nigra* with native species of California wildflowers after it is removed to a population abundance lower than 30%.
- Eradication of *B. nigra* in chaparral and scrub areas is of high importance and population abundance should be limited to less than 10% in those areas.
- Invasive population levels should be monitored for at least 10 years and farm populations should be monitored for 8 years (will be expanded on in monitoring plan)

Pre-restoration goals:

- Determine spatial abundance of *B. nigra* in 35 distinct populations in Solano County.
- Determine use and abundance of *B. nigra* in agricultural fields in Central Valley.
- Measure and quantify habitat preference of invasive populations of *B. nigra* through relative abundance measurements.

Restoration Plan

Limiting the spread of *B. nigra* is a very challenging task that will require aggressive management measures to successfully minimize invasive populations in the Central Valley while actively monitoring the use of *B. nigra* in agricultural fields. Since *B. nigra* produces an average of 13,400 seeds in June and July, actively culling invasive populations in early spring (March and April) will help limit the spread into new areas in the Central Valley (Moore 2016). Mechanical or manual culling is most effective at reducing above-ground plant biomass. Seeds can remain viable for over 10 years in a seed bank so long term monitoring in areas with invasive populations will be required to ensure the population levels do not rebound (Koch 2016). Chemical removal should be used if mechanical methods are unsuccessful at lowering the population levels but can pose a danger by effecting populations of native plants in the nearby vicinity. The effect of chemical control should be assessed before use. Focusing on eradication in chaparral or scrub environments is of high importance as the spread of *B. nigra* in these areas will lead to an increase in fires and can cause a subsequent transition to a grassland environment (CA-IPC 2016). Thus, a lower threshold of abundance of 10% is listed in the restoration goals for these areas.

An additional problem that the control of *B. nigra* faces is its extensive use in agricultural fields, where it is used both a commercial crop and as a cover or trap crop (Björkman 2014). The lack of monitoring when produced as a commercial crop can lead *B. nigra* populations spreading outside of the plot in which it is grown. The seeds are generally wind dispersed and do not travel very far from the plant when released (Palenscar 2013). Thus, requiring a boundary strip of barren land that is .25 kilometers wide around fields of *B. nigra* will limit the spread of *B. nigra.* Compliance from farmers to enact this boundary strip may be difficult to obtain due to lack of motivation, money, or land and should be accounted for.

After the removal of *B. nigra,* reintroducing native species into areas they previously inhabited will become the top priority. Species that are fast growing annuals or perennials, such as Streptanthus or Caulanthus, should be planted soon after *B. nigra* levels fall below the 30% or 10% threshold (Native Plants 2016). Native wildflowers and grasses will be able to have a similar ecosystem effect as *B. nigra* and without drastically changing the landscape. However, since *B. nigra* preferentially invades habitats that have recently been disturbed, whether it be by natural causes such as fires or by human-caused developments, ensuring native wildflower species are quickly introduced into areas with recent development or natural disturbance is crucial to limiting the spread of invasive populations. Furthermore, *B. nigra* has been shown to both indirectly compete with native plant species as well as use allopathic chemicals to limit the spread and growth of native plants (Orrock 2008). Monitoring both population levels of *B. nigra* as well as the reintroduced native plants will be needed to encourage the recolonization of disturbed area by native plant species.

Monitoring Plan:

Pre-restoration monitoring will focus on getting accurate population estimates for both the invasive populations and the crop populations in Solano County and the greater Central Valley. These estimates will be used to determine the population numbers at the 30% and 10% thresholds listed in the restoration plan. The crop population numbers will be used to assess how successful a .25 km boundary strip will be to limit the spread of *B. nigra*. Additionally, pre-restoration monitoring will designate areas of high concern based on the environmental conditions present.

Being an annual herb with a high seed output, the invasive populations of *B. nigra* will require intensive monitoring ensure the control measures enacted are successful (Moore 2016). Mechanical or chemical culling will take place annually in March and April for three years. Short term monitoring of invasive populations include population estimates in the 35 distinct populations every six months for the first three years. Population monitoring in areas of high concern will occur at a higher frequency of every three months for three years after culling to ensure the successful reintroduction of native plants in these areas. *B. nigra* is an early-successional species and will often decrease in abundance once native plants are reintroduced (Palenscar 2013). If population abundance is not reduced to 30% of the original abundance in the first three years, culling will continue at an annual basis. As complete eradication is nearly impossible due to the rapid growth rate and invasive nature of *B. nigra*, a 30% threshold is a reasonable goal to set. Areas of high importance have a 10% threshold and may require more intensive monitoring and culling for the first three years. Similarly, if the threshold is not reached, culling will continue at an annual basis.

Short term monitoring for *B. nigra* where it is grown as a crop will take place three times a year for three years: once before the seeds are planted, once during harvest, and once after harvest. Population estimates will be measured as the number of plants present within or beyond the .25 km boundary strip. Since *B. nigra* is grown as both a commercial crop and cover crop, the times of monitoring may vary between different populations (Björkman 2014). *B. nigra* generally does not dehisce very far from the adult plant and adaptive management may allow for the boundary strip to decrease in size to allow farmers to maximize the size of their fields.

Continuous long term monitoring of invasive plant populations will be required as seeds in seed banks can remain variable for up to 10 years and mechanical culling through tilling can bring seeds up to the soil surface and allow them to germinate (Koch 2016). If the population abundance thresholds are reached in the first three years, monitoring will take place twice a year in the 35 distinct populations for ten years. For long term monitoring of agricultural fields, determining and implementing a successful boundary field will occur in the first three years. At that point, monitoring will take place at a reduced frequency of twice a year for 8 years.

Adaptive management will be crucial in this restoration plan. Improving the plan will require determining the most effective and efficient size of a boundary strip as well as how quickly and successfully invasive populations are able to rebound from culling and if the listed thresholds are attainable or need to be altered. Ideally, this plan will develop over the course of eight to ten years and allow for changes to be made that maximize the success of the various measures enacted.

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California Poppy (Eschscholzia californica)

Raymond Niem

Background and Justification:

The California poppy (*Eschscholzia californica*) is an annual or perennial wildflower native to California. The flower is characterized by its beautiful orange/yellow cup-shaped flowers and was proclaimed the state flower of California in 1903 (Smith 2010). The flower is native to most of the western United States, spanning across many different habitats, including desert, coastal, valley, and foothill (Smith 2010). The flower is grown by many gardeners and landscapers for decorative use, due to its beauty and popularity as the state flower. This species is very important because it is an abundant food resource to many insects and indirectly helps small mammals. The California poppy is rich in pollen which attracts many pollen feeding insects. Although the flower only comprises less than 5% of small mammal diet, increased insect abundance allows for more food for smaller mammals and birds (Smith 2010). If not managed correctly, the California poppy may become weedy or invasive and can displace many desired vegetation. Due to its ornamental use within many gardens, the flower is widely distributed across the United States and found in many different countries where the flower may also be invasive (Leger 2003).

Literature Review

Growth Characteristics:

- California poppy is a flowering herbaceous annual to a deep rooted perennial (Smith 2010).
- California poppies exhibits a growth form that is low-spreading to erect, standing .5-2.0 feet (Smith 2010).
- They will begin to flower and set seed during spring and summer (Kirkpatrick 1998).

Reproduction:

- Most California poppies will germinate in cool wet, winters or during spring (Kirkpatrick 1998).
- Spring-germinated seedlings can reproduce their first year, generally blooming from August until frost (Kirkpatrick 1998).

- Seed capsules are cylindrical in shape and dehisce longitudinally from the base when ripe (Smith 2010).
- The primary method of seed dispersal is an explosive ejection of the seeds that can go as far as 6 feet (Smith 2010).
- California poppy optimally germinates at 10-65 cm above water table (Cook 1965).
- Seeds can also germinate on a variety of different soils and parent materials, including serpentine (Espeland 2000).
- Seeds can stay dormant for up to 10 years within optimal storage conditions. In room temperature storage, seeds may stay viable only up to 5 years (Smith 2010).
- Cold and smoke can increase germination of poppy seeds (Montalvo 2002).

Range:

- The California poppy occurs naturally in western North America from the Colombia River south to Baja California and from the coast of California eastward to the Great Basin, and the Sanoran desert (Cook 1965, Smith 2010).
- The California poppy has been seen to grow in other countries like Chile where the flower is invasive (Leger 2007).

Habitat/Requirement:

- The California poppy was a wide range of habitats, like coastal, valley, foothill, desert, grassland, at elevations below 7000 feet (Smith 2010).
- Poppies can also grow on disturbed areas such as roadside, agricultural fields, and dry river beds (Leger 2005).
- Optimum light conditions for the poppy is day long light (greater than 12 hours) and flowers will close during low light levels like during the night or cloudy days (Smith 2010).
- Poppies prefer to grow on very well drained soils where roots can fully develop (Cook 1965).
- Poppies cannot grow on soils that are frequently saturated soils or less than 6 cm above water table depth and will see a decline during very wet years (Cook 1965).
- Populations will decline when competition for light and water becomes intense (Smith 2010).
- California poppy is susceptible to the herbicide active ingredients pendimethalin and DCPA, and the active ingredients oxyfluorfen, dicamba, and pronamide in post emergent (Smith 2010).

Tolerance:

- The California poppy has tolerance to many variables including high temperatures, droughts, variable precipitations, and a wide range of soil fertility, textures, and chemistries (Smith 2010).
- The California poppy is also able to recover from freezing events (Smith 2010).
- California poppy seeds can recover fast after fires, as long as the seeds banks aren't too damaged, due to the smoke promoting germination of the seed (Montalvo 2002).

Interaction:

- The California poppy relies on the pollination services of insects, for example beetles, thrips, honey bees, bumble bees, and hover flies (Espeland 2000).
- The California poppy is a weak competitor and will likely be displaced when around a stronger competitors (Leger 2003).
- There are some insects that will damage the plant. Aphids, thrips, and leafhoppers will feed on the sap of the plant. Beetles will eat the pollen from the flower. Lepidopteran will eat leaves and flowers of the plant (Smith 2010, Leger 2005).

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<u>Management Plan of the California Poppy</u>

Goals:

The California poppy (*Eschscholzia californica*) is a flowering herbaceous annual or perennial plant native to a wide range of habitat in California. The main restoration goal of the California poppy is to establish the species within the site and determine if the population is able to self-maintain or will require continued assistance. Resources and environmental conditions within the site will dictate whether the plant species will be able to self-maintain or not. Ideally, after initial introduction and management of the site, the plant species will be able to self-maintain the population without the need of assistance. Our restoration goals should be:

- Establish the California poppy seeds within an optimal area (go to Restoration plan to find specific details).
- Manage and monitor California poppy for at least 2 years to ensure new seedlings are able to sprout and flower to help create a seed bank to buffer against disturbance.
- If seedlings are unable to sprout unassisted, long-term management may be required (pesticide/herbicide, fertilization, etc.) to help create optimal conditions for seed establishment.
- If the species is able to self-maintain, monitoring should be done every few years or so to ensure the population is still able to self-maintain.

Restoration Plan:

Choosing a site is very important to ensure the establishment of the California poppy. The California poppy optimally germinates at 10-65 cm above water table, although can survive periods of drought, and seeds cannot survive under prolonged inundation (Cook 1965, Smith 2010). The optimal location to plant seeds would be upland or riparian zones, where the depth from water table is greater than 10 cm and soils that are well drained. It is important to also avoid areas where waters can pool during the raining season, to avoid saturation of soils or complete inundation. It is also important to grow in areas where shading is low or there is no shading, as poppies grow best in full sun, or 12 hours of sunlight. (Smith 2010).

California poppies are typically weak competitors and will be outcompeted when placed alongside grasses. The best establishment site would be low on stubble or cleared, where the seed can be sown solitarily. It is recommended to use 18-24 seeds per square foot when planting solitarily (Smith 2010). Depth of sowing will depend on the type of seed. Non-dormant seeds should be sown ⅛ inches while dormant seeds should be sown between ½ and ¼ inches into the soil (Smith 2010). Too much fertilizer can cause over production of leaves, causing a loss of flowers. To ensure that the poppies won't have to compete with other species, the use of herbicides against invasive weeds and grasses may be necessary. Weeding should be done at prior to seeding as any established invasive may be strong enough to exclude the poppies (Kirkpatrick 1998). It is important to note that some chemicals may be damaging to the poppies and should not be used around them. These chemicals include pendimethalin and DCPA, and the active ingredients oxyfluorfen, dicamba, and pronamide (Smith 2010). Any herbicide containing any of these chemicals should not be used near the

When growing California poppies, it is optimal to seed rather than transplanting. Typically, California poppies are not tolerant to transplantation unless the plant is very young (Smith 2010). Sowing seeds should occur during the fall, where the seed can fully utilize the natural winter precipitation. If winters are too harsh, then the seeds should be sown during the spring (Smith 2010). Typically, the poppies will begin to flower when temperatures begin to warm during the following spring, and fruits will mature through mid-summer, although may vary depending on environmental conditions and resources (Haggerty 2008). California poppies require the presence of bees, as they are their primary pollinators.

California poppies are prey to a variety of pests and disease. Insects, such as aphids, grasshoppers, thrips, and Lepidopteran larvae, are the most common pests for poppies and will consume parts of the plants (Smith 2010). They will not only cause physical damage to the plant, but can also infect plants with diseases. Some physical characteristics that can indicate a pest problem is leaf stippling and/or malformed leaves, reduced floral count, and spots (Smith 2010). To prevent the possibility of pest damage, insecticides may need to be used. Although it is important to be careful what insecticide to use, as bees an important pollinator to the plant. California poppies are also at risk to many other diseases such as mold. These diseases may be brought out by induced plant stress, so the best way to avoid these diseases are by ensuring soils are well drained, adequate sunlight, and low humidity (Smith 2010).

Monitoring Plan:

California poppies are able to reach reproductive maturity the following year after seed germination. It is important to closely monitor the population within the first year to see whether the plant is well adapted to the site and if it can produce seeds for reestablishment. During the raining season, it will be very crucial to monitor the seedlings as over saturation of soils with water, or prolonged periods of inundation, may prove fatal to the plants. If the area proves to be too saturated during the raining season, then a new area may need to be chosen where soil saturation levels are much lower. Over saturation may also increase the risk of the plants to get a disease. Leaves, roots, and flowers should be looked at closely for any signs of disease, such as spots, malformations, and/or damages. Any poppies that show signs of infection should be removed to prevent spread.

During the spring, the poppies will begin to bloom and should also be carefully monitored for any damage caused by pests. Some insects will feed on the plant and can damage them. If any damage is seen on plants, then insecticides should be used, with caution however, as California poppies also require bees to help pollinate. Other plants may also try to encroach onto California poppy sites. Herbicides should be used if grass species are seen invading into designated poppy sites, although be sure not to use chemicals that can be harmful to the California poppy (listed above). Toward summer, the California poppy will begin to fruit and their seeds will begin to germinate at the fall (Haggerty 2008).

Continuous, long-term monitoring is important see if the California poppies are able to self-maintain and reestablish on the site. Although after, intensive monitoring of at least 3 years, if the plants have shown to be well adapted and are able to reestablish, monitoring can be reduced to once every few years. If plants are unable to survive without assistance, then moderate maintenance and yearly monitoring may be required. If continuous monitoring is not possible, monitoring for the first 3 years after restoration should provide enough information on whether the poppies are able self-maintain or not and if continued maintenance will be required.

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Ripgut Brome (Bromus diandrus)

Ajay Rajamani

Background

Ripgut Brome (Bromus Diandrus) is an invasive annual grass found in many California mixed grasslands that prove problematic to restoration sites. Originally form the Mediterranean, Ripgut Brome is characterized by its long, rough awns that make it inedible for most herbivores (USDA, 2017). It is often considered undesirable due the fact that it is poor forage and because it can damage native ecosystems (California Invasive Plant Council, 2004). Ripgut Brome is known to exclude native plant species by forming a layer of thatch that prevents other plants from growing and by outcompeting native grasses for resources (Forero et. al. 2016). Invasive annual grasses like Ripgut Brome also promote fire when they senesce in the dry season, which poses a further threat to native species that are less adapted to fire and can pose a fire hazard near urban areas (DiTomaso & Kyser, 2013). In this fact sheet we will examine the ecology of Ripgut Brome and suggest several methods for its control.

Literature Review

Growth and Life Cycle

Ripgut Brome is an annual cool season grass (USDA, 2017). In California, seedlings emerge in the fall after the first rains and can grow up to 2.5 feet tall (DiTomaso & Kyser, 2013). Flowering and seed production occurs between April and June, after which the seeds are released and the plants dry out and senesce (DiTomaso & Kyser, 2013). Dense stands of Ripgut Brome can produce more than 1000 seeds per square meter, and seeds typically persist in the seed bank for 2-3 years (California Invasive Plant Council, 2004). This allows for Brome populations to re-sprout every fall.

Habitat

Ripgut Brome tends to favor areas that are frequently disturbed (such as farm fields, roadsides, and rangelands) and is able to survive in almost any soil type (California Invasive Plant Council, 2004). As a result, Ripgut Brome is widespread across California and is common near human settlements (California Invasive Plant Council, 2004). It can also invade areas with poor soil that have fewer competitors, such as arid sandy environments (DiTomaso & Kyser, 2013; Forero et al. 2016). Ripgut Brome does well in areas covered in thatch because such areas stimulate the germination of its seedlings (Forero, Davy, Barry, Bartolome, & Larson, 2016). However, it is not often found in wetlands does not do as well in areas with frequent flooding (California Invasive Plant Council, 2004).

Impacts

Ripgut Brome is classified by the California Invasive Plant Council as a moderate severity threat to native species (California Invasive Plant Council, 2004). The seeds of Ripgut Brome have long, rough awns, making the entire plant unpalatable to most grazers after seed maturity (DiTomaso & Kyser, 2013). As a result, dead brome tends to accumulate and form a thatch layer that excludes native grasses and forbs while further stimulating the growth of more Brome (DiTomaso & Kyser, 2013). In addition, when Ripgut Brome senesces during the dry season it becomes easily ignitable fuel, causing it to promote frequent fire in ecosystems where it is present (DiTomaso & Kyser, 2013). This can be detrimental to any woody species in the area that are unable to keep up with the frequent fires (DiTomaso & Kyser, 2013). This can also be a concern in areas close to human settlements where Ripgut Brome can pose a fire hazard.

Control Methods

Fire

Controlled burning can be an effective management tool to reduce Ripgut Brome infestations when carried out correctly (Moyes, Witter, & Gamon, 2005). The ideal time to burn Ripgut Brome is before seed dispersal and when favorable vegetation (native bunchgrasses, etc.) is beginning to go dormant for the summer (DiTomaso & Kyser, 2013). This window is usually in mid spring (California Invasive Plant Council, 2004). Burning after the seed dispersal, however, is not recommended because this can result in an increase in Brome the following season (DiTomaso & Kyser, 2013). In addition, burning when seed moisture is low is recommended in order to maximize the number of seeds killed in the burn, reducing the ability of Brome infestations to re-sprout (Sweet, Kyser, & DiTomaso, 2008).

Herbicides

Herbicides can be employed alongside fire and other methods to control Ripgut Brome. For native grass restoration, branched-chain amino acid inhibitors such as sulfosulfuron and sulfometuron are attractive options due to the fact that they are effective against Ripgut Brome and other annual grasses but have relatively little impact on perennial grasses (DiTomaso & Kyser, 2013). This allows easy treatment of large areas where Ripgut Brome may be interspersed with native plantings. However, the ideal time to apply these herbicides is immediately after emergence, limiting their usefulness if later season control is needed (DiTomaso & Kyser, 2013). Glyphosate (Roundup) is a non-selective herbicide that can be applied post-emergence to any rapidly growing Bromes with high effectiveness (DiTomaso & Kyser, 2013). It can be applied early in the season before the emergence of perennials to reduce competition against native grasses or later in the season to remove more mature stands of Brome.

Herbicides are best paired with another form of control to limit the risk of Ripgut Brome populations developing resistance. A study by Escorial et. al. showed that Ripgut Brome populations can exhibit up to 35% resistance to Sulfosulfuron and 25% resistance to Glyphosate in the worst cases, suggesting that resistance may develop quickly in sites where herbicides are the sole control against Ripgut Brome (Escorial, Loureiro, Rodríguez-García, & Chueca, 2011). Pairing herbicide use with prescribed burning or grazing is an effective way to control Brome with limited risk of herbicide resistance (DiTomaso & Kyser, 2013).

Grazing

Grazing is effective when carried out before Brome seedlings reach maturity and produce seed (DiTomaso & Kyser, 2013). Once the plants develop awns they are not palatable for most herbivores and cannot be controlled through grazing (California Invasive Plant Council, 2004). However, grazing done before this point can be effective at suppressing Ripgut Brome invasions, especially when paired with herbicide application (DiTomaso & Kyser, 2013).

Mechanical Control

Mechanical control can be effective when performed before seeds reach maturity (DiTomaso & Kyser, 2013). Small patches can be pulled by hand or with tools (DiTomaso & Kyser, 2013). Shallow tillage or discing after initial germination can reduce populations in the early season by killing seedlings (DiTomaso & Kyser, 2013). Mowing is effective when done immediately after flowering but before seeds mature, but should be done repeatedly for best effects (DiTomaso & Kyser, 2013).

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Part II

Management Plan for Ripgut Brome

The goal for restoration should be to eradicate Ripgut Brome from the grassland, or failing that manage it in a way that allows native perennial grasses to outcompete it. The feasibility of eradication and management techniques will vary from site to site, and as a result goals must be adjusted based on the site characteristics, extent of Brome invasion, and available tools. In general, restoration goals will be as follows:

1. Kill all Ripgut Brome on site and remove dead plant litter.

    - Any mature Brome and seedlings should be wiped out before they are able to produce viable seed. Mature stands of Ripgut Brome can produce up to 1000 seeds per square meter, making it imperative to remove all plants in order to prevent re-invasion (California Invasive Plant Council, 2004).

    - Ripgut Brome is a threat to native forbs because it leaves a heavy litter layer that promotes its own growth. Removing the litter layer prevents this (California Invasive Plant Council, 2004).

2. Prevent regrowth by reducing the soil seed bank.

    - Seeds of ripgut brome are typically viable for two to three years, with a small proportion persisting up to 5 years in the soil (DiTomaso & Kyser, 2013).

Intensive management of the site for 3 years can exhaust the seed bank enough to reduce brome sprouts to small, isolated patches (DiTomaso & Kyser, 2013).

3. Establish native perennial plant cover and exclude Ripgut Brome seedlings from the area

- Ripgut brome is a fast growing annual that can quickly invade bare or thatch-covered soil areas (California Invasive Plant Council, 2004). Eliminating these areas by establishing native perennial plant cover will exclude Ripgut Brome from the site, preventing re-invasion (Moyes, Witter, & Gamon, 2005).

Management Plan

Management for Ripgut Brome will consist of 3 phases:

1. Removal of mature plants

2. Seed bank depletion

3. Exclusion

1. Removal of mature plants:

The best way to clear Ripgut Brome from a site is through prescribed burning, which not only clears aboveground biomass and litter but also kills seeds on mature plants (DiTomaso & Kyser, 2013; Sweet, Kyser, & DiTomaso, 2008). Burning should carried out in spring when the plants are mature but before seeds have been dispersed (DiTomaso & Kyser, 2013). Burning after seed dispersal is not recommended because seeds that have been shed will not be killed by the heat of the fire (DiTomaso & Kyser, 2013). If fire is not feasible for the site, a combination of mowing and herbicides can be used (DiTomaso & Kyser, 2013). Mowing should be carried out in spring when plants are beginning to produce seeds but before seeds are mature in order to minimize re-sprouting (DiTomaso & Kyser, 2013). It may be necessary to mow multiple times before the Brome stops re-sprouting (DiTomaso & Kyser, 2013).

2. Seedbank depletion

Depleting the seed bank is critical to controlling Ripgut brome due to the fact that it is a fast growing annual, and can continually re-invade the site as long as there is dormant seed in the soil (California Invasive Plant Council, 2004). In the central valley, solarization is a very fast and effective method for killing seeds in the soil (Moyes, Witter, & Gamon, 2005). After the site has been cleared of vegetation in the spring (preferably through burning), clear plastic sheets are used to cover all of the bare soil on the site for one month during the summer (Moyes, Witter, & Gamon, 2005). The intense solar radiation and heat during this time is trapped and amplified by the sheets, sterilizing the soil seed bank (Moyes, Witter, & Gamon, 2005). This has been shown to eliminate all Ripgut Brome seeds in the area (Moyes, Witter, & Gamon, 2005).

If solarization is not feasible, whether due to cost or labor, multiple years of monitoring and tillage can be used to exhaust the seed bank through attrition (DiTomaso & Kyser, 2013). In this scenario the site should be left bare through the summer and checked for sprouts in the fall after every rain event. If there are many germinating Ripgut Brome seedlings then the area should be shallowly tilled to eliminate them (DiTomaso & Kyser, 2013). This should be done after every major seedling germination in order to force as many seeds as possible to come out of dormancy, and continue through the spring until germination stops (DiTomaso & Kyser, 2013). After 3 years of post-germination tillage most of the seed bank should be exhausted (DiTomaso & Kyser, 2013).

3. Exclusion

Ripgut Brome does not grow well in undisturbed areas with perennial grass and forb cover, and as such it is critical that the site be re-planted immediately after management of the seed bank is concluded (Moyes, Witter, & Gamon, 2005; Forero, Davy, Barry, Bartolome, & Larson, 2016). Any areas of bare soil are vulnerable to re-invasion from surrounding areas or any remaining seeds in the seed bank (DiTomaso & Kyser, 2013). Therefore, it is imperative when re-vegetating the site to minimize the number and size of bare gaps in the vegetation. Once new the plantings are established Ripgut Brome will not be able to re-invade easily (Potts, Suding, Winston, Rocha, & Goulden, 2012).

Monitoring Plan

Ripgut Brome can re-establish itself even after it has been completely removed from a site if seeds disperse in from surrounding areas (DiTomaso & Kyser, 2013). Seeds of Ripgut Brome can travel long distances by sticking to animals, and as a result careful monitoring is required to prevent re-invasion of a restoration site (California Invasive Plant Council, 2004).

Because Ripgut Brome seeds can lay dormant for up to 5 years, the site should be monitored closely for at least 2-3 years following restoration (DiTomaso & Kyser, 2013). The site should be checked every year between February and March by knowledgeable personnel who can identify Ripgut Brome on sight, in order to catch any re-sprouts before they mature and produce seed (California Invasive Plant Council, 2004). Brome often establishes in recently disturbed areas such as trails, roadsides, and bare soil areas, so special attention should be given to these and other areas that have been recently disturbed (Forero, Davy, Barry, Bartolome, & Larson, 2016). It is critical that if any stands of Ripgut Brome are found that they be killed and removed before they produce viable seeds, or else Brome will be re-established in the seed bank (DiTomaso & Kyser, 2013; California Invasive Plant Council, 2004). This can be done by mechanical removal with hand tools or with targeted application of herbicides (DiTomaso & Kyser, 2013).

The site should checked after any major disturbances that leave bare ground (such as Fire, heavy grazing, mass erosion, etc.) to make sure that Ripgut Brome does not establish itself in newly opened habitat (DiTomaso & Kyser, 2013). Ripgut Brome can sprout any time between the first rains in fall and senescence in late spring (DiTomaso & Kyser, 2013; California Invasive

Plant Council, 2004). The site should be checked at least twice a month between February and May in order to identify any patches of Ripgut Brome and remove them before they drop seed.

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Arroyo Lupine (Lupinus succulentus)

Shelbie Spencer

Part I:

Species Background and Justification:

Arroyo Lupine (*Lupinus succulentus*) is an annual California native herb, which has become ruderal in various areas on the West Coast. This specific species of Lupine may have been previously preadapted for colonization, because its natural populations are most commonly found in habitats which exhibit a considerable degree of disturbance (Harding & Mankinen, 1972). Because these species occur in disturbed areas, episodes of colonization are constantly initiated. Which means, depending on the available genetic information, founders can be traced back to their original natural parent population. This is interesting because these populations offer unique opportunities for genetic and ecological analysis on population differentiation during early stages of colonization (Harding & Mankinen, 1971). Because this species is ruderal it is able to occupy meadows, grasslands, openings in chaparral and any area with heavy, moist soil which makes it quite popular throughout most California (CNPS, 2017). This species is also important because it has the ability to fix nitrogen which improves soil quality and attracts more natives to the new and improved location (Johnson and Bentley, 1988). This fact alone makes Arroyo lupine exceptionally unique because it desires to be in locations which are undesirable and it assists in the restoration of the site through the remediation of the soil and attraction of other native plant species.

Literature Review:

Growth Characteristics:

- Arroyo lupine is a fleshy and robust annual herb about eight to 40 inches tall with a hollow, mostly glabrous, or non-hairy stem with many long stemmed leaves divided palmately into seven to nine oblong leaflets (Munz, 2004).
- The wild type flowers of L. succulentus are usually dark blue with a white sulcus on the banner (Harding & Barnes, 1976).
- The blue to purple flowers are in whorled clusters three to six inches long (Munz, 2004).
- Arroyo lupine flowers between February to May (Sholars, 2017).
- Arroyo lupine has an average height of 1-4 feet (CNPS, 2017).
- When growing in the San Joaquin Valley, L. succulentus germinates with winter rains and will typically begin flowering in March (Borders, 2017).

Reproduction:

- The wide upper banner petal has a white patch near the center that turns magenta after the flower has been pollinated, which signals bees that there is no more pollen available (Munz, 2004).
- Arroyo lupine is pollinated by bees, because they are strong enough to pull the petals apart to get to the pollen (CNPS, 2017).
- Lupinus fruit is a roughly hair legume pod that can be up to 5 centimeters long and around 1 centimeter wide (CNPS, 2017).
- Fruits are mature when they are dry and brown with no green color remaining, and the seeds inside are light to dark brown with a mottled appearance and a hard consistency (Borders, 2017).
- Lupinus species have hard seed coats that typically require a certain amount of weathering in order for seeds to germinate (Borders, 2017).
- Arroyo lupine shows no evidence of a significant interaction between pre-germination heat shock and seed growth (Hanley et al, 2001).

Range:

- Arroyo lupine is found below 3,000 feet in many types of open habitat, including disturbed and waste places, throughout California (Munz, 2004).
- The distribution of L. succulentus is disjunct with the largest concentration along the Pacific Coast of California.
- This coastal group is represented by many populations from Mendocino County, California, to northernmost Baja California, Mexico.
- These populations occur in the foothills of the North Coast, South Coast, Transverse, and Peninsular Ranges and on the off-shore islands of San Clemente, Santa Catalina, Anacapa, San Miguel, Santa Cruz and Santa Rosa (Harding & Mankinen, 1972).

Habitat/Requirements:

- Arroyo Lupine preforms best in soils that are well-drained, and often containing organic matter deposited by occasional flooding (Mielke, 1993).
- Arroyo lupine Prefers moist clay or heavy soils in full sun (CNPS, 2017).
- Arroyo lupine is mostly found in meadows, grasslands, openings in chaparral or any areas with heavy, moist soil (CNPS, 2017).
- Optimum Soil Temperature for Germination: 55F--70F (CNPS, 2017).
- Arroyo lupine requires a pH of 6.0-8.0 (CNPS, 2017).
- Arroyo lupine prefers a soil with slow-medium drainage class (CNPS, 2017).

Tolerances:

- Most water tolerant of all the lupine species (CNPS, 2017).
- Arroyo lupine can tolerate cold up to 25° F (CNPS, 2017).
- Can tolerate some shade, but prefers sun (CNPS, 2017).
- Can tolerate an annual precipitation range of 3.6" - 56.2" (CNPS, 2017).
- Can tolerate a humidity range of 0.59 vpd - 40.22 vpd (CNPS, 2017).
- Can tolerate an elevation range of 35' - 4373' (CNPS, 2017).

Interactions:

- Because of the close link between nitrogen content and alkaloid level in L. succulentus, foliage from plants growing in low-N environments is likely to be as poor as foliage from plants growing with abundant available nitrogen, at least for generalist herbivores (Johnson and Bentley, 1988)
- Specialist herbivores, however, are usually able to detoxify their host-plant's defenses and, in some cases, may use them as a source of nitrogen (Johnson et al, 1987).
- Surveyed surface soils in habitats with Arroyo lupine displayed significantly higher pH levels, compared to their open sand and forested counterpart areas (Pfitsch & Williams, 2009).
- Various interactions at low pH may influence the ability of legumes to establish symbiotic associations with nitrogen-fixing bacteria (Pfitshc & Williams, 2009).
- Arroyo lupine is known to attract various bee and butterfly species (CNPS, 2017).
- This species is toxic and is usually not consumed by most herbivores (CNPS, 2017).
- Arroyo lupine can alter ecosystem productivity because it releases N into the soil immediately around itself which can either be beneficial or harmful to potential plants attempting to occupy that same space (CNPS, 2017).

Management Considerations:

- The effect of defoliation results in not only a loss in biomass, but a significantly lower ability to fix nitrogen. nitrogen. The effect of defoliation may be especially damaging to very young N-fixing plants which have not had time to develop an extensive root and nodule biomass or adequate carbohydrate reserves (Johnson et al, 1987).

- Reduced herbage growth under flooded conditions was accompanied by reduction in leaf area; this reflected both the failure of immature leaves to reach full expansion and the inhibition of axillary shoot growth. Moreover, with progressive deterioration, wilting and leaf shedding also contributed to the reduction in leaf area.
- Chlorosis and the development of necrotic lesions were symptomatic of flooding injury under more extreme conditions (Broue et al, 1976).
- L. succulentus is a good species for stabilizing or restoring disturbed or degraded areas (Hickman, 1993).
- Being the most water tolerant of all lupine species; *Lupinus succulentus* is used cultivated as an ornamental plant for flower borders, native plant and wildlife gardens, and in natural landscaping projects (CNPS, 2017).
- The amount of fertility and moisture generally dictates the height of the plant (CNPS, 2017).

Arroyo lupine prefer soils with above average moisture in their natural range, (such as slope bottoms, canyon or ravine bottoms, north facing slopes or shaded soils with above average moisture retention.). Once established, these plants should still thrive with little or no additional irrigation in years of normal precipitation, as long as they are planted in their natural range and in spots with above normal moisture retention characteristics. If you plant them in drier soils, they'll need additional irrigation, but usually not more than 1x per week and only in the dry season (CNPS, 2017).

Part II: Management Plan for Arroyo Lupine

Goals:

The species Arroyo Lupine (*Lupinus succulentus*) is a native annual herb that is most frequently found in disturbed habitats throughout California. The big-picture restoration goal is to determine how to effectively enhance and maintain a self-sustaining population of Arroyo lupine into a disturbed habitat of interest for restoration. Restoration of this species is important because Arroyo lupine is ruderal and prefers disturbed sites so that it can fix nitrogen and distribute this transformed nitrogen back into the soil to increase soil health and attract beneficial native plant species which do not have nitrogen fixing capabilities. Our goal should be to direct seed and transplant Arroyo lupine throughout areas in California which have experienced disturbance and/or are poor in plant available nitrogen. This species can aid to the remediation of the ecosystem services of the land while also attracting and aiding the success of other California natives.

Therefore, the restoration goals should include:

- Goal: Establishment of Arroyo lupine to increase available wildlife habitat and forage.

- Objective: Plant and direct seed Arroyo lupine derived from local communities and populations because it can provide food for local wildlife such as squirrels, rabbits, and other small mammals. This also means to reduce threats such as harmful invasive plants which encroach and even choke out lupine and other natives.
    - Measurable criteria: Aim to establish greater than 25% cover of Arroyo lupine on the area of interest so that if individuals perish from herbivory, frost, competition, or disease then there are enough individuals to persist and add seeds to the seedbank. Also, around 25% cover within the area of interest is an idealistic estimate so that the lupine individuals are not in direct competition with one another for resources.

- Goal: Establish Arroyo lupine to improve water quality to improve local streams, rivers, and other open waterways inside of and/or near the restoration site of interest.
  - Objective: Plant and direct seed Arroyo lupine in herbaceous upland areas because this native annual herb requires little to no fertilizers or pesticides, and this decrease in chemical based solvents will be beneficial for water quality.
    - Measureable criteria: Plan to reduce the quantity of commercial pesticides and fertilizers on the site by 90%.
- Goal: Establish Arroyo lupine to reduce soil erosion and improve soil health in the area of interest.
  - Objective: Arroyo lupine will develop and accumulate enough individuals over time to secure the topsoil with their rooting systems while fixing N back into the soil. Since Arroyo lupine is an annual herb, it dies after each season and its dead plant biomass will assist in contributing to the accumulation of thatch over time, and will eventually turn into organic matter after it is decomposed. This species is known to have symbiotic relationships with mycorrhizal fungus which enhances soil biota, nutrition and structure. Also, planting lupine on slopes will assist with holding the soil together to reduce slope related erosion events, and hopefully minimize surface runoff to some extent.
    - Measureable criteria: ideally we would want to reduce soil loss to less than 5 Mg/ha per year.

The goals are feasible if periodic monitoring is available at the site to ensure that the species does not die from frost, excessive herbivory, or other stress inducing factors as mentioned in Part 1. Ideally, short-term monitoring for around 2-4 years would be best to make sure that the annual species is able to increase in population density over time. However, this does not account for natural disturbances such as irregular fire regimes, sudden periods of inundation, and extreme temperature fluctuations, which could potentially impact this species from being successful over long periods of time, resulting in an extended monitoring duration.

The pre-restoration goals should be to survey the area:

First, to survey the area to assess the location and conditions (soil texture, pH, salinity) of the site and see if it matches the parameters and requirements of the species enough that implementing this lupine species could actually make a difference in the landscape, and attract other natives. Arroyo lupine grow most successfully below 3,000 feet with the largest distribution along the Pacific Coast of

California (Munz, 2004). This species is the most water tolerant of all the lupine species and it is common in meadows, grasslands, openings in chaparral or any areas with soils containing moist clay and a slow-medium drainage class (CNPS, 2017). Its germination rates are also highest with local pH of 6.0-8.0, and soil temperature of 55F-70F (CNPS, 2017). Therefore, these areas which should be determined in the pre-restoration phase, should be closely monitored for the seedlings of Arroyo Lupine. Second, to measure how many other nitrogen fixing plants are already existing within the site of interest so that the site does not experience an overload of nitrogen fixers, because this may cause unnecessary competition between the lupine and other species. Third, to monitor near these areas of high salinity, high soil temperature, and array of soil textures, and also areas where the Arroyo lupine has high germination rates to see what specific conditions allow for the success of the species. Lastly, to assess the natural history of the site (mentioned in monitoring plan below) to see if it has a consistent or inconsistent fire regime, because the lupine family has a strong positive relationship with fire, and occasional instances of prescribed burns are very beneficial for the germination of this species.

Restoration Plan:

Arroyo lupine grows most successfully in direct sunlight, in soils that are well-drained, have a heavy clay content and often contain organic matter deposited by occasional flooding (Mielke, 1993)(CNPS, 2017). For planning the establishment of Arroyo lupine into our area of interest, we should collect seeds from various local populations in close proximity to the site that we want to restore so that those individuals are to some extent used to the climatic conditions of the area, as opposed to purchasing seeds from a vendor. Also the density of seed collection will depend of the local population density of the area we are collecting seeds from. Meaning, we will collect more seeds from a dense patch of lupine, and fewer seeds from a smaller patch of lupine to make sure we leave seeds for that population to contribute to its own locations seedbank, so that if we need to repeat the seed collection process, we can do so if needed. The Lupine species have seed morphs with differing seed coat permeability, and germination is often enhanced with moist stratification and scarification (Grigore & Tramer 1996). All Arroyo lupine seeds should be inoculated with Rhizobium bacteria, which assist in the formation of nitrogen fixing nodules which benefit initial establishment of the species into poor soils (Allen & Allen 1981). Even though there is value in transplanting adults, seed planting is far more efficient than translocation because it eliminates expensive greenhouse propagation and handling of plants, and allows more rapid establishment or a greater number of plants. Seeds and seedlings should be planted in the mid to late fall (October/November) so that the seeds are able to be planted, then utilize the seasonal rain the early spring to grow and establish before the dry season in the summer. Also, seeds and seedling plantings should occur each year during the monitoring plan since this species is an annual, to ensure the persistence of the species and accumulation of seeds into the seedbank. This species will require some minimal irrigation when it is initially planted to encourage growth but it is the most water tolerant lupine species, so once it is in its adult form the irrigation rate can decrease significantly. Most likely to irrigate we will use recycled water and non-permanent drip irrigation because it can be removed when prescribed burns and/or tillage are needed.

Because fire has a significantly positive effect on the survivorship of lupine, the species will initially decline with fire suppression (Swink & Wilhelm 1994), and have greater biomass and seed production after dormant season fire (Grigore & Tramer 1996). Lupine species survive fire impacts by persisting and spreading vegetatively, and probably reproduce by seed during years without late-season fire. Dormant season fire is well known for its positive effects on herbaceous plant biomass, flowering, and seed production, including such effects on lupine (Grigore & Tramer 1996). However, high rates of seedling mortality could occur if burns are prescribed after lupine germination (Grigore & Tramer 1996). Multiple factors appear to affect lupine survivorship, including pre-planting Rhizobium, inoculation, burn versus non-burn treatments, rainfall and temperature variability, and open canopy effects on light levels. These factors are hierarchical and appear to interact, with weather extremes having an overriding effect on fire and light levels, and fire interacting with canopy light level and having an overriding effect on inoculation. A previous restoration study of another lupine species in Illinois State Park planted 66 greenhouse seedlings, and 742 seeds, and had the highest success rate when the seedlings were inoculated with rhizobium (38.7%) and the seeds were burned (26.8%) (Bowles & McBride, 1995). Seeds should also be implemented before and after burning to increase yield.

When observing lupine species, peripheral populations of lupine are highly subjected to root borers, herbivores, pathogens. Whereas, the central populations exhibit high population density, lower levels of phosphorus in their tissues, and lower herbivory; which should give this species enough resources to restore nitrogen and organic matter to soils. The individuals on outer edge of the population will die from either excessive herbivory, over accumulation of phosphorus, or diseases. However, the middle cluster of lupine will be successful because there is an ongoing competition for phosphorus; whereas, the outer lupine will take up all the phosphorus into their tissues; which makes them became a key food item for herbivores (Eviner, 2017). Arroyo lupine is sensitive to phosphorus deficiency (Clark, 2014). To ensure the success of this species, the soil should be tested for phosphorus and in areas high in phosphorous plant a high density of lupine, and in an area low in phosphorus plant fewer lupines. Also, take samples from the soil of the location of which the lupine seeds came from and try to match that within the restoration site. Depending on soil test results, an application of 250-1000 lb/acre of superphosphate may be required to prevent yield reduction. Poor sandy soils may require 25-50 lb/acre potassium and in some areas potassium and sulfur are applied (Duke, 1981). The roots of the plant can increase phosphorus availability by acidifying the rhizosphere. This property may be beneficial to which associated plants (Jansen, 2006).

Lupines can cause livestock poisoning due to their high alkaloid content, and Lupineosis can occur when lupine is fed as dried forage. This disease is caused by toxins produced by the fungus *Diapore toxica* that colonize lupine plants. This disease is characterized by severe liver damage, resulting in loss of appetite and condition, lethargy, jaundice, and often death in cattle and sheep (Clark, 2014). The easiest way to solve this problem is to fence off the newly established populations of lupine, so that they are not available for forage. Aphids can be a problem for Arroyo lupine, and are mostly found during budding and early pod stages. Their direct feeding effects will reduce crop yields and lead to reduced growth of the inflorescence (flower) and/or pod formation. A simple way to solve this problem is to apply lady bugs to the plants affected by aphids, because the lady bugs are natural predators to aphids.

Monitoring Plan:

The monitoring techniques should include:

- The first step of the monitoring plan should be to get rid of as much invasive plants as possible in order to create space for the ideal 25% cover of Arroyo lupine within the area of restoration.
    - This can be done by analyzing invasive plant monitoring plans and implementing the require actions to remove the pest species.
- Once there is open space for planting, begin planting native wildflowers (Arroyo lupine) in the mid-late fall (October/November) and ensure there is an establishment of a mosaic of patches of California natives so that the lupine will be spread throughout the site and able to give fixed nitrogen back into the soil to support the mosaic of native species.
    - This can be done by creating a comprehensive plan in stages of removal of invasive plants; followed by a planting of native grasses and wildflowers; followed by chemical or physical spot removal of any persistent invasives; and finally the re-planting of Arroyo lupine seeds to help it accumulate in the seedbank.
- Monitoring of Arroyo lupine should last for a minimum of 2-4 years because this species is an annual herb, and it may take multiple re-plantings of seeds and seedlings to actually establish and contribute to the seedbank.
    - This monitoring time is subject to change and may require more time during instances of extreme drought, and irregular fire regimes, and climate change.
- Monitoring should be occurring during periods when we expect to see progression or failure of the species, so probably in late mid-summer during periods of drought and mid-winter during possible instances of frost.
    - Monitor in early spring to measure persisting individuals and early fall to measure percentage of survival and die off. Also, during instances of extremely low temperatures, it would be valuable to wrap juvenile lupine in fleece to protect the newly established individuals from the winter frost.
- If the implementation of this species results in failure to create a cover over 20-25%, then the next step would be to plan a prescribed burn to the area with the ideal conditions for lupine growth and the burning should assist with the germination of the seeds from previous year and hopefully help with increasing yield.
    - This process can be repeated until we see a 20-25% cover of Arroyo lupine within our entire restoration site.

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Russian thistle (*Salsola soda)*

Jenna Yonenaga

Background and Justification

Salsola soda, commonly known as Opposite-leaf Russian thistle, is an invasive weed that has become common to Northern California wetlands. First introduced in 1968 in the San Francisco Bay, *S. soda* has now been documented at most wetland habitats throughout the Bay Area (Grossinger et al., 1998). Because the plant is a halophyte that can tolerate saline soils, it is often found in open marsh plains, saline basins, mudflats, and upland areas with occasional tidal inundation (Grossinger et al., 1998). It also thrives in disturbed areas, making it a common plant in levees, dredged or wrack slurries, disturbed soil sites, tidal banks, and recently restored habitat (Mariott et al., 2013). *S. soda* is a successful invasive species because of its ability to easily colonize disturbed habitats and to outcompete native species by forming dense mono-specific stands (Cal-IPC 2007). It is also easily spread both by floating seeds and fruit through water, and also through vegetative rhizomes and root fragments (Mariott et al., 2013). *S. soda* is important because of its ability to transform native landscapes, by outcompeting and decreasing niche space for native species, such as California seablite and pickleweed. These changes in landscape can also have negative impacts on other species, such as native shorebird populations (Tamasi, 1998). This plant is categorized as a moderate-level invader that has the potential to severely alter the native wetland ecosystems throughout California (Cal- IPC 2007).

Literature Review

Common names:

- *Opposite-leaf Russian thistle, Alkali Russian thistle, Mediterranean Saltwort, Glasswort*

Plant characteristics:

- *S. soda* is an annual weed in the *Chenopodiaceae* family, which means it completes its life cycle in one year (Marriott et al., 2013).
- It is a glabrous, succulent that is found to be green, red or brown at maturity. Plant remains fleshy at maturity with calyces 3.5 m long (Baye, 2007, California Noxious Weeds, 2016).
- Grows in enclosed, dense stands and often dominates landscape (Tasami, 1998).
- Found to be 0.7 meters tall at maturity (Mosyakin, 1996).
- It is a shallow rooted halophyte, which means it can grow in soils with high salinity. However, it is not an obligate halophyte (Marriott et al., 2013).
- Is categorized as an invasive weed in California by the Cal- IPC (Invasive Plant Council); ranked as having moderate impact (Cal-IPC 2007).

Reproduction and Dispersal:

- *S. soda* reproduces mainly through both seeds and vegetative regeneration (Mariott et al., 2013).
- As annual plants, they produce approximately 1500-2000 seeds each life cycle (California Noxious Weeds, 2016).
- Seeds remain viable in seed bank for approximately 1-3 years (short) (Mariott et al., 2013).
- *S. soda* flowers in early summer, and produces solitary, bisexual flowers (California Noxious Weeds, 2016).
- Can disperse through floating seeds and as roots and rhizomes fragments (Marriot et al., 2013).
- Fruits are buoyant and can travel long distances (Cal- IPC, 2007).
- Spreads through water, animals, humans and vehicles (Marriot et al., 2013).

Natural Range:

- *S. soda* is native to Southern Europe (Grossinger et al., 1998).
- Found in Mediterranean coastal habitats from South Italy to Africa (Grossinger et al., 1998).

Invaded Range:

- First documented invasion in July 1968 in salt marsh by Dumbarton Bridge, San Francisco Bay, California (Grossinger et al., 1998).
- Invasions throughout San Francisco Bay wetlands from South to North regions in Northern California (Mariott et al., 2013).
- *S. soda* found from Tubbs Island in the San Pablo Bay (North Bay) to A15/A16 levee (South Bay) (Mariott et al., 2013).
- Also reported to be invasive in Candlestick Park, SFB Refuge, Alameda Shoreline, Emeryville Marina, Hoffman Marsh, Richardson Bay, Chevron Marsh, Point Pinole and Suisun Bay. Found in Bodega Bay one year. (Grossinger et al., 1998).
- Also found in San Diego Bay (Grossinger et al., 1998).

Habitat Requirements:

- *S. soda* is found in open marsh plains, saline basins, mudflats, berns (habitats beside road), and vernal pools (Grossinger et al., 1998).
- *S. soda* can tolerate saline soils above high tide. It is often found in upland marsh areas that are only inundated for some periods during the summer (Grossinger et al., 1998).
- Commonly found at high-tide wrack lines. These are areas where debris from high tide are left on land (Baye, 2006).
- Easily invades and colonizes disturbed habitat. Levees, dredged or wrack slurries, disturbed soil sites, tidal banks, and recently restored habitat are often dominated by *S. soda* (Mariott et al., 2013).
- However, *S. soda* also has the potential to invade undisturbed marshland habitat and vernal pools (Cal- IPC, 2007).

Competitors:

- *S. soda* has potential to outcompete other native and endangered wetland plants.
- These plants include, pickle-weed (*Salicornia virginica*) and California seablite (*Suaeda californica*), Owl's clover (*Castilleja ambigua ssp. Ambigua) and Point Reyes birds' beak (Cordylanthus maritimus spp. Paustris* (Baye, 1998, 2006*).*
- Native seedlings are especially vulnerable to competition by *S. soda* (Baye, 2006).

Management Considerations:

- Cutting, grazing or burning invasive *S. soda* is unfavorable, as the plant can re-sprout and establish again. These management actions may also spread vegetative material throughout landscape, furthering spread of the weed (Mariott et al., 2013).
- *S. soda* often invades newly restored marshland sites due to the disturbed soils. Monitoring and hand-pulling of the plant is recommended to avoid further invasion (Baye, 2006).
- Removal of *S. soda* is recommended before the flowering stage (favorable to remove at seedling stage) to avoid seed dispersal. Plant material removed should be bagged and discarded to avoid spreading vegetative materials (Baye, 2006).

- *S. soda* has a relatively short-lived seed bank (1-3 years), which allows for more feasible eradication of the plant (Mariott et al., 2013).
- Current eradication methods of *S. soda* only include hand-pulling of individual plants. Methods of common Russian thistle (*S. australis*) have included mechanical tilling, biological control using moths, and pesticide and herbicide application (Baye, 2006, California Noxious Weeds, 2016).
- These methods could be applied to *S. soda.* However, must first consider differences in habitat and seed dispersal of the plants. *S. australis* is found in semi-arid agricultural areas and their seeds are distributed by wind. The same management strategies may not work for *S. soda* in wetland habitats (California Noxious Weeds, 2016).

<u>Impacts on native ecosystems:</u>

- *S. soda* shares similar niches to many native wetland plants; the plant displaces native species and alters the natural ecosystem (Tamasi, 1998).
- When *S. soda* establishes on previously un-vegetated areas, shorebirds are negatively impacted. Their visibility to see predators is drastically decreased due to the dense stands of vegetation, thereby making them more vulnerable to predation. *S. soda* has the potential to impacts populations of native shorebirds (Tamasi, 1998).
- The plants invade the space needed for other native and endangered species. Because *S. soda* grows in dense, robust stands, it outcompetes other marshland species such as California seablite and native pickleweed. *S. soda* especially interferes with native seedling establishment and abundance (Baye, 2006).
- It also invades previously un-vegetated areas, which decreases niche space for species that required low-density habitat (Baye, 1998).
- Invasion by *S. soda* forms mono-specific stands, decreasing species diversity in local ecosystems (Cal-IPC 2007).

** Unable to find information on the human impacts, such as climate change, on *S. soda.* However, we can predict that disturbance of natural ecosystems increases with human impacts and developments, there will likely be increased invasions by *S. soda*. Changes in hydrology can also impact salinity and tidal currents. Changes in salinity and tidal levels may also change the range of habitat *S. soda* can tolerate. **

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Management Plan for Russian Thistle (*Salsola soda*)

Goals:

Russian Thistle (*Salsola soda*) is a highly invasive weed that is currently established and documented in many wetland habitats in San Francisco Bay, San Pablo Bay, and even in Suisun Bay (Grossinger et al., 1998). In this restoration site, *S. soda* should be controlled and ideally fully eradicated due to its ability to successfully establish in disturbed areas, its ability to outcompete native seedlings, and its ability to transform native landscapes by forming mono-specific stands that decrease niche space and biodiversity (Tasami 1998, Mariott et al., 2013). The numerous negative impacts of *S. soda* establishment make its eradication a high priority. There are both short term and long term goals that need to be followed to successfully eradicate the invasive weed.

Short Term Goals:

- Fully eradicate *S. soda* seedlings and established stands by hand pulling and removing fragmented vegetative material from the site. (Methods in Restoration Plan)
- Identify newly disturbed areas within the restoration site and focus eradication efforts of *S. soda* in these areas.

Long Term Goals:

- Create monitoring plan for at least 3 years after restoration site is established to survey for new *S. soda* seedling establishment. New seedlings should immediately be removed from the site to limit establishment of plant stands.
- Limit disturbed sites as *S. soda* is most successful in disturbed soil areas. Create precautionary measures that limit the creation of newly disturbed soils such as decreasing heavy vehicle and machinery use.
- Reduce points of introduction of *S. soda* by human causes. Create precautionary protocol to ensure that people who are entering the site are aware of their ability to spread material and spread invasive species.

Feasibility:

Eradicating *S. soda* completely from the site is a very idealistic and difficult task. Because the main method of eradication is hand pulling of individual seedlings and stands, a large amount of manual labor and subsequent funds are necessary to complete the proposed goals. Continuous and sustained monitoring of the site for new establishments also requires a large amount of work and funds.

If the species is monitored and controlled for at least three years as proposed, *S. soda* populations will likely decrease. However, there are always new introductions from the outside environment and chances for establishment. Although completely eradicating the species may be very difficult, successfully decreasing their population on site will reduce the negative impacts of *S. soda* on the surrounding community and ecosystem (Tasami 1998).

Restoration Plan

1. <u>Remove *S. soda* seedlings and established stands</u>
    - *S. soda* in past restoration projects have been eradicated by solely relying on hand pulling of seedlings and fully established stands (Baye 2006). Because *S. soda* can reproduce by root and vegetative material, hand-pulling ensures that all plant material is being removed (Baye 2006). Using less labor-intensive eradication methods such as mowing or burning would actually promote new growth of the weed as vegetative material is spread even further and should not be utilized (Mariott et al., 2013).
    - When removing *S. soda* from the site, the whole plant including the roots should be removed from the ground, and immediately removed from the site. This can be done by collecting the material in garbage bags and moving them off site (Baye 2006).
    - Ideal removal of *S. soda* would occur constantly throughout the year at the seedling stage. However, removal of *S. soda* is recommended during spring and early summer before *S. soda* flowers and produces seed. Removing before seeds are produced ensures that labor and funds towards eradication are used most efficiently (Baye 2006).
    - Although ideally all areas on site would be surveyed for eradication, depending on the amount of funds and time available, there should be a focus on disturbed soil areas. These areas with high disturbance that are most vulnerable to *S. soda* invasion should be identified as high priority eradication sites.
    - Eradication efforts for *S. soda* should continue for at least 3 years after restoration, as the plant has a 1-3 year seed bank period. If eradication from the whole site is not possible, the high priority sites should be monitored for at least 3 years. To ensure success and to deter reestablishment, eradication efforts should continue even after the 3-year period (Baye 2006).
    - Other eradication methods such as pesticide, herbicide and biological control are potential methods for *S. soda* eradication. However, there are no prior documented uses of these methods, so negative consequences on the surrounding community and ecosystem are largely unknown. Pesticide and herbicide use could effectively kill *S. soda* weeds; however there could be negative impacts on other species in the area. Biological control using insects and integrated pest management could also be successful; however, there is the possibility of introducing an invasive species that could negatively impact or change the natural system (California Noxious Weeds, 2016).

2. <u>Limit human disturbance of site</u>
    - *S. soda* is most successful in areas with disturbed soil sites, making it especially successful in newly restored areas (Mariott et al., 2013).
    - Precautions should be taken both during the restoration process and after to limit human caused disturbance to the site. This can be done by limiting heavy vehicle and machinery use whenever possible. These precautions to limit the creation of newly disturbed sites should decrease the success of new *S. soda* establishment by decreasing their preferred habitat conditions.

3. <u>Limit points of introduction by humans</u>

- *S. soda* is very easily spread by vegetative, root material and seed. Humans are a large cause of introduction of *S. soda* and other invasive species into new habitats by accidental dispersal (Mariott et al., 2013).
- Precautions should be taken by people working on the restoration site, and those visiting the site to decrease the risk of introduction of *S. soda.* This can be done by creating a precautionary protocol for people entering and leaving the site. This can include measures such as checking one's clothing, gear and shoes before entering and leaving the site for plant material and staying on provided trails.

Feasibility:

The feasibility of removing all *S. soda* seedlings and stands may be difficult because it is so demanding in terms of continuous manual labor and subsequent funding to continue removal for 3 years. However, sustained eradication efforts in only selected high priority sites should be more feasible.

Creating protocols and precautions to limit human caused disturbance and human caused introductions are very feasible as they do not require lots of labor of funding. Managers need to be responsible for these protocols to ensure people on the site are following them for these efforts to be successful.

Monitoring Plan:

To effectively monitor *S. soda* establishment within the restoration site, there is a pre-restoration, during- restoration, and post-restoration monitoring plan. During each phase the ecosystem is in, there will be different levels of monitoring and monitoring of different parameters.

Pre-Restoration:

- Before restoration of the site occurs, the area must be monitored to survey existing establishment of seedlings and stands of *S. soda.* A full survey of the entire site should be conducted to record the location of abundance of *S. soda*. This information can then be used to determine high priority sites that should have focused eradication efforts. This pre-restoration survey will provide critical information on the extent of effort needed to control the species. If there are few established *S. soda,* less work and funding is needed for the plan. If there are many established *S. soda,* much more work and funding is needed for eradication.
- This first pre-restoration survey will be very time-consuming and manual labor intensive but only needs to be conduced once. This survey will be very useful and necessary to determine the trajectory of the restoration plan.

During Restoration:

- During restoration, eradication of *S. soda* will be occurring at the high priority sites and at other sites, which are economically feasible to eradicate. Ideally all areas of the site will be eradicated of *S. soda*. These areas that are having *S. soda* actively removed, should be monitored. Date and number of *S. soda* removed should be recorded.
- During this restoration period, other native species will be planted and there will be many disturbed sites due to planting, machinery and other necessary tasks. These disturbed sites and areas with newly native plants are most vulnerable to invasion by *S. soda.* These areas should be actively monitored to ensure that there is no establishment of the invasive plant (Baye 2006).
- Disturbed soil areas should be monitored throughout the restoration process to ensure that there is no *S. soda* establishment. Seedlings should be immediately removed if found and recorded.
- Areas with newly planted invasive plants should also be actively monitored. *S. soda* seedlings can outcompete native seedlings, reducing native plant establishment. During this vulnerable stage, the new native seedling sites should be heavily monitored for *S. soda* seedlings and found seedlings should be removed and recorded (Baye 2006).
- During restoration, the ecosystem is very vulnerable to invasion by *S. soda* and therefore monitoring should occur frequently. If possible the high priority sites, disturbed sites, and sites with native plant seedlings should be monitored every week to ensure establishment of *S. soda* does not occur.

Post-Restoration:

- After restoration of the site is completed, there still needs to be continued and sustained monitoring of the area for new *S. soda* establishment. *S. soda* has a seed bank of 1-3 years; therefore monitoring and continued eradication of new establishments should continue for at least 3 years, if not longer (Baye 2006).
- Post-restoration monitoring does not need to occur as frequently, and can occur every 1-3 months or what is economically feasible. This post-restoration monitoring is very important to ensure that new establishment does not occur and develop large stands that negatively impact the ecosystem. Because *S. soda* can be introduced from outside variables it is necessary to continue to actively monitor and remove them from the site.
- If possible, all parts of the site should be monitored. However, high priority sites, disturbed areas, and planted native areas should be prioritized for monitoring of *S. soda.* If new *S. soda* plants are found, they should be immediately removed from the site.

<u>Feasibility:</u>

The monitoring plan for *S. soda* is critical to ensure that new establishments of *S. soda* do not occur after the many efforts and funds gone into eradicating them. There is always the possibility for new establishment from the outside environment so it is necessary that there are continued active monitoring and removal. The pre-restoration, during-restoration and post-restoration plans are feasible; depending on the amount of funding and available help the monitoring can occur more often or less. However, having more continued and sustained monitoring is very important to the success of the eradication plan and to control the negative impacts of *S. soda* on the ecosystem.

Future Research Needed:

S. soda is a very under-studied invasive species that is present in many of California's wetlands. There is still little information available on the life-history, ecology and biology of the plant and there are few specific restoration projects on the plant. More information is definitely needed to improve the restoration goals and plans of this project.

- Future research on the biology, reproductive cycle, and life-history of the plant is needed to improve plans. Having this information could help understand reproductive patterns and subsequent dispersal patterns of the plant into the site; this can help create more pointed and successful management plans. Ecological studies could be conducted to understand these questions.
- Having information on *S. soda* interactions with other biotic species and abiotic factors would also be very useful. There is little information on *S. soda* interactions with other plant species (especially Central Valley species) and other animals. There is also little information on *S. soda* interaction with its abiotic environment. We do not know if there are impacts of the plant on native soil, hydrologic systems, or if it has allelopathic defenses. Understanding the interactions *S. soda* has at a larger community and ecosystem level can help provide information to make more holistic management plans that take into consideration other species.

Potential Research Answered by Restoration Plan:

There is definitely the ability to use the information gathered through the restoration site and monitoring of the species at this site to further understand the species. By monitoring the sites and recording the species abundance and distribution throughout the site, we have a very useful data set that can be used to understand a multitude of questions. The distribution data can be analyzed with soil-type data, other species presence data and climatic data to understand the relationships between *S. soda* and its abiotic/biotic parameters. GIS could be used to map this data and to perform spatial analysis.

Experimental plots could be installed in conjunction to the restoration plan. Plots of actively removed *S. soda* could be compared to plots still have remaining *S. soda.* These plots could then be used to ask questions about the impacts of restoration on soil type, vegetation type, animal presence and much more. These comparison plots could be used as a baseline to ask further questions on how removal of *S. soda* changes the abiotic habitat, biotic interactions and the present community.

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Wetland Animals

The Red Eared Slider (Trachemys scripta elegans)

Shelby Baker

PART 1:

Background and Justification:

Red Eared Slider turtles over time have become a widespread invasive species. Starting in the 1900's, Red Eared Sliders were caught from the wild in order to be sold as pets in the United States. By the 1950's, the idea of these turtles as pets became very popular, so in order to keep up with being able to export these pets these turtles became farmed (Burger, 2009). This then lead to the spread of this turtle around the United States, as well as being exported overseas to be sold as pets. Eventually over time humans began releasing their pet turtles into the wild when they didn't want them anymore or they became too big, without the knowledge of how it would eventually negatively impact systems due to their invasive traits (Burger, 2009). We should care about these invasive turtles because of the negative impacts they are creating on our native turtle populations (Thomson, 2010) and because they are the most widely introduced invasive reptile on earth (Lambert, 2013). Currently, there are many Red Eared Slider populations that have taken over the homes of native turtles species, and we as humans need to find effective restoration and management options to remove these invasive Red Eared Sliders in hopes to restore some of the native turtle populations.

Literature Review:

Growth characteristics/ Life History Stages:

- For Red Eared Slider populations, sex ratios will very depending on the season (Tucker, 2008).
- Most males are able to be sexed once their plastron lengths reached 100mm. If turtles had a plastron longer than 100mm but no visible male secondary sexual traits then the turtles are considered to be juvenile females (Tucker, 2008).
- Male Red Eared Sliders start to mature around age 3 and females turtles tend to have more regular growth and mature when they are close to age 5 (Tucker, 2008).
- In most cases, once the Red Eared Slider turtle becomes mature, their growth rate slows significantly (Willingham, 2001).
- Once female Red Eared Sliders have become matured, they have to go through long nesting journeys which expose the females to various dangers, that male Red Eared Sliders are not susceptible to (Tucker, 2008).
- Adult Red Eared Sliders are more male biased due to the fact that males mature at a younger age than the female turtles do. This results to there always being more adult males than adult females in a given population despite the sex ratio of immature turtles being balanced (Tucker, 2008).
- The turtles growth rate can greatly impact its fitness capabilities, and its measurements of hatchling mass (Willingham, 2001). For example, larger sized turtles are usually

more beneficial and natural selection has commonly favored larger hatchlings (Willingham, 2001).

- The age when Red Eared Sliders mature can have either positive or negative impacts. This is because when a Red Eared Slider matures at a younger age, it will be introduced into the breeding population sooner which allows more chances of mating over its lifetime. However, earlier maturing turtles may not be big enough to compete in the breeding population, as well as being less able to avoid predators (Willingham, 2001).
- Hatchling size also impacts their success rate to making it to maturity. If the turtles hatchling size is large, it has better chances at making it to maturity because studies show that they are better at surviving predation attempts and this is due to the fact that they are able to right themselves and take cover more quickly compared to smaller hatchlings (Willingham, 2001).

Reproduction and Nesting:

- Turtles that are nesting tend to respond more to the timing of rainfall than to the amount of rainfall. The authors observations conclude that rainfall stimulates nesting activity on the following day (Tucker, 1977).
- Hatchlings emerge and begin moving during daylight hours (Tucker, 1977).
- An experiment was done to test if sizes of hatchlings differ with time. Early hatchlings tended to be heavier than late turtle hatchlings (Tucker, 1977).

- Red Eared Slider nesting seasons are quite variable. Experiments have shown nesting seasons to occur between the end of April until mid July, and mid June to the first week of July have been recorded (Tucker, 1977).
- Due to increasing annual temperatures the start of turtle nesting seasons tend to be earlier and the length of the nesting season tended to increase (Tucker, 2008).
- Despite that nesting season lengths vary, the time of day that Red Eared Sliders nest are mostly consistent. Nesting females tend to avoid nesting during the heat of the day therefore, Red Eared Sliders prefer to lay their eggs in the morning hours and not so much during midday hours (Tucker, 1977).
- It is important that the Red Eared Sliders nests have damp soil when they lay their eggs (Tucker, 1977).
- Environmental cues help trigger Red Eared Slider responses on when to nest, and females often nest on the same days. A possible benefit of female Red Eared Sliders nesting on the same day is that it could help reduce the first night predation on nests (Tucker, 1977).
- In conclusion, environmental cues, like temperature and rainfall all have important effects on when Red Eared Slider turtles will decided to nest (Tucker, 1977).
- Red Eared Sliders can expand rapidly because the female turtles are able to lay up to 6 batches of eggs per year, and each batch can contain up to 30 eggs (Ewing, 2017).

Diet/Eating:

- Red Eared Sliders are opportunistic omnivores (Burger, 2009 and Nishizawa, 2014).
- The protein based foods that Red Eared Sliders could have in their diet include: earthworms, ghost shrimp, crayfish, small fish, tadpoles, and frogs (Burger, 2009).
- Younger Red Eared Sliders tend to be more carnivorous than adults, but as they mature their diet becomes more omnivorous. The reason for this is because there is usually a slight change in the habitat as the Red Eared Sliders grow and become able to occupy greater depths of the pond or their habitat. Plant vegetation is more common compared to animal prey with an increasing depth (Burger, 2009).
- These turtles have a preference for moving prey and can be aggressive feeders (Burger, 2009).
- Depending on the season, it will affect the availability of the invasive turtles prey. For example, their diet will consist of plant vegetation and a mix of animal prey in the summer months whereas, their diet will be vegetation dominant in the winter months (Burger, 2009).
- Red Eared Sliders do not have the best striking availability when it comes to getting their food, but they exhibit a significantly shorter gape cycle time compared to other turtles. Therefore, Red Eared Sliders are able to complete their feeding in a shorter amount of time (Nishizawa, 2014).
- Red Eared Sliders tend to have a broader diet then native turtle species (Lambert, 2013).

- Red Eared Sliders will search for food during the day using their eyesight to help detect their prey in the water. Shallower waters are more ideal for the turtles when searching for food because increased sunlight allows for better visibility. (Burger, 2009).
- These turtles forage for most of their day by swimming around slowly in the shallow areas of the pond or habitat they are in (Burger, 2009).

Species Range:

- The range that Red Eared Slider turtles are natively found includes the Mississippi Valley from Illinois to the Gulf of Mexico and extends as far east as West Virginia and as far west as eastern New Mexico (Ewing, 2017). So these Red Eared Sliders are native to the eastern United States (Lambert, 2013).
- However, Red Eared Slider turtles have been introduced to many counties in California for example in: Contra, Butte, Costa, Kern, Lake, Los Angeles, Marin, Sacramento, Yolo, San Diego, San Luis Obispo, San Francisco, Santa Barbara, Tulare, Shasta, Santa Clara, Yuba, and Ventura (Ewing, 2017).
- This invasive turtle hasn't only just spread to areas in the United States. High densities of this species have been found on every continent except for Antartica (Thomson, 2010). It has specifically invaded countries of Africa, Asia, and Europe (Nishizawa, 2014).

- Red Eared Sliders are commonly found near densely populated humans areas and are less dense in less human impacted areas. This could be due to the release of these turtles that were once pets (Thomson, 2010).
- More commonly found in urban areas rather than rural areas (Thomson, 2010 and Lambert, 2013).

Habitat Needs, Preferences, and Requirements:

- Red Eared Sliders inhabit freshwater habitats. This includes: streams, lakes, marshes, swamps, ponds, wetlands, and rivers (Ewing, 2017).
- Red Eared Sliders prefer waters that are slow moving and habitats that have soft bottoms (Ewing, 2017).
- Red Eared Sliders had higher abundances at sites with shallower slopes at the waters edge, deeper water depths near the edge, more disturbances nearby, and steel mesh substrates (Lambert, 2013).
- These Red Eared Sliders need access to basking sites (Thomson, 2010).

Basking Sites:

- The turtles basking is highly dependent and varies on weather conditions, the time of day, and the time of year (Thomson, 2010).
- Red Eared Sliders are more commonly found in urban areas (Thomson, 2010 and Lambert, 2013), which have less basking sites available. So as a result, these basking sites become a limited resource for Red Eared Sliders and native turtles. However these

Red Eared Sliders are better competitors then the native species so they tend to dominate the optimal basking sites (Lambert, 2013).

- Red Eared Sliders are more abundant at basking sites that have warmer water temperatures and that have more exposure to sunlight (Lambert, 2013).
- After the turtles have foraged for food they have to bask for extended periods of time in order to activate their metabolism (Burger, 2009).

Tolerances and Affects of Disturbances (Temperature, Pesticides):

- At low temperatures, studies have shown that Red Eared Sliders are able to bite faster than their native Asian turtle relatives (Nishizawa, 2014).
- Red Eared Sliders are superior compared to native turtles in thermoregulation (Nishizawa, 2014).
- The sex of Red Eared Slider hatchlings are affected by temperature and therefore the sex of hatchlings are directly connected to climatic variables for example climate change/global warming (Tucker, 2008).
- Unlike most native turtles, Red Eared Sliders are able to handle human disturbances and are commonly found in areas near human populations (Thomson, 2010).
- Red Eared Sliders may begin to nest earlier as a possible result from warming temperatures (Tucker, 2008).
- At higher temperatures (~31 C), female Red Eared Sliders are produced whereas males are produced at lower temperatures (~26 C). Therefore, as temperatures increase this

will lead to more female Red Eared Sliders than male ones (Tucker, 2008 and Willingham, 2001).

- In middle temperatures, this is known as the "critical temperature sensitive period" where any exposure to estrogens or endocrine disrupting compounds can have an affect and alter expected gonadal sex outcomes (Willingham, 2001).
- Studies have shown that lead affects behavior and survival of Red Eared Slider turtles (Willingham, 2001).
- Polychlorinated biphenyls (PCBs) are able to impact the sex of Red Eared Slider embryos (Willingham, 2001).
- Pesticides found in the environment can alter Red Eared Sliders fitness, sex determination in hatchings, and sex steroid physiology (Willingham, 2001).
- Pesticides not only create endocrine disruption in Red Eared Sliders, but they can also interfere with the turtles thyroid pathway causing them to be in a hyperthyroid state (Willingham, 2001).

Negative Impacts Towards the System:

- This invasive turtle species are removing native turtle populations in many countries because they are better food competitors. They are better food competitions not due to their striking availability but because they are able to exploit more desirable food in a shorter amount of time (Nishizawa, 2014).

- Red Eared Sliders have been known to have the potential of spreading diseases. Cases have shown that Red Eared Sliders are capable of transferring parasites to native turtles, which can easily be spread throughout the drainage (Thomson, 2010).
- Red Eared Sliders outcompete native species for preferred basking sites, and this makes native turtles have to go to lower quality basking sites (Lambert, 2013).
- Due to the introductions of the Red Eared Slider turtles, they have caused native turtle populations to substantially decrease in size, and have even caused some native turtles to be listed as endangered species (Lambert, 2013).
- These Red Eared Sliders are successful invaders that have rapid maturation, high dispersal capability, and high reproductive rates that allow them to do better then native turtles (Lambert, 2013).

Restoration/Management options:

- Techniques of using hoop nets have been used to sample populations and catch aquatic turtles. Currently, they are the most commonly used turtle trapping device (Brown, 2011). Therefore, the use of hoop nets can be an effective way to manage and remove invasive Red Eared Slider turtles.
- These hoop nets allow turtles easy entrance into the trap, but they are difficult for the turtles to escape the trap (Brown, 2011).
- In order to attract Red Eared Sliders into the hoop nets, turtles are baited with fresh fish carcasses (Tucker, 2008).

- Red Eared Slider turtles are less likely to be able to escape the hoop nets, compared to painted and snapping turtles (Brown, 2011).
- To reduce the number of these invasive turtles, locating and controlling large breeding populations that currently exist as well as working towards reducing the number of Red Eared Sliders that humans release into the wild will help reduce these invasive turtles (Thomson, 2010).
- Certain basking site characteristics favor different turtle species. Therefore, as a possible restoration method to get more native turtle species back, would be to modify urban environments optimal for the native species in hopes to increase the native turtle populations (Lambert, 2013). A suggestion in order to do this could be to create basking sites that are more protected from human activities since native turtles are negatively impacted from human activities. Management efforts could create basking sites located in the center of the largest pools as well as increase the terrestrial and aquatic vegetation around the waterway and to also to put up barriers that could act as visual screens to make native turtles feel more safe from human activities (Lambert, 2013).

Other Information:

- The main predator of Red Eared Sliders are humans because they are often killed by cars, taken by kids, or hooked by fisherman. Although, other predators of this invasive turtle can be raccoons, otters, skunks, birds, as well as ants and maggots that can invade the turtles eggs (Burger, 2009).

- The time that these invasive turtles are most susceptible to disturbances, predators, or danger is when they are hatchlings. This is because they are the smallest at this age allowing predators to easily find them when they are foraging in shallow waters (Burger, 2009).
- Red Eared Sliders are commonly known to be aggressive species. An example that shows this is that when the young turtles are swallowed by fish they will try and hold their breath while chewing on the stomach lining of the fish until the fish regurgitates the turtle back up (Burger, 2009).
- Their primary defense against predators is their shell so as a result a lot of energy is used by the turtles to construct and maintain their durable shell (Burger, 2009).
- These invasive turtles are susceptible to viral and bacterial infections since they do not have the strongest immune systems (Burger, 2009).

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PART 2: Goals, Management and Monitoring Plans

A. Goals:

The Red Eared Slider (*Trachemys scripta elegans*) is an invasive freshwater turtle that is found in various waterway habitats in the Central Valley. This species of turtle is very successful at invading and taking over habitats, which negatively impacts native turtle species. Therefore, our most ideal goal would be to completely eradicate the Red Eared Sliders from all of the waterways. This then would allow for the native turtles to reestablish themselves without continuous competition of the Red Eared Sliders. However, during our restoration plan we will need to access whether or not completely eradicating the invasive Red Eared Slider is realistic and possible, and secondly if it would be feasible to accomplish. Therefore, our restoration goals would include:

- Determine whether completely removing Red Eared Slider populations is possible and feasible.
- If the species cannot be removed completely, we should reduce the populations of Red Eared Sliders where native turtles and Red Eared Sliders can live together, without the native turtles populations decreasing or becoming impacted.
- An important pre-restoration goal is to monitor the sites and estimate the number of Red Eared Sliders that are present. It is crucial to know the starting population size of the turtles, so that we are able to determine whether our restoration goals have been

successful and if we have gained any progress in decreasing the number of individuals in the Red Eared Slider population.

- Continuous monitoring and management to ensure that the invasive turtles population stays at low densities.

B. Restoration Plan:

After surveying the site and estimating how many Red Eared Sliders are present in the population, we must begin to capture the turtles to remove them from the area. There are multiple ways that this can be done:

- Turtles can be captured by hand or through various trapping devices.
- We can drain the water body, making it easier to find and remove the Red Eared Sliders from the area.
- Hoops nets, and baited cages can be used to capture the turtles.

If we choose the method of capturing the invasive turtles by draining the water body that the turtles live in, we would first need to recover and relocate all the native fauna. Secondly, we would need to create a barrier around the site so that when the water body is drained, the invasive turtles do not just escape. When a water body is drained quickly, up to 75% of turtles will emigrate the site (GISD, 2017). Therefore, we will set up the site with secured barrier fences and pitfall traps to avoid any turtles from escaping. This method would be best done at the time of the year when the water level is at its lowest point. The benefit to this method of capturing is that once the site is drained it will be easier to locate the invasive turtles and then remove them. The downfall to this method is that it could disturb and negatively impact the native species present at the site, especially if they are not recovered and relocated properly.

Another method of capturing is through using baited cages. Red Eared Sliders spend a lot of time basking in the sun because it is crucial in order to activate their metabolism (Burger, 2009). Therefore, a very practical spot to place these baited cages would be on their basking sites since turtles will defiantly be present there. In addition, baited cages should be placed in areas where Red Eared Sliders were the most seen and recorded during pre-restoration observations. We will bait the cages with dead fish that have been previously kept in a freezer to maintain freshness. Each baited cage will need to be checked daily, and restocked with bait when needed. As for the cage that we will be using, we will try a combination of traps that are made out of mesh netting, metal caging, and black plastic mesh. Using a combination of different traps will allow for us to see which trap works best at our site, based on the capture success. In past studies, other researchers have used these different styles of cages and have concluded that turtles may have preferential differences in the traps they go to. One group of researchers found that metal cages tended to capture less turtles (Davis, 2005). Therefore, a downfall to using metal cages to capture turtles might not be as effective since it is hypothesized that the "smell" of these metal cages are unappealing to the turtles since they could have released an odor or chemicals into the water (Davis, 2005) Although, the benefit to using these metal cages is that they would be very durable. Therefore, with this restoration plan we will have to access and monitor which cage works best at trapping the invasive turtle, and we can adjust the cages we use along the way if we encounter one cage working better then the others.

An additional method to capturing turtles is the use of hoop nets. Hoop nets are a very common turtle trapping device and are often superior to other trapping devices. These hoop nets are specifically designed to allow turtles to enter easily but are made difficult for the turtles to escape (Brown, 2011). A concern to using these hoop nets is that we might end up catching native turtle species. However, studies have shown that the escape rate in hoop nets for the invasive Red Eared Sliders are a lot lower than the escape rate of native turtle species (Brown, 2011). We will check these hoop nets daily and when doing so if we do find any native turtle species we will simply just release them back into the water.

After we have captured the turtles from our site, there are a few options that we can do with the captured turtles:

- Euthanize the turtles.
- Relocate the turtles to their native habitat.
- Put turtles up for adoption or find an organization like a zoo to take the invasive turtles in.

A common practice used by humans to eradicate invasive species is to euthanize the invasive species that they catch (Ohnouna, 2016). Therefore, this is one option of what we could do with the invasive turtles we capture at our site. The benefit to euthanizing these invasive turtles is that it allows for native species to repopulate and to stop being harmed from the negative impacts they create. However, the downfall of euthanizing turtles is that there has been a great amount of controversy over whether this method is ethical or not. Many think that this is not an appropriate method, and as a result should not be allowed.

Another idea is to take the turtles we have captured and relocate them to their native habitats. The Red Eared Sliders native habitat ranges from the Mississippi Valley from Illinois to the Gulf of Mexico and extends as far east as West Virginia and as far west as eastern New Mexico (Ewing, 2017). The benefit to relocating the turtles to their native area is that we would be avoiding euthanizing the turtles that many individuals find to be unethical. However, the problem with relocating these turtles to their native habitats is that it could create many environmental problems and concerns. Transplanting the Red Eared Sliders back into their natural habitats could introduce new genetic combinations as well as potential diseases to the native population (Ohnouna, 2016). Therefore, there would be high risk in transporting the Red Eared Sliders back to their native habitats.

Additionally, the turtles we capture at our site could be put up for adoption to willing pet owners. This would allow the turtles to be able to continue living but without negatively impacting the native fauna. Although, this method is not completely sustainable. This is due to the fact that there is high risk that humans could potentially contract salmonella from the turtles (Ohnouna, 2016). Also, humans are the main reason why the Red Eared Slider has become the most widely introduced invasive reptile on the earth in the first place (Lambert, 2013). So putting the turtles up for adoption may not be the best idea since humans have been releasing their pet turtles into the wild for years when they no longer want them or they become to big (Burger, 2009). Alternatively, a zoo or a different type of organization could take in some of the Red Eared Sliders that we have captured. As long as they keep the turtle in a contained area then the turtles will not be an issue to the native wildlife.

Another aspect of our restoration goal that needs to be considered is the time of the year that Red Eared Sliders reproduce and lay their hatchlings. This is a crucial time since this is when the turtles populations will be spreading, which is exactly what we want to avoid happening. Red Eared Slider nesting seasons are quite variable. Experiments have shown nesting seasons to occur between the end of April until mid July, and mid June to the first week of July have been recorded (Tucker, 1977). Even though the turtles nesting season lengths vary, the time of day that Red Eared Sliders nest are mostly consistent. Nesting females tend to avoid nesting during the heat of the day therefore, Red Eared Sliders prefer to lay their eggs in the morning hours and not so much during midday hours (Tucker, 1977). With that being said, it is important for us to come into the site after morning hours when the turtles have already laid there eggs. We can use detection dogs to help assist us to locate turtle nests and the hatchlings (GISD, 2017). Another way is to observe and follow where the females are going, which will most likely lead us to eggs that the turtles have laid (GISD, 2017). It is important we come into the site to examine for eggs since Red Eared Sliders reproduce rapidly. Female turtles are able to lay up to 6 batches of eggs per year, and each batch can contain up to 30 eggs (Ewing, 2017).

The last aspect in our restoration plan is to acknowledge that we cannot just focus on the site we are trying to restore itself. However, we will need to focus on the surrounding areas of the site as well. Looking at the surrounding areas and protecting it makes sure that invasive Red Eared Sliders are not immigrating into our site, as we are trying to get them out.

C. Monitoring Plan:

As perviously mentioned, before restoration occurs we need to monitor the site to access the current status of invasion. This will allow us to know whether our restoration efforts are making an impact towards removing the invasive turtles out of the site or if we need to come up with better ideas.

One important goal for our restoration plan was that if the Red Eared Sliders could not be eradicated completely from the site, we should at least then reduce the populations of Red Eared Sliders where native turtles and Red Eared Sliders can coexist and live together, without the native turtle populations decreasing or becoming negatively impacted. In order to know what this appropriate balance between the native and invasive turtles are, we will need to monitor not only the Red Eared Slider population, but we will also need to monitor the native turtle species populations. Without monitoring the native turtles, we won't know how the invasive turtles are impacting their success. Monitoring the native turtles will also let us know the changes in the native species populations based on how many invasive Red Eared Sliders are present at the site. If we monitor that the native turtle species populations are beginning to decline, we will need to make an effort to reduce some of the invasive turtles in the population because if this happens, that means there is too many invasive turtles at the site for the native species to succeed.

We have listed a few techniques on how the invasive turtles should be captured and removed. Therefore, during our restoration we will need to monitor which methods and/or what type of bait cage is the most successful at capturing the invasive turtles. We will measure successfulness by the number of turtles caught per cage. The cage that captures more turtles on average is what we will consider the most successful cage type and we will continue to use that particular method moving forward.

Nesting times during the year will be very important times to monitor our site in order to look out for nests with turtle hatchlings. This is because nesting times are when the turtles will expand their population, so monitoring is really key in order to make sure we have the proper control on the Red Eared Slider population. Since morning is usually when females lay their eggs (Tucker, 1977), we will need to monitor a little after morning for any potential hatchlings and then we can properly remove them.

Due to the fact that the Red Eared Sliders are an invasive species, it will always have the advantage and out-compete the native turtles in their habitat. Therefore, if we are not able to completely eradicate the invasive turtle from our site, we will need to routinely check the site (multiple times each year, focusing on reproductive periods) and take actions when the invasive turtle population spikes too high.

In order to determine the status of invasive turtles, basking sites can be routinely observed through binoculars and we would record the number of invasive turtles we see versus the number of native turtles we see. Another way to monitor the presence of the invasive turtles in the site is through Environmental DNA (eDNA). This is a powerful tool to detect and monitor species, and it has become more commonly used over the years (Davy, 2015). Turtles and other organisms shed small amounts of DNA into their habitat, so sampling eDNA from the environment rather than directly from the organism allows for quick detection of how many species are present in the water without having to visually see them (Davy, 2015).

Lastly, there are a few unanswered questions that would help complete our restoration plan. It would be helpful to know exactly how many invasive Red Eared Sliders can coexist with native turtle species in a given site without impacting the native's population. However, after our research and lots of monitoring I believe we will be able to have a better understanding of the appropriate balance of invasive and native turtles in a site. Additionally, knowing how far around we need to protect our site would help with a successful restoration.

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<u>American Beaver (*Castor canadensis*)</u>

Lauren Bottoms

Part I: Species Background and Justification

Background and Justification

The North American Beaver is an important species to consider when doing a restoration project because of its importance as an ecosystem engineer and a keystone species. An ecosystem engineer is a species that can change, maintain, or create habitats for themselves and other species by utilizing biotic and abiotic resources that are available to them (Rosell et al. 2005). A keystone species can be a plant or an animal that plays a significant role in the way that the ecosystem functions and without it would likely be entirely different or fall apart. In addition to having a significant impact on the habitat, they also affect the availability of organic matter due to the activity referred to as tree felling. Felling is the process of taking down individual trees, which they later use to help build their dams and sometimes for consumption. However, when beavers do consume the trees that they fell, they hardly ever consume all of it, leaving the rest to decompose and add organic matter into the soil. Due to their dam building, beavers help to maintain wetlands by slowing the flow of water from the site. In addition, they help to prevent erosion, raise the water table, and purify the water (Anderson 2002). The North American Beaver used to be one of the most abundant species in North America. However, following colonization, their abundance began to suffer due to overexploitation because of the fur trade. There were large efforts to revive the beaver population through re-introduction programs and protection. Due to these efforts, the beavers are thriving once again with a stable population and are listed as least concern (Cassola 2016).

Literature Review

Species range:

The North American beaver, as its name suggests, naturally occurs throughout North America with the exception of the peninsular part of Florida, the tundra, and deserts in the southwestern United States. Beavers can also be found all the way down into the northern part of Mexico. In addition to its natural range, the North American beaver has also been introduced to Argentina, Belgium, Finland, Germany, Luxembourg, and Russia. (Cassola 2016)

Habitat requirements:

The North American beaver needs to have a constant supply of water available to them, whether it is a stream, pond, or lake. They prefer to have a fairly stable level of water available throughout the year (Allen 1982). Within their habitat, beavers create cover referred to as lodges which they construct with mud, sticks, and rocks. In addition, they will create their dams in areas that have shallow and slow moving water. The sites that beavers choose to dam are often large and flat, so that they will easily flood, and have a good food supply.

Diet:

Beavers are an herbaceous species and consume the leaves, twigs, and bark of woody plants as well as aquatic and terrestrial vegetation. Their preferred woody food choices in order are: aspen, willow, cottonwood, and alder (Allen 1982). Generally, beavers prefer to eat deciduous trees and will often girdle coniferous trees in order to kill them and create room for the deciduous trees to grow (Link 2004).

Predators:

Since adult beavers are typically fairly large, 13-32 kg and 900-1170 mm in length, they are not as susceptible to predators as their young. Some of the most common predators include wolves, wolverines, black and brown bears, lynx, and otters. However, it is important to note that humans are also considered predators to beavers. Humans can affect beavers by manipulating their habitat, through pollution, and by killing them for their pelts (Anderson 2002).

Behavior and Lifespan:

In the wild, beavers can live anywhere between 10 and 20 years. They live in family groups that often include approximately 8 individuals. These family groups are territorial and exhibit behaviors to guard their territories. The first behavior is marking their territory by creating piles of mud around their territory and then rubbing these piles with anal and castoral secretions. Another way they defend their territory is by using their large tails to slap the water and create loud, startling noise to scare other beavers away. Beavers are nocturnal animals. One of their most distinct behavioral traits is the building of dams and lodges, which was briefly discussed in the habitat requirements section (Anderson 2002). In order to create their dams, beavers fell trees, which is essentially the process of chewing on the tree causing it to fall down.

Reproduction:

They are monogamous animals that mate for life. Females and males generally reach sexual maturity around age 3, however they will leave their colony the year before and travel several kilometers away to start their own colony. If a mate dies, a beaver will find a new mate. Mating occurs between January and March and following approximately 110 days of gestation, a litter is born between April and June. Females have one litter per year which have between 1 and

4 offspring. The female and male beaver both provide parental care to the young for the first 1-2 years of life by providing them with food and protection (Anderson 2002).

Part II: Goals, Management, and Monitoring Plan

A. Goals

a. Reintroduce, maintain, or increase the beaver population in Central California

Since beavers are a keystone species, reintroduction and improvement of the beaver population over a long time scale will be able to help with restoration of sites and may assist in the improvement of other species of plants and animals. Many rare, endangered, and threatened species are reliant on beavers. Additionally, beavers may be able to help with the improvement of California's wetlands (Lundquist and Dolman 2016). The amount of beavers that can establish and maintain a stable population at the site will depend primarily on habitat space and food availability. There can be a higher density of beavers at a site if there is a high diversity of plant types and high stream channel splitting. A typical beaver colony includes a pair of adults (which are monogamous), 2-3 yearlings, and 2-4 kits. Once young beavers reach maturity, around age 3, they will leave their colony to start a new colony of their own. These colonies need to be spaced apart from each other, but the distance depends on the quality of the habitat. If the habitat is high quality, colonies will be approximately 150-200 meters apart from each other. On the other hand, if the habitat quality is poor, colonies will be separated by 5-10 kilometers. Thus, beavers need more space from other colonies if the habitat is not suitable. I believe that a good start to introducing beavers would be to introduce 2 adult pairs of beavers that have just reached sexual maturity and allow them to try to establish colonies at the site.

b. Improve Habitat quality and provide areas for them to habituate

Beavers are generally very adaptable creatures, the two main resources that will affect their success at a site are the availability of water and the type of food. Beavers have to have a water source to colonize whether it is an existing pond, lake, river, or stream. Having a constant source of water for the beavers will be one of the most crucial aspects of this restoration project. Beavers use the banks of these water sources to make burrows, which they will need as soon as they are introduced. According to research done by Allen (1982), the beavers prefer to have stream gradients that are less than or equal to 6% where they make their burrows. Burrows, as well as the water itself, provide the beavers protection from predators such as mountain lions, wolves, and coyotes. They often prefer shallow and slow moving water in which they are able to create their dams (Lundquist and Dolman 2016). Beavers prefer ponds, small lakes, and slow-moving streams, but they will also establish themselves in man-made ponds, reservoirs, or drainage ditches. In addition to good habitat areas and water needs, there needs to be a large quantity of food available to them. The site should have at least some medium sized plants, such as shrubs, that they can utilize to build dams and create lodges. However, it is better if there are trees in the 2.5-15.2 cm dbh size class that then create 40-60% canopy cover at the site. Beavers are herbaceous animals and will eat nearly any plant material including leaves, grasses, and blubs. However, their preferred foods are aspens, willows, cottonwoods, and aldersIt is preferred that greater than or equal 50% of the woody vegetation at the site is dominated by aspen, willow, or alder. In addition, it is also important to reduce the amount of competition between deer and elk for their preferred food (Allen 1982).

c. <u>Control problematic beaver behavior while increasing their beneficial effects</u>

Beavers can become an animal involved in human-wildlife conflicts because of the way that they manipulate the environment. Control should be implemented so that the beavers do not damage particular aspects of the environment that negatively impact humans.

d. Feasibility

All of these goals should be feasible and relatively easy to achieve with fairly regular monitoring. Initially, it may be difficult to determine the carrying capacity and the population size of the beavers because the California Department of Fish and Wildlife does not monitor their current population numbers. In addition, in most of the counties in California, it is legal to trap as many beavers as you want as long as you have a permit and are doing it within the allowed season. If someone believes that they are experiencing damage done by a beaver, they can also apply to get a kill permit. With these permits, people do not have to report the number of beavers that they take (Lundquist and Dolman 2016). Thus, the most difficult part of the restoration might be monitoring the effects of humans on the given population.

B. Restoration plan

a. Reintroduce, maintain, or increase population

Information on the current numbers and distribution of beavers can be found by using the Beaver Mapper tool, which shows sightings of beavers in California and Oregon. These sightings are submitted by the public, however it cannot be viewed until you apply for and are approved for access. This is because of the fear that people will use it to find and kill beavers. However, once granted permission, all of the data can be viewed ("Beaver Mapper"). Additionally, it will likely be necessary to complete sampling efforts on specific sites to obtain their current population data and determine approximate carrying capacity. In order to calculate carrying capacity, you must find population size, change in population size with time, and intrinsic rate of increase. With this information, you can use this formula to calculate carrying capacity:

$$K = \frac{rN((1 - N))}{\frac{dN}{dt}}$$

Where: N= population size

$\frac{dN}{dt}$ = change in population size

and r= intrinsic rate of increase

If beavers need to be introduced to the site, they must be transported by the California Department of Fish and Wildlife. This is because the California Department of Food and Agriculture has determined that beavers can potentially pose a threat to other native wildlife, agriculture, and public health. Thus, they do not want the public to have the ability to introduce beavers where they can potentially pose a threat (Lundquist and Dolman 2016).

b. <u>Habitat</u>

Pick a site that already has available water or that will have water available once some restoration has been done. Shallow and slow moving water is preferred and it is necessary that there is constant water at the site year-round. There are no exact numbers on the level of water depth that beavers need, it just has to be deep enough that it can surround their lodge plus have enough room for an underwater exit. Since beavers adapt pretty well to any given environment, it is mainly important to ensure that in addition to a constant water source, there is preferred food for them to eat. While it is preferred to have some deciduous tree species such as alder or willows for the beavers to eat, they will also persist on any herbaceous vegetation, as long as there is enough of it. Based on research conducted by MacDonald (1956), he estimated that 6 acres of 30’ aspen or 18 acres of mature willow would support a colony of beavers. There have been many studies that have tried to quanity the amount of vegetation a beaver needs to consume per day, but the results have greatly varied. The range of estimates is 1 lb/day- 4.5 lb/day (Henkerk 2009). If there is no woody vegetation at the site, it is recommended to plant fast and easy-to –grow species such as willow and cottonwood (Pollock et al. 2015). Also, if beavers are already in the site, it may be necessary to protect young trees so that the beavers do not harvest them too early. Next, the easiest way to reduce the amount of competition for food with elks and deer is to build a fence that excludes them from reaching the food source. Finally, the beavers must have some type of cover to protect themselves from predators. Beavers will create cover for themselves either by creating lodges out of woody material or by digging burrows in the water banks. Woody species or water banks with a gradient less than or equal to 6% must be available at the site so that the beavers can create cover for themselves.

c. <u>Control</u>

Beavers are species that are often involved in human-wildlife conflicts due to the way in which beavers manipulate the environment. First, the public is often concerned about flooding in areas that are near homes. In order to prevent this, flood control devices can be inserted through the dam, which inhibits water from flowing over the top and creating the sound of running water which signals the beavers to build. Next, damage to trees in another big concern with the presence of beavers. There are a couple ways in which damage to trees can be prevented. First, trees can be wrapped with a 3 foot high galvanized welding wire, this wire is strong and can withstand the sharp incisors of the beavers compared to chicken wire. When installing this wire, it is important to leave room for the tree to grow. The next method that can be used is painting the trees with a mix of latex paint and coarse sand (Lundquist and Dolman 2016).

C. Monitoring Plan

Beavers are nocturnal animals that will need to be monitored either before sunrise or after sunset. In addition, viewing the beavers can often be challenging as they can become aggressive if they are cornered on the land. Because of this, beavers should be approached very slowly and also downwind as their sense of smell is better than their eyesight. If it is possible, beavers should be viewed from as far away as possible as to not disturb or aggravate them. It will be important to have data on their activity at the site to determine how they are utilizing the habitat. For instance, you can determine where they are preferentially building lodges and foraging. In addition, if you are able to view the animals, you can obtain information on their population and determine whether it is decreasing, stable, or increasing. Abundance data is important to obtain when trying to determine how your population is doing. Abundance data should be collected every year and should occur after litters are born, around June.

Monitoring should occur very frequently following the introduction of beavers or initial restoration at the site, preferably bi-weekly, but at least monthly for the first year. By monitoring early on, the observer can determine how the population is responding to change and if any imminent changes need to be made. During this time, it is important to determine if the beavers can establish themselves. If the colony is having a difficult time establishing, you can provide the beavers with additional materials to build or with food.

Monitoring should also occur at longer time intervals if possible. Beavers become sexually mature around 3 years of age, at this time it would be important to monitor the beavers and determine whether or not they are capable of reproducing. In addition, by monitoring over a longer period of time, the observer can determine the number of individuals surviving as well as their utilization and state of the habitat.

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Western Pond Turtle Emys/Clemmys/Actinemys marmorata

Anna Britzman

Part I: Background and Justification:

Global efforts to conserve biodiversity often prioritize species with unique niches due to their irreplaceable roles in their ecosystems. The Western Pond Turtle is a unique species, in that it is the only freshwater turtle native to California (Leidy et al 2016). Due to its seasonal migration and resulting role in both freshwater and terrestrial ecosystems, this species is of special importance. The species is rapidly declining due to the combination of invasive predators, human disturbances, and the lasting effects of commercial harvesting from eight decades ago (California Herps 2017). However, since the species is not listed under the Endangered Species Act, habitat plans have not been made for it by the Fish and Wildlife Service, and until it is listed, research will likely be focused more on more critically endangered species. Given the declining state of the turtle, a better understanding of the contributors to its decline must be acquired, so that scientists can effectively conserve the species' habitat and prevent further threats to the species.

Literature Review:

Physical Characteristics

- The western pond turtle is 3.5-8.5 inches long, with dark brown, olive brown, or black coloring and a low unkeeled carapace. Its patterns vary between lines or spots spanning from the centers of the scutes. Its legs have cream to yellow coloring with speckles. Its head has black spots, and may have yellow coloring (California Herps 2017). This coloring acts as camouflage against the muddy and rocky habitats that it occupies.
- Hatchlings are 1 inch long (California Herps 2017).

Behavior and Diet

- Diurnal (California Herps 2017)
- They are easily alarmed, and will abandon basking sites when approached by people (Lambert et al 2013)
- Basking allows individuals to elevate their body temperatures, thus increasing metabolism for proper digestion and increasing effectiveness in feeding, reproduction, growth, predator avoidance (Lambert et al 2013).
- They are omnivorous; their diet consists of aquatic plants, invertebrates, worms, frog and salamander egg larvae, crayfish, carrion, and less frequently, frogs and fish (California Herps 2017)

Habitat

- Western pond turtles are habitat generalists, thriving in manmade reservoirs, water treatment ponds, and agricultural ponds, as well as natural rivers and seasonal creeks of different sizes (Pilliod and Stafford 2013).
- Generally, the turtles live in larger populations due to higher reproductive success and survivorship in small, high elevation ponds; however, size and age structure remain constant at sites with different elevations; overall, an interaction of elevation and latitude influences growth (Germano and Riedle 2015)
- The turtles' limiting resources are basking sites in urbanized areas (Lambert et al 2013)
- Turtles thrive in swales (Pilliod and Stafford 2013)

Range

- Their elevation ranges from sea level to 2000m elevation (Germano and Riedle 2015).
- Western pond turtles range from Washington to Baja California; they are declining in many parts of range (Lambert et al 2013)
- Within California, they are found in intermittent streams in Mediterranean-climate regions (Leidy et al 2016)
- Historic ranges include waterways fed by the Sierra Nevada, many of which are now blocked by dams in mountainous regions and agriculture in desert regions (Germano 2016)
- Some new habitats have also been made available to the turtles that were not historically, including agricultural areas and sewage drainage sites where water is now found year-round (Germano 2016)

Movement

- These turtles forage and mate in water, then migrate to terrestrial environments to nest (Leidy et al 2016)
- During the dry season they congregate in remnant pools; declining pools provide cues to move upland; this occurs by August or early September (Leidy et al 2016)
- Turtles travel less than 343m from ponds; they participate in terrestrial overwintering 10-30 weeks out of the year
- Turtles do not migrate together out of ponds; rather, they depart individually over a period of 2-8 weeks, in different directions; some even stay in ponds all year round (Pilliod and Stafford 2013)

Reproduction/Life History

- Some adults live over 50 years (Germano and Riedle 2015)
- Average clutch size is 4.5-5.7 (Germano and Riedle 2015)
- These turtles have a higher rate of reproduction at higher elevations; the average clutch size is 6.3 eggs in these regions (Germano and Riedle 2015)

- In habitats with lower elevation, the turtle has the faster primary growth but reached smaller sizes at adulthood (Germano and Riedle 2015)
- They mate in April and May once adults are 8-10 years old (California Herps 2017)
- Females lay .5-2 clutches per year (California Herps 2017)
- Invasive species such as the American Bullfrog are often listed as predators, however these are local threats, and further studies would have to occur before labeling them range-wide threats to the turtle (Germano 2016)
- Hatchlings are vulnerable to predation by American Bullfrogs in aquatic habitats, subadults are vulnerable to terrestrial predation by raccoons and black bears, and adults are vulnerable to river otters in aquatic habitats. Adults were not found to be predated in terrestrial habitats. (Vander Haegens 2009)
- Stable population is 53 individuels over 4 ha (Lambert et al 2013)

Climate Change Threats

- Turtles are sensitive to temperature during incubation; temperatures above 29°C for at least 30% of the incubation period increase the chance of being born female. With increasing global temperatures, this could lead to an imbalance between males and females in a population, resulting in demographic stochasticity and lower diversity (Christie and Geist 2016).
- Incubation lasts less time than average when the temperature increases slightly, which may be seen in the wild due to gradual global warming. However, in the case of an extreme weather event such as a drought, the incubation time is extended (Christie and Geist 2016).
- High mortality is linked to drought, however it is unclear if direct or indirect mortality causes are to blame; it would be beneficial for conservation efforts if this topic was studied in more detail (Leidy et al 2016)
- The effects of fire on turtles are largely unknown; more studies should be done on this in the future, especially given the likelihood of more extreme weather events occurring with global warming, and the impacts on the sex of the newborns incubated in warmer than average regions

Biotic and Human-Caused Threats

- Habitat loss due to human interference is a major threat in Southern California, the Central Valley, and the Bay Area of San Franscisco and Oakland (Germano and Riedle 2015)
- The presence of human activity near freshwater habitat can have a negative impact on turtle behavior; specifically, basking periods interrupted by human disturbance are shorter than undisturbed basking periods (Nyhof and Trulio 2015)
- Introduced species (i.e. T. s. elegans) are cause of decline for native species through competition or acting synergistically with ecosystem modification and human activities (Lambert et al 2013)
- Predators such as the American Bullfrog are more prevalent on terrestrial habitats than aquatic ones, and prey more on young turtles, since larger turtles are often too big to

capture. Turtles over 90 mm carapace length are more likely to avoid capture in aquatic habitats (Vander Haegen et al 2009)

- It is known that grazing is detrimental to population growth, however there are limited studies on this cause isolated from others in relation to the western pond turtle (Vander Haegen et al 2009)
- There was a die-off in 1990 due to an upper respiratory disease, however there is no evidence for this contributing to population decline today (Vander Haegen et al 2009)

Other Abiotic Threats

- Pesticides have enzyme and hormone disrupting capabilities; they can disrupt the endocrine systems of animals (Khan and Law 2005)
- Some chemicals bioaccumulate in the fatty tissue of organisms and can interfere in organisms' hormone or chemical messengers (Khan and Law 2005)
- There is limited knowledge on the effects of herbicides on the western pond turtle, but another freshwater turtle, the common snapping turtle, has the highest rates of abnormal development such as unhatched eggs and deformed organisms, at sites with the most contamination (Khan and Law 2005)

Management

- Management practices can be based off of current habitat gain; construction of artificial ponds for watering livestock and other purposes have increased sites suitable for the species; future management sites can be based off of these sites, or make use of sites already under these conditions (Germano and Riedle 2015)
- In 2015, there was a petition to the USFWS to list the species, however since it is still not listed, management is less likely to occur in a timely manner (Germano and Riedle 2015)
- It is listed as endangered in Washington, sensitive in Oregon, and of special concern in California (Lambert et al 2013)
- One management strategy to improve a limiting resource is to provide basking areas that are protected from human activities (Lambert et al 2013)
    - Provide basking sites in the center of the largest pools
    - Increase terrestrial/aquatic vegetated area round waterways
- More research is needed to determine whether impacts of drought are direct or indirect, so that actions can be taken to mitigate the effects of drought on the species (Leidy et al 2016)
- Limit the number or times of operation of motor vehicle traffic adjacent to habitat, as well as the vehicle traffic near habitat; avoid driving during peak basing times; conceal turtles form trail use with high vegetation (Nyhof and Trulio 2015)
- Examples of stable populations such as that in the San Joaquin Desert, where year-round water is present due to agriculture and there is no local poaching, can be models for future management projects (Germano 2016)
- Management projects focused on extirpating the turtles' predators should be focused in terrestrial systems where hatchlings are more at risk, since predators usually target the young, smaller individuals (Vander Haegen et al 2009)

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Part II: Goals, Management, and Monitoring Plan

Goals:

A. Increase western pond turtle populations in both aquatic and terrestrial ranges, such that population stability can be maintained in low-flow seasons in terrestrial habitat, and high-flow seasons in aquatic habitat (Pilliod and Stafford 2013).

B. Improve habitat needs
   a. Provide basking habitat. Enough basking space should support 3-5 individuals per hectare per day from February through August. Basking sites should have steep slopes in the middle region and along the water's edge, shallow water depths near the edge, few disturbances, and concrete substrates. Basking sites should be less shaded and far from paths (Lambert et al 2013).
   b. Provide vegetation and prey in aquatic and terrestrial habitats. Since western pond turtles prey on a diversity of plants and animals, restoration of specific species do not need to be conducted. Instead, the presence of aquatic plants, invertebrates, worms, frog and salamander egg larvae, crayfish, and carrion will come naturally with the maintenance of native terrestrial and aquatic vegetation (California Herps 2017). To do so, herbicides that affect aquatic ecosystems through runoff should be limited in waters as much as possible. In addition, 80% vegetation cover should be maintained to reduce erosion and maintain ecosystem services. While an exact percentage is not known, 80% allows for majority coverage to reduce the chance of erosion and allow accessibility to terrestrial animals.
   c. Provide pools that decline in the dry season, such that less than 5% of the reach has water cover by late summer, and the remnant pools do not exceed 9-168cm of depth. Declining should occur by August or early September (Leidy et al 2016).
   d. Reduce the presence of invasive species, including competitors such as *T.s. elegans* (Lambert et al 2013) and predators such as the American Bullfrog (Vander Haegen et al 2009). Eradication will include the manual capture 'electro-frogger' technique to locate and capture juvenile and adult bullfrogs at rates that exceed replacement. This involves electro-shocking the frogs, and euthanizing them using freezers (Vietch et al 2011).

C. Feasibility
   a. The goals listed for the improvement of habitat quality and increase in population is feasible for the City of Dixon stormwater detention basin site. While western pond turtles benefit from population sizes of approximately 13 individuals per ha of surface area as seen in the Arboretum at UC Davis, more extensive population density studies were not found (Lambert et al 2013). The removal of invasive species using electro-frogging is $400/night/2-person team, which may prove to be a limitation, however it is more manageable on a small site such as the site at hand, compared to a larger site that would take more time to complete the elimination of invasive species (Vietch et al 2011).

Restoration Plan:

A. Increase Population
    a. To accurately count current local western pond turtle populations, studies of population densities will be required. To account for annual variations, data collection will be taken for multiple years. Mark and recapture methods may be used to count population growth patterns over these years.

B. Improve Habitat Needs
    a. Basking habitat should be maintained through control of vegetation cover, maintenance of slope steepness, and prevention of disturbances. To maintain low vegetation cover, mowing can occur during the dry season from September through January when turtles are upland and will not be disturbed (Leidy et al 2016). To maintain slope steepness, erosion should be minimized. To do this, overgrazing will be avoided. By avoiding grazing year-round, this will be achieved. Disturbances such as fires and flooding will be avoided through active management the first 2-3 years after the initial restoration. While the direct impacts of fire on turtles are unknown, conditions that prevent fires include maintenance of some standing water in the pond year-round, and avoiding buildup of dead vegetation. Grazing will prevent vegetation buildup. Inflow from urban runoff will prevent drought conditions.
    b. Vegetation and prey in aquatic and terrestrial habitats will be maintained through maintaining ecosystem services. Aquatic vegetation has greater chances of survival with decreased nutrient input from agricultural and urban runoff. This can be prevented through education programs in the Dixon neighborhood that will be developed adjacent to the site. As soon as the neighborhood is built, flyers should be put in all mailboxes of residences that runoff into the basin with information concerning the dangers of non-point source pollution in riparian habitats. Due to the connection between the terrestrial and aquatic ecosystems, the maintenance of the terrestrial ecosystem is also critical. Vegetation communities within 180m buffer around the pond should consist of roughly 70% Blue Oak Woodland, 20% Chamise-Red Shank Chaparral, and up to 10% of Coastal Scrub and Juniper (Pilliod et al 2013). This will prevent erosion of terrestrial soil into the pond, as well as maintain the soil chemistry and other ecosystem services of the site.
    c. Pools must decline in August to early September, through January, to 9-168cm depth (Leidy et al 2016). To ensure this, inflow to the detention basin will be limited during these months. If a higher amount of precipitation occurs such that water levels exceed these levels during the dry season, outflow will be increased accordingly.
    d. Removal of invasive species is important for the maintenance of the western pond turtle populations and prevention of a species outcompeting or over predating it. While electro-frogging is the most efficient method, if invasive populations are still at the colonization stage of invasion, it would be more cost effective to remove species by hand (Vietch et al 2011). While it would take considerable organization to involve the public in invasive removal, this would be more

efficient to have more individuals in the field at once, and it would foster local support for the project through investment.

Monitoring Plan:

A. Current monitoring of western pond turtle populations coupled with historic data of population dynamics should be used. To assess the pre-restoration conditions for the turtle, pre-restoration counts will be made. A post-restoration count will also be made annually 2-3 years after the project is completed to ensure that the count stays at stable levels.
B. Assessment of aquatic and terrestrial habitats will be made concurrently. The percent cover and survivorship trends of vegetation will be assessed during the spring. Lower percent cover is needed for perching sites than other habitat sites. If the vegetation cover on basking sites is high enough that there is not an 80% increase in individuals basking from winter to summer, active grazing will take place. This is based on data from the UC Davis arboretum in which 87% increase occurred in a healthy ecosystem (Lambert et al 2013). Water levels will also be monitored at least twice a year (once during the wet season and once during the dry season) for the first 2-3 years after restoration, to ensure that turtles have reliable indicators to move inland during the dry season and toward the water in the wet season. Invasive species such as the American Bullfrog and *T.s. elegans* will also be monitored, and if the western pond turtle population declines by 10% in a year with the presence of an invasive species, the invasive populations will be checked, either through electro-frogging or manual efforts. A specific percentage population decline is not provided in the literature to indicate harm. However, the relatively small size of the site and corresponding small carrying capacity for western pond turtles on the site means that a loss of a small number of turtles leads to a larger impact of genetic diversity loss in the local population. Herbicides will not be used since they could harm the western pond turtle and other ecosystem dynamics.

Research Needed:

A. Habitat needs including basking sites, aquatic and terrestrial vegetation cover, pool seasonality, and removal of invasive species are all crucial concepts regarding the survival and success of western pond turtle populations. While general knowledge in riparian ecosystems is valuable for forming restoration plans, site-specific conditions such as abiotic and biotic conditions including water table, soil and water limiting nutrients, and species composition make site-specific monitoring critical to the local success of native species such as the western pond turtle. This data will help to construct a site carrying capacity for western pond turtles, so that management can be made more specific to the site needs.
B. Although this plan recommends electro-frogging and grazing to prevent overpopulation of invasive animals and plants, comparing different methods before utilization on site would be ideal. Different herbicides and trapping procedures can be studied to determine the most effective and efficient methods for this site.
C. If extreme weather events such as drought, fire, or flooding occur on the site, their effects on the western pond turtle can be measured. This will be valuable to other similar riparian sites, and directly applicable to future management on this site.

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Tricolored Blackbird (*Agelaius tricolor*)

Daniel Ellison

Part I, Species Background and Justification

The Tricolored Blackbird (*Agelaius tricolor*) is a colonial nesting songbird that is nearly endemic to California (Breedy 2008). tricolors historically produced some of the largest breeding colonies of North American passerines. Since the 1930s, populations have shown significant declines including 44% in the last six years. The population in 2004 was estimated at 145,000 individuals, which is significantly smaller than single historical colonies (Meese 2014). As a result, Tricolored Blackbirds have been classified as endangered since 2006 by the IUCN red list (BirdLife International). This decline is primarily accredited to the loss of wetland breeding habitats in the California central valley. (Weintraub & George 2012). The Tricolored Blackbird Working Group has set a long-term population target of 750,000 birds. (Keiller and Rodd 2011). The conservation of Tricolored Blackbirds will rely on our ability to conserve and restore their breeding substrate and foraging habitats (Hamilton and Meese 2006).

Species Range

- The majority of Tricolored Blackbirds, >99% in 2000, occur in California. In most years, 90% of the species' breeding adults are found in the central valley. There are also small nesting colonies in Oregon, Washington, Nevada, and coastal Baja California (Breedy 2008).
- A 2011 census found that 89% of Tricolored Blackbirds breed in the San Joaquin Valley and Tulare Basin (Keiller and Rodd 2011).
- Although a permanent resident of California, Tricolored Blackbirds make extensive movements in the breeding season and winter (Breedy 2008).
- During the winter they are common and around the Sacramento–San Joaquin River Delta and coastal areas. Few birds occur north of Sacramento county or in the southern San Joaquin valley in winter (Hamilton 1998).

Habitat Needs

- Tricolored Blackbirds need suitable nesting areas, such as flooded marsh vegetation or thorny vines (Churchwell 2002).
- Tricolored Blackbirds historically nested in Tule and cattails, but they now also nest in Himalayan blackberry, tamarisk, nettles, and giant cane (Campbell 1998).
- Nesting habitat must be large enough to support a minimum of 50 breeding pairs. This can be a small area because upwards of 20,000 have been found in a 10 acre area (Granholm 2008).
- However, areas smaller than 100 ha including foraging habitat are responsible for only a minor share of tricolor nesting effort (Hamilton 2004).
- Foraging sites need to be within 3 miles of nesting site (Campbell 1998).

- Open water must be within 500 meters in order for a breeding colony to be established (Hamilton 2004).
- Sunflower, alfalfa, dairies and rice fields can serve as an insect source, though natural shrub lands are preferred (Meadows 2008, Churchwell 2002).
- Foraging tricolors are attracted to ephemeral pools (Hamilton 2004).
- There is a current shift toward nesting on grain silage fields at dairies, in 2008 50% of breeding Tricolored Blackbirds nested on silage fields (Keiller and Rodd 2011).
- In 2011 88% of tricolors were surveyed in nonnative plants and crops (Keiller and Rodd 2011), and in 2014 79% were surveyed in triticale fields and Himalayan blackberry (Meese 2014).

Diet

- Fall and winter diets are primarily composed of seeds and cultivated grains, such as rice and oats (Breedy 2008).
- During the breeding season tricolors primarily forage on insects and up to 91% of fledglings diets are composed of insects (Granholm 2008).
- Tricolors exploit outbreaks of ephemeral insects, and are known to move to track insect abundance (Breedy 2008).

Predators

- Predators include Black- crowned Night Herons, Ravens, Coyotes, and Raccoons (Churchwell 2002).
- Swanson's hawks can also be responsible for massive nest destruction (Granholm 2008).
- Night Herons have destroyed entire colonies of > 15,000 nests, and in upland habitats such as dairies, Coyotes cause huge losses (Hamilton 2004).

Reproduction

- Tricolored Blackbirds are colonial nesters (Campbell 1998).
- Nesting effort takes 41-45 days. The first Colonies are established in late march, although the majority begin in mid april (Campbell 1998).
- There is low breeding site fidelity between years, but we do not know how tricolors choose breeding sites (Meadows 2008).
- Typical breeding densities are one nest per every 1-6 square meters, although density's can be much higher in Himalayan blackberry (Hamilton 2004).
- Tricolored Blackbirds are itinerant breeders, meaning they can breed twice a year in different locations. Many birds will nest in the San Joaquin valley or Sacramento county and then nest in the Sacramento valley or further north following nest failure or the successful completion of their first nesting attempt (Hamilton 1998).
- The majority of nesting occurs between mid-march and late July. However, second nesting attempts can run as late as November in the Sacramento valley (Granholm 2008).
- Cook and Toft (2005) found that tricolors nesting in Himalayan blackberry had significantly higher reproductive success than colonies located in tules and cattails.

- Colonies located on tamarisk can have similar reproductive rates to those on cattails; however, those on silage fields have smaller average clutch sizes than those on other vegetation types (Weintraub & George 2012).
- There is a positive correlation between the depth of water underneath nesting sites and nest survival (Weintraub & George 2012).

Decline

- Tricolors have experienced huge population declines since at least the 1930's. The global population is now smaller than single historical colonies (Cook and Toft 2005).
- The primary reason for the decline is the loss of habitat including the reduction of wetlands to water diversion and the widespread central valley conversion to agriculture (Weintraub & George 2012).
- Thousands of nests have been destroyed by silage harvesting when colonies establish in silage fields located on dairies (Hamilton 1998).
- An unknown number of tricolors are shot each year to protect ripening rice because of their similarity to unprotected Red-winged Blackbirds (Meese 2014).
- The expansion of native predators such as Black-crowned Night Herons, Coyotes, and Ravens, due in part to human management activities, are far more destructive than any invasive plants or animals (Hamilton 2004).
- The Tricolored Blackbird has been listed as endangered by the IUCN Red List since 2006 (BirdLife International).
- In 2004, the most recent population estimate, tricolor populations were estimated at 145,000 (Meese 2014).

Restoration

- Human entrance into colonies can cause abandonment during settlement and egg laying and should be avoided. However, colonies in urban parks show negligible losses due to disturbance and respond well to roadside traffic (Hamilton 2004).
- When temperatures are high, flyovers by crop dusters can cause hatching failure by flushing incubating females (Hamilton 2004).
- Tricolors may be unaffected by pesticide caused poisoning (Hamilton 2004). However, insecticide application in nearby foraging habitat can reduce food for tricolors (Meese 2014).
- Dairies are now payed to delay harvest where colonies are established, preventing losses of entire colony cohorts. However, this is not a long term solution (Keiller and Rodd 2011).
- Black-crowned Night Heron management may be necessary for establishment of colonies in cattail marshes (Hamilton 2004).
- If water levels are allowed to fall underneath nests, mammalian predation will increase, while raising water levels can flood nests. In wetlands where water levels are directly manipulated, it is recommended to maintain consistent water levels throughout the tricolor nesting season (Hamilton 2004).
- Flooding during the breeding season can help to increase insect abundance, and grazing of foraging habitat can promote ideal foraging habitat, <15 cm tall vegetation (Breedy 2008).

- Additional knowledge about site selection in tricolors is needed for proper management and restoration (Meadows 2008).

Part II: Goals, Management, and Monitoring Plan

A. Goals

a. Promote the establishment of Tricolored Blackbird breeding colonies in central valley wetlands where they have historically occurred but no longer are present. Because of the decline in this species, it may be necessary to encourage breeding colonies in novel wetlands. This will require surveying of individual sites and consulting with the annual Audubon Society Tricolored Blackbird survey results as well as historical records to determine the current and historical presence or absence of colonies (Meese 2014, Keiller and Rodd 2011). Where, or when, breeding colonies are established the goal should be to increase the population of nesting tricolors and maintain or increase the breeding success. This will require a yearly census of Tricolored Blackbird populations and fledging rates. The population can be estimated through a partnership with the Audubon Society's annual survey. Although the population goal at each site will depend on size and habitat quality, nesting densities of one female per square meter is desirable but densities as low as one female per six square meters is acceptable (Hamilton 2004). More invasive and time-consuming measurements will be necessary to determine the fledging rate. What a "good" fledging rate is not well studied. However, many populations experience nearly complete nest loss due to predation or poor foraging habitats, this will be easy to determine (Hamilton 04).
b. Improve habitat needs
    I. Provide flooded cattail or bulrush habitat for breeding colony establishment with pooled water deep enough to discourage entrance by terrestrial predators beneath vegetation from early April until late June. In sites that do not flood yearly during these months, Himalayan or California Blackberry can provide nesting habitat (Campbell 1998). At these sites, the goal would be to provide sufficient blackberry cover. Breeding vegetation cover could potentially be as small as 50 square meters; a true minimum has not been assigned. This value is ascertained from the minimum colony size, 50 females, and the highest density of females in emergent vegetation 1 female per square meter (Granholm 2008, Hamilton 2004). However to justify the restoration of a site for Tricolored Blackbirds, and to increase the likelihood of colony establishment, many times the theoretical minimum of breeding habitat should be present for large colonies.
    II. Provide high quality foraging habitat within three miles of breeding site (Campbell 1998). Provide optimal foraging habitat, upland vegetation that is less than 15 cm high when possible (Breedy 2008). If this is not possible around a breeding site, agricultural fields of Sunflower, alfalfa, and rice are acceptable foraging habitat (Meadows 2008, Churchwell 2002). The size of the foraging habitat will depend on the size of the colony. Foraging habitat cannot have

insecticide applications if they are to support Tricolored Blackbirds. Limited grazing can help to support ideal foraging habitat (Breedy 2008).

c. Feasibility

B. These goals are feasible overall, especially because colonies can persist highly modified habitats such as Himalayan blackberry thickets surrounded by agricultural fields. However, it is unknown how Tricolored Blackbird choose breeding habitat (Meadows 2008). With 79% breeding on Triticale and Himalayan blackberry it is possible that a well-restored wetland site will still not attract a breeding colony (Meese 2014). However, there has been success of restoring wetlands for tricolor breeding colonies such as that at Conway ranch (DeHaven 2000). It may be difficult to achieve high reproductive success or to increase a population overtime because of the global population's current rapid decline. Restoration Plan

a. Promote establishment and increase size of breeding colonies.
    i. Efforts should be focused on sites greater than 100 ha including foraging habitat, as smaller sites represent only a small fraction of Tricolored Blackbird nesting output (Hamilton 2004). However smaller sites still have value due to the declined population trends of this species.
    ii. If there is a Black-crown Night-Heron colony at the site, its population may have to be managed to avoid high predation levels (Hamilton 2004). Other predators can also cause huge losses such as coyotes, raven, Swanson's hawks and other raptors (Churchwell 2002, Granholm 2008). Again, predator populations may need to be reduced or excluded to allow successful nesting of tricolors.

b. Improve habitat needs
    i. Establish high density emergent vegetation such as cattails and bulrushes. The area of emergent vegetation will depend on the size of the site. However, total area must be at greater than 50 m^2. However, there is a positive relationship between colony size and predation (Weintraub & George 2012). Because of this, smaller populations may be ideal, but optimal population and habitat size is still unknown.
    ii. Maintain pooled water below vegetation throughout the nesting season of early April to late July. In Sacramento valley or other northern sites, breeding season may run longer, sometimes as late as November. If water levels are managed, they should be kept near constant from the first nesting attempts until nesting has finished at the site. Water levels must not be allowed to raise enough to flood nests or diminish entirely as that can cause complete colony loss by giving access to terrestrial predators (Breedy & Hamilton 1997). Height of nesting is determined by the level of water when tricolors arrive so there is no universal water level.
    iii. Ensure adequate foraging habitat is within 3 miles maximum from the breeding habitat. Closer foraging habitat will better attract breeding colonies (Campbell 1998). Shrubs and grasses can be grazed, mowed, or burned to encourage the ideal foraging habitat of <15 cm vegetation (Breedy 2008). However, burning

should not be done during or shortly before the nesting season, typically April through July, as it may decrease insect abundance.

iv. Alternatively, cultivated Sunflower, alfalfa, dairies and rice fields can serve as an insect source (Meadows 2008, Churchwell 2002). Any foraging habitat should not have insecticide application particularly during the nesting season (Meese 2014).

v. If a Blackberry nesting colony is the goal, promote growth of blackberry. In Himalayan blackberry, nest density is far greater than that in emergent vegetation, 6 females per square meter, so smaller areas can support a breeding colony (Hamilton 2004). Research is needed to determine how nesting success differs between Himalayan and California blackberry. Himalayan blackberry houses a large percentage of nesting pairs and provides higher fledging success than emergent vegetation (Cook and Toft 2005). Although some tricolors nest in California blackberry less is known about its quality as a nesting habitat

vi. Ensure there is an open water supply within 500 m of breeding habitat. (Hamilton 2004).

vii. Entrance into the breeding habitat should be avoided throughout the breeding season if possible (Hamilton 2004).

viii. Flyovers by low flying aircraft such as crop-dusters should be avoided during the breeding season. Especially when temperatures are hot, as flushing of females can cause hatching failure (Hamilton 2004).

C. Monitoring Plan

a. Tricolor populations should be monitored for the foreseeable future or until the global population can make a recovery. This has been defined as 750,000 bird by the Tricolored Blackbird Working Group. If tricolors are not already breeding at the site, their presence/abundance should be assessed in late April following the protocol of the Audubon Society's Tricolored Blackbird survey (Keiller and Rodd 2011). Once a breeding population is established, or before, a partnership with Audubon should be made so that the site is included as one of their survey sites. This survey only occurs every three years so additional surveying will be needed on off years. For sites located in the Sacramento Valley, it may be necessary to performs multiple assessments as the breeding season may begin significantly later (Granholm 2008).

b. After five years if a colony has not been established nesting or foraging habitat may need to be increased or improved.

c. A rough assessment of predation rates should be determined to decide if predator management is necessary. Ideally, this would be accomplished by visual surveys or other non-invasive methods. If entrance into the colony is required, it should be done late in the nestling period to avoid nest abandonment (Hamilton 2004). Again, the timing the nesting season will depend on the site and the year. It is not clear what constitutes excessive predation, but if over 75% of nests are destroyed predator management will likely be necessary.

d. If surveys reveal low fledging rate without high predation, there is likely a limited insect food source (Keiller and Rodd 2011). If this is the case, actions should be taken to improve foraging habitat. This may involve grazing or mowing to promote ideal foraging habitat or limiting insecticide application on nearby farmland.
e. If after 5 years minimum nesting habitat size does not exceed 50 m^2 there has not been a breeding colony at a site, emergent vegetation or blackberry will need to be planted to increase nesting habitat to that threshold. If a site has blackberry nesting habitat the minimum size is more of an unknown.

D. Uncertainty

a. There are clear gaps in our knowledge of Tricolored Blackbird habitat needs. We still need to study what the minimum breeding habitat size is to support a colony and how that varies between vegetation types. We also do not know how California blackberry compares to Himalayan blackberry for habitat choice and nest survival. Most importantly, it is still unclear what que tricolors use to assess habitat quality, and how we could encourage them to nest in particular places. Some rough estimates for reproduction give .25 fledglings per nest (Keiller and Rodd 2011). This is undoubtable contributing to the decline in the species, but it is not known what healthy fledging rates should be.

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Geese in Small Wetlands

Elisa Fernandes-McDade

Background

The Central Valley has lost over 95% of its wetlands to agriculture and urban development, and yet, over 5 million geese migrating along the Pacific Flyway use the remaining 5% each year (Frayer et al., 1989; Central Valley Joint Venture, 2006). Millions more remain year-round to breed in the wetlands. The Central Valley is a refuge for the commonest species as well as the threatened species like the Cackling Goose (*Branta hutchinsii*). Geese in the Central Valley also serve as an important centerpiece of cultural events, including the Snow Goose Festival and youth hunter education classes. Federal duck stamps sold for waterfowl hunting generated around $1.1 million nationally in 2015 for the woefully underfunded refuge system (Bird Conservation Committee, 2015). It is critical to promote geese populations in small, local wetlands in order to promote ecosystem health and support the traditions of Central Valley communities.

Ecological Literature Review

Central Valley wetlands are highly disturbed systems maintained by dam-controlled flows, levees, and bypasses. The total wetland area fluctuates annually depending on the amount of rainfall and agricultural fields that are flooded in a given year, meaning that the ecological challenges geese face will vary in response to these factors. Geese may face increased competition and disease in years where wetland habitat is limited, and they may stress those ecosystems they are concentrated in by overgrazing (Gilmer, 1982).

Geese typically begin arriving from the north in August and leave in March. Wetlands are artificially flooded from September to October to accommodate waterfowl, and then the wetlands are drained between March and April to stimulate the germination of obligate moist-soil native plants. In general, migrating geese prefer deep, open ponds between 18.8-24.3 cm. with sparse short emergent vegetation (Isola et al., 2000; Harris, 2001). However, resident or breeding geese shift to a preference for shallow water under 25 cm. during spring for rearing young.

Species-Specific Literature Review

The primary goose species in the Central Valley are Canada Goose (*Branta canadensis*), Aleutian Canada Goose (*Branta canadensis leucopareia*), Cackling Goose (*Branta hutchinsii*), Pacific White-fronted Goose (*Anser albifrons frontalis*), Tule White-fronted Goose (*Anser albifrons gambelli*), Lesser Snow Goose (*Chen caerulescens*), and Ross's Goose (*Chen rossii*) (Gilmer et al., 1982). The Cackling Goose, Aluetian Canada Goose, and Tule White-fronted

Goose are of special concern because of their low numbers. A number of conservation and hunting organizations—including Ducks Unlimited, California Department of Fish and Wildlife, Pacific Flyway Council—provide species-specific publications.

The Pacific Flyway Committee (2016) recommends creating microhabitats within wetlands to include both open water and short grass fields to increase species diversity and draw birds away from economically-valuable crops. Snow Geese are considered pests by many farmers because of high depredation on agricultural fields and the management priority is now population control. Ross's Geese appear very similar to Snow Geese, but they are rarer, often outcompeted where they cooccur with Snow Geese and especially hard hit by avian cholera (Subcommittee on White Geese, 1992). Cackling Geese populations are also dominated by their more common relative, Canada Geese, on wintering grounds. Wetlands near urban and suburban areas present riskier habitat for Cackling Geese because resident Canada Geese closely associated with these human environments compete aggressively with migratory geese for food and habitat (Guerena et al., 2016).

Goals

1. Diversify habitat within the reserve (short term, large scale)
    a. Create and manage microhabitats in the reserve to foster species diversity throughout the year. Habitat needs will vary within each species and season, so developing a strategy for the separate microhabitats is critical. The following habitats should be included: 1) upland/grazing habitats, 2) shallow, vegetated ponds less than 25 cm. deep, 3) deep, open ponds greater than 25 cm. deep.
    b. Seed upland habitat and increase percent cover of the following species: swamp timothy (*Heleochloa schoenoides*), ryegrass (*Lolium multiflorum*), smartweed (*Polygonum lapathifolium*), maize (*Zea mays*), and winter wheat (*Triticum aestivum*). Although they are not all native to California, these pasture species are nutrient dense, high in iron and protein content which is essential for highly-mobile migrating flocks (Bogiatto et al., 2009; Smith et al., 1995). Providing food on the reserve will also direct geese away from agricultural fields where wintertime goose depredation causes economic damage to valuable crops (Subcommittee on White Geese Pacific Flyway Study Committee, 2013).
2. Increase species diversity (long term)
    a. Record the following 7 goose species and subspecies in the reserve: Canada Goose (*Branta canadensis*), Lesser Snow Goose (*Chen caerulescens*), Pacific White-fronted Goose (*Anser albifrons frontalis*), Aleutian Canada Goose (*Branta canadensis leucopareia*), Cackling Goose (*Branta hutchinsii*), Tule White-fronted Goose (*Anser albifrons gambelli*), and Ross's Goose (*Chen rossii*) via direct counts, reporting neck collars, and banding if possible (Mini et al., 2011).

b. The commonest Central Valley species, Canada Goose, Lesser Snow Goose, and Pacific White-fronted Goose may already occur on the reserve, but threatened species such as Aleutian Canada Goose, Cackling Goose, Tule White-fronted Goose, and Ross's Goose are still primarily found in older, established wetland reserves (e.g. Sacramento National Wildlife Refuge complex) despite efforts to attract greater numbers of them to small wetlands scattered around the Central Valley. Maintaining microhabitats will encourage many species to use the reserve and conducting point counts year round will allow reserve managers to evaluate diversity.

3. Support and monitor Cackling Goose populations (long-term)
    a. Cackling Geese should receive special consideration because of their threatened status and because they have been a target species of a number of management plans, including the *Pacific Flyway Council Management Plan for the Cackling Canada Goose* and the *Arctic Goose Joint Venture Strategic Plan*.
    b. Attract Cackling Geese away from agricultural fields with pasture habitat to reduce local crop depredation.
    c. Conduct direct counts every year and record individual Cackling Geese using the reserve during every 3-year interval (2017-2020, 2021-2023, etc.) after initial restoration. The Pacific Flyway Council reviews population data every 3 years to check that the population is increasing inform management plans, and help set bag limits (Cackling Canada Goose Subcommittee, 2016).
    d. Band a Cackling Goose within every 3-year interval after initial restoration.

Restoration Plan

1. Improve upland habitat
    a. Uplands are defined as the zone 0.5-0.8 meters above mean higher high water (MHHW) level (Fulfrost et al., 2015).
    b. Grassy uplands provide foraging habitat to migrating geese in addition to acting as a buffer that prevents municipal runoff from bringing in contaminants—i.e. excess nitrogen from fertilizer, cement mixer washings, vehicular oil, pesticides, and heavy metals—and invasive plants (Zedler and Leach, 1998). In the absence of management, invasive plants in the uplands will spread to lower elevations in the marsh, causing competition with native plants in other zones (Wasson and Woolfolk, 2011). Therefore, it is important that the upland habitat receives equal management attention to that of the wetland portion of the reserve.
    c. Seed uplands with nutrient-dense species such as swamp timothy, ryegrass, smartweed, watergrass, maize, and winter wheat. Use local ecotypes when possible to capitalize on their physiological adaptations to conditions at the site.
    d. Soil disturbance and flooding are key components of these plants' life cycles. In the first year after the site has been burned, the site should be disced before

August to sufficiently disturb the soil, then the site should be irrigated sometime after August 1st and before October 15th to stimulate growth and increases the probability of long-term establishment (Zedler and Leach, 1998). The site should be disced between July and August of the following year in areas where vegetation is forming dense thickets in order to maintain a pasture-like or grassland habitat preferred by geese.

e. Invasive plants should be managed in uplands and wetlands through mowing, discing, and prescribed burns. Uplands should be mowed and burned between July 15th and August 30th to avoid disturbing ground-nesting species. Then, the site must be exposed to the sun for 2-3 months without further disturbance to desiccate the remaining subterranean plant growth (Smith et al., 1995). After this drying period, disc uplands with a finish disc.
f. In drier years, the uplands should be irrigated to promote plant survival.

2. Increase habitat diversity within ponds
    a. Establish a seasonal flood regime to coincide with waterfowl migration. Ponds should be flooded to a depth of 12-30 cm. beginning in October, 18-30 cm. between November and December to coincide with peak goose abundance (Bogiatto et al., 2009; Isola et al., 2000; Harris, 2001; Smith et al., 1995). In the first year, ponds should be drained between March and April over a 2-3 week period to stimulate the germination of obligate moist-soil native plants and provide shallow water habitat (<18 cm) for resident/breeding waterfowl (Zedler and Leach, 1998). Slower drawdowns encourage germination of a wide variety of plant species and it concentrates invertebrates in small, shallow pools that are ideal for duck foraging.
    b. In semi-permanent wetlands where drawdown is not part of traditional management practices, then ponds should be drained only once every 5-7 years between March and April to prevent overgrowth of emergent vegetation and return suspended/dissolved nutrients to the soil (Zedler and Leach, 1998). One drawback of not draining annually is that moist-soil plants like Swamp Timothy may not become established in the short-term, but abstaining from draining saves labor costs and increases invertebrate populations.
    c. Emergent vegetation must be controlled year round in a semi-permanent wetland to prevent the pond from being overgrown. In the deepest parts of the wetland, there should be <1% emergent vegetation. In parts of medium depth (18-20 cm), emergent vegetation must cover <60% of the surface area. Vegetation can be controlled via burning and discing with the stubble disc (this equipment effectively removes emergent vegetation) between July and August.
    d. The habitat needs of all waterfowl need to be balanced and, unfortunately, the needs of ducks and Tule Greater White-fronted Geese conflict with those of all other California goose species: ducks and Tule Geese prefer highly vegetated

ponds whereas the majority of goose species prefer open water. Increasing and decreasing pond cover represents a trade-off between these two groups of birds because even in a scenario where pond habitat is split evenly between the two (i.e. 50% cover), habitat will still be limited for both groups. Although the aim of this management plan is to promote geese, it is necessary to recognize that wetland habitat is at a premium in the entire Central Valley, therefore maintaining 50% cover will accommodate the most waterfowl species while still attracting geese. Ducks and Tule Geese prefer habitats dominated by tule (*Schoenoplectus acutus*), watergrass (*Echinochloa crusgalli*), alkali bulrush (*Scirpus robustus*), and cattails (*Typha spp.*) (Shuford and Gardali, 2008). Pickleweed (*Salicornia spp.*) and cordgrass (*Spartina spp.*) are less preferred but are still common components of waterfowl habitat in the Central Valley.

Monitoring Plan

1. Habitat Management
    a. Invasive plants must be managed in order to enhance available goose habitat and provide adequate food over winter. Invasive plants must continue to be managed in uplands and wetlands through mowing, discing, and prescribed burns.
    b. Research Question: Are native plants and target species establishing in the uplands? Uplands and wetlands should be surveyed once before flooding and after drawdown to determine any changes in percent cover of target species over the course of a year.
2. Population Management
    a. Point counts and neck collar resighting serve as the primary method of waterfowl management. Baseline counts should be conducted before restoration takes place to find out which species—native, special status, and exotic—currently occur on the reserve. Post-restoration counts should be conducted once every 3 weeks (maximum once per day between 5:00 a.m. and 11:00 a.m.) during the peak breeding season (May 1st-June 30th) and fall migration (November 1st-February 28th). If this amount of monitoring is not feasible, one biweekly counting period during the aforementioned dates will suffice. Counters should record each species seen, the number of individuals of each species, age and sex (when possible), neck collar number (if applicable), and characteristics of the habitat* each species is using (Hickey et al., 2008).
        i. *percentage of open water, percentage of emergent vegetation cover, average vegetation height, and water depth (Isola et al., 2000).
    b. Make note of diseased birds when they are spotted and which part of the reserve they are using. Avian cholera is of special concern in California because outbreaks are most common during fall migration and they are capable of killing

up to 1,000 birds in a single day (USGS, 1999). Signs of cholera include throwing the head back while swimming, circular swimming, erratic flight patterns, lethargic behavior, convulsions, discharge around the mouth, and bloody stool. Remove diseased bird carcasses and dispose of them immediately to avoid further soil, water, and direct contact contamination. Should a cholera outbreak become sufficiently severe, managers can consider draining the wetlands early. Research will need to be conducted to determine whether the rate of infection in the reserve increases as flock numbers increase.

c. Banding waterfowl is a monitoring strategy employed statewide to track long-term population trends. This method allows wildlife managers to record data on individual birds in addition to contributing to large-scale monitoring projects that inform management plans for threatened species like Cackling Geese. Banders must obtain a banding permit from the California Department of Fish and Wildlife to band birds during fall migration (November 1st-February 28th). Floating mesh wire traps are ideal for catching geese because finer wire can result in entanglement or injury. Traps should be set in the deepest (>24 cm.) section of the pond, pre-baited with shelled yellow corn for 3 weeks prior to banding activities, and posted with a sign stating the trap's purpose to avoid conflict with the public (North and Hicks, 2017). Data should be recorded according to North American Banding Council guidelines.
d. Research Question: What waterfowl species are wintering and breeding in the reserve pre- and post-restoration?
e. Research Question: Are Cackling Geese using the reserve post-restoration?

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Ducks in Small Wetlands (in general)

Kloey Helms

Part I: Background and Justification

Yarris et al. (2016) cites the Central Valley as supporting up to 6 million waterfowl every year, making it one of the most important habitats for dabbling duck populations. Dabbling ducks are a group of duck species found in the central valley (as well as other locations) composed of mallard, northern pintail, gadwall, green-winged teal, wood duck, blue-winged teal, and American wigeon (Ducks Unlimited, 2016). Dabbling ducks provide rice farmers with the ecosystem service of breaking down straw, and ducks in general are good indicator species for habitat health as well as a food source for many people (Blanco et al., 1996; Ducks Unlimited, 2016). During the 19th century, waterfowl populations were estimated to be about 30 million birds (Ducks Unlimited, 2016). Nevertheless, habitat loss caused that number to drastically decline and about 25 years ago, North American waterfowl populations reached a historic low (U.S. Fish and Wildlife Service, 2016). Since then management plans, such as the North American Waterfowl Management Plan, and other policies have been put in place to help restore these populations (U.S Fish and Wildlife Service). Organizations, such as Ducks Unlimited, are also working to improve duck population sizes. Currently, it appears that no dabbling duck species are listed on the endangered species list (Cornell University, 2015). However, new challenges, such as human population growth altering waterfowl habitat and increasing water quality and quantity issues, are causing concern for future populations (Ducks Unlimited, 2016).

Species Information:

Habitat Requirements

- Most species require seasonal wetlands (flooded in the fall), rice fields (flooded in the winter), and harvested cornfields (Ducks Unlimited, 2016).
- Many species can occur in permanent wetlands (marshes, bogs, etc.) or ephemeral wetlands (Cornell University, 2015).
- Most dabbling ducks seem to need grassy areas for breeding. Most females require vegetation in order to cover/hide their nests. Gadwalls specifically require grasses be at least a foot tall (Cornell University, 2015).
- Gadwalls require uplands with lots of vegetation (Cornell University, 2015).
- Wood ducks especially need wet areas with trees (for nesting) (Cornell University, 2015).
- Most of the waterfowl habitat today is on public land or owned by private duck hunting clubs (Gilmer et al., 1982).

- Drought and human demand for water has made obtaining the amount of water necessary for these habitats increasingly difficult (Yarris et al., 2016).

Range

- Depends on species but mallards (which are the most abundant duck in North America) occur year-round in a large portion of the United States. Some populations in Canada will migrate to the southern U.S. (including California) or Mexico during the winter (Cornell University, 2015).
- Most dabbling ducks seem to stay in California year round or spend their non-breeding time (winter) in California (Cornell University, 2015).

Diet

- Due to the drought and climate change, there is a large concern over food shortage (Ducks Unlimited, 2016).
- Need animal matter for protein during breeding season and will eat mainly seeds/vegetation during migration (Cornell University, 2015).
- Animal matter could include larvae, snails, worms, tadpoles, insects, beetles, caterpillars, etc. (Cornell University, 2015)
- Vegetation could include seeds, rice, water lilies, millet, grasses, seeds of pondweeds, corn, smartweed, duckweed, etc. (Cornell University, 2015).
- For wintering waterfowl that come to the central valley during the winter, it is important for them to have access to winter flooded-rice fields. Trying to manage wetlands to provide the same amount of food provided by the rice fields would cost around $2 billion (Ducks Unlimited, 2015).

Life Cycle

- Ground nesting birds (expect wood ducks) that require dry land close to water but will also likely nest in artificial nesting structures (Cornell University, 2015).
- Incubation period seems to range from about 20-40 days (Cornell University, 2015).
- First two weeks of life are vital since this is when the mother hen has to expend a lot of energy to protect the ducklings. Females experience greater death rates than males during this time and nutritional stress is also a concern so ducks need high protein diets (insects) (Ducks Unlimited, 2016).
- Time to maturity varies depending on the exact species of duck. For mallards, they reach maturity in 4-6 months (Cornell University, 2015
- After the post breeding period, ducks continue to require protein as they molt (Ducks Unlimited, 2016).
- Ducks migrate to southern areas (including California) in cooler months in search of food (Ducks Unlimited, 2016).
- Ducks will migrate again back to their breeding grounds where the female will choose the breeding area (either by site of her birth or where she hatched a nest previously) (Ducks Unlimited, 2016).

- Many dabbling duck species will arrive in the central valley sometime between late August and early September and depart in March(Ducks Unlimited, 2016).

Interactions with predators

- Dabbling ducks experience greater nesting success and hatching rates in a wetland environment when predation is reduced (Duebbert & Lokemoen, 1980).
- Major Predators include red foxes, skunks, raccoons, and badgers (Duebbert & Lokemoen, 1980).

Response to Human Disturbance

- Species differ in their response to human disturbance. In a study by Pease et al. (2005), the northern pintail was the species least affected by human activity.
- Generally, the dabbling ducks seemed to be less bothered by vehicular traffic than a person walking by/getting close to the ducks (Pease et al., 2005).

Management

- Some dabbling ducks, specifically mallards, require moist wetlands through the summer in order to breed (drought is making this difficult to manage) (Ducks Unlimited, 2016).
- Utilization of mechanical and natural barriers to decrease exposure to predators, as well as predator management, could increase duck production (Duebbert & Lokemoen, 1980).
- Human disturbance can cause waterfowl to expend energy (by fleeing) and thus preventing human disturbance (especially in times of nutritional stress) is important (could include rerouting/closure of walkways during breeding season) (Pease et al., 2005).
- Human activity is greatly changing the wintering areas used by migratory birds so management in these areas is especially important in order to preserve population sizes (Gilmer et al., 1982).

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<u>Part II: Goals, management and monitoring plans</u>

A. Goals

1. Maintain duck populations in small wetlands
    a. While ducks are at stable populations now, climate change and alteration of wetlands by humans are decreasing the amount of available habitat so this goal could prove to be more challenging in the long-term (Ducks Unlimited, 2016).
2. Enhance habitat required
    a. Provide at least 4 hectares of habitat (amount found for wood ducks/difficult to find exact size requirement for other species) to reduce the probability of ducks getting diseases such as avian influenza, avian cholera, and avian botulism (Ducks Unlimited, 2016 & Sousa & Farmer, 1983). If possible include an island to provide even better loafing habitat (Smith et al., 1994). Loafing is the act wandering or lounging around and for ducks that means it requires an open area to sun and groom themselves (Ducks Unlimited, 2016).
    b. Ensure water depth is between 6-10" to provide best feeding habitat and provide protection from predators to breeding ducks in the summer (Smith et al., 1994). The species that winter in the central valley (non-breeding) and wood ducks (year-round) require marsh- and pond-like conditions (Cornell University, 2015).
    c. Provide grassy areas for cover, especially during late spring and summer (trees for wood ducks/at least one foot tall for gadwalls) (Cornell University, 2015). But ensure cattails and tules do not cover more than 60% and provide barren loafing areas in the fall (Smith et al., 1994). Amount of area required will vary depending on density of ducks found at the site.
    d. Ensure adequate availability of "protein-rich invertebrates" for pre-breeding and breeding ducks, and provide wintering and year-round ducks with nutritious seeds (Smith et al., 1994). This could be quite a substantial amount since invertebrates a primary food source for ducks.
    e. Ensure protections from predators during late spring and summer in addition to providing ample vegetative cover. This could include directly managing predator populations through things like trapping. It could also include utilizing fencing or vegetative barriers, such as shrubs or trees. While trees are required wood duck habitat they also provide habitat for avian predators (Duebbert & Lokemoen, 1980 & Smith et al., 1994).
    f. Reduce human disturbance, especially direct human interaction with/close proximity to ducks during times of nutritional stress (when wintering from November-February), and consider restricting hunting if populations start struggling (Pease et al., 2005 & Fleskes et al., 2007).

B. Restoration Plan

1. Maintain duck populations
    a. Since mallards are the most abundant duck species in California, most of the knowledge on duck ecology in the central valley is based on them. However, more data collection is still needed to learn about how management affects mallards. More studies are also required to learn more about the population dynamics of the other duck species present in the central valley.
2. Enhance Habitat
    a. The habitat needs to be large enough to prevent the outbreak of fatal diseases and promote breeding. The nest densities observed at a wetland in the central valley averaged to 2.78 nests per hectare (Ringelman et al., 2016). If disease outbreaks increase and breeding decreases, replenishing habitats with water during a drought year could increase habitat area and allow duck populations to spread out. Although it is unlikely to be an option, adding additional, quality wetland habitat would alleviate the problems of disease and reduced breeding.
    b. If water supply permits, wetlands should be flooded by mid-October to provide sufficient habitat for wintering migratory and year-round ducks. During the winter months, the water needs to be shallow enough (under 12 inches) to promote feeding on seeds at the bottom of wetland ponds. Wetlands that stay flooded throughout most or all of summer with water depths between 6-12 inches provide good breeding habitat and access to invertebrate prey. Irrigation is also essential during spring and summer to ensure growth of the plants used for the wintering diet. (Smith et al., 1994)
    c. If wetland is not flooded year-round then at least one irrigation during spring and summer is preferred to ensure good seed production. Adequate vegetation cover (at least one foot for gadwalls) is necessary to protect ducks from predators. Although the wood ducks prefer young trees and shrubs for their cover, the trade off is that this could invite avian predators (Sousa & Farmer, 1983 & Smith et al., 1994). However, emergent wetland plants such as cattail and soft rush can satisfy wood duck cover requirements if trees and shrubs are not available (Sousa & Farmer, 1983). At the end of the summer months it may be necessary to disc, mow, and/or burn tules and/or cattails if they occupy more than 60% of a pond (Smith et al., 1994). The best method is to disc in July or August and then mow and burn about two months later. When discing it is important not to break through the clay pond bottom, as this would negatively affect the water holding capacity. (Smith et al., 1994)
    d. Establishing plants important to the diet of ducks (watergrass, smartweed, swamp timothy, sprangletop, ammannia, chufa, burhead, beggarticks, annual atriplex, goosefoot, and brass buttons) provides them with essential nutrients to get through winter (Smith et al., 1994). If there is not enough wetland habitat or water available then conservationists work with rice farmers to make rice plantations more duck friendly (Blankenbuehler, 2016). However this method is not preferred, as the rice crop does not have the same nutritional value as the seeds found in wetlands. A dry period of about 2

months is necessary to ensure ample amounts of invertebrates for breeding ducks. (Smith et al., 1994)

e. Management of predators, such as red foxes, skunks, raccoons, and badgers, could help increase nesting and hatching success. Management could include direct control of the animals but use of mechanical and natural barriers is recommended. (Duebbert & Lokemoen, 1980)

f. Keeping humans from walking or biking near birds from November to March when the birds need to conserve energy will require installation of fences, rerouting of walkways and/or promotion of viewing waterfowl from vehicles (which do not disturb them nearly as much) (Pease et al., 2005).

C. Monitoring Plan

1. Monitoring for population size will initially require comparisons to other central valley wetlands. It will be necessary to monitor during restoration to assess if the ducks are taking to the site. Since amount of quality wetland habitat is decreasing so much, it will be important to continue monitoring throughout the years to look for decreased breeding and disease outbreaks. Although funding is not typically abundant for monitoring, birders often keep great records of waterfowl species and could potentially contribute to recordkeeping.
   - **i. Monitor for:**
     1. Decreased breeding, disease, and population size: year round

2. Some of the most important habitat aspects to monitor are vegetation coverage and water depth. Vegetative coverage should be monitored for success of plants essential for the ducks' diet. Monitoring of vegetation, for things such as percent cover of cattail and success of watergrass, will need to continue seasonally since ducks require such different vegetation coverage each season. If we enter another drought year it will become increasingly important to monitor for water depth. Most duck species prefer the wetlands to have shallow water (at least 6 inches) for the most of the year. Fall would be the most important season to monitor because of the beginning arrivals of wintering migratory ducks. If there is not sufficient water to keep the wetland moist most of the year and the plant species begin to wilt, then project managers and conservationists may want to start looking into other options such as working with rice farmers.
   - **ii. Monitor for:**
     1. Vegetative coverage and type: seasonally
        a. Need plenty of seeds in fall/winter and coverage with loafing area in spring/summer
     2. Water
        a. Flooding (at least 6 inches): late fall and winter
        b. If necessary, irrigation: spring/summer to ensure plant growth

3. In order to improve this restoration plan more data is needed on the ecology of ducks in the central valley. Even though there is the most knowledge about mallards, there is still not much data on how habitat management can impact mallard nesting rates (Central Valley Joint Venture, 2007). There is even less data on exact habitat requirements of the other dabbling duck species and sustainable density of duck populations.

iii. **Monitor for:**
    1. Specific requirements such as sustainable habitat size and adequate amount of invertebrates and loafing area size

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Western Grebe (Aechmophorus occidentalis)

Roberto Maravilla Plancarte

Literature Review

A. Background and Justification for Restoration

The western grebe (*Aechmophorus occidentalis*), was once hunted for its beautiful white plumage; however, it's numbers been reduced drastically due to the combined effects of hunting, habitat loss, and pollution (Feerer and Garret 1977). Although the western grebe is listed as a species of least concern, this primary due to the large range they inhabit. Individual populations, once numbering in the thousands, have been reduced to less than a hundred in some locations (Burger 1997, Feerer and Garret 1977). The western grebe's numbers may be further confounded by their striking similarity to Clark's Grebe (*Aechmophorus clarkii*), once thought to be the same species, they share many of the same habitats and food sources (Storer and Nuechterlein 1992).

B. Species Information

Species Range

- Year-round range; along the coast of southern Alaska and British Columbia down to Baja California, Mexico; range extends inland to western Texas and south into central Mexico, range extends west into central California at some its narrower segments and to western Texas at its widest (Storer and Nuechterlein 1992)
- Breeding range: limited to freshwater lakes adequate for breeding; extends from the western edge of Wisconsin to central Oregon and Washington, down from west central Saskatchewan and central Alberta to Colorado (Storer and Nuechterlein 1992)
- Migratory routes: may overlap with breeding and year-round ranges; from the south-eastern edge of South Dakota to northern Texas, stretching from Kansas to eastern Colorado at its widest (Storer and Nuechterlein 1992)

Habitat Needs:

- Breeding range requires large areas of open water, such as freshwater lakes, with emergent vegetation (e.g., bulrushes) for building nests and cover from waves (Allen et al. 2008a)
- Most nests built at a minimum water depth of 25 cm (Storer and Nuechterlein 1992)
- Non-year-round migratory populations overwinter near the ocean in estuaries, salt/brackish bays, sheltered coasts, and rarely on freshwater lakes (Storer and Nuechterlein 1992)
- Roost on open water in groups or on nests (Clowater 1998)

Diet and Foraging:

- Piscivorous, foraging for fish in open fresh or salt water (Storer and Nuechterlein 1992)
- Opportunistically prey on crustaceans, polychaete worms, salamander, insects, and some bottom-dwelling fish (Storer and Nuechterlein 1992)
- Dense areas of cattails, or any vegetation where fish can hide, may prevent them from adequately foraging (Williams 1982)

<u>Predators:</u>

- Adults are preyed on by mink, river otters, and occasionally bald eagles in marine colonies (Storer and Nuechterlein 1992)
- Raccoons are known to take both adults and eggs from nests (Storer and Nuechterlein 1992)
- Other common predators: common ravens, American crows, and owls (Burger 1997)
- Chicks are often taken by Herring Gulls and California Gulls (Storer and Nuechterlein 1992)
- Colonies in British Columbia have been observed to be preyed on by orca whales (Storer and Nuechterlein 1992)

<u>Behavior and Lifespan:</u>

- Spend most of their time in the water and are generally awkward on land (Storer and Nuechterlein 1992)
- Flight is swift and direct, but seldom used outside of migration with flight muscles quickly atrophying after arrival at breeding grounds (Storer and Nuechterlein 1992)
- Most common causes of death include rough weather, exposure, and predation by gulls (Allen et al. 2008b, Storer and Nuechterlein 1992)

<u>Reproduction:</u>

- Nested constructed by both male and female out of material gathered from underwater, floating on the surface or emergent vegetation (Storer and Nuechterlein 1992)
- Most nests at least 2 meters apart from each other, and are placed on the leeward side of vegetation for protection from waves (Allen et al. 2008a, LaPorte et al. 2014)
- Nesting can occur form April until August, but has been observed to occur as late as December when water levels are highly variable (Parmelee 1997)
- Monogamous until chicks are several weeks, it is unknown whether parents reunite in later years (Storer and Neuchterlein 1992)
- Human proximately is known to scare off parents from their brood leaving them exposed to direct sunlight and predators (Feerer and Garret 1977, Storer and Neuchterlein 1992)
- Some populations can become accused to humans and allow them to come into close contact (Parmelee 1997)

Restoration:

- Some decline due to weakened egg shells and lack of prey can be attributed to agricultural practices such as pesticide use and the draining of lakes (Feerer and Garret 1977)
- Elevated levels of heavy metals have been observed in some populations no negative effects (Burger and Eichhorst 2007)
- Since these birds rarely fly breeding grounds must contain sufficient levels of fish to maintain the population (Storer and Neuchterlein 1992)
- Restoration must include water-interspersed clumps of emergent vegetation for nesting and as protection form wind (Storer and Neuchterlein 1992)

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Goals, Management, and Monitoring Plan

A. Goals

a. Reduce common anthropogenic sources of western grebe mortality such as fluctuations in water level due to reservoir manipulations, injuries from motorboats, litter, and the abandonment of young due to human disturbances (Storer and Neuchterlein 1992). Nearshore colonies have also suffered great losses due to oil spills (Hampton, et al. 2003; Smail, Ainley, and Strong 1972).

b. Improve the nesting success of western grebes in lakes with high amounts of human traffic through the use of informative signage and barriers where necessary (Ivey 2004).

c. Enhance and Maintain Habitat

i. Restore wetland habitat historically occupied by western grebes throughout California, particularly areas that they currently occupy in large numbers such as Eagle Lake, Clear Lake, Lake Almanor, and Thermalito Afterbay (Ivey 2004).

ii. Increase the availability of native emergent and submerged vegetation for nesting. Colonies are often established in hardstem bulrush (*Scirpus acutus) (Ivey 2004); however, they have also been observed in* alkali bulrush (*S. maritimus*), cattail (*Typha* spp.), giant burreed (*Sparganium eurycarpum*), Baltic rush (*Juncus balticus*), common reed (*Phragmites australis*), reed canarygrass (*Phalaris arundinacea*), saltgrass (*Distichlis spicata*) and water smartweed (*Polygonum amphibium*) (Storer and

Neuchterlein 1992; Burger 1997). Submerged vegetation used in nest building includes sago pondweed (*Potamogeton pectinatus*), curly pondweed *(P. crispus)*, long-leaf pondweed (*P. nodosus*), broad-leafed pondweed (*P. natans*), bladderwort (*Utricularia vulgaris*), water milfoil (*Myriophyllum* spp.), muskgrass (*Chara* spp.), and filamentous algae (Ivey 2004).

iii. Increase the availability of the small fishes, such as year-class-one yellow perch preyed on by western grebe (Forbes and Eichhorst 1990).

iv. Reduce use of pesticides in California lakes for example the bioaccumulation of DDD sprayed in Clear Lake, CA poisoned the local population of western grebes (Moats and Moats 1990).

d. Feasibility

i. Could prove to be very expense, but given that California is home to a significant portion of extant western grebe, it may very well be worth the cost (Ivey 2004).

B. Restoration Plan

a. Reduce Mortality

i. Educating the public with interpretative signs warning boaters about nesting and foraging western grebes in the area may increase grebe survival. Community outreach activities, such as campfire talks, may increase conservation ethic (Ivey 2004).

ii. Closing off areas that are important to grebe nesting, such as within 50m of bulrushes, will also provide grebes with further protection (Ivey 2004).

Natural wave and wind barriers that make it difficult to boat through the area may also have the same effect (Allen 2008a, Allen 2008b).

b. Improve Habitat

    i. Introduce native plant species used for nesting, the birds do not seem to care for which species they are using, whether it be tules or cattails, so long as it provides the same structural function in their nest building of covering the nest, providing cover from waves and wind (Ivey 2004, Allen 2008a).

    ii. Grebe feeding does not interfere with sport fishing; however, since they are primarily piscivourous, about 80% of diet, fist about 9cm long must be available at the site (CDFW 2005a). Western grebes are susceptible to the heavy metals, such as mercury, that may accumulate in fish.

C. Monitoring Plan

a. Monitor the establishment and persistence of grebe breeding colonies throughout their historic range. Monitor breeding colonies during breeding season, courtship from April to May and nesting from May to August (CDFW 2005a), for three years. This period should be long enough to ensure the population of grebes returns regularly.

b. Grebes are reluctant to leave a breeding site after they establish, they are more likely to not breed and wait for conditions to improve.

c. Grebe population falls below 50% of baseline, immediate action to determine the cause should be taken. California is a stronghold (e.g., Clear Lake, CA colony). Vegetative plant cover falls below 20% reseeding or some other form of repopulation should be undertaken. Propagules can be sourced from nearby populations of appropriate species.

d. Most difficult part will be securing habitat that can be restored lake or improving lake quality.

e. Confounding factors leading to decline of species. Pollution, disease, and accidental take.

f. Keep eye out for signs of avian botulism, such as paralysis, types E (found among fish eating birds) and C (found in wild birds and livestock) have been observed in Californian populations (Ivey 2004). This should be monitored for year round, but budget constraints may instead require that signs instructing individuals report all dead birds to the proper authorities be posted instead of monitoring.

D. Research Needs

a. Response to lack of standing water

b. Are western grebes philopatric or nomadic? We know that they migrate, but do they always travel to the same places.

c. Response to sustained interaction with human activities.

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<u>California Tiger Salamander (*Ambystoma californiense)*</u>

Vivian Connolly

Background

The IUCN Red List of Threatened Species has the California Tiger Salamander (*Ambystoma californiense*) listed as vulnerable because its numbers have decreased by more than thirty percent over three lifetimes. The IUCN also has *Ambystoma californiense* listed as a "synonym" for *Ambystoma tigrinum* and therefore I will assume this species is also vulnerable and that any information I find for one of these species will also count for the other. Currently, the IUCN reports that tiger salamanders are also extinct in 55-58% of their historic breeding sites and "gravely threatened" in the San Francisco Bay Area and San Joaquin Valley. Tiger salamanders provide several ecosystem services that make them essential to any wetland including control of mosquito populations, acting as a detritivore of a wetlands dead matter, and reducing sulfur concentrations in a wetland by up taking it during metamorphosis (Hocking and Babbitt 2014).

Literature Review

Species Requirements

Habitat

- Tiger salamanders require wetland habitats to reproduce and surrounding grasslands for them to burrow in over winter (Bolster 2010).
- They are found at elevations no higher than 457 m (Bolster 2010).

Food

- Young tiger salamander larvae eat zooplankton and older larvae eat aquatic invertebrates such as snails and tadpoles and adults eat terrestrial invertebrates (Bolster 2010).

Disturbance- Grazing

- Tiger salamanders benefit from grazing because the stock ponds for livestock to drink from can actually serve as a habitat for them (Bolster 2010).
- Grazing also controls burrowing squirrel and gopher populations and allows more burrowing space for tiger salamanders (Bolster 2010).

Moisture Tolerance

- The semi-permeable skin of the salamander means it has a higher moisture requirement than species without such skin (Bolster 2010).

Temperature Tolerance

- Salamanders require a temperature between 18 and 21°C (UC Davis Office of the Attending Veterinarian Standards of Care 2015).

pH Tolerance

- Salamanders require pH levels between 6.5 and 7.5 (UC Davis Office of the Attending Veterinarian Standards of Care 2015).

Spatial Scale

Dispersal distance

- Semlitsch et al. (2003) found that once a salamander species reproduces at what they call its "core wetland" it will disperse through an "aquatic buffer" zone and into its "core terrestrial habitat" which is on average 117-218 m from the core wetland.

Temporal Scale

Life Stages

- Tiger salamanders begin in the larval stage in aquatic environments then go through metamorphosis and move to terrestrial environments where they grow from juveniles into adults (Bolster 2010).
- Tiger salamanders take two to five years to reach sexual maturity (Bolster 2010).
- Breeding usually takes place in January and metamorphosis between May and July. December to February is when tiger salamanders are most vulnerable because they are above ground looking for a breeding site (Bolster 2010).
- Females do not live long enough to reproduce twice (Bolster 2010).
- Habitat fragmentation is dangerous for tiger salamander populations because it makes finding breeding sites more difficult (Bolster 2010).

Species Characteristics

Predators

- If a habitat has year-round standing water for two or more years, it becomes a habitat for tiger salamander predators including non-native fish, non-native salamanders, bullfrogs, and crayfish (Bolster 2010).
- Introducing mosquitofish to control mosquito populations is also dangerous for tadpoles and is unnecessary because tiger salamanders are themselves predators of mosquitoes (Bolster 2010).
- Tiger salamanders have even more predators closer to urban areas including birds and raccoons (Bolster 2010).

Competition

- A hybrid of tiger salamanders and barred salamanders (introduced as fishing bait) produce more fit offspring than just tiger salamanders. In dry habitats, the tiger salamander is then even more susceptible to desiccation because it is less fit (Bolster 2010).

Pathogens

- Pesticide use is known to decrease tiger salamander immune system efficiency and in turn makes them more susceptible to amphibian pathogens such as ranavirus and chytridiomycosis (Bolster 2010).

Species Response

Climate Change

- Tiger salamander populations naturally fluctuate a lot and therefore an extreme event like drought has the potential to wipe out an entire population (Bolster 2010).

- Another factor that affects a specific tiger salamander population is where it is located in relation to agricultural land. If it is located downwind, pesticide concentrations will be higher and reduce said salamander population (Davidson et al. 2002).

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Management Plan:

A. Goals

- Habitat loss is the number one contributor to salamander declines and therefore restoring habitat is the most effective management option (Bolster 2010).
- Salamander breeding takes place in January, which is only one month out of the year and therefore increasing their population will require human intervention (Bolster 2010).
- Salamanders are also endangered by predator species which need to be controlled to save salamanders.

- Salamanders are a carnivorous species and therefore human intervention is needed to provide sufficient prey (Bolster 2010).

B. Restoration plan

Habitat

- Salamanders spend their lives on land and in water. When they are on land, they are almost always burrowed underneath the ground (Bolster 2010).
- Salamanders need leaves, logs, and other debris to burrow under to avoid predators and prevent desiccation. Therefore, vegetation that sheds leaves and branches is favorable and fallen debris should never be cleared (Bolster 2010).
- Enriching soil in the habitat with compost has been proven to increase soil moisture which will aid in preventing desiccation and means salamanders will have a better chance of finding optimal burrows (Arias 2016).
- Allowing livestock to graze on salamander habitat would not be deleterious to them because stock ponds serve as additional habitat for salamanders. Livestock also forces out squirrels and gophers that take burrowing space from salamanders (Bolster 2010).

Spatial and Temporal Scales

- Control burn should not be used to restore other aspects at a site because it leads to habitat fragmentation that prevents salamanders from finding breeding or burrowing grounds (Rothermel 2006).

- Captive breeding and subsequent reintroduction can help increase populations and the numbers of juveniles able to produce two years later (salamanders are sexually mature at age two) (Bolster 2010).

Species Interactions

- Bullfrogs and crayfish are two major predators of salamanders. One way to control these species is by introducing largemouth bass, which feed on them preferentially. However, there is a lack of research on how using this one species to control these other species will affect a third species, salamanders (Garcia 2012). Another solution is draining the water body that the predators live in during the dry months when salamanders are in burrows (Doubledee 2003).
- Near urban areas, raccoons, opossums, etc. become predators as well so setting traps will control them (Bolster 2010).
- Mosquitofish should not be introduced to control auxiliary mosquito populations because they will also feed on salamanders (Bolster 2010).

Diet

- Introducing more of the salamander's prey will lead to increased populations. Their prey includes zooplankton, snails, and other invertebrates (Bolster 2010).

C. Monitoring plan

Habitat

- Although debris shouldn't be cleared, weeds should be cleared because they will take moisture from the soil that could've been used by salamanders or other plants (Arias 2016).

- All construction, mining, pesticide use, and other human activities that occur near the wetland need to be heavily monitored because runoff could change the pH, which is something that salamanders are very sensitive to (Arias 2016).

Spatial and Temporal Scales

- Monitoring how far a salamander moves away on land from its aquatic breeding site will determine how much land around a water body needs to be kept under conditions preferred by salamanders.

Species Interactions

- There is a lack of research on how hybrid species produced by California tiger salamanders and other salamanders will affect native California tiger salamander populations (Bolster 2010).

Diet

- Salamander and its prey's populations form a predator-prey relationship and therefore both need to be monitored to restore salamanders.

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Freshwater Aquatic Invertebrates

Misti Marsh

- Aquatic invertebrates can be used as a bioindicator of water quality and ecosystem health (Voshell, 2002)
- Aquatic invertebrates are at the base of the food web and important organisms in the ecosystem (Voshell, 2002)
- Family biotic index can be used to assess water quality to attain a water quality rating of very poor, poor, fairly-poor, fair, good, very good or excellent (Zimmerman)
- The EPT Index can be used to assess water quality. This method measures the total number of distinct taxa within the groups, Trichoptera, Ephemeroptera, and Plecoptera and establishes a poor, fair, good-fair, good, or excellent rating (EPT Index, 13)
- Aquatic invertebrates can be grouped using the functional feeding groups: shredders, collectors (gatherers or filterers), grazers (scrapers), and predators (EPT Index,, Allan, 2009)
    - Shredders break down large pieces of carbon
    - Collectors collect smaller pieces of detritus
    - Grazers will graze periphyton off surfaces
    - Predators eat other smaller consumers
    - The proportions of each feeding group will be determined by physical characteristics (e.g., water velocity, substrate, water depth, amount of light, type of carbon inputs, etc.) at each site.
- Aquatic invertebrate community composition will also depend on water quality, water movement, water temperature, and type and amount of vegetation (Allan, 2009)
- Tolerance to disturbance and conditions can be differentiated into the following groups: very sensitive, somewhat sensitive, facultative, somewhat tolerant, and very tolerant (Voshell, 2002)
- Type of movement for some invertebrates can be described by (Voshell, 2002)
    - Climbers: organisms prefer to move by climbing on vegetation. For climbers to survive vegetation must be present. Typically found in lentic-littoral and lotic-depositional zones.
    - Crawlers: tend to stay close to the firm substrate. Like to hide in-between gravel, stones, pebbles, cobbles or large pieces of organic matter.
    - Clingers: Tend to have limited movement and hold their position on firm substrate. Usually in swift moving water. Prefer lotic-erosional zones.
    - Sprawlers: move on top of the fine-grained substrate without sinking in. Prefer lentic-littoral or lotic-depositional zones.
    - Swimmers: move through water column by swimming.
    - Burrowers: dig into the fine sediment substrate.

Taxonomic Orders of invertebrates:

- **Plecoptera (Stoneflies):** All stoneflies will hatch in the water. The remain aquatic during their larval stages. They will undergo an incomplete metamorphosis into a terrestrial adult stage. (Voshell, 2002)
    - Rolledwinged Stoneflies—Family: Leuctridae
        - 7 genera, 55 species in North America
        - Found in lotic-erosional zones
        - Variable water velocity requirements
        - Crawlers
        - Shredders
        - Most are very sensitive. One genus is very tolerant to low pH
    - Small Winter Stoneflies—Family: Capniidae
        - 10 genera, 152 species in North America
        - Found in Lotic-erosional zones
        - Prefer coarse substrate with coarse organic matter
        - Crawlers
        - Shredders
        - Very sensitive to stressors
    - Winter Stoneflies—Family: Tainiopterygidae
        - 6 genera, 35 species in North America
        - Found in lotic-erosional zones
        - Can survive in variable substrate, water flows, and temperatures
        - Crawlers
        - Most are shredders, some are collector-gatherers
        - Most are somewhat sensitive to stressors
    - Nemourid Stoneflies—Family: Nemouridae
        - 12 genera, 71 species in North America
        - Found mostly in lotic-erosional zones
        - Prefer small streams higher in the watershed but some can survive in small rivers lower in the watershed
        - Crawlers
        - Need coarse substrate with large pieces of organic matter
        - Most are shredder but some are collector-gatherers
        - 1-2-year life-cycle
        - Most are somewhat sensitive to stressors
    - Green Stoneflies—Family: Chloroperlidae
        - 13 genera, 103 species in North America
        - Found in lotic-erosional zone
        - Prefer small streams
        - Need cool water
        - Found in swift currents
        - Require gravely substrate
        - Crawlers
        - Most are predators but some are scrapers or collector-gatherers
        - Typically, one generation per year but some take 2 years

        - Very sensitive to stressors
    - Perlodid Stoneflies—Family: Perlodidae
        - 30 genera and at least 122 species in North America
        - Mostly found in lotic-erosional zones
        - Most prefer fast moving, cool water
        - Crawlers
        - Most are predators
        - Most are somewhat sensitive to stressors
    - Common Stoneflies—Family: Perlidae
        - 15 genera, 72 species in North America
        - Found mostly in lotic-erosional zone, but sometimes in lentic-erosional zones
        - Prefer small streams
        - Crawlers
        - Predators
        - Many have a two-year life-cycle
        - Most are very sensitive to stressors
    - Giant Stoneflies—Family: Pteronarcyidae
        - 2 genera, 10 species in North America
        - Found in lotic-erosional zones
        - Prefer small streams higher in the watershed
        - Prefer fast currents with large organic debris
        - Crawlers
        - Most are shredders, some scrapers
        - Very sensitive to stressors
    - Roachlike Stoneflies—Family: Peltoperlidae
        - 6 genera and 20 species in North America
        - Found in lotic-erosional zone
        - Like cool, small streams
        - Crawlers
        - Shredders
        - Very sensitive to stressors
- **Ephemeroptera (Mayflies):** All mayflies hatch in the water. The remain aquatic during their larval stages. They will undergo an incomplete metamorphosis into a terrestrial adult stage (Voshell, 267)
    - Primitive Minnow Mayflies—Family: Siphlonuridae
        - 4 genera, 26 species in North America
        - Found in lotic-depositional, or lentic-littoral zones
        - Prefer silty substrate with vegetation
        - Swimmers or climbers
        - Prefer still water
        - Mostly collector-gathers
        - Tolerance to stressors is facultative
    - Ameletid Minnow Mayflies—Family: Ameltidae
        - Found in lotic-erosional, lotic-depositional, or lentic-littoral zones
        - Can live in small streams or brook
        - Prefer rocky or gravelly substrate
        - Collector-gatherers or scrapers

        - Very sensitive to stressors
    - Small Minnow Mayflies—Family: Baetidae
        - Found in lotic-erosional, lotic-depositional, or lentic-littoral zones
        - Still water to moderate water velocity
        - Mostly swimmers, clingers, climbers
        - Collector gathers
        - Most are facultative to stressors, while some are somewhat to very sensitive
    - Pronggilled Mayflies—Family: Leptohyphidae
        - 9 genera, 74 species in North America
        - Mostly found in lotic-erosional zones but some in lentic-littoral zones
        - Prefer swift flowing water
        - Prefer gravelly or rocky substrate
        - Crawlers, clingers
        - Collector-gatherers some scrapers
        - Most are somewhat sensitive to stressors
    - Flatheaded Mayflies—Family: Heptageniidae
        - 14 genera, 126 species in North America
        - Most are found in lotic-erosional zone, some found in lentic-erosional
        - Can survive in slow to swift water velocities
        - Clingers
        - Mostly scrapers but some collector-gathers
        - Most are somewhat sensitive to stressors
    - Spiny Crawler Mayflies—Family: Ephemerellidae
        - 8 genera, 90 species in North America
        - Mostly found in lotic-erosional zones while some are found in lotic-depositional or lentic-littoral
        - Can do well in any water velocity
        - Found in a variety of substrates
        - Mostly crawlers
        - Mostly collector-gatherers and scrapers, some shredders
        - Most are somewhat sensitive to stressors
    - Small Squaregill Mayflies—Family: Caenidae
        - Found in lentic-littoral or lotic-depositional zones
        - Prefer still water
        - Sprawlers
        - Collector-gathers
        - Do well in silty substrates
        - Most are facultative to stressors, while some are somewhat to very sensitive
    - Little Stout Crawler Mayflies—Family: Leptohyphidae
        - Most found in lotic-depositional zone, some found in lentic-littoral
        - Do well in silty substrate
        - Eggs typically overwinter allowing use of seasonal waterbodies
        - Collector-gathers
        - Some species have subimago larval stage
        - Tolerance to stressors is facultative to stressors
    - Brushlegged Mayflies—Family: Isonychiidae
        - 1 genus, 17 species in North America

        - Found in lotic erosional zones
        - Prefer swift water
        - Like shallow riffles with large pieces of organic matter
        - Collector-filterers
        - Somewhat sensitive to stressors
    - Common Burrower Mayflies—Family: Ephemeridae
        - Found in lentic littoral and lotic depositional zones
        - Prefer soft sediment substrate
        - Most are collector-gathers
        - Facultative to very sensitive to stressors
- **Trichoptera (Caddisflies):** All caddisflies hatch in the water. The remain aquatic during their larval stages. They will undergo an incomplete metamorphosis into a terrestrial adult stage (Voshell, 370)
    - Trumpetnet and Tubemaker Caddisflies—Family: Polycentropodidae
        - 7 genera, 76 species in North America
        - Lotic-erosional, lotic-depositional, or lentic-littoral
        - Clingers
        - Predators or collector-filterers
        - Somewhat sensitive to somewhat tolerant
    - Fingernet Caddisflies—Family: Philopotamidae
        - 3 genera, 42 species in North America
        - Lotic-erosional
        - construct <1-15 micron net to filter out food as water passes through net
        - clingers
        - collector-filterers
        - somewhat sensitive
    - Common Netspinner Caddisflies—Family: Hydropsychidae
        - 12 genera, 149 species in North America
        - Lotic-erosional
        - Fast flowing water
        - Spin net to filter out food as water passes through net
        - Clingers
        - Most are facultative to stressors
    - Giant Case Maker Caddisflies—Family: Phryganeidae
        - 10 genera, 27 species in North America
        - Lentic-littoral or lotic-depositional
        - Climbers
        - Shredders or predators
        - Most are facultative of stressors
    - Strongcase Maker Caddisflies—Family: Odontoceridae
        - 6 genera, 13 species in North America
        - Lotic-erosional or lotic-depositional
        - Burrowers, crawlers, clingers
        - Scrapers, collector-gatherers
        - Very sensitive to stress
    - Northern Case Maker Caddisflies—Family: Limnephilidae
        - 51 genera, 300 species in North America

        - Lentic-littoral, lotic-depositional or lotic-erosional
        - Climbers, crawlers, Sprawlers, or clingers
        - Shredders, collector-gatherers, scrapers
        - Most are facultative of stressors
    - Uenoild Case Maker Caddisflies—Family: Uenoidae
        - 5 genera, 46 species in North America
        - Lotic-erosional
        - Clingers
        - Scrapers
        - Somewhat sensitive to stress
    - Saddlecase Maker Caddisflies—Family: Glossosomatidae
        - 6 genera, 80 species in North America
        - lotic-erosional or sometime lentic-erosional
        - clingers
        - scrapers
        - very sensitive to somewhat sensitive to stressors
    - Humpless Case Maker Caddisflies—Family: Brachycentridae
        - 5 genera, 36 species in North America
        - Lotic-erosional
        - Climbers or clingers
        - Shredders, collector-gatherers, collector-filterers, or scrapers
        - Very sensitive to stressors
    - Lepidostomatid Case Maker Caddisflies—Family: Lepidostomatidae
        - 2 genera, 80 species in North America
        - Lotic-erosional or lotic-depositional
        - Crawlers or climbers
        - Shredders
        - Very sensitive
    - Longhorned Case Maker Caddisflies—Family: Leptoceridae
        - 8 genera, 113 species in North America
        - Lentic-littoral, Lotic-erosional or lotic-depositional
        - Variable water flow needs
        - Climbers, crawlers, Sprawlers
        - Predator, shredders, or collector-gatherers
        - Facultative to sensitive to stressors
    - Micro Caddisflies—Family: Hydroptilidae
        - 15 genera, 220 species in North America
        - Most lentic-littoral, some lotic-depositional
        - Climbers and clingers
        - Predators or algae eaters
        - Tolerance to stressors is facultative
    - Snailcase Maker Caddisflies—Family: Helicopsychidae
        - 1 genera, 4 species in North America
        - lotic-erosional or lentic-erosional
        - clingers
        - scrapers
        - Tolerance to stressors is facultative

- Free-living Caddisfly—Family: Rhyacophilidae
    - 2 genera, 127 species in North America
    - Lotic-erosional
    - Fast moving water
    - Most are predators, some are shredder or scrapers
    - Crawlers
    - Very sensitive
- **Amphipoda**: Side Swimmers or Scuds. 3 families: Hyallelidae, Gammaridae, and Crangonyctidae (Voshell, 247)
    - About 150 different species in North America
    - Found in lotic erosional, lotic depositional, lentic littoral, and subterranean zones
    - Feed on detritus
    - Can be in several different functional feeding groups
    - Most species have a one year life-cycle
    - An important food source for many larger aquatic invertebrates
    - Tolerance to stressors is facultative
- **Coleoptera (Beetles):** Aquatic beetles hatch in the water. Then they metamorphose into an adult which can be aquatic or terrestrial depending on species (Voshell, 352)
  - Riffle Beetles—Family: Elmidae
    - 24 genera, 97 species in North America
    - Larvae and adults are aquatic
    - Found in lotic-erosional and lentic-littoral zones
    - Clingers and climbers
    - Scrapers, collector-gatherers
    - Most are facultative to stressors, but some are somewhat sensitive
  - Whirligig Beetles—Family: Gyrinidae
    - 4 genera, 56 species in North America
    - Both larvae and adults are aquatic
    - Found in lentic-littoral, and lotic-depositional zones
    - Larvae are climbers and swimmers
    - Adults are surface swimmers
    - Predators
    - Facultative stress tolerance
  - Long-Toed Water Beetles—Family: Dryopidae
    - 5 genera, 13 species in North America
    - Found mostly in lotic-erosional zones
    - Collector-gatherers and scrapers
    - Facultative to stressors
    - Eggs placed in plant material or in the soil
  - Predaceous Diving Beetles—Family: Dytiscidae
    - 44 genera, 509 species in North America
    - Found in lotic-depositional and lentic-littoral zones
    - Larvae and adults live in water
    - Predators
    - Facultative to somewhat tolerant to stressors
  - Water Scavenger Beetles—Family: Hydrophilidae
    - 20 genera, 192 species in North America

        - Both adults and larvae are aquatic
        - Mostly found in lentic-littoral or lotic-depositional zones
        - Larvae are climbers
        - Adults are swimmers
        - Larvea are predators
        - Adults are collector-gatherers and predators
        - Most are somewhat tolerant to stressors
    - Water Pennies—Family: Psephenidae
        - 6 genera, 16 species in North America
        - Larvae found in lotic-erosional zones
        - Adults are terrestrial
        - Clingers
        - Scrapers
        - Tolerance to stressors is facultative
    - Crawling Water Beetles—Family:
        - 4 genera, 67 species in North America
        - Both adults and larvae are aquatic
        - Found in lotic-depositional and lentic-littoral zones
        - Shredders and predators
        - Somewhat tolerant
- **Hemiptera (True Bugs):** aquatic true bugs hatch in the water and will undergo an incomplete metamorphosis into an adult. Larvae have similar appearance to adults but lack developed wings (Voshell, 324)
    - Water Striders—Family: Gerridae
        - 9 genera, 47 species in North America
        - Mostly found in lentic-limnetic or lotic-depositional zones
        - Predators
        - Skate on surface of water
        - Somewhat tolerant
    - Water Boatman—Family: Corixidae
        - 17 genera, 125 species in North America
        - Found in lentic-littoral and lotic-depositional
        - Swimmers
        - Collector-gatherers
        - Very tolerant to stressors
    - Back Swimmers—Family: Notonectidae
        - 3 genera, 32 species in North America
        - Found in lentic-littoral and lotic-depositional zones
        - Swimmers
        - Predator
        - Have a painful bite
        - Very tolerant to stressors
    - Giant Water Bugs—Family: Belostomatidae
        - 3 genera, 22 species in North America
        - Mostly found in lentic-littoral zone, some found in lotic-depositional zone
        - Climbers and swimmers
        - Predators

    - Very tolerant
  - Broad-Shouldered Water Striders—Family: Veliidae
    - 6 genera, 34 species in North America
    - Mostly found in lentic-littoral and lotic-depositional zones
    - Live on the water's surface
    - Predators
    - Somewhat tolerant
  - Creeping Water Bugs—Family: Naucoridae
    - 4 genera, 23 species in North America
    - Found in lentic-littoral, lotic-erosional zones
    - Crawlers, climbers, and swimmers
    - Predators
    - Have a painful bite
    - Adults can overwinter in the substrate
    - Unknown tolerance but thought to be somewhat tolerant
  - Water Scorpions—Family: Nepidae
    - 3 genera, 13 species in North America
    - Found in lentic-littoral and lotic-depositional zones
    - Climbers
    - Poor swimmers
    - Predators
    - Somewhat tolerant to stressors
- **Diptera (True Flies): True flies** hatch in the water. The remain aquatic during their larval stages. They will undergo a metamorphosis into a terrestrial adult stage (Voshell, 395)
  - Black Flies, Crane Flies, Non-Biting Midges, Biting Midges, Dixid Midges, Phantom Midges, Phantom Crane Flies, Mosquitos, Shore Flies, Brine Flies, Rat-Tailed Maggots, Flower Flies, Dance Flies, Aquatic Snipe Flies, Soldier Flies, Horse Flies, Deer Flies, Moth Flies
    - All are somewhat to very tolerant to stressors
  - Mountain Midge, Net-Winged Midges
    - Both are very sensitive to stressors
- **Odonata (Dragonflies and Damselflies):** Odonates hatch in the water and will undergo an incomplete metamorphosis into an adult. Larvae have slight resemblance to adults with visible wing pads (Voshell, 288)
  - Skimmer Dragonflies—Family: Libellulidae
    - 35 genera, 156 species in North America
    - Mostly found in lentic-littorial and lotic-depositional zones
    - Breath through rectum
    - Propel themselves by filling rectum with water and shooting it out
    - Sprawlers and climbers
    - Predators
    - Most are very tolerant, but some are facultative to somewhat sensitive to stressors
  - Clubtail Dragonflies—Family: Gomphidae
    - 13 genera, 109 species in North America
    - Found in lotic-depositional, lentic-littoral, or lotic-erosional zones
    - Breath through rectum

        - Propel themselves by filling rectum with water and shooting it out
        - Mostly burrowers and a few sprawlers
        - Predators
        - Most have a 2-year larval phase but it can vary between 1-4 years
        - Somewhat sensitive to stressors
    - Darner Dragonflies—Family: Aeshnidae
        - 11 general, 38 species in North America
        - Most are found in lentic-littoral zones, while some are found in lotic-depositional, or lotic-erosional zones
        - Breath through rectum
        - Propel themselves by filling rectum with water and shooting it out
        - Eggs are typically placed inside plant
        - Climbers in still water
        - Crawlers in the water is moving
        - Predators
        - Somewhat sensitive to stressors
    - Narrowwinged Damselflies—Family: Coenagrionidae
        - 16 genera, 15 species in North America
        - Most found in lentic-littoral zones, some found in lotic-depositional or lotic-erosional zones
        - Eggs are typically placed inside plant
        - Climbers, sprawlers, and clingers
        - Most prefer soft sediment with vegetation
        - Most are somewhat tolerant to very tolerant
    - Spreadwinged Damselflies—Family: Letidae
        - 2 genera, 19 species in North America
        - Most found in lentic-littoral zone
        - Always found on or around aquatic vegetation
        - Able to make use of ephemeral sites
        - Prefer still water or slow moving water
        - Climbers
        - Most are very tolerant to stressors
    - Broadwinged Damselflies—Family: Calopterygidae
        - 2 genera, 8 species in North America
        - Found in lotic-erosional zones
        - Prefer moderate water velocities
        - Climbers
        - Move very slowly
        - Predator
        - Most are somewhat tolerant, while some are facultative to stressors
- **Gastropoda (snails):** Bithyniid Snails, Vivparid Snails, Hydrobiid Snails, Pleurocerid Snails, Ancylid Snails, Planorbid Snails, Lymnacid Snails, Physid Snails (Voshell, 208)
        - Found lentic littoral and lotic depositional zones
        - Most are primary consumers that feed by scraping their radula across surfaces collecting algae and detritus.
        - Eggs are laid in water on vegetation or rocks
        - Lunged snails

            - Typically have a 1 year life-cycle
            - Can hibernate
            - Somewhat tolerant
        - Gilled snails
            - Typically have a 2-5-year life-cycle
            - Somewhat sensitive
            - Require moderate to high dissolved oxygen levels
- **Annelida: Aquatic Earthworms, Leaches** (Voshell, 197)
        - Segmented
        - Found in lentic-littoral, or lotic-depositional zones
        - Earthworms are Collector-gathers
        - Earthworms can reproduce sexually or asexually
        - Their feeding turns the upper 5-10 cm of substrate helping keep the area aerobic
        - Very tolerant
        - Most leaches are predators but a few are parasites
        - Leaches reproduce sexually
- **Megloptera:** (Voshell, 342)
    - Dobsonflies, Fishflies, Hellgrammites—Family: Corydalidae
        - 7 genera, 22 species in North America
        - Mostly found in lotic-erosional zones, and sometimes in lotic-deposition and lentic-littoral
        - Need slow to fast water flow
        - Most are crawlers but some are burrowers or sprawlers
        - Predators
        - Most are facultative to stressors; some are very tolerant
    - Alderflies—Family: Sialidae
        - 1 genera, 24 species in North America
        - Found in lentic-littoral and lotic-depositional zones
        - Occurs in variable types of habitats
        - Burrowers
        - Predators
        - Facultative to very tolerant to stressors
- **Platyhelminthes (Flatworms):** (Voshell, 193)
        - over 200 fresh water species in North America
        - Most live in the lentic-littoral zone
        - Scavenger of dead animal matter
        - Most prey upon small soft bodies invertebrates some are collector-gathers
        - Slither along substrate and vegetation
        - Have two eyespots
        - some reproduce sexually with eggs laid in water and will hatch in a few weeks or they can go into dormancy until the following Spring.
        - Some can utilize a cyst phase to survive when conditions are not adequate
        - Somewhat tolerant
- **Bivalvia:** (Voshell, 218)
    - Asian Clam
        - Burrower

        - Lentic littoral or lotic depositional
        - Likes well oxygenated water
        - Prefers sandy/muddy substrate
        - Can alter improve water quality
        - Collector-filterer feeder
        - Somewhat sensitive to facultative
    - Zebra Mussels
        - Can be found in lotic depositional, lotic erosional, lentic littoral, or lentic profundal zones.
        - Collector-filterers
        - Can live up to five years
        - Non-native, can be invasive
        - Prefer slow moving water
        - Need water with high levels of dissolved oxygen
        - Cling to rocks and prefers rocky substrate
        - Facultative tolerance
    - Fingernail or Pea Clam
        - Can be found in lotic depositional, lotic erosional, lentic littoral, or lentic profundal zones.
        - Can live in all water velocities
        - Can live in any type of substrate except bedrock
        - Burrowers
        - Collector-filterer feeding group
        - Facultative to somewhat tolerant
    - Mussels
        - Can be found in lotic depositional, lotic erosional, or lentic littoral zones
        - Require high concentrations of calcium carbonate in the water
        - Typically found in water 2-6-meters deep
        - Prefer a slow to moderate current
        - Collector-filterers
        - Burrowers
        - Somewhat sensitive to facultative
- **Arachnida (Water mites):** (Voshell, 234)
        - Typically, 2-3mm in size
        - Resemble a spider in appearance
        - Most are found in lentic littoral zones among vegetation
        - Most are predators as adults
        - Larval stages can be parasitic
        - Generally, exhibit facultative tolerance but that can vary by species
- **Isopoda (Aquatic Sow Bug):** (Voshell, 244)
    - Family: Asellidae
        - Lotic erosional, lotic depositional, lentic littoral, or subterranean zones
        - Slow moving
        - Avoid light
        - Omnivores that can belong to any of the functional feeding groups
        - Have gills

        - All aquatic isopods have marsupium which is a pouch on the thorax which hold the eggs
        - Prefer small bodies of water
        - Somewhat tolerant
- **Decopoda** (Voshell, 242)
    - Crawfish—2 families: Astacidae, Cambaridae
        - 12 genera, 315 species in North America
        - 10-150mm in length
        - Habitat can vary by species
        - Most commonly found in lotic erosional, lotic depositional, lentic littoral, subterranean
        - Can survive in a variety of water velocities
        - Prefer shallow water
        - Most live 2-3 years
        - Facultative tolerance to most disturbances and stressors but can be sensitive to pesticides and herbicides
    - Shrimp—family: Palaemonidae
        - 2 genera, 15 species
        - Found in lotic deposition and lentic littoral zones
        - Prefer quiet and shallow waters
        - Feed on aquatic plants
        - Scrapers and predators
        - Unknown tolerance to stressors
- Cladocera
    - Water Fleas--Daphniidae *Daphnia*
        - Food source for many other invertebrates and fishes
        - Planktonic (zooplanktonic)
        - Filter feeders that feed on algae/bacteria/protists/detritus

Part II

Management Plan for Freshwater Invertebrates in Constructed Wetlands within the Central Valley

Management for freshwater aquatic invertebrates is an essential component in successful constructed wetlands because these invertebrates are an integral part of the food web. These invertebrates can be helpful to humans, since they can be used as bioindicators of water quality. Without these invertebrates, many migrating and non-migrating birds, fish, bats, and turtles will not be able to use the site as habitat.

Goals:

- To determine what invertebrates are present with current conditions.
- To introduce and maintain 60% coverage of emergent and submergent vegetation that will provide habitat and sustenance for aquatic invertebrates and dissolved oxygen to the water.
- To increase dissolved oxygen levels to fall within the range 5-10 ppm.
- To shift the community of aquatic invertebrates from very tolerant and somewhat tolerant species, which are currently present at the site, to a community with a blend of somewhat sensitive, facultative, somewhat tolerant, and very tolerant species.
- To provide aquatic vegetation that can support aquatic invertebrates that can be described by their type of movement as climbers.
- To establish and maintain a diverse community of aquatic invertebrates that can provide essential ecosystem services (e.g., food for wildlife and regulation of pests).

- Regulating services
    - Wetlands are prime habitat for mosquitos. Since mosquitos can pose a risk to human health (e.g., West Nile virus, Zika, Malaria), mosquito presence is a concern. As larvae and pupae, mosquitos are prey for fish and many aquatic invertebrates (e.g., predaceous diving beetles, all members of Odonata order, and water scavenging beetles). Establishing populations of these invertebrates can help control mosquito populations.
- Supporting services
    - Being food for other organisms
        - Killdeer, Semipalmated plovers, Blacknecked stilts, Grebes, Swainson's Hawks, American Avocets, Western Pond turtles, fishes, bats, salamanders, etc.

Restoration Plan:

1. Identify what bugs are present with current conditions.
    a. A sample of the aquatic invertebrates can been done with a 500-micron D-framed Net. The collected sample can be placed in ethanol and sent to the lab for identification.
        i. A more affordable method would be to identify live specimens down to family and return sample to wetland within a reasonable time (30 minutes).
    b. Currently there is a silty substrate with little to no aquatic vegetation in a lentic zone. So, it is likely that invertebrates that can be described by their type of movement as sprawlers, swimmers, and burrowers will be found (Voshell, 2002). Ideally, the we would also like to see climbers in this type of environment. For climbers to be able to survive aquatic vegetation will need to be introduced. (See Part 1 for information on sprawlers, swimmers, burrowers, and climbers)
2. Habitat requirements for aquatic invertebrates
    a. Food

    i. To achieve and sustain a diverse aquatic invertebrate community, there must be an input source of coarse particulate organic matter, CPOM, or fine particulate organic matter, FPOM (Stewart and Downing 2008).
        1. Primary CPOM/FPOM source would be vegetation, both autochthonous and allochthonous. Both living plant material and detrius will provide an adequate source of organic matter (Voshell, 2002).

b. Native plants have been shown to support a greater macroinvertebrate richness than exotic vegetation (Bryant, 2007). Therefore, native vegetation will need to be introduced and exotics will need to be controlled. Having submergent vegetation interspaced with emergent can increase the abundance of invertebrates (Voight, 1976).
    i. Native Submergent plants
        1. *Elodea canadensis Michx.* (Jepson Floral Project)
        2. *Ceratophyllum demersum L*. -- Hornwort or Coon's tail (Calflora)
            a. Transplants should be used and acquired from a reputable dealer to avoid any transferring any invasive species hitchhikers.
    ii. Native Emergent Plants
        1. *Bulboschoenus maritumus/Scirpus maritimus*
            a. *B. maritumus* can be introduced.
                i. This plant will need to be managed to prevent it from becoming invasive. When the plant begins to overwhelm the system, it should be mowed down (Popko and Walton 2013).
                ii. This plant has also been shown to support Odonata richness and decreased mosquito larvae/pupae populations (Popko and Walton 2013).

c. Water Quality
    i. Dissolved oxygen at the site was measured and determined to be too low to adequately support a diverse community of aquatic invertebrates (0> but <4 ppm).
        1. The introduction of the previously mention aquatic vegetation will increase dissolved oxygen concentrations.

d. Providing vegetation and improving water quality will naturally shift the community of invertebrates from very tolerant and somewhat tolerant species to a community with a blend of somewhat sensitive, moderately tolerant, somewhat tolerant, and very tolerant species.

3. Disturbances

   a. Mechanical disturbances--Invertebrate communities are resistant to mechanical disturbances, such as mowing, tilling, and disking, during Fall. Winter populations can drop slightly with mechanical disturbance but will rebound quickly. Mowing is preferred over tilling or disking because mowing has shown to result in diversity similar to a site with no mechanical disturbances (Gray 1999). Burning and grazing have been shown to have to have similar effects to disking (Kostecke 2005).
   b. Flooding
      i. Bank vegetation should be unaltered prior to flooding to increase the invertebrate diversity. If control of vegetation is required, then it is best to mow the area 5-9 weeks prior to predicted flooding (deSzalay and Resh 1997)

Monitoring Plan:

1. Monitoring of bugs
   a. Annual D-framed net samples should be taken for the first 5 years. This can occur at any time during the year and day. Since community composition and population size can vary seasonally it would be best to take sample close to the same time every year to be able to compare data.
      i. We want to see more invertebrates that are moderately tolerant, somewhat tolerant, and facultative than very tolerant species.
         1. If there are only very tolerant species present and there is 60% vegetation cover, then the water should be tested for contaminants (e.g., heavy metals, pesticides, herbicides, etc.).
      ii. We also want to see at least one invertebrate that is labeled as a climber.
         1. If none are present after 3 years and aquatic vegetation is present, then the water quality should be tested to try to determine why the site is not supporting these aquatic invertebrates.
   b. If any sample shows a significant increase in mosquitos, then action should be taken.
      i. First, check for presence of wetland vegetation. If less than 60% of wetland area is covered by vegetation in late spring (e.g., submergent and emergent plants), then replanting should occur.
      ii. If vegetation is adequate, then the addition of a native fish such as California Roach, *Lavinia symmetricus*, should be considered.
         1. Mosquito populations should be checked again 3-4 weeks after addition.
      iii. If the mosquito populations are still large, then a larvicide should be used
         1. Two applications of Vectolex®CG at a rate of either 19 or 23. 6 kg/ ha should be used (Walton 1998).

2. Monitoring of plants
    a. Annual inspection of the site for invasive plant species should occur.
        i. Aquatic invasive species can alter water chemistry and significantly alter the invertebrate community and should be removed immediately.
            1. Visual inspections should be done twice a year, once in early spring and again in fall, looking for invasive emergent and submergent plants. Prevention is key.
        ii. If *B. maritumus* or any other wetland vegetation is found to cover more than 60% of the area of the wetland, then the area should be mowed burned, or grazed during summer when water levels are low and access with a mower is possible.
        iii. If aquatic vegetation is filling more than 60% of the water, then physical removal will be required.
3. Monitoring of Water Quality
    a. Dissolved Oxygen should be measured in spring or in summer. Dissolved oxygen is affected by photosynthesis and cellular respiration from vegetation, so readings should be on the lower end of the acceptable range (5 ppm) in the morning or when there is little sunlight. At the end of the day a higher reading (up to 10 ppm) is acceptable.
        i. If dissolved oxygen levels are low, then more native aquatic vegetation should be introduced.
        ii. If dissolved oxygen levels are above the acceptable range, then removal of aquatic vegetation will be required.
4. More information is needed to determine the amount of vegetation required to adequately support an abundant and diverse invertebrate population. Monitoring of invertebrates can help determine what percentage of vegetation will be adequate to support a diverse invertebrate community but not cause any negative effects on other wildlife or ecosystem services (e.g. limiting water access for waterfowl, flood control, etc.).

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Bullfrog (Rana catesbeiana)

Rebecca Spranger

PART 1

A. Background and Justification

The Bullfrog (*Rana catesbeiana*) is an invasive amphibian, which threatens many native California amphibians and fish. It was first introduced to California in 1896 and has become widespread through out the state (Hothem, 2009). Amphibian populations have been declining in the recent past due to environmental changes as well as competition with invasive species such as the Bullfrog. The Bullfrog has proven to be a major predator of native frogs along with their prey. This causes a decrease in biodiversity and negatively impacts other organisms by increasing the probability of spreading disease (Huss). Native populations of other frog species are declining rapidly in the Sacramento Valley but are less severe the closer you move to coastal range (Fisher, 1996). The Bullfrog is native to the East coast of North America and its population has steadily spread and increased in size. All research done on this species demonstrates that it is hard to control and eradicate. It is a generalist so it can take over many different types of habitats.

B. Literature review

Habitat needs:

- Bullfrogs can be found in many different aquatic systems. Some of these include lakes, ponds, reservoirs, marshes, streams, and irrigation ponds (Lithobates Catesbeianus).
- Bullfrogs breeding grounds are found in more modified habitats compared to native species. Bullfrogs are also commonly found in habitat that is next to the floodplain of a channel instead of near the main channel that have sand or gravel bottoms (Fuller, 2010).
- Bullfrogs can be found in desert areas that contain adequate irrigation to form their ideal habitat (Morey).
- Ideal habitats for Bullfrogs include still, deep water that includes stationary floating plants and an open canopy. For early life stages of bullfrogs, rooted vegetation provides egg and larval protection while the open canopy allows the sunlight to warm the eggs and speed up developmental rates. The sunlight also encourages the green algae to grow, which is an important food source for the larvae (Fuller, 2010).
- If there is not enough vegetation cover Bullfrogs will struggle to survive (Morey).

- Bullfrogs can survive in colder climates by hibernating in the water but prefer waters at 30-35 °C (Morey).

Range:

- Bullfrogs are native to the North Eastern United States, from the Mississippi River and the Great Lakes to Florida and up the coast. Bullfrogs are considered invasive in many countries including the Western United States, Western Canada, Mexico, Brazil, Japan, China, and Italy (Adams, 2007).
- Bullfrogs are more abundant in the Sacramento Valley and become less common when moving towards the coastal range (Fisher, 1996).
- Most invasive species, including the bullfrog, thrive in lower elevations. Bullfrogs have been found in areas up to 4000 feet in elevation. This has caused native species to live in higher elevations so the two species do not co-exist often (Fisher, 1996).
- The average home range of a bullfrog is a 10 foot radius. Males tend to have larger home ranges than females (Morey).

Diet:

- Bullfrogs (*Rana catesbeiana*) eat a more wide range of prey than its native comparisons (Foothill Yellow-Legged Frog (*Rana boylii*) and the Northern Pacific Treefrog (*Pseudacris regilla*)) Bullfrogs consumed a diet of terrestrial as well as aquatic prey. (Hothem, 2009).
- Bullfrogs primary diet is invertebrates but will consume other organisms such as fish, lizards, snakes, turtles, rodents, and other frogs (Morey).
- Vertebrates and beetles were found in the stomach of the Bullfrogs but were absent in the other two species. They also have been known to consume Foothill Yellow-Legged frogs, which suggests that Bullfrogs will prey on other frog species (Hothem, 2009).
- Tadpoles diet consists of algae and diatoms and occasionally other plant materials (Morey).

Reproduction/lifespan:

- Breeding season occurs from March to July (Morey). A single adult female can produce 10,000-25,000 eggs. Sexual maturity in Bullfrogs occurs at one to two years of age for males and two to three years of age for females (Lithobates Catesbeianus).
- Eggs take 6 months to metamorphosis (Moyle, 1973). Permanent water is necessary for larval development. Tadpoles are about 14cm in length and take 2 years to morph into a frog (Morey).
- Bullfrogs are very territorial with territory ranging from two to five meters wide and are polygamous (Lithobates Catesbeianus). Females will lay their eggs in their partner's territory and the male will defend against other males (Morey).
- Adult bullfrogs can grow up to two pounds in weight and be eight inches long. Their lifespan ranges from 7-9 years (society 2017).
- Bullfrogs need moisture to disperse so they most often disperse at night or in wet weather. These frogs can swim to another area or also be carried by stream flows (Slafkosky).

Negative Impacts/interactions:

- *Bd* Disease
    - Bullfrogs are thought to be a *Bd* tolerant carrier. The earliest recorded infected bullfrog was in 1928 in Sacramento County (Huss).
    - It is still unsure if Bullfrogs are tolerant carrier but there was a study that used Bd-PCR assay to test a collection from the California Academy of Science of Bullfrogs for presence of *Bd*. It was only found in 19.2% of the specimens (Huss).
- Foothill Yellow-Legged Frog
    - The Bullfrog competes with the Foothill Yellow-Legged Frog, which is native, during all stages of life. It competes for breeding locations as well as food. The Bullfrog is also a predator of the Foothill Yellow-Legged Frog; it will consume this species along with many other frogs (Hothem, 2009).

Management considerations:

- There has been minimal success with trying to control bullfrog populations. Burning is one mechanism that has been attempted and burning has displayed that there were more animals captured after a burn compared to the control group. This suggests that burning could be a way to increase animal diversity if an invasive organism has started to take over (Hankins, 2009).
- Decreasing suitability of habitats for breeding would help control Bullfrog populations. This can be done by decreasing water depth and increasing the flow/activity of the water (Fuller, 2010).
- Direct removal is the simplest way to try and eradicate Bullfrogs, however, it is not always effective because the species is density dependent, which means the population size is positively correlated to how many available resources there are. Direct removal of juveniles has proven to be the most successful because it will have the biggest effect on growth rate (Adams, 2007).
- Bullfrogs overwinter as larvae so changing their habitat to be seasonal flooding can act as an effective population control.

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PART 2

A. Goals:

- To eliminate at least half of the Bullfrog population with active management (various methods are explained in restoration plan) in the area in order to allow the native species population to become stable and to be able to coexist with Bullfrogs.
- For the next two years, continue to support bullfrog absence by modifying the habitat back to a more natural state that is ideal habitat for native species. This will help prevent the bullfrog population from having an advantage by maintaining inadequate habitat for them.
- Keep outside bullfrog populations from entering the site by blocking off immigration access and decreasing the number of frogs that escape from commercial or research use.
- Continue to monitor the area for at least six years to see if the bullfrog population becomes re-established. At least six years is needed to continue to monitor because bullfrog populations are known to fluctuate intensely.
- After four years, less frequent long-term monitoring can be implemented by surveying the bullfrog population size in that area to make sure that it does not increase dramatically.
- If the bullfrog species becomes abundant again, more extreme short-term management tactics will have to be done such as eradication of the whole population.

B. Restoration Plan:

Complete eradication of a bullfrog population from a certain site is unfeasible. This is because a female bullfrog can produce 10,000-25,00 eggs during each breeding season (Lithobates Catesbeianus). Also, elimination of 99% of all bullfrogs with out doing any other restoration techniques will result in failure to remove this species. Other active management tools such as habitat modification and prevention are necessary to keep bullfrog numbers down.

Direct removal has proven to be the most effective method in order to significantly reduce bullfrog population sizes. Culling juveniles is the most effective way to reduce the size of the population because removing most, but not all eggs or larvae have been shown to actually increase survival because it eliminates competition. In addition, killing adults is also not ideal because killing adult bullfrogs increases the survival of juvenile frogs that may have been prey for the adult frogs. Direct removal is the simplest way to try and eradicate bullfrogs, however, it is not always effective because the species is density dependent, which means the population size is positively correlated to how many available resources there are. In order for this reduction to be beneficial to native species, it would have to be done every two years with a mortality rate higher than 65% (Adams, 2007). This would have to be done more than once because a bullfrog's lifespan is 7-9 years of age meaning it would take more than one time of removing the frogs to remove a majority of each generation (society 2017). Direct removal can be accomplished through capture and cull as well as regulated shooting/hunting. Studies have shown that increasing adult mortality through hunting has decreased the species equilibrium population density (Martz, 2014). This is not a well-supported technique because if mass numbers of adults are killed more often than every other year, it will lead to an extreme fluctuation in bullfrog population size. The bullfrog population fluctuates because it is overcompensating for the extreme loss of individuals (Doubledee, 2003).

After more than half of the individuals in the population have been removed, the next step is to alter the area's habitat. Altering the habitat can either be by manipulating the area to disservice the bullfrog's need or by returning the area to the natural regime. The site should be surveyed to determine what aspects of the environment can be changed to favor the native species. Bullfrogs thrive when still, deep water is present containing floating plants and an open canopy from the vegetation on land (Fuller, 2010). Seasonal flooding would benefit native species since bullfrogs overwinter as larvae. This area could be drained for part of the year to allow native species to have a chance of competing with bullfrogs. Since bullfrogs need permanent water to metamorphosis, disturbing this cycle will inhibit the survival rate of tadpoles. Another way to decrease reproduction rates would be to make the site an unsuitable breeding ground. Vegetation should be taken out of the water, which will leave bullfrog eggs and larvae less protected from predators. Shrubs and trees should also be planted along the banks to provide adequate canopy cover, which will prevent the larvae's primary food source, algae, from growing. Along the banks of this area, gravel bars will be put in as well as making more shallow, active flow areas so that the native species ideal breeding habitat is more abundant and hopefully they can coexist with the bullfrogs (Fuller, 2010).

Once a reduction in the bullfrog population and habitat restoration has been completed, there must be a plan to keep additional individuals from immigrating into the study area. Either of these two previous steps will not matter if we cannot control the movement of other bullfrog populations into our newly altered area. Bullfrogs require moistness to disperse; therefore they most often navigate land at night or during wet weather (Slafkosky). Decreasing the quality of habitat that is outside the study area may help prevent other bullfrogs to try and cross that barrier. To decrease the quality, we will eliminate vegetation cover that acts as predatory protection as well as any scattered streams or puddles of water. Encouraging hunters and commercial industries in that area to increase their capture of bullfrogs would help to limit the number of individuals that disperse as well (Moyle). This is not something that would be long-term because it is unfeasible to upkeep the habitat between sites as well as monitor hunting activity. This would just need to be done for a couple years, until the native species population has time to recover and a fighting chance at coexisting naturally with the bullfrog populations.

C. Monitoring Plan:

Ideally, this area would be monitored for six years after restoration during the breeding season because of the 7-9 year life expectancy of a bullfrog. This would allow for almost a whole generation cycle and also allow for multiple data sets to be acquired for a data trend. Pre-restoration monitoring techniques include surveys of the study site to determine how abundant bullfrogs are (via visual or auditory surveys), what makes up the habitat (vegetation quadrats), and how many native frog species there are and how abundant they are. This recorded data should be continued to be taken every two years. Every two years is the ideal time period because it takes a tadpole 2 years to become sexually mature. Post-restoration monitoring should record the same kind of data but also note if the altered habitat is still intact. Monitoring this site for 6 years after the initial restoration will allow for a multiple year trend, which can show us whether the bullfrog population remained low. If the population did not significantly increase, the restoration effort can be seen as a success. After the initial 6 years, a less frequent, long-term monitoring plan can be established based on the site-specific needs to make sure that the bullfrog population stays low.

If the restoration plan fails, a more extreme measure might have to be taken in order to remove the bullfrogs. In this case, eradicating the entire bullfrog population may be necessary. To do this the study area's water would be drained to guarantee a hundred percent egg and larvae mortality rate (Martz, 2014). Knowing what exact habitat would be preferable to bullfrogs at this specific site would improve the restoration plan immensely. It would also be beneficial to know how to alter this specific habitat to aid the native species survival. In order to do this though, the native species located in this study area would have to be known as well as their particular needs. Another helpful point would be to know the surrounding area of the site. This could affect how immigrating frogs could be regulated as well as how harsh outside influences might be on the study area. This project can help determine if applying both eradication and restoration methods can be more beneficial than doing one or the other. It can be compared to other projects that only accomplished one of these implementations to see how much more or less successful it was.

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Riparian/Upland Animals

The Western Burrowing Owl *(Athene cunicularia)*

Celia Duffy

PART I:

A. Why do we Care?

The Western Burrowing Owl (*A. cunicularia*) is a small, diurnal owl which enjoys arid grassland and has been severely diminished in numbers in the last half century. It lives underground in burrows made by ground squirrels or other small rodents. Locally, its biggest threats are habitat destruction from building and conversion to orchard agriculture in addition to the pest control of small rodents. In Yolo County, there has been a 76% decline since 2006. Known breeding pairs in the area are still in decline such as the 1 remaining pair in Davis which lives on a vacant lot soon to be developed ("Status of Burrowing Owls in California"). The bird is considered an indicator of ecosystem health and therefore its decline suggests local ecosystems are not thriving. Essentially, these owls cause environmental changes that impact other species and resource availability. The Burrowing Owl Conservation Network (BOCN) wants to reverse the bird's decline to maintain a functioning ecosystem. This includes constructing artificial burrows and re-establishing colonies in restoration projects as has been successful in other areas (Yolo Habitat Conservancy Plan 2015).

B. Species information

Species range

On the West from Canada to Panama and east all the way to Texas in addition to Florida and the Caribbean (Poulin et al. 2011)

Though it is a resident (non-migratory) bird in many areas of California (including Yolo County), northern birds or those at high elevations migrate in a "leap-frog" fashion towards Mexico in winter (Shuford 2008)

There are 91 records of burrowing owls in Solano County in 2012 from the last ten years (since 2002). Most of these records are from agricultural lands east and southeast of Dixon, in the northeastern portion of the Solano county (Solano County Water Agency)

Habitat needs

Low-vegetation (less than 6”), well-drained and available burrows (Solano Water Agency)

Less than 30% canopy cover (Wildlife Research Institute 2005)

Have adapted to edges of cattle pasture, row crop agriculture and urban settings such as near airports and parking lots where burrows available and vegetation low enough (“Status of Burrowing Owls in California”)

Some models suggest that fire plays an essential role in owl population maintenance as it is the only natural process which reduces shrub levels (Machicote & Villarreal 2004)

Diet

Insect including Orthoptera, Dermaptera, and Coleoptera

Rodents including the pocket gopher, California vole and house mouse (Trulio 2012)

In fewer cases they also eat small reptiles, amphibians, birds, fish and crustaceans

Predators

Natural predators are horned owls, hawks, foxes, badgers

Domestic dogs and cats

Though, their greatest threats right now are certainly human habitat destruction, pest management and climate change which can reduce nest success (Macías-Duarte & Conway 2015)

Behavior and lifespan

Burrowing owl nest alone or in spread out colonies of 4-10 pairs

After hatching, owlets stay underground for 2-4 weeks until slowly moving to satellite burrows where they will be fed by adults for 6-8 more weeks.

Mid-September they will molt into adult plumage and leave independently to find their own burrows

Once established, owls will spend majority of their time within 600 meters of their burrow (Solano Water Agency)

Reproduction

Courtship in February to early March then females lay eggs in burrows and incubate for 28-30 days. Males are collecting food.

In California, this breeding season can run through August ("peak" breeding April to July).

Legal Status

It is listed as Endangered in Canada, Threatened in Mexico and, though not nationally listed as Endangered in the US, 9 states including California have listed it as a species of special concern. There have also been several movements to add it to the US Endangered species list. (Shuford 2008)

Pesticides and Agricultural Management

Since the owl's diet is largely insect-based, they are susceptible to carbamate and organophosphate. Impact can be direct (sprayed on burrow) or indirect (owl eating sprayed insect) (Mineau et al. 1999)

Fall tillage may destroy burrows and trap owls inside

Flooding destroys nests and drowns owlets and adults (Solano Water Agency)

Restoration

Suggestions include maintaining low vegetation through mowing or planting low-growing species, supplement areas with artificial burrows, control off-leash pets (Shuford 2008)

Example timeline for mowing management: mid-February (5") owls pair and choose burrows. Mid-May chicks will be emerging and need short vegetation to see predators and for adults to find prey. Mid-June (4") cutting will keep vegetation low throughout the dry summer while adults still feeding juveniles. Cow grazing is the ideal method as their dung also attract beetles and is used by the owls around their burrows (Wildlife Research Institute 2005).

There is a history of success dating back 20 years to Palo Alto where new habitat was made and colonized by 3 pairs of owls (Trulio 1997). Though, owls which have been relocated show strong original site fidelity (Delevoryas 1997)

Studies from British Columbia show successful reintroduction of captive-bred owls in 2001 including surviving at release sites, raising young and overwintering or migrating and returning (Leupin & Low 2001)

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PART II:

A. Goals

Provide habitat needs

Create year-round attractive habitat (with emphasis on nesting season, February to May) with low grasses (<6"), without heavy risk of predation (effort to exclused cats and dogs and minimization of large bird predators such a hawks and crows), stopping the use of all pesticides, and ensuring a healthy population of ground squirrels or other small burrowing rodents (with the end goal of creating 100-200 rodent burrows/acre) (Solano Water Agency). If rodent burrows are insufficient, artificial burrows would be installed to reach said density. It is unclear the exact size preferred for this burrowing area nor its distance to the foraging habitat (discussed below) but it is clear the owls need openness near where they are nesting and dense vegetation in which to find prey (Trulio and Higgins 2012). This habitat must also be safe from flooding which would destroy nests and drown owlets and adults (Solano Water Agency).

Create (separately) quality foraging habitat This requires dense, tall grasses (>2'), shrubs or brush piles (between 80-100% ground cover) to promote insect and rodent population in areas neighboring burrows (Trulio and Higgins 2012). This habitat needs to be within approximately 600 meters of nesting habitat as once owls are established they spend the majority of their time within 600 meters of their burrow (Solano Water Agency)

Population goals

1 owl pair per 30 acres (Trulio and Higgins 2012)

1 successful new chick/year/pair once residency begins

Trade-offs

Clearing vegetation or keeping it low may be detrimental to other desirable plant communities such as native shrubs or trees which may otherwise thrive in restoration area.

It may be unfeasible to completely keep domestic or feral cats out of owl restoration areas.

The bare ground owls prefer may be less aesthetically pleasing to locals or nearby communities seeking to use the area for recreation or wanting to see thriving plant succession.

Owls may simply never come or relocated owls may return to their original homes.

B. Restoration Plan

Maintain and/or increase the population of ground squirrels (California ground squirrel, *Spermophilus beecheyi*). These burrows also aerate the soil and mix organic matter. This can be accomplished by installing dirt mounds which attract the ground squirrels. In addition, ensuring limited disturbance and pesticide use will enhance squirrel habitat. If squirrels are not desired, it is also possible to create artificial burrows (900 cm^2 and 10 cm wide) (Yolo Habitat Conservancy Plan 2015). The denser the burrows the greater preference of burrowing owls (100-200 burrows/acre is ideal) (Trulio and Higgins 2012). If completely absent, ground squirrels can be relocated to artificial burrows in restoration area.

Enhance habitat needs by creating ideal ground cover. Owls prefer 55% bare ground, less that 30% shrub canopy cover and grasses to be kept less that 6" year-round (Wildlife Research Institute 2005). There are some accounts of burrowing owls present in taller grass by using a burrow atop a mound though this is not preferred (Trulio and Higgins 2012). This can be done by planting low-growing vegetation, mowing (tractor or hand-held) or cow grazing (an ideal method as their dung also attracts beetles and is used by the owls around their burrows) (Wildlife Research Institute 2005). Fire could even be used as some models suggest it can play an essential role in owl population maintenance as it is the only natural process which reduces shrub levels (Machicote & Villarreal 2004). These methods do not harm nesting burrowing owls as they take haven underground (Dechant et al. 1999). Whichever method chosen, it is essential to keep grass low in mid-February (when new burrows are chosen), mid-May (when chicks are emerging) and mid-June (keeping vegetation low throughout the dry summer while adults feed their juveniles) (Wildlife Research Institute 2005). In high precipitation years, this schedule may need to be increased even if just targeted mowing around the burrows.

For protection, amble natural perches will be installed if not present. Installing 2'-3' high perches near burrows will further encourage owl habitation as they are used for detecting predators and hunting for prey. However, perches much larger than this (such as large trees) often encourage large predators (larger owls or hawks) and are therefore discouraged. A low fence or other barrier should be installed to clearly mark the area and discourage humans and domestic cats and dogs from entering it. Signs describing the project and educating the public should be posted as well.

Promote habitat for owl prey (insects, amphibians, rodents and reptiles) through rock and dust piles (2'-3' in height). Small rodents also typically favor heterogeneity. They prefer non-mowed sites with densely planted native perennials, shrubs and mixed grasses. Some examples of these species include *Ceanothus ssp, Lupinus ssp, Rosa ssp, Salvia ssp,* among many others which will be planted in designated foraging areas outside nesting burrows.

If goals are not met, existing burrows will be examined if there are any. Even in the right burrow density, owls still may not have the right mosaic of landscapes to immigrate.

New research from neighboring efforts (such as Santa Clara Valley Auburn Society's owl restoration efforts) will be examined and either new attempts to create natural or artificial burrows or to change vegetation managements techniques will be reviewed.

If owls never take up residency because the site never completely fits their needs, it may be considered wasted time and money. Vegetation kept low may have suppressed larger successional species such as shrubs and trees which could provide habitat for other species besides the owl. However, burrows home many more species in addition to the owl (such as salamanders, frogs and other rodents) in addition to aerating and mixing the soil in effect still positively benefiting the site.

C. Monitoring Plan

Either trained volunteers or a burrowing owl biologist should monitor ground squirrel, small rodent and insect populations as well as number or burrows, height of grass and canopy cover. If owls do immigrate, their number and reproductive success should be monitored. This will be done once a year and result in yearly management changes. 1 owl pair per 30 acres is considered a success. 1 successful new chick/pair/year is thereafter considered a success. If either of these goals are not achieved, management of burrows and vegetation will continue. If grass in the burrow area is exceeding 6" at all throughout the year, mowing management should be increased. If burrow numbers are less that 100/acre (after sufficient time for ground squirrel repopulation), then artificial burrows should be dug to reach this threshold. If any owls have immigrated to the site, management changes should be considered only after consulting a burrowing owl biologist. If goals are not met after a reasonable time (several years of squirrel repopulation and/or artificial burrow establishment) project goals may need to be reassessed and it is possible the project is not feasibility.

If there is successful immigration, monitoring will also include yearly documenting which sites owls preferred in terms of surrounding vegetation (height, species, distance to taller vegetation), burrow number and prey available (insect, rodent, amphibian and small reptile densities) as this information can be used improve future restoration projects. Level of monitoring these many prey populations is time consuming and expensive and therefore can only be completed within reason. As it is lesser studied, it would be more important to focus on distribution of burrow and foraging sites and the distances between them most preferred by the owls.

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<u>Bumble bees (Bombus sp.)</u>

Breahna Gillespie

Part I: Justification and Species Introduction

Justification

Essential to the floral composition and succession of ecosystems, native bees play a crucial role. Bees take on most the pollinating of native plant species. This pollination can provide large genetic diversity in the visited flower. Native species van be either generalist or specialized; those that are specialized tend to be efficient pollinators of those specific plants. Not only is this essential in natural ecosystems, it is also relevant for agricultural production (Kremen et al. 2002). European honeybees (*Apis mellifera*), an introduced non-native bee species pollinate agricultural fields and have extended their range into adjacent natural sites. European honey bees both domesticated and feral have declined since 1946 by 50-70% (USDA 1980). Native bee species have declined as well since both the introduction of European honey bees (Kremen and Ricketts 2000), the use of insecticides (Metcalf & Luckmann 1994), and the degradation and fragmentation of ecosystem (Allen-Wardell G et al. 1998). To maintain current site conditions or even restore, the decline of native bee populations must be mitigated by focusing on these disruptions.

Species Range

- Have a various range of impact due to the large populations of native bumble bees and solitary bees.
- Of the 4,000 bee species found in the United States, over 1,600 native bee species have been recorded in California (Frankie et al. 2005)

Habitat Needs

- The slope and soil compaction were the strongest indicators for nesting on a community-level examination. Distribution of nesting material was also related to the distribution of the bees (Sardiñas and Kremen 2014). Different nesting material can be utilized by different bumble bee species
- Of the many species of California native bees, most are either bumble bees (*Bombus sp.*) or solitary. Most solitary bees nest in the ground. The selection of a nesting site can be particular and appear to be limited by substrate, proximity to pollen and nectar sources, nearness to water (Linsley 1958). The closer the colony is to optimal foraging ground, a lesser energy expenditure is needed

Diet

- Bumble bees are considered “generalists” and visit broad array of flowers (Thorp et al. 2002). They do not need a specific species but need flowers to be present from late winter to early fall with a high abundance of flowers during the spring and summer months.
- Native solitary bees can be either specialist or generalists (Linsley 1958).
- Pollen is the main diet for the larva and is formed into almost doughy loafs; nectar is used as a supplemental for bumble bees. They often go between flower-visits of pollen collection to one that provides nectar. This is high-energy source (Thorp et al. 2002).

Predators

- For the larva, there are four groups that prey or negatively impact their development in their nests: those which prey on the egg, those which prey on developing or full-grown larva, those which starve the larva to death by eating the stores of food, those which feed on old cell and burrow refuse and accidentally have a negative effect on the host bee (Lisley 1958).
- For adult bees, robber flies tend to have the largest biotic effect on the bee population. Other predators can include crab-spiders. Parasites are almost exclusively flies (Linsley 1958).
- Further competition is given by the European honey bee. The recovery of the non-native bee can adversely impact populations of bumble bees in that they are out-competed for nectar-sources (Thomson 2016).

Behavior and Lifespan

- Bumble bees can live on average 4-6 weeks. More importantly, native bumble bee colonies are annual—a new colony emerges every early spring, derived from the efforts of the previous colony. Honey bees, on the other hand, are perennial and maintain presence by consuming their honey stores over the winter (Hatfield et al. 2012)
- Bumble bees unable to attain the proper nectar might resort to robbing the flower by nipping outside the floral parts to gain access to the nectar. This reduces potential pollination from other bees and over all decreases seed production (Buchmann and Nabhan 1996).
- At cool temperature bumble bees can shiver their wing muscles before foraging. This allows them to adjust their temperature and forage in cold weather that other insects re unable to withstand (Thorp et al. 2002).

Reproduction

- Some species cluster nest. They mate over the nesting site, males patrol, females active. Some mating may occur in the burrow itself. For the most part, mating occurs at or in the vicinity of a flowers providing pollen. (Linsley 1958).
- Proterandery, or the emergence of males before females is typical in solitary bees. This provides the immediate opportunity for fertilization in female bees (Müller1882).

- When the larva hatches, it feeds on the food stores, passes through a number of instars, and requires a certain number of weeks to complete development. This sequence of events is followed by a diapause for a majority of the year when conditions are unfavorable (Linsley 1958).

Decline

- Decline has occurred because of a number of factors. The introduction of honey bees has lowered native populations by both competition and introduced pathogens (Kearns et al. 1998). Pesticides places on crop plants have negatively impacted native bees and reduced populations.
- Habitat fragmentation has also inhibited native bees. They are unable to forage on flowers and cannot migrate to areas with better opportunities (Kearns et al. 1998).
- Besides these two causes of decline, the introduction of invasive alien plants, climate change, and introduced pollinator species of the invasive plants should also be noted as possible reasons for overall declines (Crenna et al. 2017).

Restoration

- **Wildfire can restore some native bee populations as they are adapted to this natural disturbance and it can remove some harmful factors (ie European honey bees, pesticides, etc.) (Cane and Love 2016).**
- The restoration of habitats will promote bee persistence and the colonization of intensely managed agriculture lands (McGonigle et al. 2015).

Part II: Goals, Management, and Monitoring Plan

A. Goals

a. Maintain and/or increase California native bumble bee populations by focusing on management of landscape fragmentation and habitat loss, pesticide use, and controlled decrease of insecticide use (Potts et al. 2010).

b. Improve habitat needs (large scale):

i. The intensification of farming practices has been seen as a cause of the decline of native bumble bee (*Bombus*) populations. This intensification has decreased natural habitat and subsequently increased habitat fragmentation, in associated loss of biodiversity (Goulson 2003). So, a provision of natural vegetation for both nesting, forage, mating, and hibernation is needed. Leguminous crops, which are essential in providing nitrogen for rotated agriculture crops, also provide a nectar and pollen resource (Goulson et al. 2005). The florescence provided by typical agricultural practice can be complimentary and adjacent to the native ecosystem (Willmer, Bataw & Hughes 1994). However, it should not replace natural resources as bumble bees need a season-long supply of pollen and nectar resources (Carvell et al. 2006). Measurement of flight distances shows that different species of bumble bees can range from 275m to 750 m. Body size and colony size are significant predictors of flight distance (Hatfield et al. 2012). If the quality of the foraging habitat is high, whether in amount of flowers or nectar and pollen, bumble bees flight distance decreases.

ii. Reduce or stop use of severe insecticides which are sprayed over many of the species the generalist bumble bee commonly visit. Bumble bees are particularly sensitive to pesticide use during springtime, when queen are founding colonies and colony size is incredibly small (Hatfield et al. 2012). In trying to avoid honeybees, insecticides are sprayed in the morning, as bumble bees are more active in cooler temperatures and low light levels (Thompson 2001). Systematic pesticides that accumulate in the pollen or nectar of flowers are of particular concern. The food brought back to the colony is then consumed by the larva, which later results in lower reproductive success (Hatfield et al. 2012). The sensitivity of the bees is still high, even sublethal levels can decrease overall reproductive success. The increased usage of neonicotinoids and the global decrease in bumble bee colonies worldwide suggests a harmful impact. As they are in particular sensitive, switching the timing or the severity of the pesticide is essential in perpetuating bumble bee colonies.

iii. Remove or drastically reduce (greater than 70%) highly invasive European honeybees (*Apis meliffera*) that can outcompete native bumble bees and prevent adequate forage for the plant species (Thomson 2004). Both the forager return rates and pollen foraging efforts decreases with increasing proximity to *Apis* colonies and lowers overall fitness of the forager. *Apis* has been known to forage up to 14 km away; however, their foraging activity is usually within a 1 km radius of the colony (Thomson 2004). The reproductive success and perpetuation of the bumble bee colony was positively correlated with distance to the *Apis* colonies in measurement of the gyne number, gyne ratio, mean gyne size, and male sightings.

c. Feasibility:

The list of goals provided for the improvement of the habitat, the decrease of insecticides and removal of *Apis* are feasible, and can be implemented on a range of sizes. It is difficult to estimate the number of bumble bee colonies in a specific species; interspecific competition between bumble bee species is also difficult. Nonetheless, the quality of habitat (the floral biodiversity and abundance) can have high inter-annual variability. Quantitative studies of native bumble bee populations for California are very rare. The Xerces Society is dedicated to the preservation of terrestrial invertebrates and could be a resource of volunteers in the bumble bee conservation (The Xerces Society for Invertebrate Conservation).

B. Restoration Plan

a. Maintain/Increase Population:

i. Few studies have established a baseline of bumble bees and have a historical account in California. A baseline will need to be created for the local bumble bee colony sizes and densities in interested sites. A survey of all *Bombus sp* show the biodiversity and can provide wide pollination of a variety of plants. This will require at a minimum of three years of data collection of both the bees and the habitat. We aim to see an increase in both colony size and abundance in the area of the site.

b. Improve Habitat Needs:

i. Bumble bees are generalist feeders and are the first to become active in late winter and last to hibernate in the fall. Because of their high foraging rate over a long period of time, they visit a wide range of plant species. Flowers present during early- and late-season are particularly crucial as at these times determine the successful establishment of later colonies (The Xerces Society for Invertebrate Conservation). Generally, bumble bees tend to prefer perennial plants because they tend to have higher quantities of nectar. Sowing a mixture of both annual and perennial grassland species as margins could negate many of the problems with favoring one plant habit over the other (Pywell et al. 2005). Planting in a 6m margin sown with four agricultural legume species and four fine grass species at 20 kg ha^{-1}, produced the highest flower abundance with a succession of forage plants flowering over the 3-year trial period (Carvell et al. 2006). A wildflower mixture (21 native wildflower species and four fine grass species at 37 kg ha^{-}) produced few flowers in the first year of establishment but flower abundance increased over the three. While grass does not provide nectar and pollen for bumble bee consumption, perennial bunchgrasses can provide nesting areas and other refuges for emerging colonies. Both mixtures led to a rise in bumble bee biodiversity and abundance; by the third year, the wildflower mix was as valuable as the pollen and nectar mixture (6-m margin sown with four agricultural legume species and four fine grass species at 20 kg ha^{-1}). A benefit to the wildflower mix, persistence for up to ten years. The grassland species mixture are likely to need re-sowing within 5 years.

Management of the landscape is crucial for bumble bees. Sites for nesting and overwintering must be maintained in order to keep a population of bumble bees present on the reserve. Mating for the production of new queens occurs mainly during late summer, early fall. While it is not unusual for queens to choose above-ground nesting sites, typically, underground sites are preferred. Ground-nesting mammal populations can provide future nesting sites in abandoned burrows (The Xerces Society for Invertebrate Conservation). Therefore, large patches of agriculture lands, grasslands, and wildlands should be kept undisturbed and untilled to provide secure nesting sites for the future queens. Ideally, downing leaf litter, wood, or other brush should occur during the summer to provide potential overwintering sites. Overwintering new queens can be easily disturbed: so tillage should not occur during this time. Other activities that might be needed to maintain the site (pesticide application, fires to remove vegetation, etc.) can be used during this period.

ii. Timing insecticide use for certain periods of the growth of an ecosystem could minimize the deleterious impact on the bumble bee colonies. Pesticide risk assessments are often carried out for honeybees but neglected for bumble bees. For example, pyrethoids are applied in early morning or evening which avoid honeybee phenology but are when bumble bees are most active (Goulson et al. 2003). Colonies produce new queens during summer and autumn of the year. Unlike *Apis* which is perennial, the *Bombus* is annual and the new generation is reliant on the prior generation's preparation of the new queens (Thomson 2004). Therefore, the best time to apply pesticides are the winter when the bumble bees are hibernating (The Xerces Society for Invertebrate Conservation). The use of margins in agriculture (at minimum 6m wide) acts as buffers against pesticide and fertilizer drift and behave as refuges for wildlife (Marshall & Moonen 2002).

iii. Little literature covers the removal of *Apis*; establishment of the honey bee is the goal of most agriculture ventures. Bumble bees, tend to outcompete *Apis* by having more available resources plant species. The buzz pollination, infamous to bumble bees should be noted in determining vegetation type. Planting species that can only be accessed by bumble bees, papilionaceous flowers (which can only be opened by large bumble bees); those that are only opened by buzz pollination (tomatoes, potatoes, and some berries) should be planted as well. This passive planting of bumble bee-preferred flowers could slowly extirpate any localized honey bee. Removal of by hand is hardly feasible—established honey bee colonies may hold up to 15,000 individuals.

C. Monitoring Plan

a. Monitoring of bumble bee populations is relatively quick, easy and inexpensive. It should take into account (1) overall declines in pollinator density (both native and non-native), (2) reductions in species diversity or shifts in species composition, and (3) declines in reproductive success or abundance of the plant species dependent on the pollinators (Biesmeijer et al. 2006). Historical data may be found in certain archives. Simply observing and recording the abundance of native bees on flowers during site visits of 15 minutes each provide good estimates of both abundance and diversity of bees visiting that site (Ward et al. 2014). The best monitoring and counting of native bees occurs during the middle of the growing season (May-July in California). Separate the site visits by two to three weeks. Even a single 30-minute survey with 400ft of transect is adequate for assessing bee diversity. Bees are most active in warm temperatures (15.5°C) low wind speeds (<8mph) and skies should be mostly clear (Ward et al. 2014). Size and fitness of colonies should be estimated pre-restoration, during restoration, and post restoration of specific site.

b. Monitoring of habitat will include assessment of pollinated vegetation success. Floral abundance, non-abortive seeds, and establishment of seedlings should be survey in the habitat assessment. Because the abundance of flowers varies over climatic factors and over the season, monitoring should occur during peak biomass of the plant species. With the allowance of nesting sites for the bumble bee, monitor and approximate the available nesting sites. Additionally, the foraging of the planted margin vegetation should also be assessed for their effectiveness. *Apis*, a less effective pollinator but easily established should be consistently be monitored for return to previously colonized habitat.

D. Research Needs:

a. There are still unclear areas that need greater research and attention. A clear understanding of the grounds needed for nesting and foraging habitats and the detriment of certain insecticides specifically to bumble bees need to be answered for bumble bee species colonies. Habitat quality, fragmentation, biodiversity and climatic factors all interact and can cause problems on bumble bees depending on caste, size and sex. Managers will need to decide if the simple bee monitoring aforementioned will be adequate enough for approximating bumble bee colony vitality and further succession.

b. The mixture for the margin in agriculture fields (Carvell et al. 2006) was found to be effective in the United Kingdom; similar assessments need to be done to see which planting works best in the Central Valley.

c. The interaction of bumble bees with European honey bees is poorly understood (Thomson 2004). Knowing the ramifications of the presence of the introduced species could play a vital role in the vivacity of bumble bee species. Because of the lack of understanding of the interaction between these two species and the role it plays in bumble bee colony stability and perpetuation, managers should evaluate the worth in removing *Apis*.

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Swainson's hawk (*Buteo Swainsoni*)

Seongyoon Hong

Part 1. Species Background and Justification

Why do we care?

Swainson's hawk (*Buteo swaisoni*) is a large Buteo hawk of the Falconiformes, sometimes separated in the Accipitriformes like its relatives (Wikipedia). Unlike any other buteos in the western United States, Swainsons's Hawks migrate long distances, are highly gregarious, and are largely insectivorous (England, 1998). It is important to know about the ecological resources needed by Swainson's hawk because they have declined radically in California, and was listed as a threatened species in 1983 by the California Fish and Game Commission (Smallwood 1995, California Department of Fish and Wildlife). This knowledge is also important because Swainson's hawk populations are threatened by land conversions and management decisions that leave enough ecological resources for only a minimum existence (Smallwood 1995). The dramatic Swainson's hawk population decline has been attributed to loss of native nesting and foraging habitat, and more recently to the loss of suitable nesting trees and the conversion of agriculture lands which have been converted to urban land uses and incompatible crops (Department of Fish and Game 1994). In addition, pesticides, shooting, disturbance at the nest site, and impacts on wintering areas may have contributed to their decline (Department of Fish and Game 1994).

Literature review

1. Migration

    A. The Swainson's Hawk breeds in the western United States and Canada and winters in South America as far South as Argentina (California department of fish and wildlife website).

    B. They typically return to nest sites in early March to April, immediately form pairs, and begin the nesting cycle. (England 1997).

    C. In the Central Valley of California fledging occurs between 1 July and mid-August (England 1997).

    D. Migratory flocks begin to form in late August and September, and most birds are apparently on the wintering grounds by November (England 1997).

    E. The round trip journey of the Swainson's Hawk may exceed 14,000 miles (Department of Fish and Game 1994).

    F. The species is included among the group of birds known as "neotropical migrants" (Department of Fish and Game 1994).

2. Foraging requirements

    A. The Swainson's Hawk adapted to the open grasslands, it has become increasingly dependent on agriculture, especially alfafa crops, as native communities are converted to agricultural lands (California department of fish and wildlife).

B. Preferred foraging habitats for Swainson's hawks include alfafa, fallow fields, beet, tomato, and other low-growing row or field crops, dry-land and irrigated pasture, rice land (during the non-flooded period), and cereal grain crops (including corn after harvest) (Department of Fish and Game, 1994).

C. Schmutz (1987) found that this hawk is more abundant in areas of moderate agricultural development than in either grassland or areas of extensive agricultural development (England 1997)

3. Nesting requirements

A. Although the Swainson's hawk's current nesting habitat is fragmented and unevenly distributed, Swainson's hawks nest throughout most of the Central Valley floor (Department of Fish and Game, 1994).

B. Nest sites are generally adjacent to or within easy flying distance to alfafa or hay fields or other habitats or agricultural crops which provide an abundant and available prey source ((Department of Fish and Game, 1994).

C. Department research has shown that valley oaks(Quercus lobate), Fremont's cottonwood (Populus fremontii), willows (Salix spp.), sycamores (Platanus spp.), and walnuts (juglans spp.) are the preferred nest trees for Swainson's hawks (Department of Fish and Game, 1994).

D. Only trees were used as nesting substrate in California (no telephone poles, electrical transmission line towers, platforms, etc.) (Friends of the Swainson's hawk organization, 2009)

4. Diet

A. The diet of the Swainson’s hawk in California is varied, but mainly consists of small rodents called voles; however other small mammals, birds, and insects are also taken (California department of fish and wildlife).

B. Major prey item for Central Valley birds include California voles, valley pocket gop hers, deer mice, California ground squirrels, mourning doves, ring-necked pheasants , meadowlarks, other passerines, grasshoppers, crickets, and beetles (Department of Fish and Game, 1994).

C. Ground squirrels comprised 70% of prey biomass of Swainson’s hawks and these ro dents are near the upper limit of prey size that medium sized hawk is able to subdue (Schmutz, 1987)

D. When ground squirrels are relegated to small fragments of grassland and decline in n umbers as cultivation becomes the dominant land use, Swainson’s hawks probably s hift to feed on voles and mice. (Schmutz, 1987).

E. During the breeding season, Swainson’s hawks eat mainly vertebrates (small rodents and reptiles),whereas during migration vast number of insects are consumed (Depart ment of Fish and Game, 1994).

F. Birds may use in excess of 15000 acres of habitat or range up to 18.0 miles from the nest in search of prey (Department of Fish and Game, 1994).

5. Threats and tolerance

    A. The most recognized threat to Swaison’s hawks is the loss of native foraging and bre eding grounds. Other threats include climate change, infrastructure placement, disea se, pesticide poisoning, and electrocution.

    B. Habitat degradation could occur through a variety of mechanisms. 1) Fires, which eli minate nesting opportunities in Joshua trees and riparian trees for decades until the v egetation recovers, 2) Off-highway vehicle use, which lead to a decrease in prey ava ilability or prevents the long-term recruitment of new nest trees, 3) Flood control pro jects that alter normal stream and wash hydrology leading to the loss of riparian habi tat and nesting opportunities, 4) Lowering of water tables that lead to the loss of nest ing habitat or contribute to a decline in prey availability (England, 1997)

    C. Recent threats to the persistence of Swainson’s Hawks include pesticide poisonings i n wintering ranges resulting in mass mortalities and loss of habitat within the breedi ng range (Joshua, 2008)

6. Restoration and management

    1. Because Swainson’s hawks did not decline drastically in response to cultivation, the y should respond well to relatively minor conservation efforts. If small patches of na tural or seminatural cover containing trees or shrubs are strategically distributed in a gricultural areas, Swainson’s hawks are likely to remain in reasonable numbers (Sch mutz, 1987).

    2. Although Swianson’s hawks have declined dramatically in California, this decline w

as only partially attributed to agricultural development (Schmutz, 1987).

3. Protecting agricultural lands in California through conservation easements is the first step in maintaining Swainson's hawks populations (Friends of the Swainson's hawk organization, 2009).

4. West Nile Virus was one such disease that affected bird species in the Central Valle y, but to date does not seem to have impacted Swainson's hawks in large numbers. By keeping genetic diversity strong and the range of Swainson's hawks large it is po ssible to limit the impacts of diseases on the species (Friends of the Swainson's haw k organization, 2009).

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Part 2. Goals, Restoration, Management

Goals

1. Maintain and/or increase Swainson's hawk populations. The population size in the Centr al Valley is usually estimated from 280 to 420 and recently it is increased to almost 100 0 pairs (Woodbridge 1988)

2. Natural habitat

   A. Swainson' hawks prefer short vegetation such as large grassland, shrubsteppe habita ts and don't like to exist in mountainous, forested terrain. (Woodbridge 1988). So, k eep open grassland areas with scattered trees or with small clumps of trees or shrubs which is suitable habitat for Swainson's Hawks (Dechant, Dinkins, Johnsons, Igl, & Goldage 2001)

3. Foraging habitat

   A. Provide proper size of home territory. Woodbridge said that the size of home ranges in Cental Valley varies from 336 to 8718 hactares. This variation depends on conditi on of the foraging habitat such as the distribution of high-quality foraging habitat, cr op mowing or harvesting schedules (Woodbridge 1988)

   B. As a foraging habitat for Swainson's hawks, provide alfafa fields or some low-grow ing crops such as tomatoes, beans, beets, etc. These habitats help Swainson's hawks to find their preys more easily when hunting in flight. Avoid planting crops such as corn, rice, sunflower, safflower, orchards, or vineyard which are not preferred foragi ng habitat for Swainsons's Hawks. (Swainson's Hawk Program-City of Elk Grove 2

017)

C. Do not need to too much worry about water. Woodbridge said that Swainson's hawks can live in the desert and dry areas where surface water is unavailable. This means that drinking water is not always necessary for the survival of the Swainson’s hawks (Woodbridge 1988).

D. Reduce or stop using pesticides or insecticide such as toxic organophosphate pesticide to kill the grasshoppers in the Swainson’s hawks’ foraging habitat. It would be harmful for them because they mainly eat the grasshoppers in the fields. (Woodbridge 1988).

E. Woodbridge said that weedy ruderal fields and cheatgrass-dominated grazing lands are used little by foraging Swainson’s Hawks because they couldn’t provide sufficient prey population. Thus, control these kinds of weedy exotic plant species that might reduce prey availability of Swainson’s hawks in habitats. In addition, the exotic species like Russian thistle, cheatgrass and tumble-mustard (*Symbrissum* sp.) also have to be controlled because they might increase the possibility of fire, reduce cover of less fire-resistant native perennial grasses and shrubs (Woodbridge 1988).

4. Nest site

Provide riparian forest or remnant riparian trees for Swainson’s hawk nesting. Height of nest trees must be ranged from 2 to 22 m (Dechant, Dinkins, Johnson, Igl, & Goldade 2001). Woodbridge said that the most commonly used tree species in the Central Valley for the nesting habitats are Fremont’s cottonwood (*Populus fremonti*), willows (*Salixsp*.), sycamores (*Platanus sp*.), valley oaks (*Quercus lobta*), and walnut (*Juglans* *sp*.) (Woodbridge 1988). Dechant, Dinkins, Johnson, Igl and Goldade said that the minimum radius of nesting territories was 0.35 km (Dechant, Dinkins, Johnson, Igl, & Goldade 2001).

5. Feasibility

   The goals above including improving habitats and increasing the number of species are quite feasible. The main reason the population of Swainson's Hawk is decreasing is due to the urbanization removing farm land and affecting nest trees which used to provide quality habitat. Thus, if working with the resources agencies, partner organizations, and the public to preserve agriculture and promote quality conservation project within the Swainson's hawk's range, it would be feasible.

<u>Restoration plan</u>

1. Maintain populations

   To maintain population of Swainson's hawks, provide high-quality foraging habitat, suff icient nesting spots and control the harmful disturbances. The more information about ea ch factor will be followed below.

2. Natural habitat

   A. Establish suitable natural habitats like grassland, shrubsteppe habitats (Woodbridge 1988). Keep the vegetation low by mowing regularly so that Swainson's hawks can f ind their prey easily. In addition, prevent the predators from coming to these natural habitats which could eat small mammals so that decrease the prey of the Swainson's hawks.

3. Foraging habitat

   A. Swainson's Hawk foraging habitat should be mitigated within 10 miles from the proj ect site based on the hawk's foraging radius. Therefore, ideal mitigation is agricultur al lands of low growing row or field crops located within 10 miles of a project site, a nd in close proximity to other protected areas ("Swainsons' Hawk program-City of Elk Grove").

   B. It is important to keep crops low about 0-15cm heights to provide high quality foragi ng habitat when they come to these habitats after winter (Swolgarrd, Reeves, &Bell 2008). They come to the Central Valley in early March or April (Woodbridge 1988). Swolgarrd, Reeves, and Bell said that the peak number of observations of Swainson' s Hawks foraging in alfafa is observed after mowing at which the plant height is 0-1 5cm (Swolgarrd, Reeves, &Bell 2008). As Woodbridge (1988) said in the article, ha rvest or cultivation activities have a key role in foraging activities of Swainsons't Ha wks and Swolgarrd, Reeves, and Bell (2008) also showed the result that Swainson's Hawks prefer short vegetation or crops that were harvested at least once during the s eason. In addition, typical flood irrigation can also benefit the hawks by forcing sma ll mammals and insects to retreat from their hiding places (Swolgarrd, Reeves, &Bel l 2008).

   C. Using less toxic insecticide is recommended because acute toxicity from poisoning b y organophosphate insecticides used to control grasshopper outbreaks which is one o f the main prey of these hawks in alfafa result Swainson's Hawks to die (Benchard, 2010). Also trying not to spray directly to the hawks because they will die immediat ely after being sprayed by pesticide applicators while they foraged in fields (Benchar d 2010). The best way to protect Swainson's Hawks from pesticide/insecticide is stopping them from coming to the crop fields during applying these chemicals. We can do this by applying these chemicals during winter season when they are not existed in the Central Valley.

D. Weedy exotic plant species, Russian thistle, cheatgrass and tumble-mustard (*Symbrissum* sp.) have to be controlled by targeted herbicide that would not have a negative impact on other crops. On smaller scale sites, this would be removed by hand with the volunteers.

4. Nesting habitat

A. Plant trees with proper height (2 to 22 m). Trees most commonly used for nesting in the Central Valley include Fremont's cottonwood *(Populus fremonti*), willows (*Salix* sp.), sycamores (*Platanus* sp.), valley oaks (*Quercus lobata*), and walnut (*Juglans* sp.). Introduced species such as *eucalyptus* sp., pines, and redwoods also are used occasionally (Dechant, Dinkins, Johnson, Igl, & Goldade, 2001).

B. If there are some livestock around the nesting area, build exclosure around nesting trees to provide and protect nesting sites (Dechant, Dinkins, Johnson, Igl, & Goldade, 2001). In addition, if the area has not enough trees for nesting spot, it would be a good way to build artificial nest structures made of wire-basket (Dechant, Dinkins, Johnson, Igl, & Goldade, 2001).

5. Risks, Problems, Uncertainties

A. The result of decreasing pesticides is not sure. This is because if the use of pesticide for grasshoppers is decreased, the population of the prey of the grasshoppers will be increased. It has possibilities to impact on the crops which is also important factor fo r Swainson's Hawks.

Monitoring plan

1. Monitoring population
   A. As a method to monitor the population of Swainson's Hawks, roadside transects would be recommended. When monitoring distant areas from road, use boats, canoe, or on foot.
   B. Monitor at least annually.
2. Monitoring reproduction
   A. Monitor nesting areas every one to two weeks until final nest fates were determined from March to July to check the success of the nesting. (Benner, Sousa, 2009).
   B. Monitoring in the morning time is recommended. Breeding pairs seemed most active in the morning time so that it is easily to observe them. Using binoculars and spotting scopes is also recommended to reduce the disturbances during observation (Benner, Sousa, 2009).
   C. In addition, checking the old nests in the winter when the trees are leafless would be helpful to determine occupancy in the next spring. This is because the old nests are likely to be revisited (woodbridge, 1988).
3. Monitoring foraging habitats
   A. Check the use of the pesticides. Farmer education programs and restrictions on use of highly toxic organophosphate pesticides should be implemented (Woodbridge, 1988).

Research Needs

More information is needed about potential harassment and diseases which can have an impact on the Swainson's Hawks in the site. During the nestling season, Swainson's hawks can be particularly vulnerable to physical or audible harassment that is not familiar with them. Harassment that could have negative effect on Swainson's Hawks are diverse from noise (freeway noise, construction noise, farm equipment noise, etc) to any large scale activities that birds would not have usually encountered at their nest site. Therefore, knowing potential harassment around the project site would be required and even when monitoring the sites, you should remain at a distance. Second, diseases can occur and reducing population or a species and can have devastating effects. For instance, West Nile Virus was one such diseases that affected bird species in Cental Valley (but fortunately, to date does not seem to have impacted Swainson's hawks in large numbers). Diseases can spread easily when birds are roosting, or foraging together and can be passed from parents to young. So it is important to manage the diseases around the sites regularly (Bardbury, 2009).

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California Slender Salamander (Batrachoseps attenuatus)

Sierra Jasper

Part 1- Literature Review: Project background and Justification

A. Why do we care?

Suitable habitat for salamanders across the US and the World are beginning to disappear. With an increase in both climate change and urban expansion, the salamander's habitat is quickly declining. Without the restoration of these types of areas the salamander as well as all other salamanders will soon become extinct or highly threatened and endangered. Once lost, we cannot get it back that is why conservation is so integral in keeping the species alive. Batrachoseps attenuatus is of least concern according to the IUCN Red List but, the Batrachoseps attenuatus is endemic to California and a small part of southwest Oregon. This species is particularly important in the Sacramento area as the populations that are located here tend to be very isolated from the rest of the population.

B. Literature Review: Species Information

Species Range:

- Batrachoseps attenuatus is endemic to California and a very small part of southwest Oregon (IUCN Red List)
- In California, Batrachoseps attenuatus occurs throughout the coastal ranges and valleys from Lake County south to the northern margin of Monterey bay lowlands. It is also found in

several isolated locations within the Sacramento Valley in riparian habitats. A single record is known from near Shasta Reservoir, Shasta County (Boundy 2000).

- Habitat elevational range is sea level to about 4,000 ft. (Stebbins 1985)

Habitat Needs:

- Grasslands with scattered trees, chaparral, woodlands, redwood forests. It usually is found under leaf-litter, rotten logs, and surface debris when the surface is moist (IUCN Red List)
- This species can be found in a wide variety of habitats across its range including coniferous forests, oak woodlands, grasslands, chaparral, urban areas, and coastal scrublands. (Olson 2008)
- In northwestern California, this species was reported to be more abundant in older forests compared to young forests, and abundance decreased with elevation and distance from the coast. This is most likely due to more moisture present thus less cover is needed. (Olson 2008)
- Individuals tend to stay under logs, bark, rocks, boards, and other surface cover, and in damp leaf litter. They also tend to be more active on the surface during the rainy season (November–April/May for most of the range, later in moist, coastal forests) (Amphibia Web)
- Batrachoseps attenuatus is a terrestrial salamander that does not need standing or flowing water for any part of its life cycle. (Olson 2008)
- limited dispersal. Home range is only 1.7m in diameter (Miller 2005).

Diet

- Prey consist of small insects (especially springtails and small beetles), snails, isopods, mites, and spiders (Amphibia Web) (Olson 2008)
- Forages primarily under or within surface objects such as decaying logs, pieces of bark or flat rocks, in leaf litter, and in the open, near cover. They may also forage within termite tunnels and earthworm burrows. (Morey)

Predators

- Predators are not well known but include ring-necked snakes (*Diadophis punctatus,* Cunningham 1960), sharp-tailed snakes (*Contia tenuis*), garter snakes (*Thamnophis atratus*), California giant salamanders (*Dicamptodon ensatus*), and scrub jays (Olson 2008)
- They have a predator response called the unken reflex. In which they posture their body in a position that displays the color on their underside which tells their predator they may be toxic. (Brodie)
- They also have tail autonomy in response to predation. (Brodie)

Behavior and Lifespan

- Active on the surface during moist periods (usually October to May), usually at night. Aestivates during drier periods. (Morey).
- Surface activity corresponds to moist surface conditions, which for most of the range means a period of November–March/April, with local differences related to elevation, slope

exposure, and recent precipitation. Surface activity is extended in some areas, such as those receiving daily on-shore fog or in closed canopy redwood forests, where moist conditions prevail outside the rainy season. In the San Francisco Bay area, surface activity begins in October and extends to May. In the moist redwood forests of the Santa Cruz Mountains, activity may occur in all months.

- During the dry season, these salamanders retreat underground, using old root channels, earthworm burrows, or deep talus. (Amphibia Web)
- Estimated to live to at least 8 years old (Wake and Castanet 1995)
- sexual maturity between the ages of 2-4 (Amphibia Web)

Reproduction

- Reproduction is terrestrial (Amphibia Web)
- Courtship behavior probably occurs underground, but the timing is unknown. (Amphibia Web)
- Eggs are oviposited in the fall under surface cover objects or underground (Olson 2008)
- Females may not always stay with eggs. Females can breed every year. (Olson 2008)
- This is a terrestrial salamander that does not need standing or flowing water for breeding (Olson 2008).

Decline.

- Batrachoseps attenuatus is not listed as a threated species. The IUCN Red List has the California slender salamander listed as Least Concern. (IUCN Red List)
- Limited populations in the Sacramento region. (Boundy 2000).

Threats

- Disease
    - The amphibian chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*) has recently been detected in California slender salamanders in Berkeley, California (Olson 2008)
- Fire
    - Effects are unknown. Low intensity fires are likely not going to have adverse affects especially during times when the salamanders are subterranean. More research is needed. (Olson 2008)
- Chemical Application
    - Herbicides, pesticides, fertilizers may have large impacts on these salamanders as their skin is permeable and can take in lethal chemicals. The threat of chemical application is low in Oregon. (Olson 2008)
- Global Climate Change
    - Increased temperatures due to climate change could cause many adverse affects on fire, flood and other natural regimes in nature. With increased temperatures the California slender salamander may need to shift its range either up in elevation or north to cooler climates. This shift in range could cause a change in prey and predator species of the batrachoseps attenuatus. (Olson 2008)
- Fragmentation of Population
    - With increased population growth of people, expansion of urbanization may always be a threat to natural communities. Urbanization often causes other changes such

as river or topographic changes that can cause populations to become isolated. (Olson 2008).

Restoration

- Compaction of tilling of soil during hot times of the year could cause desiccation of the salamanders as they use burrows to escape the heat. (Betsie 2005)
- Land-use activities that affect surface microhabitats and microclimates may impact individuals or populations at occupied sites. (Olson 2008)
- Any use of chemicals, herbicides or fertilizers can have adverse affects since their skin is very permeable. (Olson 2008)
- Fires during warm times of the year should not have a huge adverse affect on these salamanders since they spend most of their time underground in burrows (Olson 2008)
- canopy retention, down wood management and reduced substrate disturbance would benefit this species since they rely on moisture to stay alive (Olson 2008)

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Part 2- Goals, Management, and Monitoring Plan

A. Goals

The California slender salamander is an endemic species to California and a small portion of southern Oregon. The main restoration goal is to maintain or increase the populations of Batrachoseps attenuatus (IUCN Red List). In order to maintain and increase population sizes, these habitat requirements much be implemented:

i. Provide grasslands with scattered trees for shade cover as well as leaf-litter, rotten logs and surface debris to provide surface moisture, cover as well as egg laying sites (IUCN Red List). Cover given by trees is needed more in areas away from the coast (Olson 2008). Juvenile salamanders tend to be more resilient than adults to sub-optimal leaf litter cover (Amphibian Web).

ii. Provide small insects, snails, mites and spiders as a prey source (Amphibia Web).

iii. Eliminate the use of herbicides, pesticides and fertilizers due to the salamander having highly permeable skin. (Olson 2008)

iv. Reduce fire regimes at least when these salamanders are active on the surface from November to April. Low intensity fires may not have adverse affects during periods when the salamanders are subterranean (Olson 2008).

These goals are feasible in a small scale project that can be monitored from time to time. Once the habitat requirements have been provided short term monitoring should be enough for the California slender salamander to establish. Long-term monitoring may be needed to ensure that invasive species do not come in and change the dynamic of the community of ecosystem.

B - Restoration Plan

a. Maintain/ increase population

It was found that an average density for California slender salamanders is between 2,939-3,458 salamanders per hectare (Lannoo 2005). This however does not give us enough information to determine the exact density of our location and habitat. It also does not provide us with a minimum number for the population to persist and grow. More studies will need to be conducted to determine how many salamanders will be able to survive in a certain habitat type and how many are needed to keep a population going.

b. Improve habitat requirements

i. Initially establish a grassland with some type of older forest (Olson 2008). B. attenuatus was 10 times more abundant in the old-growth compared to logged forest (Amphibia Web).

ii. If only suboptimal conditions are available, juvenile salamanders are the best option because they often are found in sub-optimal conditions under relatively smaller pieces of cover.

iii. canopy retention, down wood management and reduced substrate disturbance would benefit this species since they rely on moisture to stay alive (Olson 2008)

iv. Damp leaf litter, logs, bark, boards, and other surface cover is required for adult salamanders especially between November- May when they are most active on the surface.

v. During the dry seasons, deep root channels or earthworm burrows are required to avoid desiccation (Lannoo 2005). If these are not present naturally in the system, artificial burrows will need to be created to give the salamanders a place to hide from the heat. These salamanders also use these burrows to forage for food (Morey).

vi. Stop the use of herbicide, pesticide, and fertilizer because of the highly permeable skin of the salamander. Any type of chemical that comes in contact with the salamander will be absorbed into its body (Olson 2008).

vii. Targeted fires will most likely have little adverse affects if done during the salamander's subterranean period drying the drier months.

viii. Mowing of any sort may be more plausible during the summer months, June to October, when the salamanders are underground in burrows.

ix. Chytrid fungus Batrachochytrium dendrobatidis (Bd) is an especially dangerous disease to all amphibians so it is extremely important that any amphibians brought into the restoration area be tested for this disease before being placed in it (Olson 2008). This will prevent a rapid decline in salamander population densities.

x. Soil compaction through tilling during hot times of the year could cause desiccation of the salamanders as they use burrows to escape the heat. (Betsie 2005)

xi. Land-use activities that affect surface microhabitats and microclimates may impact individuals or populations at occupied sites. (Olson 2008)

xii. Often found in suburban yards and lots (Stebbins 1985); therefore, this salamander seems tolerant of moderate habitat alteration from human activity.

xiii. Not much is known about hatchlings but they are typically observed around December to February so special attention should be given to habitat alteration during these months.

B. Monitoring Plan

i. Monitoring the salamanders in the habitat will require abundance and densities to be measured. This can be aided through the use of cover boards and area constraint surveys. Both of these methods can help in determining the densities and abundances of salamanders to determine if the population in our habitat is growing or shrinking. These methods should be implement before restoration, during restoration, and after restoration to determine the trend of growth.

ii. Cover boards can provide the salamander with a nice a cool place to rest, which increases the biologist chances of encountering the animal.

iii. Area constraints are basically a quadrat sample of an area in which biologist sample a small plot of land and record the amount of salamanders that they find within that plot. This form of sampling helps in determining the densities of salamanders in the restored area.

iv. Monitoring should also be done during winter and spring months when the salamanders are most active on the surface. It should also be done in the beginning or end of the day when it is the coolest, since the salamanders will be less active once it starts to warm up.

v. Monitoring should be done regularly in the beginning of the restoration plan, so that changes in abundance and density can be seen and acted upon quickly if needed, but monitoring need to be as frequent for the long-term.

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<u>The Red Fox (*Vulpes fulvus*)</u>

Christina Scott

Part I: Species Background and Justification

A). Why do we care?

The red fox is a fairly common predator in North America. In North America, there are two species of red foxes, native and non native. The nonnative red foxes were first introduced to the Sacramento Valley of California in 1890(Lewis 1999). They were valued for their fur and raised on farms to provide pelts for garments. The farms were located mainly in Sacramento Valley and Southern California. When fur lost its value in the 1960's, the farms began releasing the domesticated foxes. Fox populations did not spread until the 1970's. Their range then expanded exponentially, radiating outward from points associated with established fur farms. Foxes have been able expand so easily with the help from urbanization of coastal and low-lying areas. With the destruction of native habitat, these mesopredators are able colonize niches left unoccupied by their competitors (Crooks 1999). Invasive mammalian predators contribute significantly to the decline in biodiversity with the red fox being one of the top species (Sacks 2016). The invasion of the European red fox threatens the survival of native and endangered small mammals and birds. Birds such as the endangered ground nesting birds have further declined in numbers as a result of predation from the red fox. In general the non native red fox is a threat to the native flora and fauna. If their spread is not monitored, they have can have serious impacts on lowland habitats including the restoration site.

B). Species Information

<u>Range</u>:

- The red fox has one of the widest geographic ranges due to human introducing the species to previously unoccupied regions(Lewis 199). Red foxes are found throughout most of North America. Their distribution expands from the eastern United States, throughout most of the central, and western states. In California, their ranges are mainly in the Sierras, Central valley, and coastal regions.
- The native red foxes are more cold adapted species and are found at higher elevations in boreal and montane habitats. The natives are more skittish and sensitive to human activity, causing them to avoid urbanized and disturbed habitat (Kamler 2002). The non-native foxes differ in that they are more generalists. This allows them to occur in a wider

array of habitats. The invasive red fox has a much larger range than their native counterpart. This range continues to expand with the encroachment of urban cities on undeveloped land (Kamler 2002).

- Non native red foxes have found success in human-dominated environments and have established populations close to humans, in urbanized and agricultural areas.
- In California, the foxes range includes much of the southern and central coast spanning from San Diego County to Point Reyes National Seashore. The foxes area also reported to live throughout the Sacramento and San Joaquin valleys, Shasta County, and as far east as Riverside County(Lewis 199).

Habitat:

- The nonnative red fox is a habitat generalist. They are able to adapt well to disturbed areas and have adapted well to urban environments. It has been shown that the foxes rely on disturbed urban environments for food and shelter. Within urban areas, they prefer open spaces such as city parks and large gardens. These spaces give the fox opportunities to find shelter and food (Harris 1977). In Britain, it was found that during the day, foxes prefer to stay in shaded areas under large trees or in old sheds. The foxes also share this space with each other. The availability of daytime spaces was found to be the limiting factor in fox abundance(Harris 1977).
- Besides urban areas, nonnative red foxes are found in lowland areas such as agricultural fields, marshes, and wetlands that are in close proximity to urban landscapes (Kamler 2002).

Diet:

- The diet of red foxes consists mostly of scavenged items, invertebrates, and vertebrate prey. This includes birds, small mammals, and earthworms. Fruits, livestock, and domestic animals does not make up a significant portion of their diet. In urban areas, much of their diet consists of scavenged items such as trash and food left out by people for them.
- Red foxes are known to switch prey and food types depending on season and abundance. In the fall fruits become a significant portion of their diet. Birds and rabbits become dominate parts of the diet from spring to early summer (Doncaster 1990).

Behavior, Morphology, and Dispersal:

- Nonnative red foxes fur coloration is a dark red or cherry color. They are also much larger than the native red foxes (Kamler 2002).
- Red foxes are monogamous meaning that they have one reproductive partner for a season. These breeding pairs will set up territories and defend that area from other individuals (Sacks 2016). After the breeding season, the pairs tend to break up and the young will venture from their home range to find other suitable habitats. Juveniles exhibit male-biased dispersal from their natal area around two years of age. Foxes have been documented to disperse 400 km or more from their original home range. While females have been found to disperse, their dispersal distances are not as far. Females tend to stay close to or in their natal range. This is because females will often act as nonbreeding helpers in raising pups (Sacks 2016).
- Since juveniles are the main dispersers, they are often responsible for colonizing or recolonizing areas. If population densities are low in a particular area, young foxes will quickly move into vacant areas and fill those empty spots. Areas that are subjected to intense predator control and removal showed high ratios of young to adult (Harris 1977).
- Non native red foxes exhibit high levels of fecundity, allowing them to have more pups in a litter. They also possess a high level of tameness. The foxes lack wariness of humans and comfortable around human activities. Their behavior is the result of multiple generations of selective breeding by fur-farms to produce domesticated foxes. These traits has allowed them to become better invaders by having a greater reproductive output and a higher tolerance to disturbances (Sacks 2016).

Impacts:

- Nonnative red foxes threaten both the survival of ground nesting birds and genetic integrity of native red foxes due to hybridization (Sacks 2016).
- It is estimated that 50% of all rare vertebrates in the United States are threatened by introduced predators. In California, predation from nonnative red foxes was responsible for a 50% decline of the endangered clapper rail in less than 5 years (Flemming 2006).
- In countries such as Australia, the introduction of red foxes has led to the extinction of populations of rodent and marsupial species on the mainland (Kamler 2002).
- The Prairie Pothole region of North central America produces about half of all the North America's ducks. Fox predation on nesting hens and nestlings are responsible for the decline in recruitment among duck leading to population declines. The group of ducks that are impacted the most are the dabbling ducks. For dabbling ducks, such as mallards, there has been an increase in hen mortality during breeding season. This is because dabbling ducks are upland nesters making them easier to catch. For all study areas in North Dakota, South Dakota, and Minnesota it was estimated that about 761,000 adult dabbling ducks were taken by foxes annually (Sargeant 1984).

Restoration:

- Non native red foxes threaten successful restoration efforts of lowland wetland areas. Because of their ability to adapt quickly and to a wide range of habitats, the foxes can impact the species trying to be restored. Nonnative red foxes have been responsible for the decline and extinction of native, endangered, or threatened species (Kamler 2002). If non native foxes occur in the area tended for restoration, then measures need to be taken to manage or prevent damage from this invader.
- In California there are control efforts in place to control the nonnative red fox. These methods were put in place to protect ground nesting birds from fox predation (Kamler 2002). Other countries, such as Australia and England have implemented ways to control their invasive fox populations. In Australia the main form of control of foxes is culling and poisoning. Foxes are shot at night with the use of high powered lights to stun them. A method used to deliver toxins to the foxes is through the use of mechanical ejectors. Devices such as M-44 ejectors are tubes containing poisons such as cyanide. These devices are spring loaded and are activated by the fox biting or pulling on it, causing the capsule to explode. This delivers a lethal dose of toxin, killing the animal almost instantly (Fleming 2006). The advantages to this method is that they are species specific, minimizing nontarget consequences. The disadvantage is that they are relatively expensive.
- While the location may be different than our target areas, the principles for vertebrate management are the same. They suggest a strategic approach that contains six components, 1) Define the problem quantitatively and qualitatively, 2) Develop a plan, 3) Implement the plan, 4) monitor all aspects of the plan 5) Evaluate the results collected from monitoring, and 6) Revise plan when needed in order to address issues found in parts of the plan(Fleming 2006).
- Light use of trapping and other control methods are better than intensive methods of control. This because of recolonization events by juveniles. If populations are reduced quickly and in large numbers, individuals from surrounding areas are encouraged to come into the area (Harris 1977).
- At this point in their introduction, the non native red foxes have become established in California, meaning that full eradication is not possible. The best strategies for controlling populations is getting the population to low densities through methods of poisoning and trapping. After densities are low, exclusion fences can be erected to prevent dispersers from colonizing the newly open habitat. While the densities are low, populations must be monitored in order to catch any increase in individuals who enter the restoration area. This way, control can happen quickly with minimal effort and expense.

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Part II: Goals, Management, and Monitoring Plan

A) Goals

i) Decrease populations/or eradicate non-native red foxes from the site through means of lethal control before, during, and after restoration is completed.

ii) Start first phase of eradication late November/early December and complete in March/April. Original populations should be reduced by at least 70% in the first three months of control. Reduce the remaining 30% in the last two months to at least 1-2%. This should be done before any site restoration begins.

iii) Setup and maintain physical barriers to deter/prevent re-entry during and after restoration. Construct barriers once the original local populations have dropped by 45% to prevent growth from immigration.

iv) Prevent density dependent responses by maintaining a moderate removal rate of about 35% annually after site is restored to prevent maximum population growth for red foxes. Have higher rates of juvenile removal than adults. At the end of every breeding season, from September through November, increase trapping efforts to target juvenile dispersers. Juveniles are able to breed within their first year after dispersal (Sacks 2016). Increase vigilance during this three month period and note any red fox sightings, tracks, scat, or changes in prey species densities.

v) Foster recovery of native species to limit open niche availability. This includes, but not limited to, natural predators and competitors (Crooks 1999). Research native species' needs and ecology. Alter landscapes to provide these species higher chances of survival.

vi) Develop a continuous monitoring plan to prevent densities from increasing after they are lowered. Take an integrated pest management approach with control. Use a combination of lethal (poisons, trapping, euthanasia) and non-lethal (fencing, trophic interactions) to suppress red fox densities. Modify IPM plan yearly based on previous results.

b) Feasibility

i) Trapping of red foxes may prove to be difficult, especially when trapping juveniles. At 3-6 months of age, red foxes are more difficult to trap for they lack the necessary weight to trigger it (Harding 2001). The trigger on the trap can be set to finer settings, however this can potentially lead to higher non-target consequences. It is also unclear if juveniles of 6 months of age are more or less susceptible to traps. Foxes also have the ability to recognize traps and will eventually learn to avoid them.

ii) The non-native red fox is established in California and continues to expand their range. Genetic analysis has determined that current distributions reflect a continuous population throughout California. The non-native red foxes population growth is exponential (Sacks 2016). Long term total eradication is not possible. Maintaining low densities requires constant monitoring and intervention by managers, which can be costly.

iii) Urbanization provides red foxes with shelter and food sources. Urbanization serve as corridors for dispersal increasing connectivity. More development between their preferred habitats causes the red fox to travel farther. Often humans intentionally set out food for them. This only draws them into these areas making urban spaces more suitable. Since the site is located near development, these factors will come into play. Human tendencies cannot be controlled and suburban environments cannot be altered.

B) Restoration Plan

a) Control methods

i) Use physical barriers (fences, walls, etc.) to prevent entry. Exclusion fences should be used to control the emigration of foxes. The fencing should be tall enough to discourage the foxes from climbing over. Based on other canid barrier designs, the fence should be about 1.8m high. They can be made out of wire netting or mesh and can be electric (Flemming 2006). Fencing is most effective on smaller scales and should be use to protect major nesting and highly sensitive areas (Department of fish and Game, 2015). Fencing is not completely fool-proof. Foxes my still try to get through depending on their level of desperation. Red foxes can dig or climb fences if the resource being protected is desirable enough. Fences should go at least 1 foot below the surface. In addition, they should be smoothed or electrified to deter climbing.

ii) Lethal control is necessary in reducing red fox densities. Bait containing poisons, such as compound 1080, are sufficient in removing non-native foxes. Compound 1080 is target specific and environmentally conscious. It is naturally occurring and does not break down into the environment (FAQ: Wild dogs and poison baiting 2017). Red fox specific doses can be placed in meat scraps or meat fat and delivered by strategically placing ground baiting a designated locations. In order to minimize non-target losses, bait stations need to be designed to prevent other organisms from consuming the poison (Flemming 2006). 1080 should be used sparingly and after initial populations are removed. Do not use poisons during wet season or during rainy weather. 1080 does not kill instantly and red foxes can travel significant distances from site (FAQ:Wild Dogs and Poison Baiting 2017). After poison baits are set, patrol the site and surrounding area to locate fox carcasses or dying foxes to prevent scavenging.

iii) Implement light trapping with steel-jawed leg-hold traps as a form of removal. Light trapping is more effective than intensive trapping. Intensive trapping lowers densities too quickly, encouraging dispersers to enter the area (Harris 1977). Under California law, steel-jawed leg-hold traps must be padded, have an anchor chain attached to the center of the trap, and a double swivel mechanisms along the chain. Padded leg-hold traps, also referred to as "Soft Catch" trap, are humane and designed to reduce excess injury (Department of Fish and Game 2015). The pads need to be regularly checked and replaced when worn. The treadle at the center of the trap needs to be adjusted so only the weight of a fox can set it off. Domesticated dogs and other animals of similar weight have the potential to set off traps. Therefore, traps should be placed at least 10 ft from walking paths. Place signs at site for pet owners to keep dogs on path and on leash. Leg-hold traps need to be checked daily and cannot be set within 150 yards from any structure (California Department of Fish and Wildlife).

iv) Humanely euthanize captured foxes. A lethal injection containing sodium pentobarbital will be administered to captured individuals. If trapping is carried out during breeding season, pups must be removed from den sites and euthanized (Department of Fish and Game 2015).

v) Encourage naturally occurring coyote populations. Coyotes compete with the red fox for resources. Coyote presence keeps fox densities low and discourages red foxes from becoming established. Coyotes were once present in most marsh and wetland ecosystems in California (Department of Fish and Game 2015). When coyotes disappeared from these ecosystems do to development, an open niches were created, releasing mesopredators from competition pressures. Non-native red foxes now occupy many of these niches, altering trophic levels. Mesopredator release hypothesis states that top predators have an indirect and positive effect on prey species (Crooks 1999). By maintaining a healthy population of coyotes at the site and outlying areas, red foxes will be subjected to top down control.

b) Modify Habitat:

i) Habitat modifications should be made to favor vulnerable species. For ground nesting birds, it is important to provide areas that are both safe and useful. Such as, but not limited to, creating nesting islands surrounded by water. Vegetation on these islands should be removed or kept low to increase visibility. For species that are more cryptic, adequate cover should be provided. Enhancing water quality, hydrology, soil quality, and other wetland conditions will allow for marsh plants to flourish. Established native plants will provide enough cover for small mammals and birds. Supplemental cover and nesting habitats can be provided. Pipes can be placed near nesting areas to provide shade and hiding places for chicks (Department of Fish and Wildlife).

ii) Make as much of the space as possible unsuitable for foxes. The nonnative red fox prefer sites with plenty of daytime cover and shade. It has been found to be the limiting factor in choosing daytime habitat (Harris 1997). Remove or avoid building large structures that can provide significant shade. Trees that will be large at maturity should be planted at the edges of the site or away from any sensitive areas.

iii) Red foxes make use of corridors and networks when dispersing/immigrating to new areas. Things such as flood-control channels, drainage sites, and other areas that lead into and out of the wetland serve as key entry points (Harding 2001). Construct drainage pipes and tunnels with gates at each open end and setup fencing along areas that border open areas.

C) Monitoring Plan

i) Before restoration of the site is conducted, remove or drastically reduce any established fox population. Populations at low densities are easier to eradicate than those at high densities. Initially, leg-hold traps can be set at specified locations. As populations decrease, trapping efforts must increase this is because as densities decrease, it becomes harder to find the remaining individuals (Harding 2001). When about 2% of the population remains, set out meat scraps baited with poisons (Compound 1080) to kill remaining individuals. When the remaining 2% are taken care of, erect barriers at key entry points. Identify and target these locations to catch dispersers as they immigrate into the area due to density dependent responses. There is a lag time of about three months after red fox densities are reduced before immigrants begin to recolonize the area (Harding 2001). Three months after the latest removal event, increase monitoring and setup leg-hold traps at points of entry.

ii) During restoration, red fox densities should be watched closely. If any individual sets up residence in the area for too long, the densities rise pre-eradication levels. If population begins to rise, distribute baited meat scraps.

iii) After restoration is completed, continue to monitor the site. However, trapping while populations are beginning to increase has a positive effect on maintaining low densities (Harding 2001). Focus completed restoration monitoring on younger individuals. Juvenile dispersers are the greatest priority in terms of removal. Urbanized red fox populations contain a greater proportion of young breeding foxes (Harris 1997). Removal of juveniles would limit population increase. Adults should be targeted in later phases of control. In red fox populations young females are prevented from breeding by an older more dominant female. Premature removal of an alpha female would allow younger females to increase their breeding opportunities (Harding 2001). Higher adult mortality also increases the probability of dispersers finding suitable habitat (Trewhella 1988). Take of adults should decrease during breeding season, March through April, and during dispersal events, September through November. Take of juveniles should increase from September through November.

iv) Monitor and locate neighboring satellite populations. Primarily, any population that falls within a 400km radius from the site. 400km is the known minimum dispersal distance for non-native red foxes (Sacks 2016). Track population fluctuations to ensure that local population reductions do not coincide with neighboring population increases.

D) Research Needed:

a) The exact population needs to be known. Estimations of the number of individuals removed at each phase cannot be estimated until local population is estimated. Population size also dictates how long removal will take and if it is possible. If the local population is too large, other control tactics must be considered.

b) It is not known what species are at risk of predation. Determine what native species are trying to be restored in order to assess vulnerability. This applies mainly to small mammals and birds. Once the species are introduced, track population fluctuations. Keeping track of prey abundance can alert managers to an increase in fox densities. An increase in red fox abundance is correlated with a decrease in native and threatened species (Harding 2001).

c) While native red foxes are found primarily at higher altitudes, there are some native subspecies, such as the Sacramento Valley red fox (*Vulpes vulpes patwin),* that have adapted to lowland conditions. The Sacramento valley red fox has a range that spans both sides of the Sacramento river, from Cottonwood to the Delta, and from Chico to Sacramento. The native red fox and the non-native red fox ranges overlap.

The Sacramento Valley red fox has different morphological features, such as body length and tail length, than that of the non-native red fox. About 85% of the time, both native and non-native lowland foxes can be distinguished from one another based on appearance (Sacks 2010). The right species of red fox needs to be targeted. Confirm that the non-native red fox is present at the site, not the threatened Sacramento Valley red fox.

d) Demographics of the local and surrounding populations need to be determined. Demographics and ecology of populations differ depending on location. Phenology of the local population needs to be known. While red foxes have relatively similar timing, populations living within the Sacramento valley may differ slightly from what is considered normal.

e) Connectivity and population growth rate needs to be determined for local and neighboring populations. Their exact dispersal routes and satellite populations are not known. The importance of immigration also needs to be known. Some populations of non-native red foxes are able to maintain themselves through reproduction and not immigration. Other sampled populations were found to display the opposite (Sacks 2016). The degree of isolation and connectivity play a role in these factors. Therefore, in order haves successful management, how the local population sustains its numbers needs to be known. This can be done with genetic analysis. This method, however is costly.

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