2016 ENH 160 Project: Restoration of Vacaville's Centennial Park- Middle Horse Creek

Compiled by Ben Waitman and Valerie Eviner

This project was done in collaboration with Katherine Holmes from the Solano County RCD.

INTRODUCTION TO THE REPORT

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

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

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

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

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

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

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

These individual projects were just the start of the instructional, and project-wide goal. The lab section of the class 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.

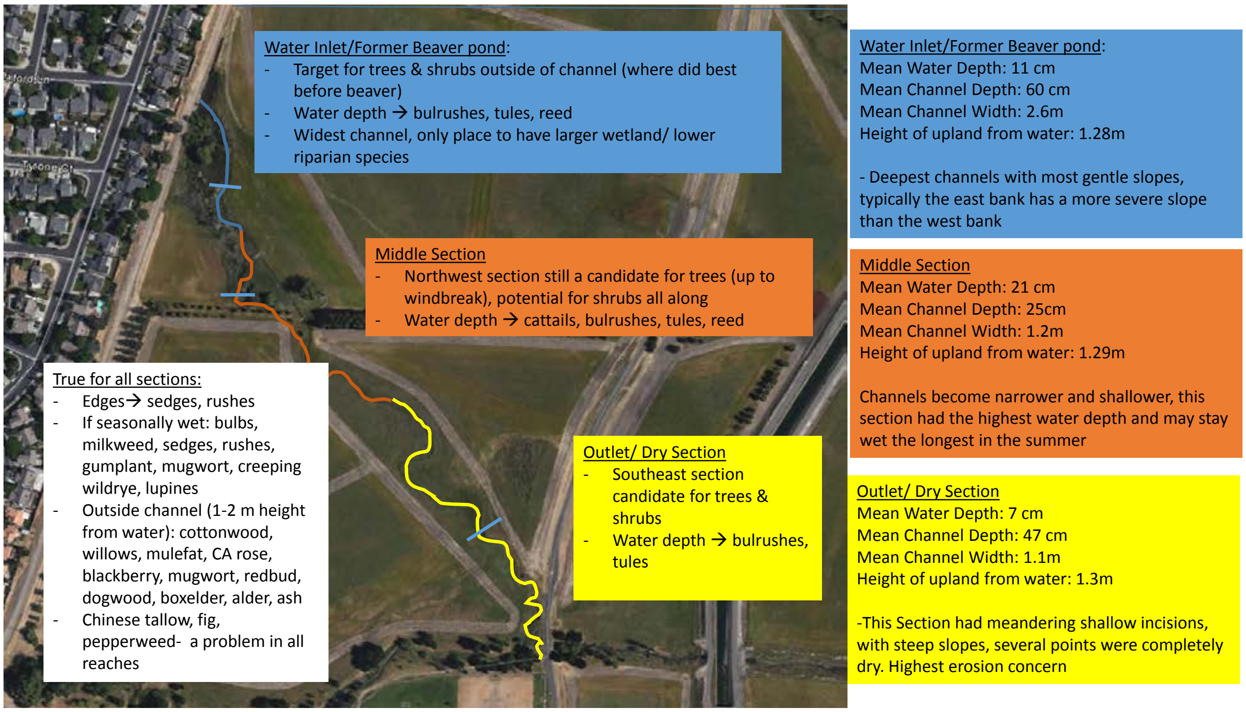
Results of these discussions can be found in the "Project synthesis" section. A full description of the students' assignment can be found in Appendix I.

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 grassland, wetland, and riparian zones, and pointing to some key holes in our scientific understanding that will aid with the implementation of restoration and management programs. The management recommendations are very preliminary due to time limitations, but the literature reviews and lists of trade-offs should provide important information for those managing California grasslands and riparian areas. We are very proud of all of the hard work, open minds and synthetic thinking that the students invested in this project.

Management recommendation summary:

Of Riparian Areas:

Based on water depth and channel topography, there are three distinct zones of appropriate plant community types for restoration of Middle Horse Creek, as detailed below.



These zones are based on the channel morphology determined in the lab topography group, coupled with the following literature review:

Wetland plant zones - depth of water/ duration of flooding

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

Woody plant zones - depth from water table

>4m

- Boxelder,
- Bay,
- sycamore,
- oaks (valley, canyon live,),
- Ceanothus
- , buckeye,
- rose,
- coyote bush
- , holly leaf cherry,
- silver bush lupine,
- toyon,
- redbud,
- poison oak
- Coffee berry,
- snowberry,
- monkey flower
- fuschia
- Chinese tallow

3-4 m

- Valley oak
- Goodings willow
- Buttonbrush
- Elderberry
- Mugwort
- redbud,
- fuschia
- maple
- Chinese tallow

2-3 m

- Valley oak
- Goodings willow
- Arroyo willow
- Cottonwood
- Ash
- White alder
- Walnut
- Sycamore
- Cottonwood
- Narrowleaf willow
- Mulefat
- Buttonbrush
- CA rose
- Blackberry
- Edleberry
- Mugwort
- redbud,
- Fuschia
- Maple
- Grape
- Chinese tallow
- Fig

1-2 m

- Cottonwood
- Goodings willow
- Buttonbrush
- Boxelder
- White alder
- Ash
- Red willow
- Arroyo willow
- Narrowleaf willow
- Mulefat
- CA rose
- Blackberry
- Mugwort
- redbud,
- Dogwood
- Spicebush?
- Grape
- Chinese tallow

<1 m

- Goodings willow
- Narrowleaf willow
- Red willow
- Aroyo willow
- White alder
- Ash
- Cottonwood
- Valley oak
- Interior oak
- Buttonbush
- CA rose
- Blackberry
- Mugwort
- Dogwood
- Grape
- Chinese tallow

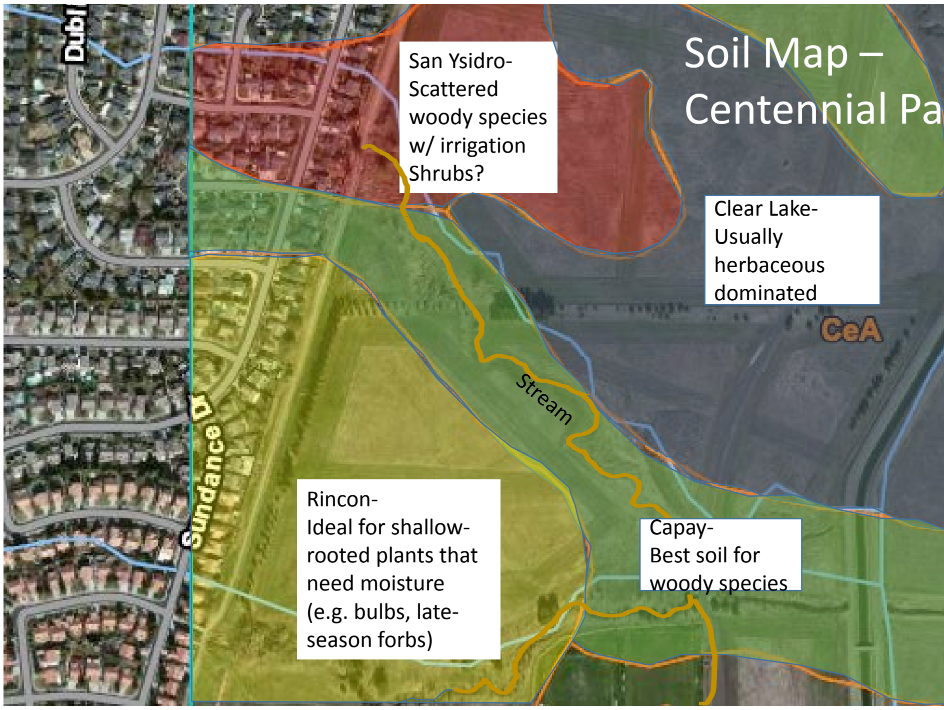
Red= invasive

Riparian herbaceous plant zones - moisture/ duration of flooding

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

Upland management recommendations

Based on soil types, the following recommendations are made:



Soils:

Capay (Ca)- best for woody species- good soil drainage and good water holding capacity

Clear Lake (CeA)-
Poor for most trees- poorly drained, frequent ponding

San Ysidro (SeB)
Potential for trees with initial irrigation- no ponding, but low water storage so generally supports shallow-rooted plants

Rincon (RoA)
Poor for most trees- shallow perched water table with high precipitation (surface soils have good water holding capacity and good drainage)

2016 ENH 160 Report- Vacaville's Centennial Park

Site Monitoring Summary

In 2016, the students enrolled in the laboratory section of ENH 160 collected data on and around the Southern tributary of Horse Creek. The area of interest included the creek itself and the surrounding upland areas, taken together this comprised the lower half of the Centennial Park restoration area.

The laboratory section of ENH 160 is structured to challenge students to work in small groups to evaluate a restoration sites potential resources and challenges for restoration. In the springs of 2016 students were broken into small groups and asked to design a data collection scheme, carry out all data collection, evaluate, and present information on six aspects that describe the southern portion of Centennial Park. These topics included:

- Site Topography
- Upland Vegetation
- Riparian Vegetation
- Wildlife Resources
- Soil Conditions
- Ecosystem Services

Students devised research after two site visits and collected data on a series of 3 hour laboratories on Monday afternoons from April 11th-May 2nd of 2016. The data collected and presentations created, in conjunction with available information on centennial park, were used by the entire ENH 160 class to create the individual species restoration plans.

General Conclusions

The reports produced by the ENH 160 lab indicates that the major influences on the restoration area are the presence of the lower tributary of horse creek and the changing soil type across the upland areas. Soil characteristics differed between soil types, as did measures for ecosystem services. Limited sampling prevents broad conclusions about the plant communities present across the large upland areas to the North and South of the southern tributary of horse creek.

The southern tributary of horse creek itself changes drastically as one travels westward from its origins in the park. The topography of the creek seems to have been heavily affected by a number of beaver dams that were removed in late 2015. The result is that it is difficult to determine what is now a typical water depth in the area. Indeed, little water was found in the creek in May of 2016 and the creek was no longer flowing by the time the laboratory students made their last trip to Centennial park.

Additionally, the greatest diversity and aerial extent of riparian vegetation is heavily concentrated at the west end of the creek, likely a result of a more available water due to the beaver dam.

Upland areas were heavily invaded by both exotic invasive and naturalized exotic grass species. However, bulbs were present across the riparian and upland areas, and concentrations were greatest near the riparian area (B.Waitman, pers. Obs).

TOPOGRAPHY – Final Report

Savannah Hadley | Terence Wu | Theresa Geib | Troy Shea

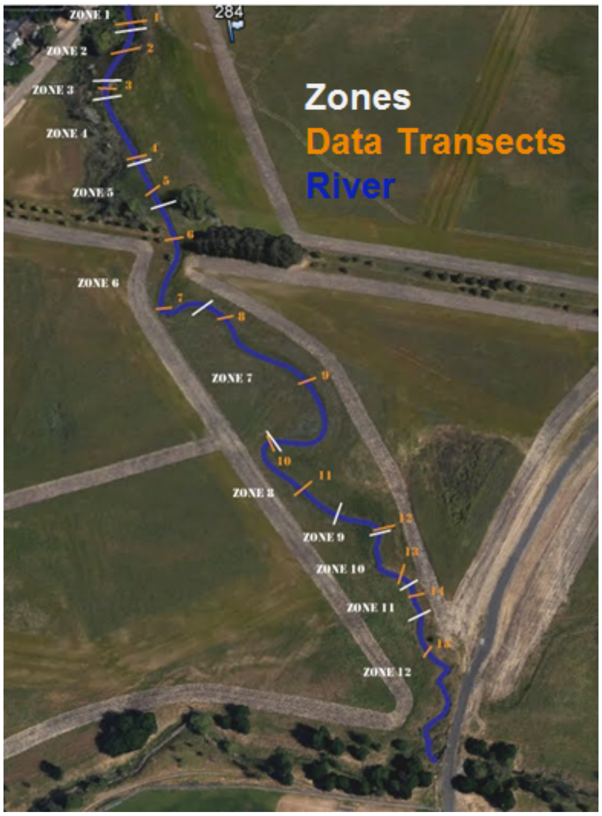
INTRODUCTION

Overview: We first surveyed the site, in search of general trends and areas of interest. Areas of interest became the focus of our measurements, and general areas were left to be looked at if we had extra time. The areas of interest pertained to the waterway, where there were more changes in elevation and slope. We walked along the waterway, using the GPS to mark the end of one zone and the beginning of a new zone, characterized by a significant change in vegetation, channel width, bank slope, etc. We also used the GPS to mark out large bends and sites, which would eventually help us trace out the waterway on a map (connecting the GPS points). After marking out the zones, we took measurements at least once for every zone, to get a rough estimate of the zone. The last day also allowed for us to retrieve a bit of data on possible vernal pools.

ZONES

Zone	Description
1	Island feature, split river, unstable slopes, storm drain (culvert) water inlet from residential area, multiple tributaries into the main creek, some trees near creek bank
2	Becomes wider, water level slightly lower
3	More flat very wide, in a single area water about 1ft deep,
4	Narrows out, water is generally ~1ft deep,
5	Wider with high water level, plants in the waterway
6	Cattail vegetation ends, creek narrows, bend, river split (right side water measured at 9cm)
7	Water at 25 cm, bend/split stops,
8	Water splits, hear water (small waterfall), water at 11cm,
9	Split stops, water level at 36 cm (deepest so far), erosion,
10	Severe erosion, very steep banks, higher on the other side
11	Erosion, steeper
12	Waterway is wider, steeper banks, huge bench, steep erosion site, end, three waterways, 2 converge

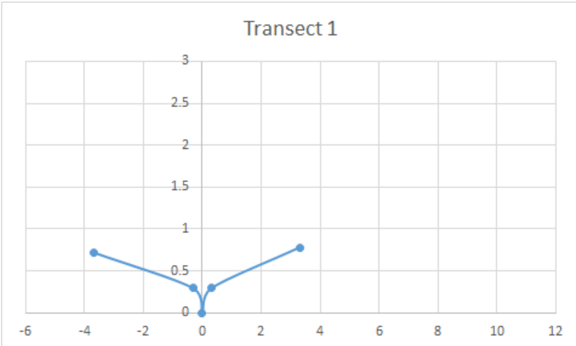
MAP



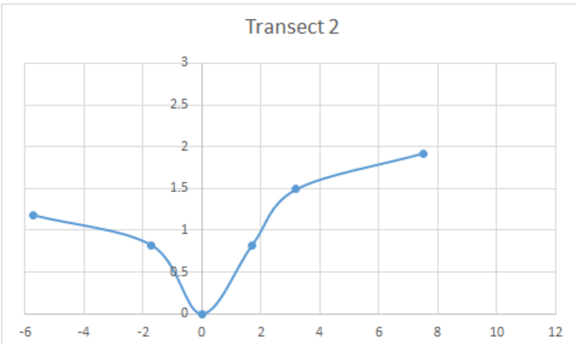
- Zones are the large areas with generally homogenous topographic features
  - Left side of drawn waterway, in white
- Transects are the measurements taken in each zone
  - Right side of the drawn waterway, in orange
- Shown as graphs below

TRANSECTS

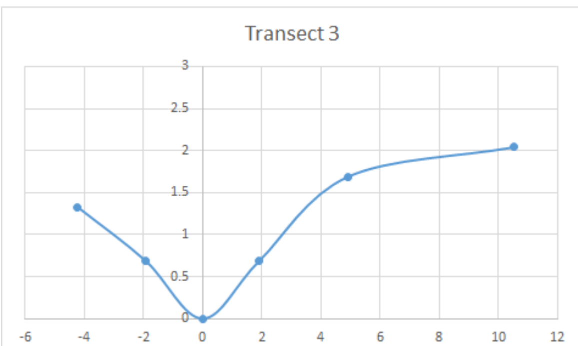
- An interesting feature observed was that there was not a noticeable sloping left "upland;" once above the lip of the bank, topography was level. On the right side of the creek there was often a sloping portion of the right "upland" after the lip of the bank.
  - "Left" upland is on the left of the map, "right" upland on the right of the map above
- The narrow, shallow zones will need to have management considerations to reduce the risk of flooding.
- Channel - waterway
  - Depth
    - We leveled a string above the water to try to keep the measurement perpendicular from the ground, and used a meter stick to measure the depth of the water
  - Width
    - The channel edge was decided to be where the vegetation ended, so we measured the distance between the edge of vegetation from one bank, to the edge of the vegetation of the other edge
    - If the vegetative edges were not of equal height, we used the height at the lower elevation
- Graphs
  - Graphs were tabulated by compiling data on width of waterway, channel depth, and the lengths and heights of the left and right bank. The deepest part of the channel was assumed to the be in the middle of the waterway. This was considered the zero point of the graph. The negative part of the x axis was for the left bank and the positive side of the x axis was for the right slope. The first point on each graph from the (0,0) marks the end of the channel and the start of the bank. Additional points mark the end of the bank or the start of the "upland." The curves applied to the graph do not represent true slopes but are an approximation based on the data we have.
- Narrow Channels
  - Transects 1, 8 (considering the sub-channels), 9, 10, 11, and 15 were less than 1m wide
- Wide Channels
  - Transects 2, 3, and 4 were greater than 2.5m wide



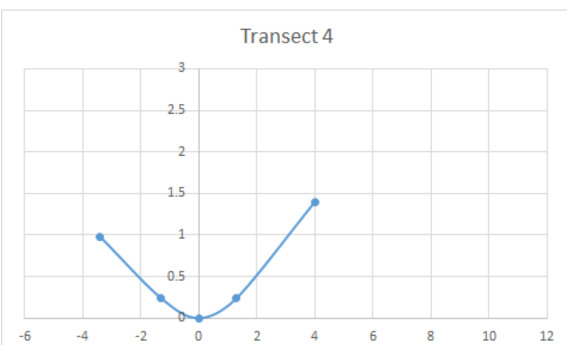
Zone: 1
Width of Waterway: 0.6m
Water Depth: 0m
Channel Depth: 0.29m
Bench: none



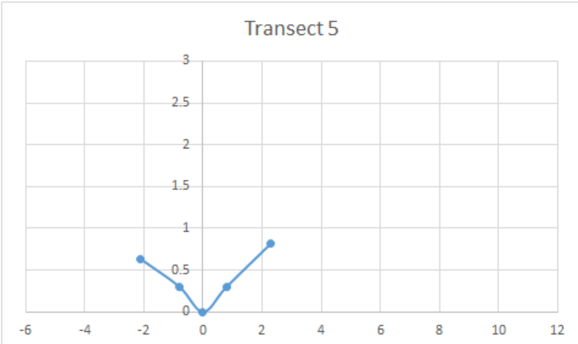
Zone: 2
Width of Waterway: 3.4m
Water Depth: 0.1m
Channel Depth: 0.82m
Bench: none



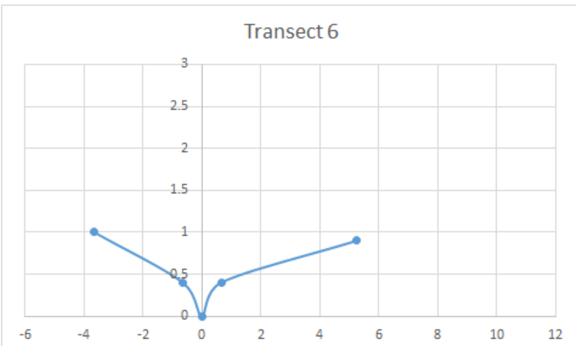
Zone: 3
Width of Waterway: 3.85m
Water Depth: 0.26m
Channel Depth: 0.69m
Bench: none



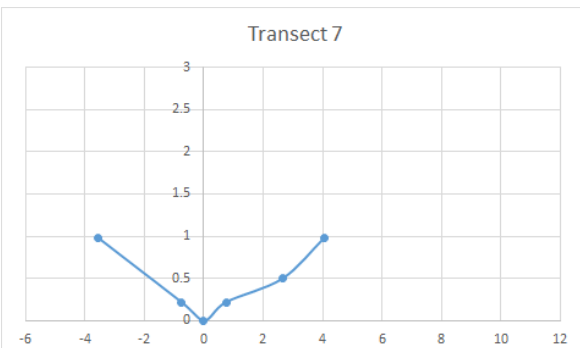
Zone: 4
Width of Waterway: 2.6m
Water Depth: 0.21m
Channel Depth: 0.24m
Bench: none



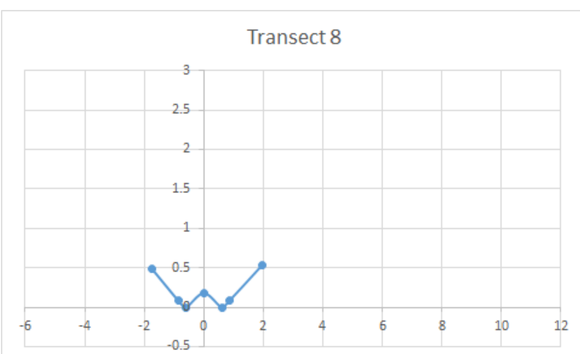
Zone: 5
Width of Waterway: 1.6m
Water Depth: 0.18m
Channel Depth: 0.3m
Bench: none



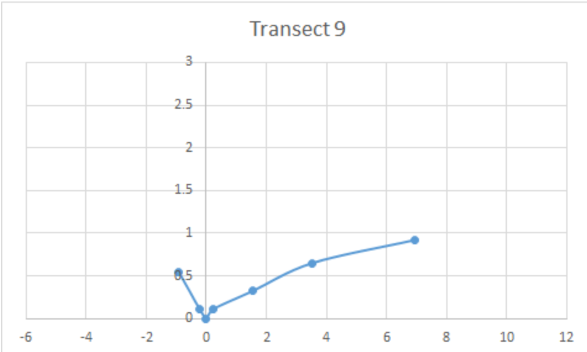
Zone: 6
Width of Waterway: 1.3m
Water Depth: 0.22m
Channel Depth: 0.4m
Bench: none



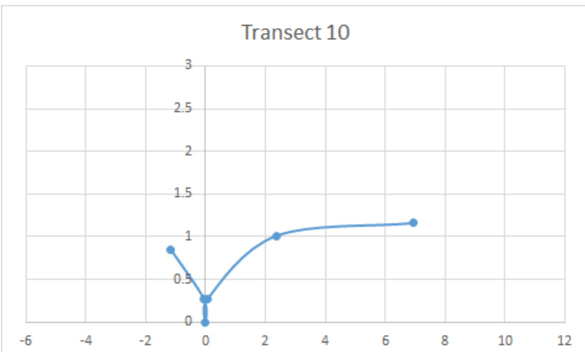
Zone: 6
Width of Waterway: 1.5m
Water Depth: 0.12m
Channel Depth: 0.22
Bench: none



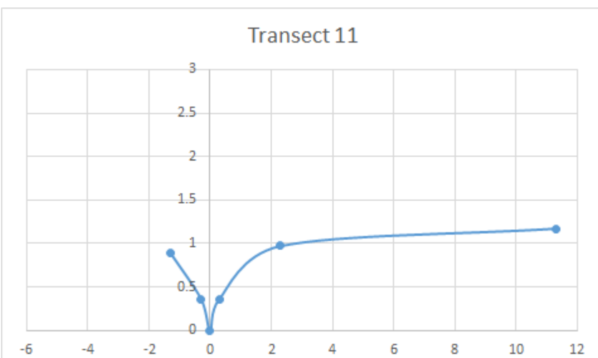
Zone: 7
Width of Waterway: 1.35m
two split channels
Water Depth: 0.03m (L), 0m (R)
Channel Depth: 0.18m (L), 0.08m (R)
Bench: none



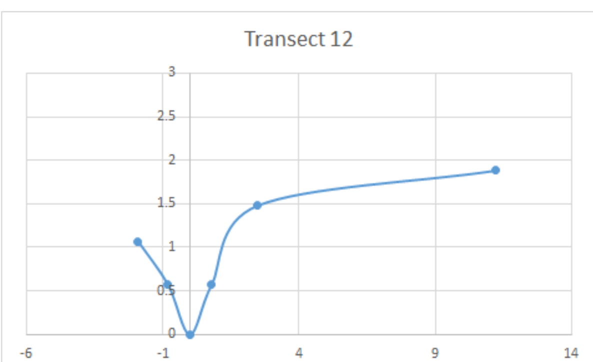
Zone: 7
Width of Waterway: 0.45m
Water Depth: 0.06m
Channel Depth: 0.11m
Bench: none



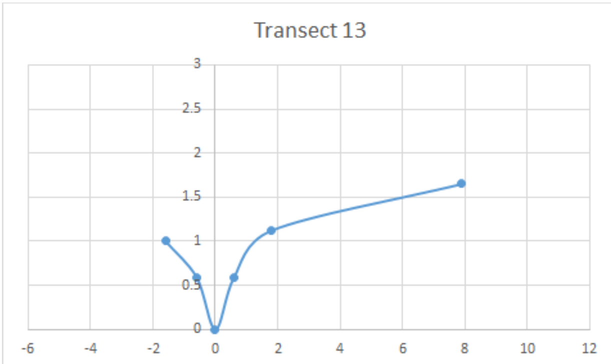
Zone: 8
Width of Waterway: 0.12m
Water Depth: 0.03m
Channel Depth: 0.27m
Bench: none



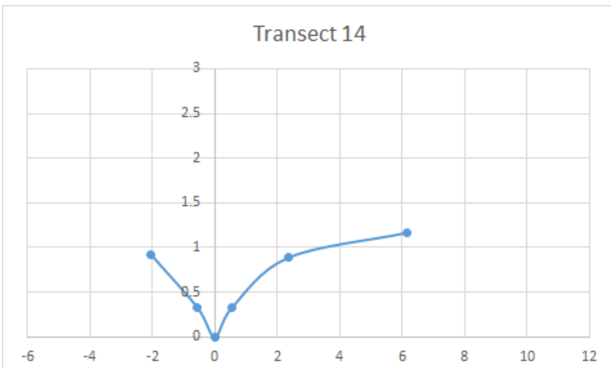
Zone: 8
Width of Waterway: 0.6m
Water Depth: 0.14m
Channel Depth: 0.36m
Bench: none



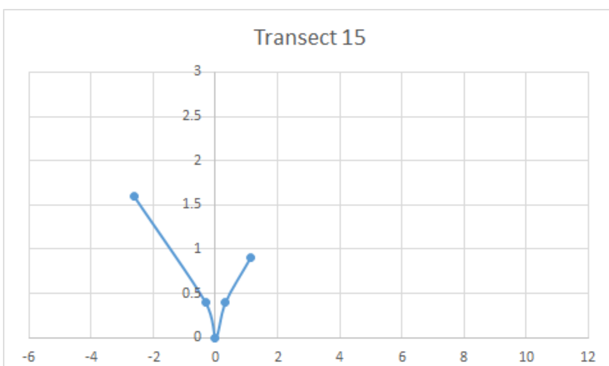
Zone: 9
Width of Waterway: 1.6m
Water Depth: 0.28m
Channel Depth: 0.57m
Bench: none



Zone: 10
Width of Waterway: 1.2m
Water Depth: 0m
Channel Depth: 0.59m
Bench: none



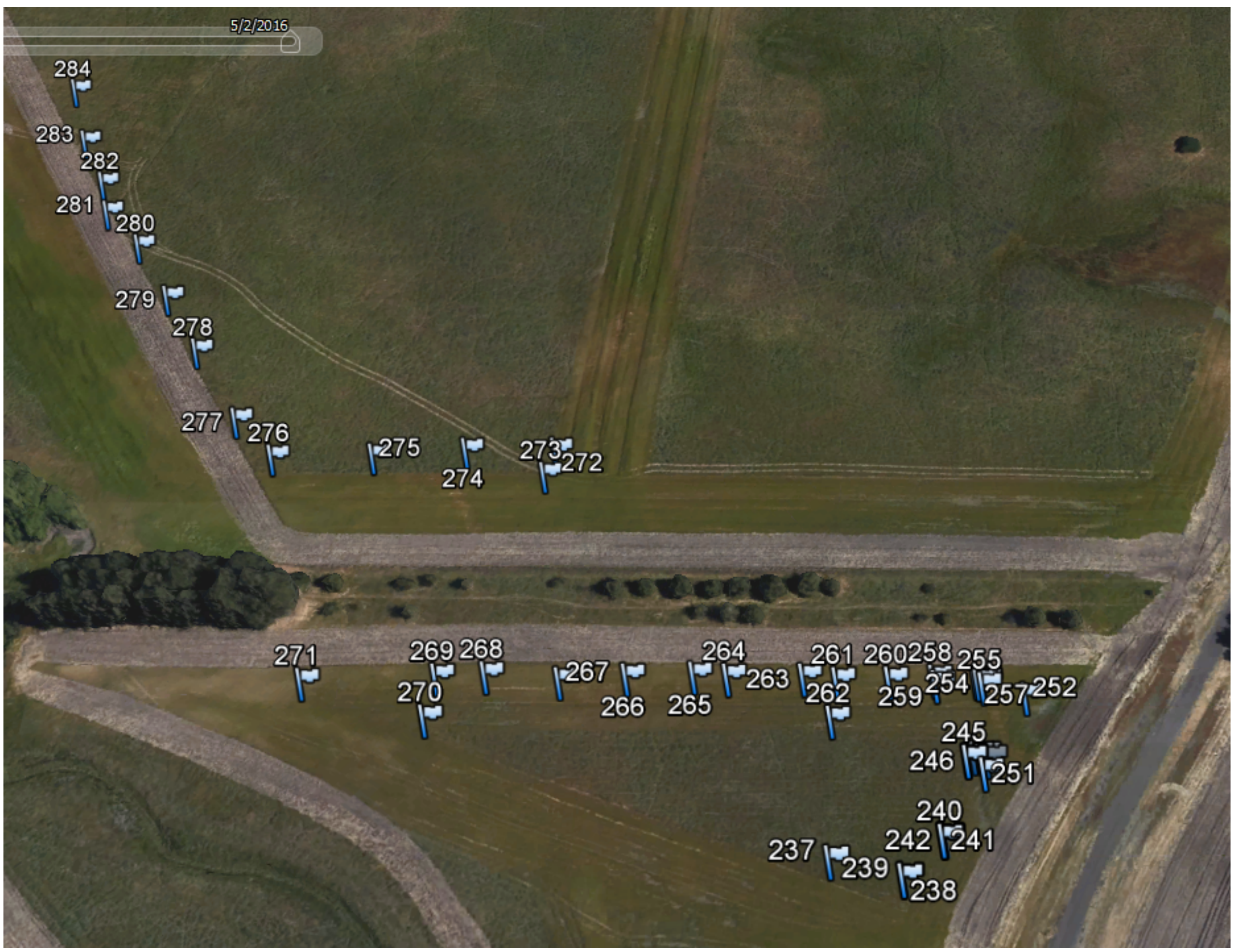
Zone: 11
Width of Waterway: 1.1m
Water Depth: 0.01 - 0.02m
Channel Depth: 0.325m
Bench: none



Zone: 12
Width of Waterway: 0.65m
Water Depth: 0m
Channel Depth: 0.4m
Bench Width: 1.4m

VERNAL POOLS

- Vernal pools areas were considered greener patches of vegetation within larger patches of senesced vegetation
- GPS points were taken along the edges of the larger bands of vernal pools, data points collected represent only a small portion of vernal pools on site.
- There were large bands as well as small patches of this distinct vegetation.
- The unnatural nature of one of the bands suggests that it may have been created by compaction from heavy equipment traveling over the area. The band was rather straight and of uniform width while either side of this band there were smaller and roughly circular in nature.
- What appeared to be very small channels were observed. These may have been a legacy of tire tracks.



CONCLUSION

We focused on the center creek areas not measuring the large water basin that was located at the end of the site by the road with the large storm drains and we did not measure the multiple creek channel splits located by the residential area. When observing the site before taking measurements, it was noticed that the large storm drains that connected waterways created many different channels that eventually combined later into the original channel. The fast, large flow of water created by those drains create large erosion events at either end of the creek that need to be further measured to create a complete restoration plan.

CHALLENGES / QUESTIONS

The main challenge we had was with water level. Measurements of water depth were taken over 3 separate lab periods so had we measured some of the later dry transects in the first week of measurements they still may have contained water in them. Ideally depth would have been measured for all transects on the same day to standardize data. Also, due to potential variations in the microtopography in the channel, channel depths may not necessarily be representative of zones as a whole. Finally, these channel depths are not representative of average or maximum channel depths over the the course of the year. This yearly data would be more useful for making planting recommendations for restoration activities.

Due to time limitations, only qualitative data of vernal pools was taken. It would be useful to determine the microtopography of the area and how the vernal pools may fit in the overall landscape (i.e. are they nestled in a depression in the larger landscape?)

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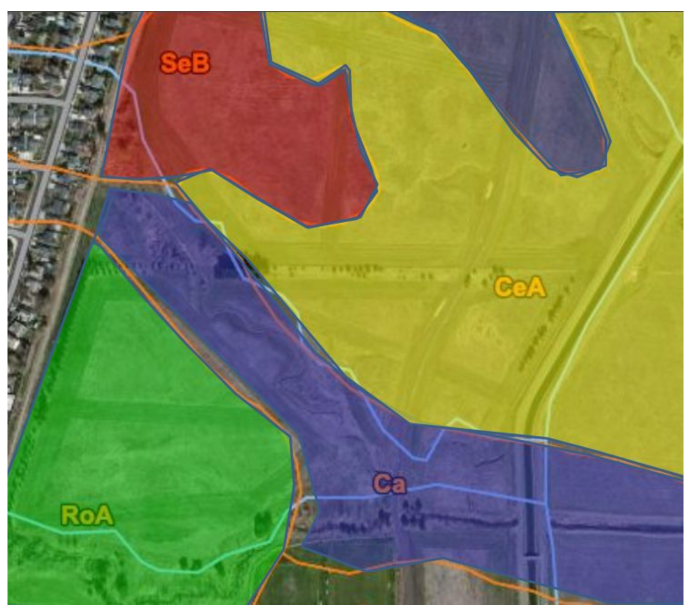
Soils

Introduction:
Soil sampling was conducted on Mondays from April 4, 2016 through May 2, 2016. Soil sampling was conducted at Centennial Park in Vacaville, California. The questions asked during the collection of soil data was aimed at gaining information that would indicate conditions that may cause interactions, interferences, or enhancements of restoration. These questions are:

- What is pH of the different soil types at the restoration site?
- What are the nitrogen, phosphorous, and potassium levels of the different soil types at the restoration site?
- What is the compaction levels of the different soil types at the restoration site?
- What is the infiltration rate of the different soil types after wetting at the restoration site?
- What is the textures of the different soil types at the restoration site?
- Are there any notable features?
- How does the data we collected compare to the Soil Survey Data?
- Are any factors tested considered to be limiting?

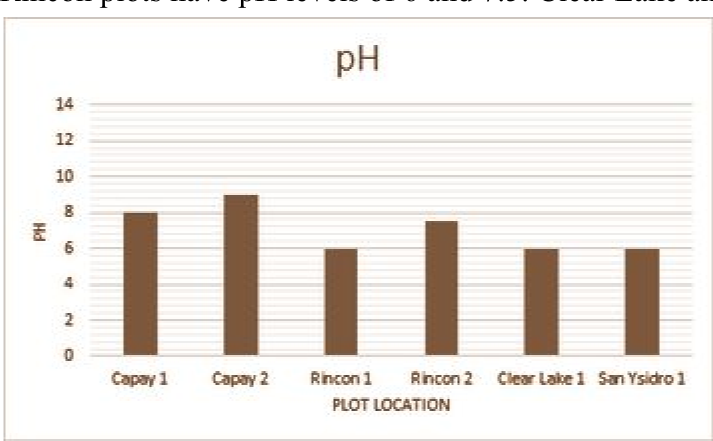


Methods:
Sampling site collection was done based on two aspects. The site was first broken down based on the soil type. Sampling was to include a minimum of one plot per soil type. There was special interest in two soil types and an additional plot was to be done in each of these soil types. These soil types were Capay and Rincon. Capay held special interest due to the riparian area which would be of great importance during restoration. Rincon held special interest due to the drainage class being “well drained” which was thought to potentially better support tree populations. Specific locations of each plot was selected once in the field and done at random. However, there was some preferences that were held in selecting these plots. It is seen that the selection of plots remained relatively close to the pathways. This was ideal for saving time in order to ensure collection of all plots. There also may be some selection based on clearer ground or sparser vegetation. Thick vegetation and litter hindered sampling and may have resulted in selecting areas with thin or no vegetation.

Texture:
Texture was done by first collecting a soil sample within the plot. The was done by first clearing away any litter or vegetation and digging down approximately 5 to 10 centimeters below the soil surface. A ribbon test was then done using a ribbon test chart.
The Capay soil was found to have a dominant texture of clay loam. Clear Lake soil was also found to have a clay loam texture. San Ysidro has the sandiest texture of sandy clay loam. Rincon was found to be siltier with textures of silty clay and silty clay loam.

Capay 1	**Capay 2**	**Rincon 1**	**Rincon 2**	**Clear Lake**	**San Ysidro**
Clay Loam	Clay Loam	Silty Clay	Silty Clay Loam	Clay Loam	Sandy Clay Loam

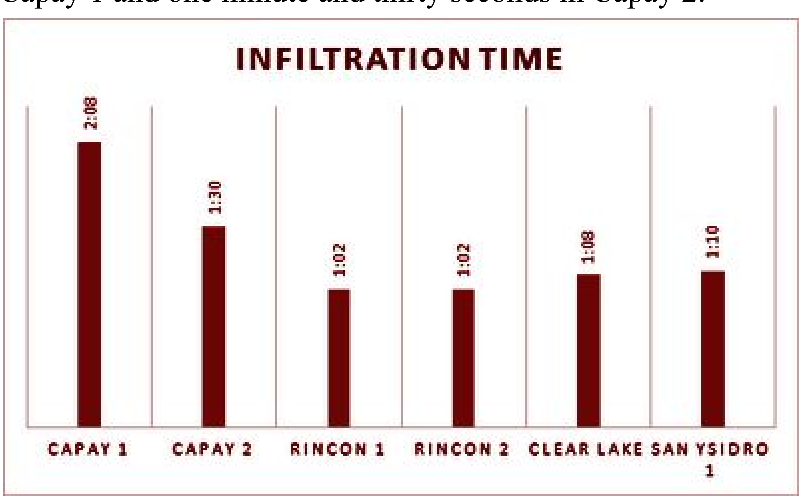
PH:
PH was done using a pH kit consisting of test tubes and small pH tablets. A soil sample was first collected within each plot by clearing away any litter or vegetation and digging down approximately 5 to 10 centimeters below the soil surface. The kit was then used as instructed. The pH ranges from 6 to 9 across the different soil types. All pH levels were close to being basic except for Capay soil plots.The Capay plots have the highest pH with levels of 8 and 9. The Rincon plots have pH levels of 6 and 7.5. Clear Lake and San Ysidro plots have a pH of 6.



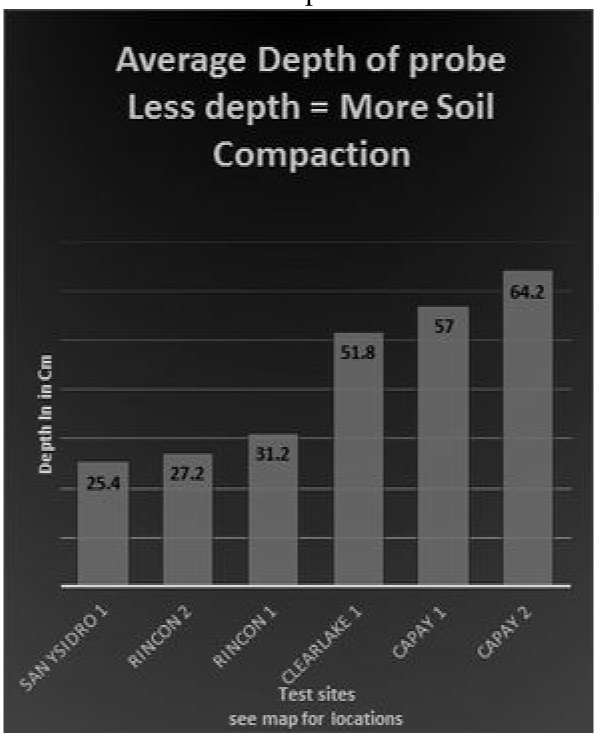
Nitrogen, Phosphorous, and Potassium:
Nitrogen, phosphorous, and potassium was done using a NPK test kit consisting of test tubes and several types of tablets for each test. A soil sample was first collected within each plot by clearing away any litter or vegetation and digging down approximately 5 to 10 centimeters below the soil surface. The kit was then used as instructed. All plot samples were collected and sampled on May 2, 2016.
All plots tested low in nitrogen. Most plots tested low for phosphorous except for Capay 1 which had a slightly elevated level and Rincon 1 which had a much higher level. Potassium had a range of amounts. Rincon showed the biggest range with Rincon 1 testing high and Rincon 2 testing low.

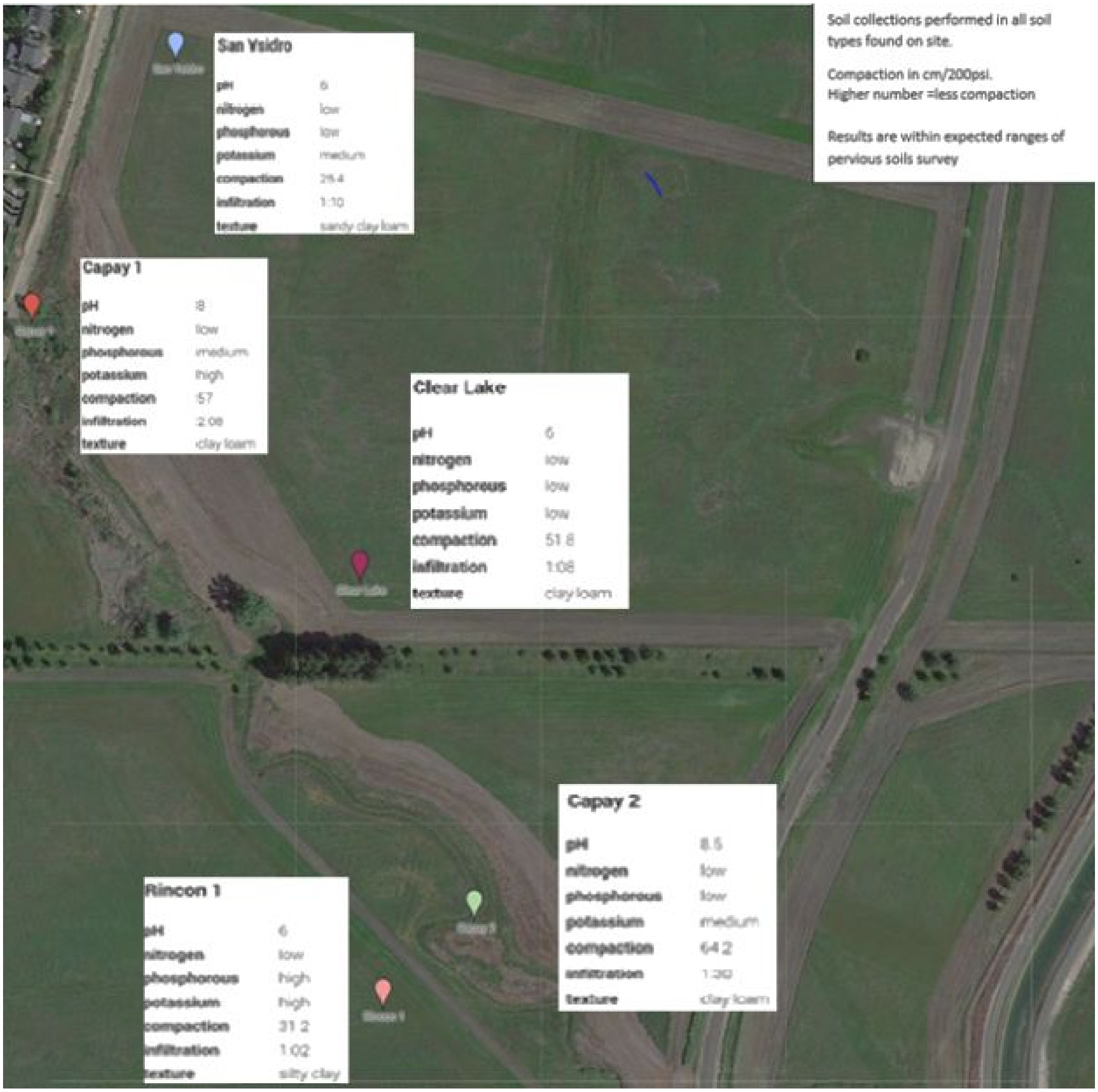
PLOT LOCATION:	Nitrogen	Phosphorous	Potassium
Capay 1	Low	Low-Medium	High
Capay 2	Low	Low	Medium
Rincon 1	Low	High	High
Rincon 2	Low	Low	Low
Clear Lake 1	Low	Low	Low
San Ysidro 1	Low	Low	Medium

Infiltration:
Infiltration was done using an infiltrometer. Each plot was first cleared of any vegetation or litter and moistened. Moisture was applied using the infiltrometer by allowing water to drain into the soil profile until drainage slowed significantly. It was at that time that the infiltrometer was filled to 50mL and timed for complete drainage into the soil. This time was collected.
Infiltration rates can be an indicator of flood potential and erosion concerns. Most infiltration rates fall at around one minute. Capay soils have the slowest rates with over two minutes in Capay 1 and one minute and thirty seconds in Capay 2.



Compaction:
Compaction was done using a penetrometer. Each plot would have 5 locations tested using the penetrometer in order to gain an average and range. The penetrometer was inserted into the soil and pressure applied until the gauge read 200psi. The length of the inserted portion at 200psi was the collected information.
Capay soils had the lowest level of compaction, on average. Clear lake was also uncompacted. San Ysidro and Rincon plots were the most compacted.





Conclusion:

All in all, the soil testing done at Centennial Park exemplified a variety of conditions amongst the different soil types along with some similarities. There were slight differences in pH and texture amongst the four soil types when compared against the original soil survey that was done in the area, most notably being the differences in pH in the capay and clear lake. However, our methods for measuring pH and determining texture were most likely less precise than the ones used for the soil survey which should definitely be considered when looking at the data that was collected this class. The infiltration and soil compactions tests may also be lacking in precision, exemplified by the discrepancy shown with Capay 1 showing to have some of the least compacted soil yet having the longest infiltration time, which doesn't make much sense. The low nitrogen readings that were measured by the NPK tests can be explained by much of the nitrogen being tied up in the vegetative growth of the current species at the site. This can serve as a good representation of competition for nitrogen being a prominent factor in the restoration project. Nevertheless, this site should still be able to sustain a majority of the recommended species for restoration providing that the ones sensitive to a higher pH (more alkaline) are planted accordingly.

Riparian/Wetland Vegetation at Centennial Park

ENH 160 Spring 2016

Leonardo Tuchman
Mayra Huerta
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Elizabeth Ridolfi

Intro:

Key questions regarding species diversity and prevalence guided our surveying and monitoring in the riparian corridor. Throughout our time there our goals aimed to get an idea of what the dominant species in the riparian corridor are and how many of those are exotic or native. Additionally, surveying at the area overall we looked at how different parts of the riparian corridor differ biologically as well as topographically. This information is crucial for determining what species are best for revegetation efforts and where restoration effort is most needed along the riparian corridor. It also aides in deciding what habitat modifications may be necessary for a successful long term restoration.

Methods:

Sampling Scheme - We divided the riparian area into four different zones along the stream based on distinguishing topographical features, which will be explained below. In the first three zones, we set up five transects per zone perpendicular to the stream bed, with one to five quadrants along each transect, depending on the length of the riparian corridor. Depending on the length, quadrants were set at 1m, 3m, 5m, 10m, and 15m along the transect. In the fourth zone, we took twenty random quadrants throughout.

Vegetation Measurement - Within all quadrants we measured the relative dominance of each species present in the quadrant based on a three-point scale (3-- most dominant, 2-- moderately dominant, 1-- least dominant). Once we collected the species dominance data for each quadrant, we totaled the species dominance scores of each quadrant in each zone, to determine what the most dominant species in each zone were. This allowed us to determine the effect of the riparian topography on the species composition, giving insight into which desired native species would establish best where along the riparian corridor.

Note: We were often only able to identify plants to genus, and not species. This may have influenced the exotic vs. native designations.

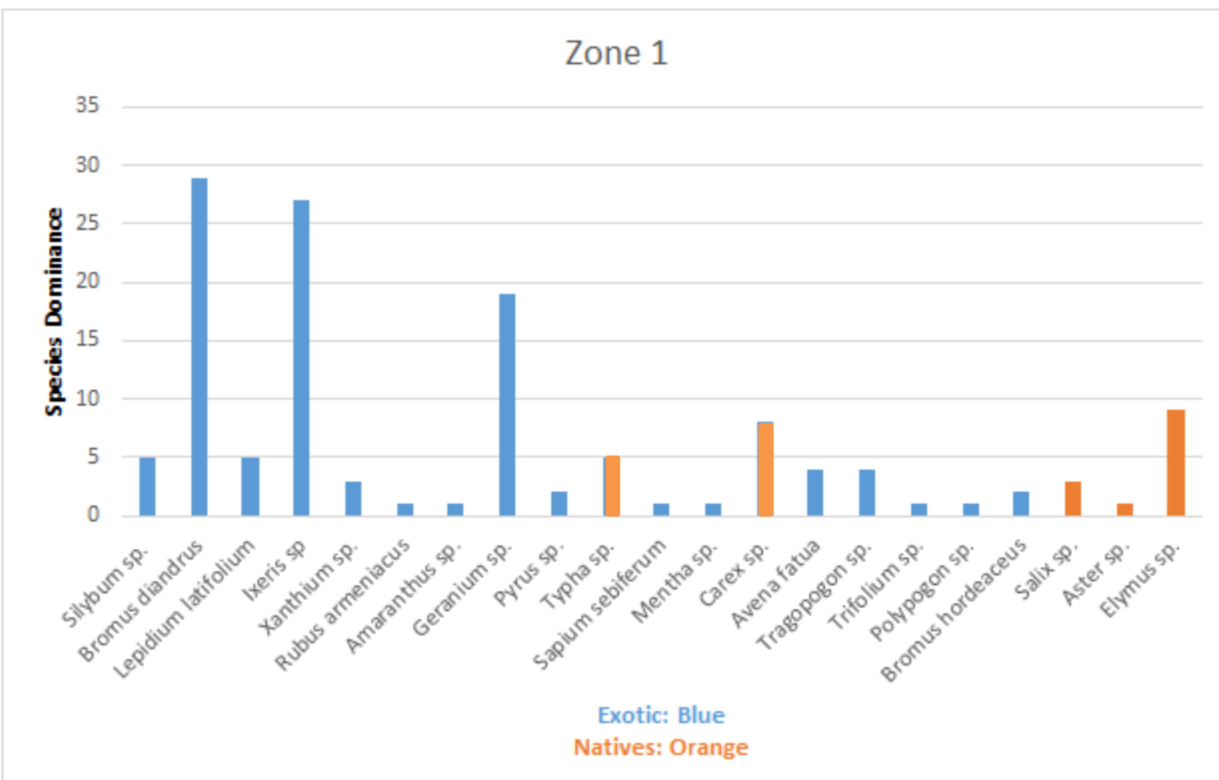
Methods

- Map of site/zones
- Zone 1
- Zone 2
- Zone 3
- Zone 4

Results/Data:

Zone 1: low grade sloped bank, riparian corridor extending up to 10m from water, water present throughout

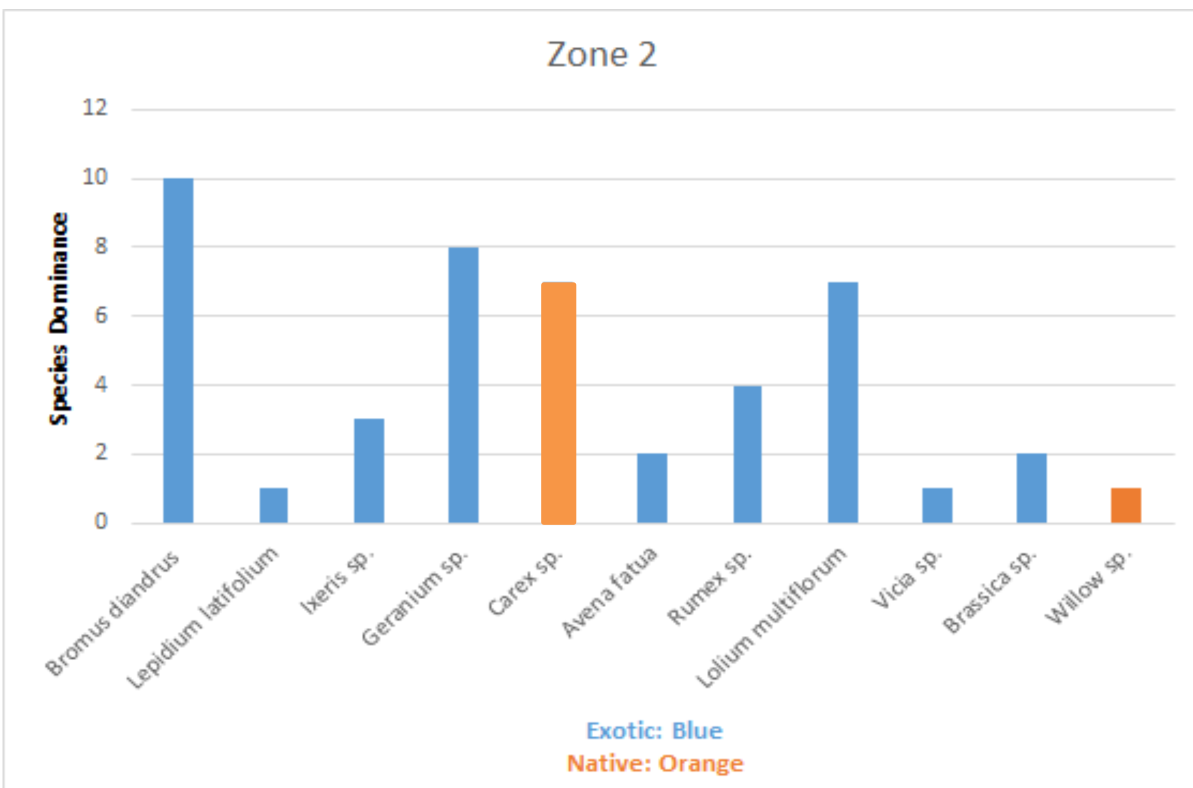
Green lines indicate transects for Zone 1.



Graph 1 shows the relative dominance of species within the zone. The most dominant species in Zone 1 are *Bromus diandrus*, followed by *Ixeris sp*. and *Geranium sp*. Natives present include *Salix sp., Aster sp., Elymus sp.*, *Typha sp*. and *Carex sp*.

Zone 2: Small channel/riparian corridor surrounded by grassland with some wetland species in the channel; all transects with only 1 quadrant each due to short (~1m) riparian corridor, 1 meter deep channel, water present at transects 1-4.

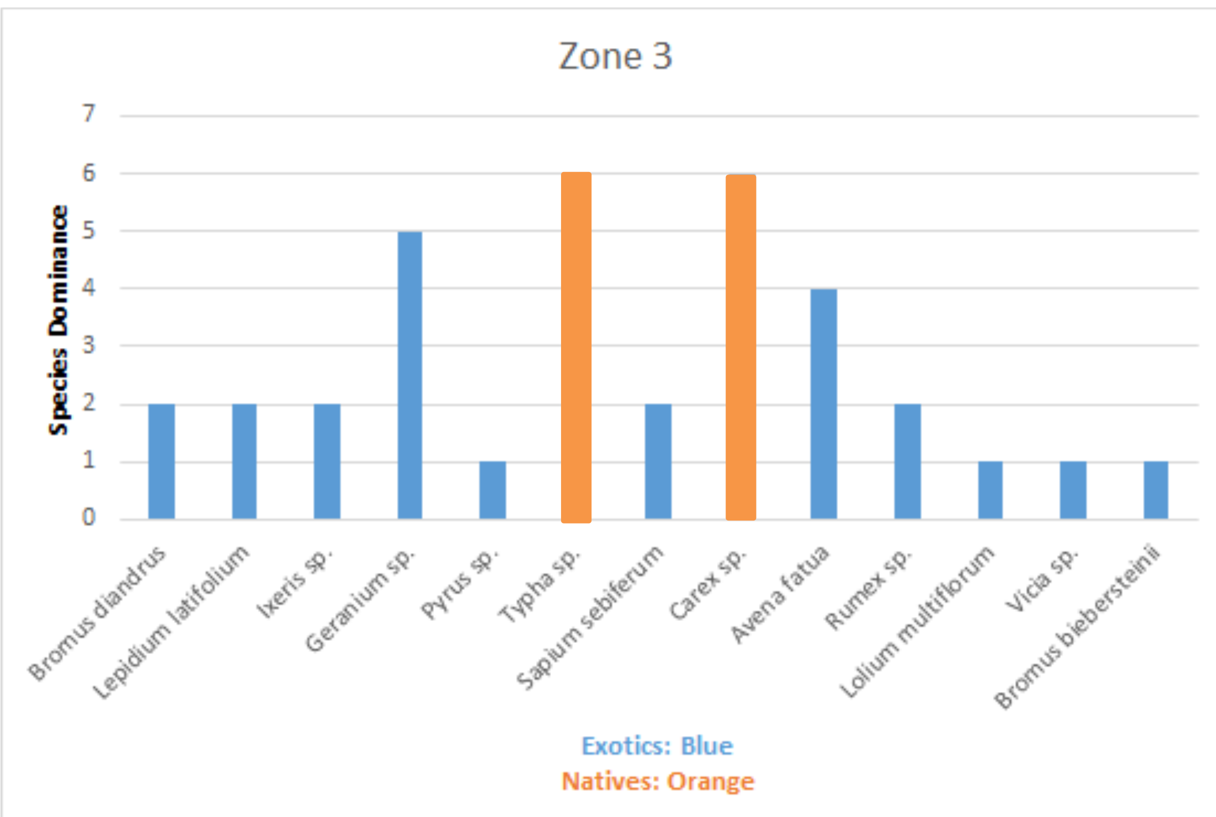
Yellow dots indicate transect locations in Zone 2, each having just one quadrant.



Graph 2 shows the relative dominance of species within the zone. The most dominant species in Zone 2 is *Bromus diandrus* followed by *Geranium sp., Lolium multiflorum, and Carex sp*. The two native species found were *Salix sp*. and *Carex sp*.

<u>Zone 3</u>: Southern end of restoration site of interest; all transects with only 1 quadrant each due to very steep and narrow riparian corridor, with a 3 meter deep channel; water present at transects 4-5

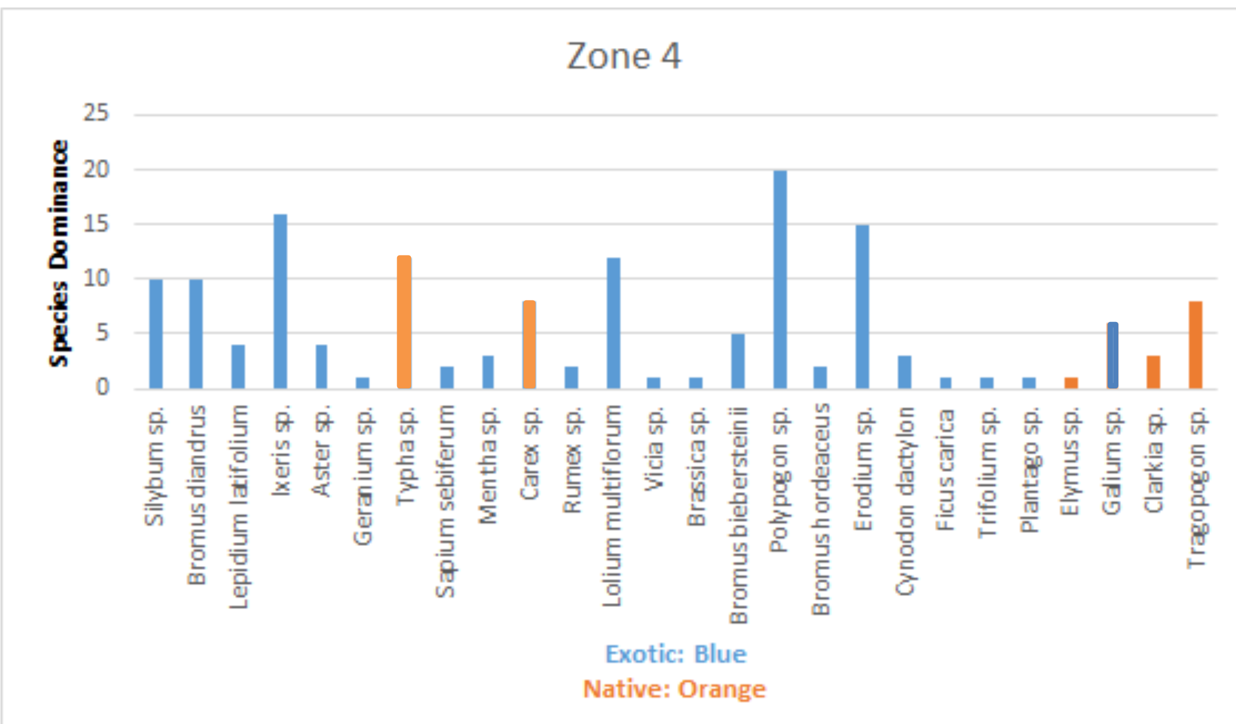
Yellow dots indicate transect locations for Zone 3, each having just one quadrant.



Graph 3 shows the relative dominance of species within the zone. The most dominant species in Zone 3 are *Typha sp.* and *Carex sp.*, both wetland species, marking a difference between the dominance of more upland species in Zones 1 and 2.

<u>Zone 4</u>: Large center island, previously inundated due to beaver activity, but predominately dry now except for a few small incised channels.

Red dots indicate location of randomly placed quadrants throughout Zone 4.



Graph 4 shows the relative dominance of species within the zone. Zone 4 has the greatest species richness due to the previous abundant water availability and large habitat area.

Conclusions:

Over the entirety of all four zones along the riparian corridor where we measured and collected data, exotics, most notably *Bromus diandrus,* are very abundant. No more than five native species were found in any of our zones. All four zones did vary in vegetative composition based on topographical characteristics. The most distinguishing topographical characteristics included bank height and grade, and stream width and depth. These are important in determining what species can survive where because of availability to access water and have support from the soil. Generally, woody species, although predominately exotic, thrived in areas just outside the channel where the ground was flat and the bank wasn't too steep or long (Zone 4), where the roots could access the water table. Notably, woody species were almost completely absent from what we termed Zone 2, or the long stretch of stream channel through grassland; an area seemingly suitable for woody vegetation. Herbaceous vegetation was often found on the banks or in the channel close to the water in the stream. Across the site, where water was available, the most successful and abundant native species were *Typha sp*. and *Carex sp.* This is encouraging as these natives have the ability to reproduce and spread, possibly outcompeting invasives and providing beneficial native habitat. Overall, although there is a great number and abundance of exotic species, the site can support the introduction and success of a variety of native species.

<u>Species List:</u>

Amaranthus sp.
Aster sp.
Avena fatua
Brassica sp.
Bromus biebersteinii
Bromus diandrus
Bromus hordeaceus
Carex sp.
Clarkia sp.
Cynodon dactylon
Elymus sp.
Erodium sp.
Ficus carica
Geranium sp.
Ixeris sp.
Lepidium latifolium
Lolium multiflorum
Mentha sp.
Plantago sp.
Polypogon sp.
Pyrus sp.
Rubus armeniacus
Rumex sp.
Salix sp.
Sapium sebiferum
Silybum sp.
Tragopogon sp.
Trifolium sp.
Typha sp.
Vicia sp.
Xanthium sp.

Centennial Park Upland Vegetation Summary

Chapter 1 Land Use History

Prior to Spanish colonization this 265 acre site was likely used by the Miwok People as a field to cultivate native geophytes for consumption as there is a large presence of bulbs still thriving in midst of invasive annual grasses. Post colonization the site was used as dry grain farming and became heavily invaded by annual grasses. The riparian area was channelized and is currently running from beneath the suburban neighborhood that borders it to the west while industrial complexes face the east side. The middle tributary is 125ft x 2100ft with upland, wetland, riparian and transition habitats. The woody species in the riparian area have been deforested. Despite this, beavers have been seen as a pest as they contribute to flooding in the adjacent neighborhood. There is annual disking of firebreaks since the amount of dry vegetation is a cause for fire concern. In the 1990's nonnative trees were planted in the south tributary which provide valuable habitat for many species. In 2012-2013 trees were planted alongside the west bike trail. In 2015-2016 a new pedestrian path was established to encourage ecotourism.

Key Ecosystem Services

The recreational site has the potential to provide wildlife habitat, wildfire control, air quality mitigation, water quality mitigation, urban heat mitigation, flood control, and water storage and provision.

Core Site Constraints

Water/Hydrology

The source of these constraints come from the seasonality of water availability, depth of water in the creek, the height of stream banks, ponding of water in the upland vegetation, and beaver activity killing woody species.

Soil Type

Ponding or flooding is a constraint on most of the soils found at the site. Other limitations are outlined in Table 1.

Table 1 Soil Types of Centennial Park and their Limitations

Soil type	Soil depth profile	Drainage/ ponding	Water storage	Bulk density/ penetrability	Nutrients, salinity	Potential uses	Vegetation type
Clear Lake Clay	Clay from surface through depth Water table can be at 48" depth	Poor drainage frequent ponding Water seldom percolates deep	Moderate (8.4 ")		Can be saline Hi P	Limited suitability for trails Could support ponds	Annual grasses and forbs Often in swales, drainageways Tules, sedges, watergrasses
Capay Silty Clay Loam	Surface- silty clay loam, 21-50"clay Below 50" Clay loam	Moderately well drained, no ponding	High (10")	Moderate bulk density 6" penetrability		Could support ponds Somewhat limited for trails	Annual grasses and forbs
San Ysidro sandy loam	Surface- sandy loam ***(lab measured sandy clay-loam)*** ** abrupt texture change 25-35" depth: Clay loam 35-54" depth: sandy clay loam Below 54": stratified sandy loam to clay loam	Moderately well drained, no ponding, low water storage	Low (3")	Low-moderate bulk density 4" penetrability	No to low salinity	Somewhat limited to support ponds Somewhat limited for trails	Shallow-rooted plants forbs, annual grasses Associated with higher exotic species than other soil types (at Jepsons)
Rincon clay loam	Surface- silty clay loam, usually continues deep through profile	Surface well drained, but subsoils slowly permeable with. Generally no ponding, but shallow perched water if high precipitation	High (9.4")		Low to no salinity	Agriculture-irrigated or non-irrigated	Annual grasses and forbs

Broad RCD Project Goals

- Create riparian trail system that loops around 2.5miles of the core habitat
- Decrease invasive species by restoring native species
- Decrease invasive species and use native plants to restore:
- Establish two tributaries of Horse Creek (16 acres)
- In channel- herbaceous plugs (sedges, rushes, grasses, etc.)
- Outside channel- riparian trees/shrubs
- Upland area (12.5 acres)
- Grasses, wildflowers

Upland Goals

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

Core Questions from the RCD

- Which areas can support which types of plant species? (where are the different "zones" of suitability for different plant community types, based on soils, hydrology, etc.?)

- Where are hotspots on the landscape for key native species of interest (e.g. woody species, native wildflowers, bulb species), and key invasive species (e.g. Chinese tallow tree, Fig, Teasel, Perennial pepperweed, Italian ryegrass, Medusahead)
- Who are the late-season wildflowers and where do they occur? (may be covered by pollinator group in ecosystem services)

Other Key Questions

- Which invasive species exist along the three zones of interest (creek side, trail side, and field)?
- Which natives exist along the three zones?
- Which areas look like the most suitable for key natives(specifically our personal species of interest; which areas have depressions for species more suited to inundation, where tree roots won't disrupt paved pathways)?
- Which areas seem most suitable for herbicide (heavily invaded)?
- Is it possible to manually dig up the native bulbs and replant them?

Chapter 2 Methods and Data Analysis

Measurements

1. Average cover class of natives and invasive species in each quadrat
2. Average height of all vegetation in a quadrat
3. Species composition by transect
4. Cover class by lifeform by soil type
5. Cover class of each species by soil type
6. Percent relative cover of each species by transect
7. Mean height of vegetation in each transect
8. Mean cover class of each invasive status by soil type
9. Max height of vegetation in each soil type

Equipment List

- Transect tape (2)
- 1-foot square quadrats (2)
- GPS units (2)
- Meter stick (2)
- Transect pins
- Data sheets
- Reference guides (as needed)

Method

Sampling efforts were stratified by soil type. We split into two groups to map patches of key invasive grasses (*Elymus caput-medusae* and *Festuca perennis*) and natives bulbs (*Tritileia spp.* and *Brodiaea spp.*) in soil type RoA. Patches were identified by site and marked with a GPS unit to facilitate finding them for future management.

For more detailed vegetation sampling the average cover class of each species present was determined in quadrats placed along transects (Figure 1). Seven 50-m transects were randomly laid out in soil types CeA (4 transects) and SeB (3 transects) with 1-ft x 1-ft quadrats placed every 10-m to determine the average cover class of each species present. Cover class was determined by first identifying all species present in a quadrat, then estimating the percent of bare ground covered by each species separately (Figure 2). Each species was then assigned a cover class based upon this estimation. These methods were adapted from the methods outlined in Appendix One: Plant Cover Estimation for Herbaceous Plants: A Quick Field Method.

Data was transcribed into an Excel file and information in native status and invasive status was added for each species. Data was then analyzed using JMP statistical software.

Limiting Human Error

- Randomness was insured by choosing a random starting and ending point for all of our transects. A random direction to walk to was chosen by twirling a stick over our heads and whichever direction it pointed when we said stop would be direction of where our next transects would be. A random number between 50-100 meter was chosen to determine how far the next transect would be.
- Walked along one side of the transect tape to ensure that the vegetation that we were sampling from wouldn't be trampled.
- Standardized cover class estimated between observers to minimize discrepancy within our data before we split into groups.

Sampling Locations

Figure 1 Transect Locations and Bulb/Invasive Grass Hotspots

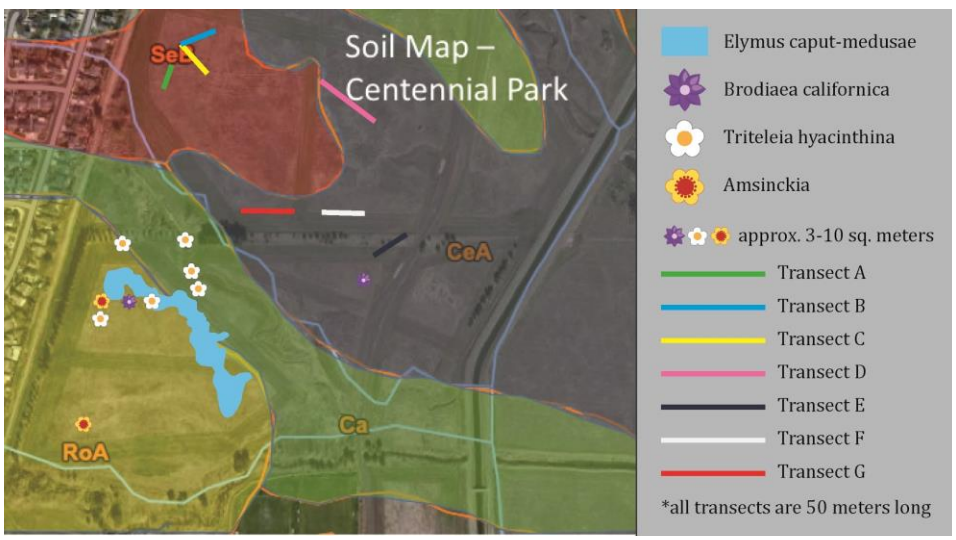
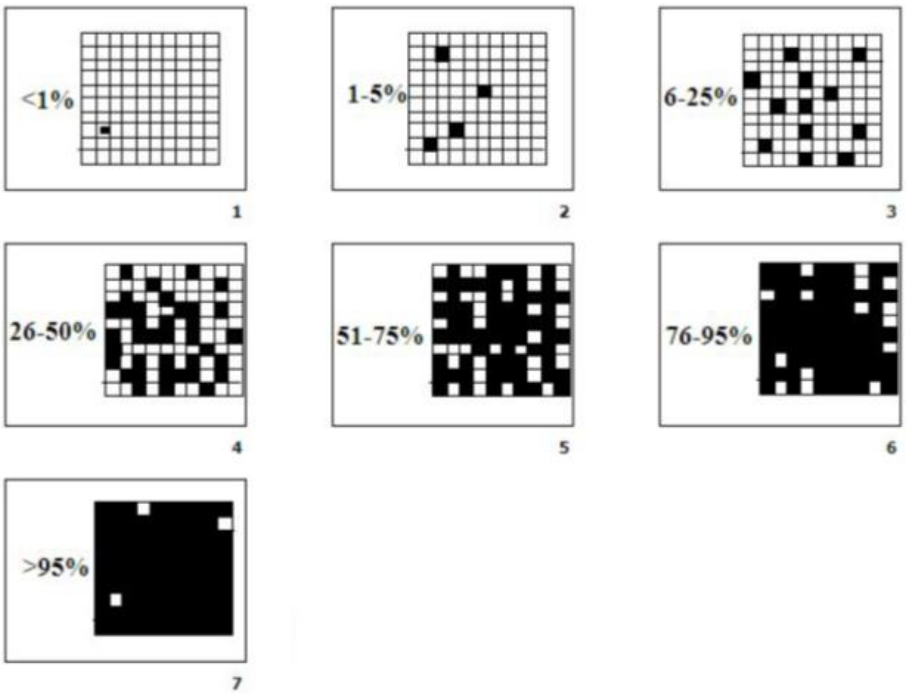


Figure 2 Visual Estimation of Cover Classes



Cover Class	**% Cover**
1	<1%
2	1 – 5%
3	6 – 25%
4	26 – 50%
5	51 – 75%
6	76 – 95%
7	>95%

Sampling Challenges

- GPS units running out of batteries significantly lowered time to collect data
- Additional GPS units were needed, at least two
- Very little time to cover a very large area
- Difficult to determine where we were on the map

- Statistical analysis needed more forethought
- Species ID
- Group member attendance/injuries

Chapter 3 Results

Species List

Asteraceae

-*Centaurea solstitialis* - yellow starthistle
-*Lactuca serriola* - prickly lettuce
-*Sonchus asper* - rough milk thistle

Fabaceae

-*Medicago polymorpha* - California burclover
-*Trifolium* - clover
-*Vicia* - vetch

Geraniaceae

-*Erodium* – filaree; storksbill
-*Geranium dissectum* - cutleaf geranium

Poaceae

-*Aegilops triuncialis* - barbed goatgrass
-*Avena fatua* - wild oat
-*Briza minor* - lesser quaking-grass
-*Bromus diandrus* - ripgut brome
-*Bromus hordeaceus* - soft chess
-*Elymus caput-medusae* - Medusahead
-*Festuca perennis* - Italian ryegrass
-*Hordeum* - Foxtail
-*Phalaris canariensis* - canary grass

Primulaceae

-*Anagallis arvensis* - scarlet pimpernel

Themidaceae

-*Brodiaea*
-*Triteleia hyacinthina*

Our visual observations and more detailed sampling showed that native species diversity was extremely low, with only five species recorded and only one species (*Triteleia*) found in great abundance. This made the perennial forbs the most abundant native species in the upland vegetation site. More information on native bulb presence and distribution described below.

Unsurprisingly, the most abundant vegetation type recorded was invasive annual grasses. Figure 3 describes the presence and invasive status of each species in each transect and Figure 4 describes the relative cover of each species present in each transect. The site was most heavily invaded by species of *Avena*, *Festuca*, *Bromus* and *Vicia*. We also found barbed goatgrass (*Aegilops triuncialis*) in transects B and E. This is a cause for concern as it was not previously noted on the site and is listed by the California Invasive Plant Council as having a potentially high impact on native ecosystems.

Soil type SeB had no native forbs while some forbs were found in soil type CeA. Each soil type had a similar percentage of native bulbs, and both soil types were dominated by non-native grasses (Figure 5). The most common species in soil type SeB were *Aegilops triuncialis* and *Centaurea solstitialis*, while the most common species in soil type CeA was *Vicia* spp. (Figure 6).

Transects C and F had the tallest vegetation while transect E and G had the shortest vegetation. The max height of the vegetation was recorded between 70-90cm and was tallest in soil type SeB. This information can be used to determine fire danger in the area and plan future management actions such as mowing or herbicide use to decrease fuel loads.

Some problems arose during the first day of sampling as we made transects just outside the perimeter of the site. This information was used and recorded as the vegetation in this area was nearly identical to much of the rest of the site where we would have recorded. If given more time, more transects should be made in areas of high bulb density and in areas adjacent to the creek.

Native Bulbs

One of the RCD's main goals was to conserve and manage the already present population of native geophytes found in the upland areas of the site. While marking bulb and invasive hotspots on the first day on the field site, we noted that much of the RoA and Ca soil types had a very large abundance of *Triteleia hyacinthina* where other vegetation was not very tall and there was direct sunlight. In patches where very tall *Avena* was found, the bulbs were not present in flowering form. We therefore suggest that these *Avena* patches be dug to examine whether bulbs are present beneath the soil to determine whether light competition has kept them from flowering. *Triteleia* was also found in patches Medusahead thatch, this relationship should also be researched further. *Brodiaea* was found scattered and in less dense patches off the site perimeters in Ca soil where transects were located. *Brodiaea* generally preferred a less directly sunny habitat as it was found usually mixed within open patches of vegetation. This confirms what is already known about *Brodiaea elegans* characteristics which state its preference for partial shade. Only one individual of *Dichelostemma* was found in the RoA soil type in the patches of *Triteleia*. Unfortunately due to time constraints positive ID's were only made for one of the genera (*Triteleia*) for the species.

Figures

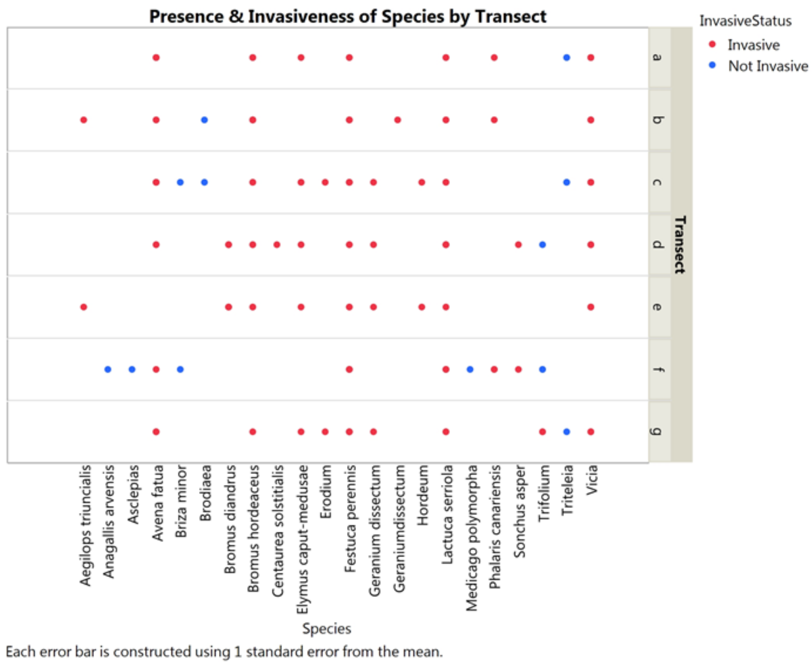


Figure 3 Illustrates the presence and invasive status of each species by transect.

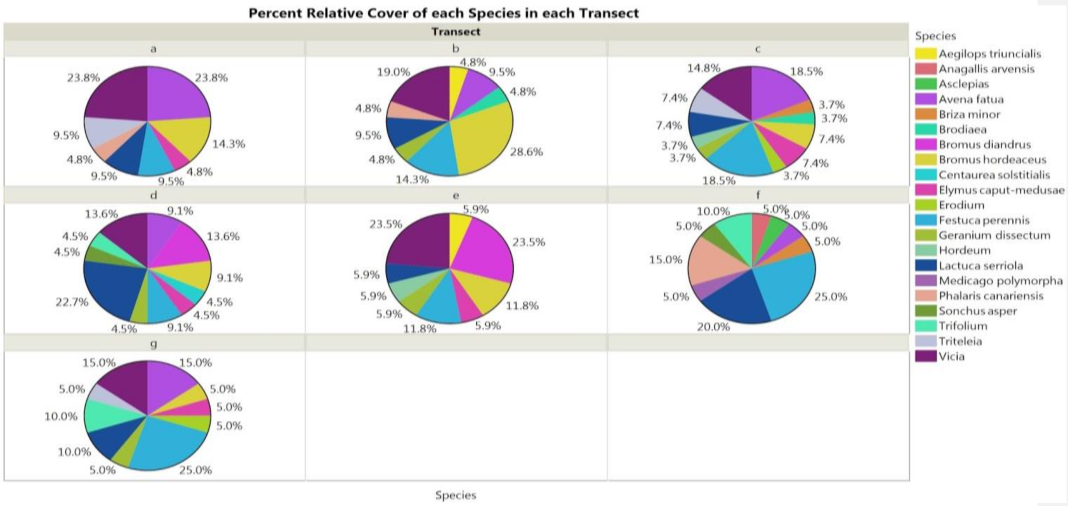


Figure 4 shows charts that display the percentage of each species found in each transect.

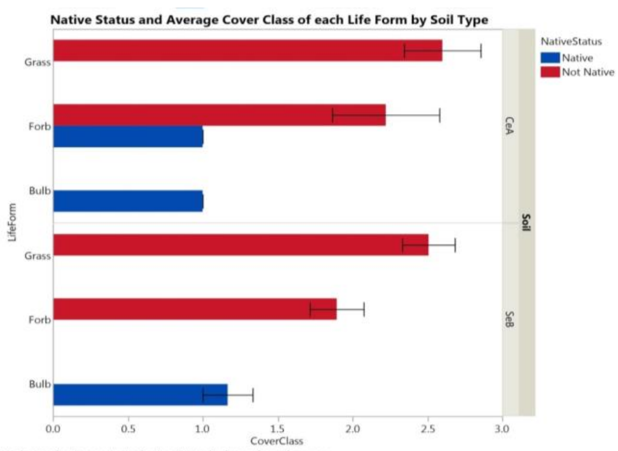
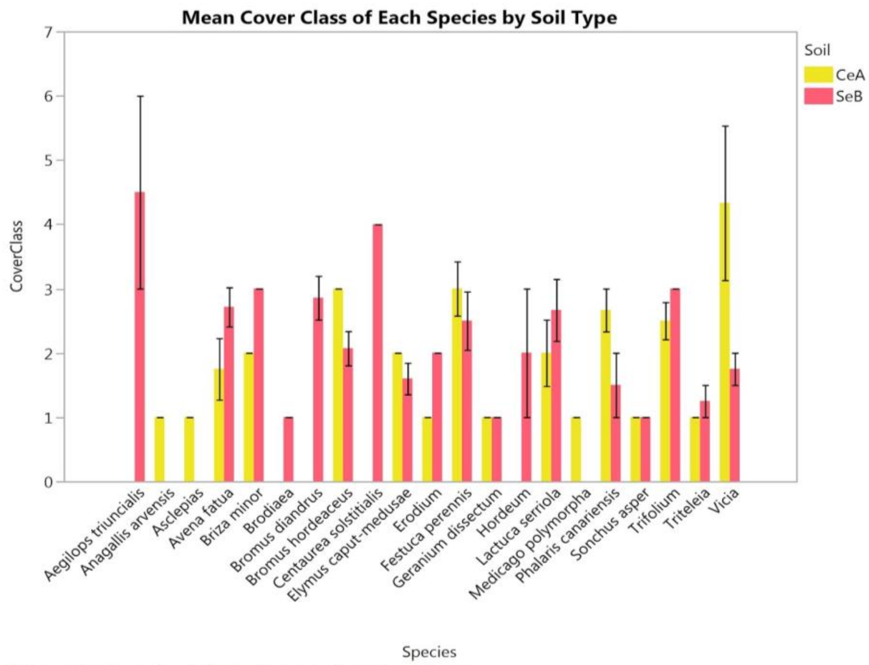


Figure 5 illustrates the presence of lifeforms found on each soil type.



Each error bar is constructed using 1 standard error from the mean.

Figure 6 Illustrates the presence of each species in each soil type that were found on site.

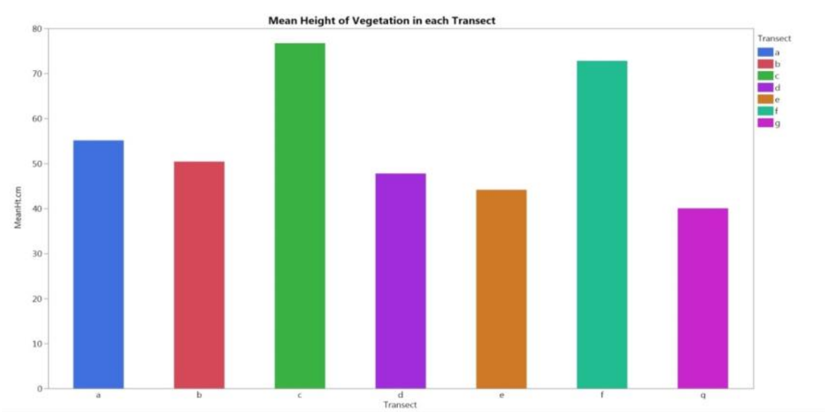


Figure 7 illustrates the average height of vegetation in each transect.

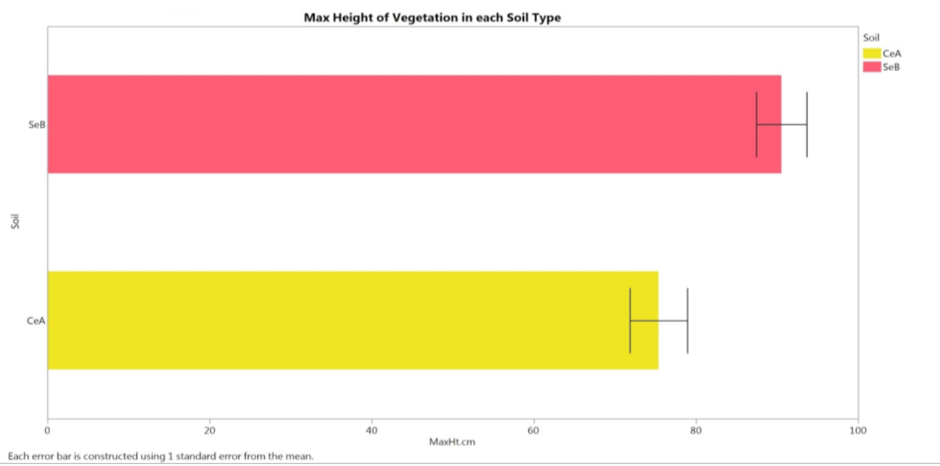


Figure 8 This graph illustrates the average maximum vegetation height found in each soil type.

Chapter 4 Appendix One: Plant Cover Estimation for Herbaceous Plants

Plant Cover Estimation for Herbaceous Plants: A Quick Field Method

In order to properly and effectively treat nuisance herbaceous (broadleaf non-woody) plants on your property you must first estimate the percent cover of that plant. If the problem species is widespread, it would be incredibly time consuming to try to count all of the plants in the entire treatment area. Instead, we can use a sampling method called the quadrat transect method that can be performed quickly. This procedure will help you estimate the nuisance plant percent cover number to input in the PESTMAN program. PESTMAN will in turn use that number to make the best possible recommendations for mechanical treatment or either broadcast or individual plant treatment (IPT) with herbicides. Follow the method below to estimate the nuisance plant percent cover. Before you get started you will need a pencil and paper and a 0.25 m^2 sampling quadrat. This can be made from 180 cm (70.9") of plastic covered steel cable with ends clamped together to form a loop or four 50 cm (19.7") long pieces of wooden dowel rod to form a square or partial square (Figure 1).

1. Find a starting point in the proposed treatment area that will allow you to traverse about 250 steps without leaving the area and choose a point on the horizon to focus on in order to walk a straight path for the entire 250 steps. If the area is small, reduce the total number of steps on the transect to 200, 150, etc.

2. From your starting point take 25 steps (or a number of steps that equals 1/10th of the total number of steps of the transect) and come to a stop. Place the quadrat on the ground with the edge of your quadrat at the tip of your right toe. If you are using the wooden dowel quadrat, form a square with one of corners at the front of your right boot. Try not to disturb or remove the plants that are rooted within the quadrat, but you may push out plants that are not rooted.

3. Observe the quadrat from directly overhead and make note of the area that the target nuisance plant's leaves, stems and fruit cover (Figure 1). Try to visualize what percentage of the ground that the nuisance plant shades. Use figures 2 and 3 as guides to determining percent cover. Record the percent cover of the nuisance plant on your paper and label the entry "plot 1".

4. Pick up your quadrat and walk another 25 steps in the same direction as before to your second plot. Repeat the estimation of percent cover and record that number as "plot 2". You will repeat this process at least 8 more times. More repetitions will yield a more accurate estimation of percent cover of the nuisance plant.

5. Now calculate the average percent cover by adding all of the percent cover values for each quadrat and dividing that number by the total number of quadrats observed.

Side-by-side Pictures of Circular and Square Sampling Quadrats

Figure 1. Example pictures of loop (left) and square dowel (right) 0.25 m² quadrats. The dewberry in each quadrat is our target nuisance plant and covers approximately 15-20% of the quadrat area.

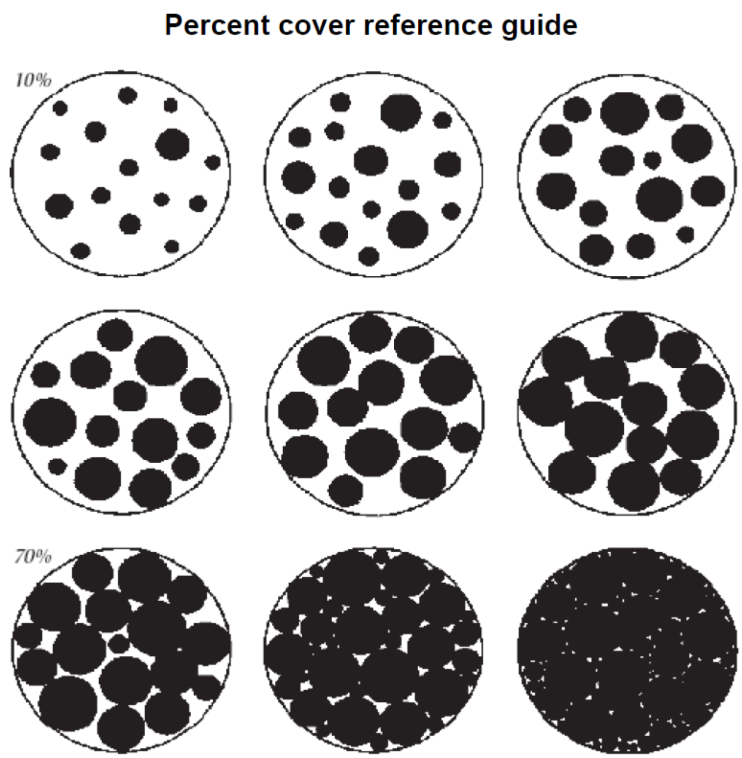


Figure 2. Percent cover reference guide. Graphic representations of increasing levels of percent cover in a circular plot area. Starting in the top left corner with 10% cover and increasing in units of 10% from left to right down to the middle left and to the right and then down to the bottom left to the right ending in a 90% cover.

Ecosystem services of a tributary of Horse Creek and surrounding upland

Chris Chen, Steven Chi, Lauren Bradt, and *Andrew Collum*

Abstract

Centennial Park in Vacaville, CA, is comprised of many interacting parts both near and far from the tributary of Horse Creek. Together these parts create a functioning ecosystem that provides beneficial services to the species present as well as to humans. In this study, field data was collected for some of these interacting factors to estimate the services that they provide. Although it would be ideal to measure every interacting part of the ecosystem provided by the study site, it was not possible to accomplish this in the time span allotted. Included in this study are the data and results for *water quality, erosion, pollination,* and *fire control.* Standard procedures were developed for each type of data collected in the field to avoid sampling bias. Random, or stratified-random, sampling was used to further avoid site selection biases.

Keywords: Coliform, pH, upland, riparian, pollinators, stratified-random, & shear.

Sampling & Mapping

*Methods***:** The initial plan for selecting survey areas included random sampling for points Fp 1-9. Number of samples per field were based on the field's size. Four sites for field A, three for field B (which included a known vernal pool) and two for field C were selected. Surveys were also done in the riparian area, designated as field R.

- Fp indicates fire and pollinator surveys (in green).
- E indicates Erosion surveys only (in red).
- Ew had erosion, pollinator, and fire surveys done, but focused primarily on potential areas for water quality surveys (in blue). Water quality surveys were completed at Ew4, Ew5, Ew7, & Ew9.

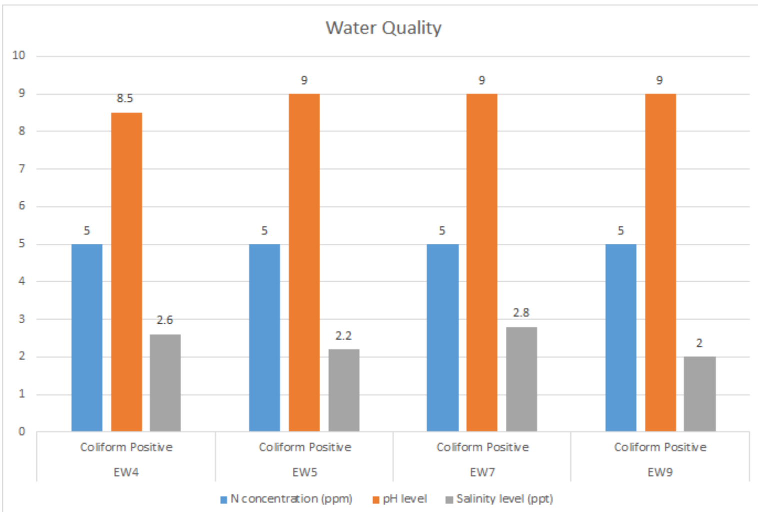
*Challenges and Revisions***:** After the initial nine sites were surveyed for fire potential and pollination, four more sites were selected - two in field A and two in field C. We felt that extra surveys were needed to get significant representations of the fields. More erosion surveys were also done at points Fp 2, 7, 10, 11, 12, & 13. We did not conduct additional water quality surveys due to a lack of testing equipment.

Water Quality

Methods: Water surveys were completed by walking the length of the creek. Several tests were conducted from the point where the water entered the restoration area to the last section where water was found. The tests consisted of the presence of coliform, nitrogen concentration, pH, and salinity. The nitrogen, salinity and pH test had swift results; however, the coliform tests required 48 hours to determine presence/absence.

*Challenges and Revisions***:** Measuring water quality was difficult because the creek tributary was dry in multiple areas and pooled into still ponds in other areas. These conditions made it more difficult to obtain reliable samples from each of the four sites. Furthermore, coliform tests took two days to process from the time of sampling and had to be taken on two separate occasions. Finally, taking samples from moving or still water posed a challenge as well. Only samples from moving waterways were taken for consistency. Reaching the creek also proved troublesome in some areas of steep erosion.

*Data Analysis and Results***:** Measurements of water quality were taken only along the tributary of Horse Creek and when there was water present in the creek. Our data showed that, throughout the length of the creek in the park, there was very little difference in any of the measured parameters throughout the creek (*Fig B)*. These results imply that there is continuity along the entirety of the creek tributary. The benefits or detriments of this result depend on the purpose of the creek for the future. A continuous habitat implies there are little or no barriers to dispersal and establishment for the species that can utilize the niche space around the creek. A continuous habitat may also be a problem because of the possibility that major disturbances can spread and disrupt the riparian ecosystem. Therefore, the continuity of the creek could be both problematic and beneficial for restoration along the riparian habitat.



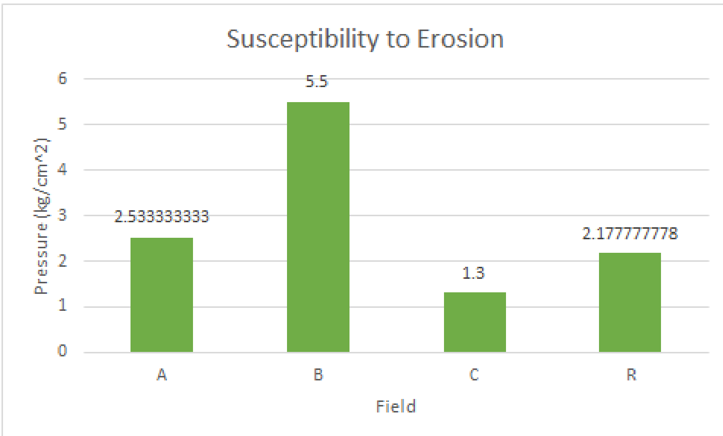
(Fig B)

Erosion

Methods: For erosion, we selected testing sites using random stratified sampling. We delineated the site into four major regions - Field A, Field B, Field C, and Field R - based on the position of the fire breaks and what kind of habitat was present (e.g. upland vs. riparian). After determining our four main fields, we randomly selected 1-9 sampling sites within each field. A 1m x 1m quadrat was laid on randomly selected spots within the quadrat to perform erosion tests. We brushed away the vegetation from this selected area and used an E-285 Pocket Vane Shear Tester to test how much pressure needed to be applied in order for the soil to break loose. The pressure value was recorded in kg per meters squared.

Challenges and Revisions: While initially sampling for erosion, we originally had just one site per upland field (i.e. Fields A, B, and C). However, we found that this would not be enough data for a thorough analysis. As a result, we returned to the site in subsequent weeks and sampled additional sites. Given this, we did not have sufficient time to sample more plots within Field B, where only one data point was obtained.

Data Analysis and Results: Since we were testing erosion using the E-285 Pocket Vane Shear Tester, it should be noted that higher pressure values are correlated with a lower susceptibility to erosion with the opposite being true. Based on this, Field R (the riparian habitat) had some of the weakest soil on the project site (*Fig. C*). This is likely due to flowing water, whose presence may be responsible for undercutting the stream banks. Additionally, Field C had a high susceptibility to erosion (*Fig C.*). This is likely because of the field's soil composition, which was probably severely waterlogged.



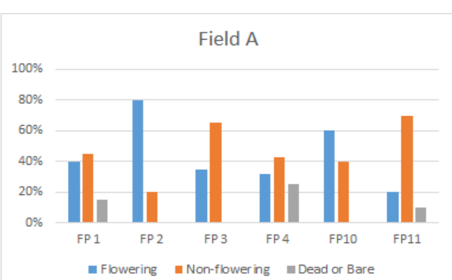
(*Fig. C*)

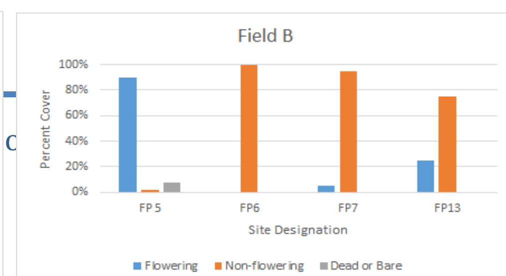
Pollination

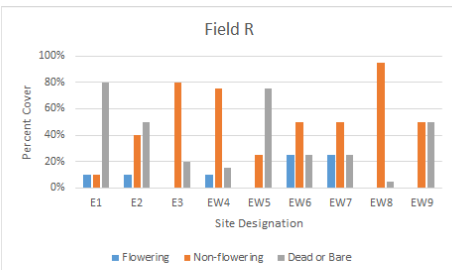
Methods: Pollination was measured in all four areas of the site. We measured both the site's ability to support pollinators by observing the flowering cover that existed on the site and by observing the actual pollinators flying on site. We walked to each of the randomly chosen points, and randomly chose a place to mark out a 1 square meter quadrat. Percent cover of flowering, non-flowering, and bare ground/dead vegetation was estimated in the randomly chosen 1 sq. m quadrats within each field. We determined flowering to include forbs and bulbs, and non-flowering to include grasses, sedges and rushes. Sightings of pollinators in each quadrat were taken within a 5 minute time period.

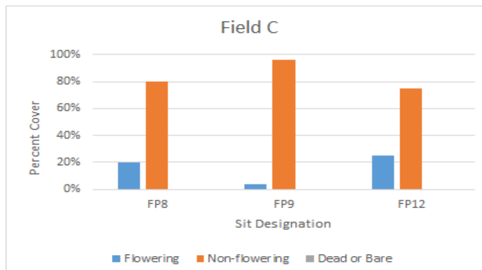
Challenges and Revisions: It was difficult to identify the pollinators that we found on the site, so in our results we identified the pollinators we found as "yellow and black bees." In addition, we did not return to each of the quadrats that we sampled for pollination in previous weeks, so the quadrats that had plants flowering later in the season could have had higher percentages of flowering cover and more sightings of pollinators. If we had more time, we would have returned to the field sites at a point later in the season and taken pollination measurements again.

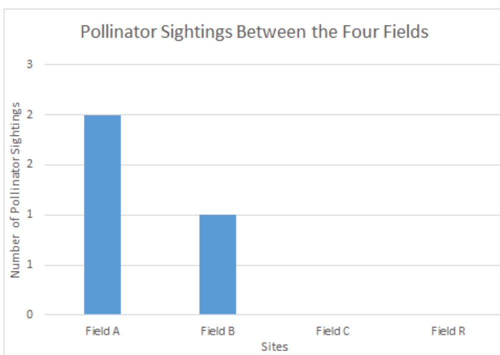
Data Analysis and Results: Field A had the most sites with high percentage cover of flowering vegetation (*Fig. D*). Fields B and C had the most with high percentage cover of non-flowering vegetation (*Fig. E* and *Fig. F).* The riparian habitat (Field R) had the greatest percentage of bare ground/dead vegetation, which was largely due to the large amount of erosion along the banks of the creek (*Fig. G*). Fields A and B were the only areas where pollinators were sighted. Yellow and black bees were the only pollinators found, and they were found in three total sightings throughout the site (*Fig. H*).











Starting from top left and rotating clockwise: (*Fig. D*), (*Fig. E*), (*Fig. F*), and (*Fig. G*)

(*Fig. H*)

Fire control

Methods: Fire control was measured as potential litter that may arise in a 1m x1m quadrat. Three plants that were growing in the quadrat were selected at random and measured for height. From the measured height we can rank the biomass accumulation and fire potential by their Relative Biomass Accumulation.

Challenges and Revisions: Data collection for fire control was focused on plant height only due to time restrictions. Originally this study sought to identify fire hazards in each region by measuring dry biomass of a defined area, rather than by height. To save time and resources we substituted height for dry-biomass. However, this may be a less accurate measure of fuel load.

Data Analysis and Results: Results of plant height data collected showed two extremes among the various fields. Sites A and R had an average plant height of 95cm to 90cm while sites B and C had average heights between 67cm and 76cm (*Fig. I*).

	Field A	Field B	Field C	Field R
Relative Biomass	0.9	0.7	0.8	1.0
Rank (1=largest)	2	4	3	1
Data Values (cm)	90	67	76	95

(Fig. I)

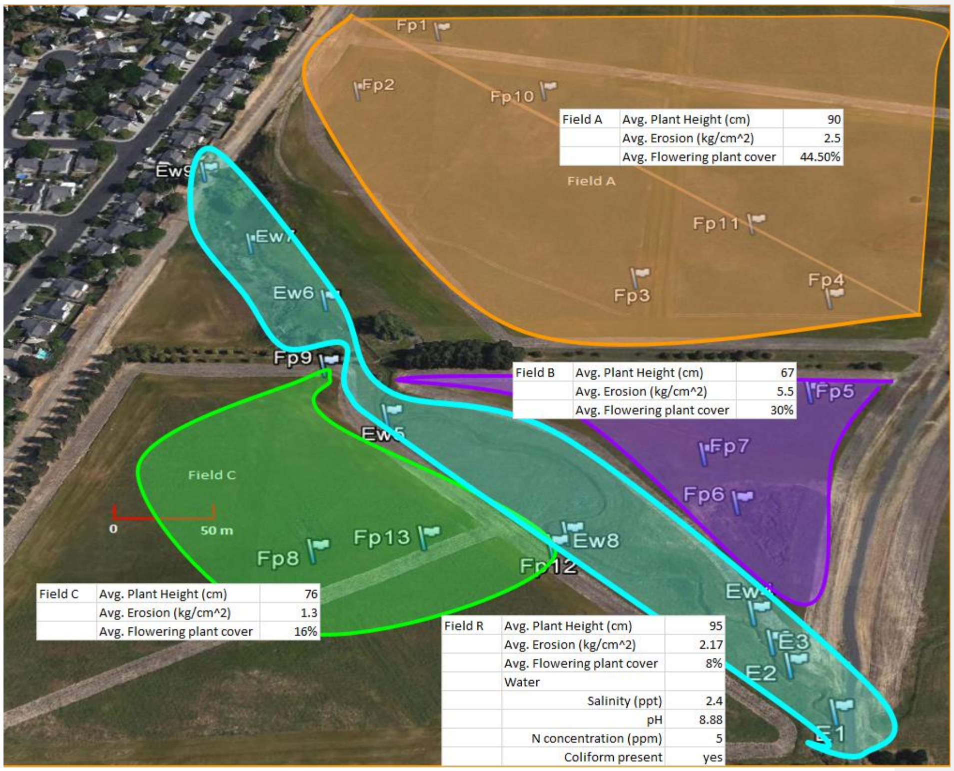
The plant height was then compared to field R, the site with the tallest average height, to develop a relative measure of biomass accumulation by height in each region. The sites were then ranked, based on plant height alone, for fire hazard (where 1=most hazardous).

Our data shows that Field R has the highest average plant height (95 cm), while Field A has the second highest average plant height (90 cm). Given this, Field R is nearest to the water table at the Horse Creek Tributary. Thus, because of the similar average heights between fields A and R, but the absence of abundant water in field A and the presence of the creek acting as a fire break in field R, it could be determined that Field A has a higher fire hazard than Field R.

Fields A and R should be monitored closely for fire control while fields B and C are likely to be less hazardous each season.

Summary, Conclusions, and Unresolved Questions

- For water quality, the coliform presence, pH levels, nitrate concentrations, and salinity levels remained relatively homogeneous throughout Horse Creek.
- Pollinators were only found in Fields A and B, where the greatest percentage cover of flowering vegetation was also present.
- When we measured erosion using the shear tester, we found that Fields R and C were most susceptible to erosion.
- Finally, Fields R and A pose a significant risk to fire hazard due to high litter accumulation.



(*Fig. J*)

Although these four topics cover a wide range of ecosystem services, we did not have enough time to answer every question that we wanted to, such as:

- What were the phosphorus levels in this tributary of Horse Creek?
- If we were given ample time throughout the day, would we have been able to see more species of pollinators? If we had returned to each quadrat throughout the season, would we have seen more pollinators?
- Is Field C's high susceptibility to erosion due to waterlogged soil or other factors?
- What is the biomass accumulation of litter in each site?

Further analysis of ecosystem services is recommended before action is taken. Restoration of this site should include as many factors as possible in the planning stage.

ENH 160L – Lab Summary: Wildlife

Kelly Kane, Alec Villanueva, Betty Lee, Katie Pierce

Introduction

To help the Solano RCD build a restoration plan for the site, five questions were proposed to guide our methods in gathering information about the wildlife present:

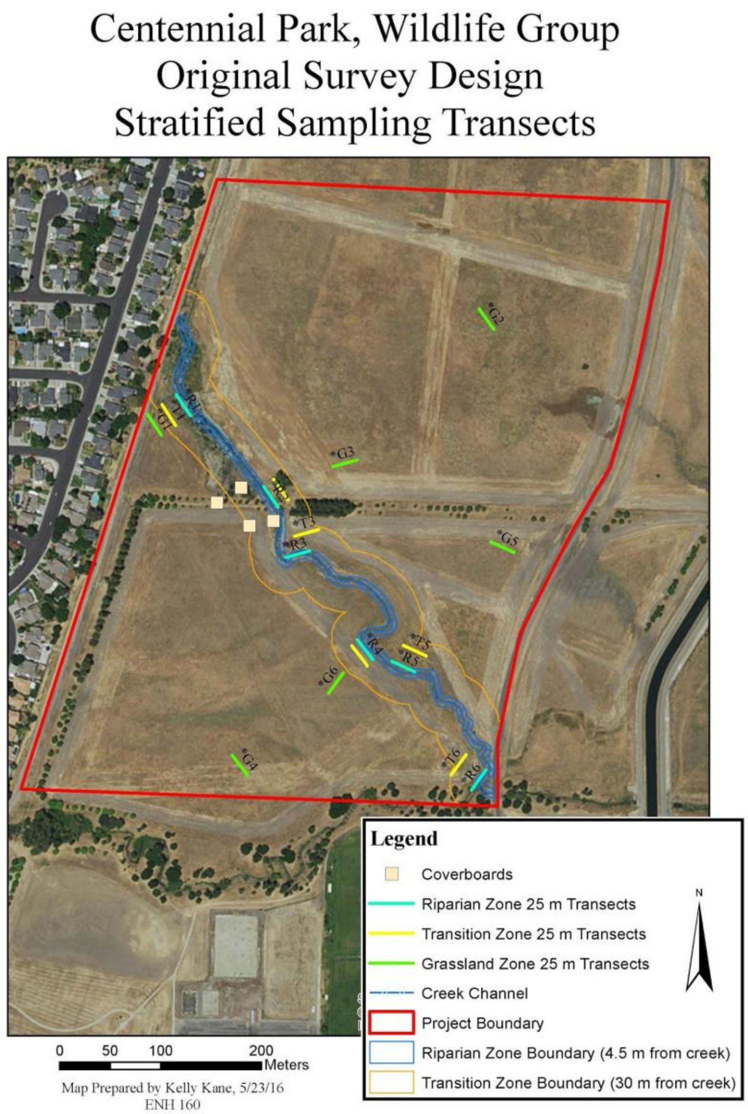
- What native and invasive species are present and in what abundance?
- Which species inhabit which habitat types?
- What habitat characteristics are present, and which species could they possibly support?
- What areas have higher habitat quality and why?
- What habitat areas can be improved to support more wildlife?

Methodology

The site was stratified into three zones: riparian zone, transition zone, and grassland zone. The boundaries of each zone are visually demonstrated in Graph 1 below. Six 25-meter transects were randomly generated within each zone. Each transect was then surveyed by two group members and any sign (scat, tracks, burrows, species presence) within one meter on either side of the transect tape was recorded. Additionally, vegetation characteristics within one meter on either side of the transects were measured and recorded. To locate each transect in the field, our site map, bearing, and pacing were utilized. A five minute bird point count was also taken at each transect. Finally, four coverboards were placed south of the creek- one in the riparian zone, two in the transition zone, and one in the grassland zone- and were checked at the end of each field day. The locations of each coverboard and transects are indicated on Map 1. To analyze the data, a list of species present in each zone was compiled in Table 1 and visually organized in Graph 2. Graph 2 also shows the proportion of non-native species to the native species present.

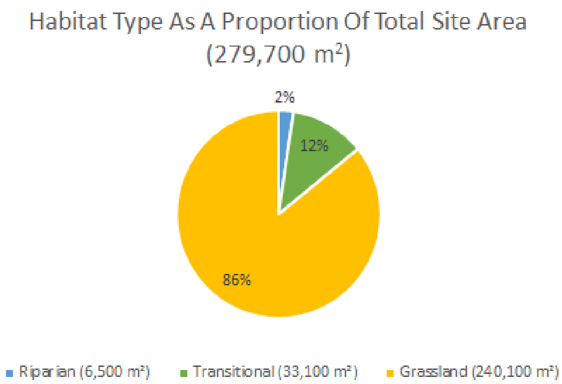
The days of the field study were 4/18/16, 4/25/16, and 5/2/16 from 2:40PM to 4:20PM. Due to time constraints, two transects in the grassland zone (G1 and G3) were not surveyed as planned.

Map

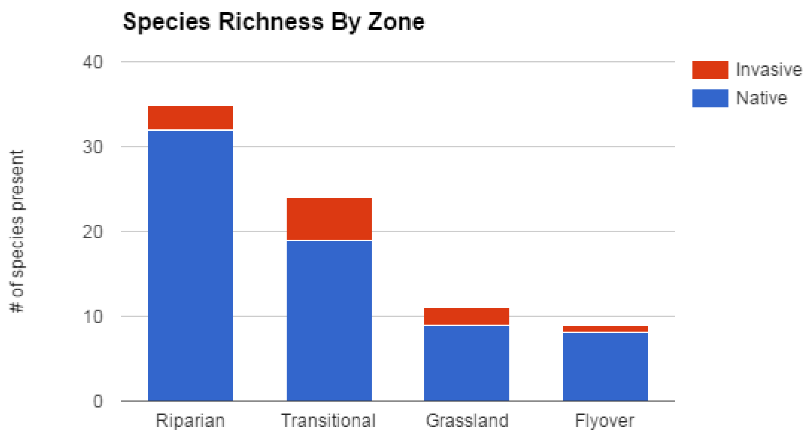


Map 1. Overall site map with planned transect (riparian, transition, and grassland zones) and coverboard locations.

Data



Graph 1. Ratios of habitat type as a proportion of total site area.



Graph 2. Species richness by zone with a comparison of non-native/invasive species to native species.

Presence/Absence						
			Habitat Type			
	Scientific Name (Invasive)	Common Name (Invasive)	Riparian	Transitional	Grassland	Flyover
Birds	*Agelaius phoeniceus*	Red-winged Blackbird	P	P	P	
	Aphelocoma californica	Western Scrub-Jay	P	P		
	Branta canadensis	Canada Goose				P
	Buteo jamaicensis	Red-tailed Hawk				P
	Buteo lineatus	Red-shouldered Hawk	P			
	Buteo swainsoni	Swainson's Hawk				P
	Butorides virescens	Green Heron	P			
	Callipepla californica	California Quail	P		P	

	Calypte anna	Anna's Hummingbird	P			P
	Cathartes aura	Turkey Vulture				P
	Charadrius vociferus	Killdeer	P	P		
	Columba livia	Rock Dove	P	P	P	P
	Corvus brachyrhynchos	American crow				P
	Corvus corax	Common Raven	P	P		
	Elanus leucurus	White-tailed Kite	P	P		P
	Haemorhous mexicanus	House Finch		P		
	Hirundo rustica	Barn Swallow				P
	Melanerpes formicivorus	Acorn Woodpecker	P	P		
	Melospiza melodia	Song Sparrow	P			
	Mimus polyglottos	Northern Mockingbird	P	P	P	
	Phasianus colchicus	Ring-necked Pheasant		P	P	
	Sayornis nigricans	Black Phoebe	P	P		
	Spinus psaltria	Lesser Goldfinch	P			

	Sturnella neglecta	Western Meadowlark	P	P	P	
	Sturnus vulgaris	European Starling		P		
	Tachycineta bicolor	Tree Swallow	P	P	P	P
	Troglodytes aedon or *Thryomanes bewickii*	Wren sp. (House Wren or Bewick's Wren)	P			
	Tyrannus verticalis	Western Kingbird	P			
	Zenaida macroura	Mourning Dove	P	P		
Mammals	*Castor canadensis*	North American beaver	P			
	Felis catus	Domestic cat		P		
	Lepus californicus	Black-tailed Jackrabbit	P	P	P	
Herps	*Elgaria coerulea* or *Elgaria multicarinata*	Alligator Lizard	P			
	Pseudacris regilla	Pacific Chorus Frog	P			
	Sceloporus occidentalis	Western Fence Lizard	P	P		
Fish	*Gambusia affinis*	Mosquito Fish	P			
Insects	*Agelenopsis spp.*	Grass Spider	P			
	Apis mellifera	European Honeybee		P		

	Coccinella Septempunctata	**Ladybug**	**P**	**P**		
	Diabrotica undecimpunctata	**Spotted Cucumber Beetle**			**P**	
	Gryllinae Spp.	**Field Cricket**	**P**	**P**	**P**	
	Odonota Spp.	**Dragonfly**	**P**	**P**	**P**	
	Syrphidae Spp.	**Hoverfly**	**P**			
	Tegenaria domestica	**Funnel Spider**	**P**	**P**		
	Vanessa virginiensis	**Painted Lady Butterfly**		**P**		
	Vespula or ***Dolichovespula Spp.***	**Yellow Jacket**	**P**			
	Xylocopa varipuncta	**Valley Carpenter Bee**	**P**			
Crustacean	***Pacifastacus leniusculus***	**Crawfish**	**P**			

Table 1. Overall species list of which species was found in each area by either direct observation or by indirect indicators of nest or scat.

Zone	Habitat Characteristics	Potential Species Supported
Riparian	● Transects R1 and R5: dominated by low-growing forbs, dead plant material, weedy invasive species (vetch, thistle, etc.), a few tall grasses. Vegetation height ranged from 0 cm- 100 cm ● Transects R2, R3, R4 and, R6: dominated by tall grasses. Vegetation height ranged from 30 cm - 130 cm ● Northwestern part of the creek: water was present, gradually sloping banks ● Southeastern part of the creek: water was not present, steep and incised banks	● Higher vegetation provides cover for medium sized wildlife such as Jackrabbits (*Lepus californicus*) and Ring-necked Pheasants (Ring-necked Pheasant) ● Trees provides nest and perch sites ● Banks on the northwestern side of the creek provide space for ground nesting birds such as Killdeer (*Charadrius vociferus*) and Green Heron (*Butorides virescens*) ● Creek provides habitat for mosquito fish and amphibians which in turn feed water birds ● Creek acts as breeding ground for bugs which in turn feed insectivores
Transition	● Transects south of the creek: dominated by tall grasses. Vegetation height ranged from 25 cm- 140 cm ● Transects north of the creek: dominated by dead plant material, bare soil, vetch, dandelions, low-growing weedy species, one willow tree (5 meters tall). Vegetation height ranged from 0 cm- 20 cm ● Majority of the transition zone was treated with herbicide	● Darker ground provides basking areas for reptiles ● Low cover from shorter vegetation make the area an easier hunting ground for raptors ● Slightly uneven and soft ground allows for easy digging of burrows for small mammals and reptiles ● Willow tree provides valuable nest and perch sites
Grassland	● Dominated by tall grasses (mainly wild oat and wild rye) and low-growing forbs ● Range of vegetation height: 55 cm-140 cm ● Vegetation pressed down in areas ● Ground was soft and incredibly uneven	● Tall grasses provide cover for medium sized mammals ● Uneven and soft ground allows for easy digging of burrows for small mammals and reptiles ● Dry areas have cracked earth that can be used as ready-made burrows ● Patches of legumes provide high quality food for seed-eating wildlife ● Trees in windbreak area provide perch and nest sites

Table 2. Descriptions of each habitat zone with our inferences of which types of species could potentially inhabit each zone.

Conclusions

Based on the data, the riparian zone supports the highest number of species. This is most likely because it supports a wide variety of birds by providing food sources such as insects, small fish, and amphibians. In terms of habitat quality, the riparian zone best sustains birds, fish, insects, and amphibians due to the presence of many trees and a fairly consistent water source. The grassland zone, however, presented higher habitat quality for small mammal species. This is due to the uneven and soft ground, dense vegetation cover, and the presence of insects and seeds as possible food sources.

Recommendations

This group recommends that the Solano RCD focus on restoring riparian zone habitat due to the high quantity of species it can support. In particular, it is recommended that restoration activity is targeted in the southeast end of the creek for planting of trees and shrubs which can provide potential habitat for many bird, amphibian and small mammal species. As for the grassland and transitional habitats, this group has few suggestions other than remove invasive species and add native forbs and grasses wherever possible.

Additionally, monofilament wattles were observed on site. Research shows that the use of monofilament wattles can cause wildlife entanglement and the plastic material photodegrades, leaving small pieces of plastic on site. Given the presence of Pacific Chorus frogs, lizard species, and likely other herps on site, this group recommends that future erosion control methods utilize natural, wildlife friendly fiber rolls, if feasible (California Coastal Commission, 2012).

Source

California Coastal Commission. “Wildlife-Friendly Plastic-Free Netting in Erosion and Sediment Control Products, Water Quality Fact Sheet.” 2012. http://www.coastal.ca.gov/nps/Wildlife-Friendly_Products

Table of Contents- Individual Topics

Planting trees in challenging soils

Background & Justification

Heavy clay soils that pool under high moisture conditions present problems for the establishment of woody species. Both environmental factors and species-specific factors affect the ability of a woody plant to establish a stable root system and survive conditions where soils pool and water displaces gases in the pore space of the soil. Oxygen deprivation, root instability, and susceptibility to pathogens are greatly increased in conditions of root submergence due to heavy ponding in soils. Tolerance to flooding conditions is influenced by the ability of the plant to cope with conditions as well as the dominant environmental conditions. In regions where woody plant establishment is desired but are subject to clay soils that pond, these considerations and more should be accounted for before planting occurs. If managed incorrectly trees are subject to permanent damage from pooling water and/or death.

Soils

The two soil series present in the site that would cause problems with pooling are the Clear Lake series and the Rincon series. The range of the Clear Lake series is concentrated northeast of the tributary of Horse Creek while Rincon series soils are concentrated to the south west of the creek. With the goal of establishing woody plants in these areas considerations of the pooling ability and heavy clay characteristics of these soil series must be taken into account.

The Clear Lake series is a poorly drained soil that is formed from fine textured alluvium **(3).** Average soil temperature should be noted because of its effects on the growth the woody plants. This series ranges from 59 to 65 degrees Fahrenheit. The Clear Lake series' structure is prismatic when dry and massive when wet with very fine pores and high clay percentage. This structure supports many fine roots from plants and most commonly supports annual, herbaceous plants that can grow between prismatic pedons in the large cracks of the soil. Woody species may have a difficult time establishing woody roots in such a finely packed soil series. The native vegetation for this series is mostly composed of grasses and forbs **(3**). Clear Lake soil is very poorly drained with low permeability and is a candidate for heavy pooling of water in the site studied.

A less likely candidate for pooling, but a series in which it may still occur, is the Rincon series southwest of the Horse Creek tributary. While Rincon soils are well drained and have high percolation, they have the characteristic of low permeability, or infiltration by water **(10**). Rincon soils are composed of clay between 35% and 45% and are commonly classified as a heavy clay loam, clay, or sandy clay. The highest proportion of clay in this soil series is concentrated near the upper horizons, which prevent infiltration by water **(10)**. However, further into the soil profile the clay becomes less prevalent and drainage is swifter. Because the upper horizons have high clay content and fine pores it is also a candidate for pooling at the surface.

While there are at least four soil types present at the site surrounding the Horse

Creek tributary, the Rincon series and Clear Lake series are the two which should present the worst problems with surface pooling of water and which are high in clay.

Limitations imposed on woody plant growth by ponding soils

Many problems for woody plants arise when they establish in heavy soils that can pond. Root damage and oxygen deficiency are at the forefront of problems to address when planting woody plants in these soils. Because waterlogged soils have their pores filled with water, there are little gases to be exchanged with a root system **(4)**. This implies that a species that cannot absorb enough gases will drown in waterlogged soils. Pooling can change the physiology of a woody species to the point that growth patterns will be influenced through processes such as changing concentration of growth regulators or inhibiting photosynthesis **(4)**.

In a report by Michael Baad, it was shown that on flooded, old fields of Clear Lake series soils, herbaceous species tend to be present at a higher frequency than woody species (16). This report showed that over half of the density of plants in a field similar to the one on our site is commonly dominated by herbaceous species. However, it also showed that large woody species could survive in the same environment. Quercus lobata, or Valley Oak, was found in a Clear Lake soil that flooded frequently (16). Although it was found at one-tenth the density of the dominant herbaceous species, this finding shows that there could be an established stand of scattered oaks across the Clear Lake series soils of the Horse Creek Tributary site.

Although it is a challenge, it is not impossible to grow woody plants on soils that pond or pool. Tolerance to high water concentration in the root zone depends on many factors of the plant and the environment including: vigor, soil conditions, timing and duration of flooding, temperature of soil and atmosphere, and quality of water **(4)**. One significant factor is the balance between woody roots and non-woody roots in the soil. Each of these two types of roots plays an important role in the health of a plant. While woody roots are more resilient to flooding, non-woody roots are essential to the uptake of nutrients and water in the soil. However, non-woody roots are disposable and may be replaced by the plant when they die. Replacement does not occur at a normal rate in a flooded soil and may result in the plant "starving" to death. Problems associated with flooding soils include uprooting of the root system, high susceptibility to pathogens due to increased stress, and insufficient nutrient absorption **(4)**.

Environmental factors also have a strong impact on the viability of a woody species' establishment in a heavy, ponding soil. In a study conducted by Ryan McShane on the distribution of riparian woody plants across the Western USA it was found that temperature and precipitation had the strongest effects on the composition of vegetation observed in different soil types **(8)**. A series of woody plant species were classified based on the environment in which they held established populations. Tamarix was identified as being suitable for arid climates with high temperatures and low moisture. This genus was also tolerant of summer drought and high salinity. Mcshane also identified that the genus Populus would do well in warm temperatures with high moisture. This study stressed the importance of species selection based on the environmental conditions when planning to establish woody plant populations **(8)**. The site surrounding the Horse Creek tributary would do well with a species which can tolerate summer drought, high temperatures, ponding soils, and strong root systems.

Amy Schrank conducted a study in Michigan regarding communities of vernal pools **(11)**. Although the results of this data are of little consequence for vernal pool communities in California's Central Valley, the methods used to analyze them are applicable to the Horse Creek tributary site. It was concluded that a hydro-period index measuring standing water persistence was correlated to the percentage of available carbon in the soil. The level of soil carbon was then related to the types of vegetation observed in or around the vernal pools. Vernal pools were then classified based on their composition and compared with the levels of soil carbon in each. Vernal sedgelands were favored at the highest level of carbon quantified. Moderate carbon concentration favored Red and Sugar maple establishment, while low carbon favored grasses **(11)**. The results of this study identify that maples, a woody species, do well in flooded soils when the soil is flooded for 60% of the time or less **(11)**. Relating this result to the Horse Creek site, it would be beneficial to choose regions to plant flood tolerant, woody species in regions with periodic pooling and not continuously standing water.

Mechanisms of woody plants for coping with heavy, ponding soils

Establishment of a woody plant community in any soil type is dependent on the physiological characteristics of the species as much as it is dependent on the environmental conditions. Selecting the right species for the conditions at a site is essential to effectiveness of the planting and maintenance costs associated with the woody species. Tolerance to temperature extremes is one of the most significant characteristics to consider when choosing a woody species **(12)**. Information climate regions is available through the USDA Hardiness Zone maps. This information includes minimum and maximum temperatures and average temperatures for a given region. Light tolerance is also a factor of plant hardiness in a region. Understanding these physiological characteristics of a species is essential in the process of choosing the right woody plant for a region **(12)**.

Moisture is also an important factor, especially in ponding soils. Evergreens, the genus *Prunus*, Junipers, and Pines are commonly intolerant of high levels of soil moisture that persist for long periods of time. The effects of soil moisture are commonly seen in the root systems of woody species **(12)**. During periods of high precipitation, such as winter in California, root systems commonly become shallow and will have a more difficult time surviving subsequent drought conditions. Woody species with a strong woody root system in combination with fibrous surface roots are well adapted to heavy precipitation followed by drought **(12)**.

The tolerance of a tree species, or individual specimen, to flooding and pooling is affected by many factors of the tree's physiology and development. Of these factors height, crown class, age, vigor, roots, and specific species variations are the most prevalent for determining tolerance to high levels of standing water. Height and crown class are correlated to one another and are influential in the ability of a plant to photosynthesize when submerged in water **(5)**. Shorter woody species may be submerged when flooding or pooling occurs while taller species can avoid submergence. Thus, smaller woody species may be prone to a decline in photosynthetic efficiency when subject to high volumes of standing water.

Vigor of a species is a contributing factor to flood tolerance as well. Vigorous trees tend to withstand submerged root systems better than less vigorous species. Vigor also affects the root system of a woody species with submerged roots. The development of adventitious and/or secondary roots above the waterline help species obtains oxygen when their main root system is fully submerged **(5)**. Plants with high vigor may be able to develop these aerial roots more swiftly when exposed to flood stress than species that grow more slowly and better survive the stress of high water exposure.

Although age is associated with better tolerance to ponding, species variations may work in combination with age to determine a plant's survivability when exposed to standing water. It is generally accepted that mature trees are more capable of withstanding ponding than young seedlings because seedlings are commonly physically damaged and cannot grow above the water line before they fall to other stresses **(5)**. However, acclimation to a highly flooded soil is more likely to occur in a young woody tree than it is in an older individual of the same species.

Flooding stress is a major abiotic stress to woody plants exposed to water that pond. It is also a driver of adaptive evolution in populations continuously exposed to this process. Soil waterlogging and submergence is collectively referred to as flooding. It results in insufficient oxygen levels, and decreased availability of carbon dioxide and other gases **(6)**.

One adaptation to flooding is the physical escape from a flooded or ponding soil. Internal aeration, adventitious aerial roots, anoxia tolerance, or high vigor to repair flood-damaged root systems are examples of physical escape from flooding **(6)**. Arenchyma is a common tissue type in plants tolerant to standing water. These tissues provide interconnected networks of gas-filled spaces and act as an oxygen reserve when roots are submerged and gaseous space in the soil is filled by water **(6)**.

The displacement of oxygen in the soil is commonly associated with reduced growth and survival of plants. Plants that are already tolerant to the conditions at a site usually do better than those that have not developed tolerance to events like flooding or ponding **(9)**. The choice of species used to re-vegetate a site is an essential decision and may determine resilience of the population regardless of other factors within the environment.

Planting Practices and Establishment

While physiological characteristics of a woody plant are important when considering where and what species to plant in soils that pond, the methods of planting and management of the established individuals greatly affects survivability. In heavy soils that pond it is recommended that the root ball of the woody species be planted so that one third to one half of the root ball is above the soil **(1)**. Doing this may increase permeability of the soil and overall drainage so ponding becomes less of a problem.

Composition of the medium in which the tree is planted is another important practice that can affect the likelihood of a soil to pond. Amendments like peat moss or compost added to the planting hole may retain water for extended periods of time and impose more damage to root systems than if they were not added **(1)**. Along with medium composition, soil compaction can affect pooling of water at the base of woody plants. Regions of high compaction decrease permeability of the soil and increase the incidence, intensity, and duration of ponding/pooling **(1)**.

Establishing raised beds or drainage pathways can help plants to cope with ponding by directing the sitting water away from the root system of the plant. Along with these practices, amending soils with gypsum helps to break up clay aggregates and increase the total pore space and average pore size of a soil high in clay content **(1)**.

Soil amendments are a strong approach to dealing with soils of high clay content that pond. Soil texture, compaction, available nutrients, drainage, and other factors that influence ponding are affected by soil amendments and can be improved for tree establishment when organic amendments are applied. However, organic versus inorganic amendments result in effects on microbial activity where non-decomposed organic amendments increase microbial activity and deplete soil nutrients faster **(7)**.

Although soil amendments in the right proportions may benefit the establishment and survivability of a woody tree, it is commonly recommended that a planter not amend a soil. Because amending the soil alters the composition of the soil the tree cannot acclimate to native soils and become less vigorous when their root systems extend beyond the amended portion of the soil **(7)**.

Long Term Goals

A. Establish a stable population of woody species

Those that can overcome the environmental conditions of the site should be able to reproduce on a consistent time scale. High fecundity and fertility are long-term goals. These values can be measured in subsequent seasons through offspring densities. Survivability of the species and the individuals chosen for planting may rely on many factors of the woody individual and environment. Measure long term survivorship rate of the initial cohorts planted at the site to determine the fitness of the chosen individuals.

B. Overcome the difficulties presented by soils at the site

Limitations on woody plant growth in ponding soils may result in physiological changes of the woody individual and influence growth patterns. Changes in the concentrations of growth regulators, inhibition of gaseous exchange through root systems can result in plant death. Soil amendments may help to decrease the severity of negative soil effects on woody plant growth. Approximately 50% of the soil where woody species will be established should be amended for future cohort establishment.

C. Utilize the correct species for long term establishment

Physiological responses to ponding soils should be considered when selecting a species. Some responses may be shown in the ratio of fine to woody roots to cope with flooding conditions and/or dense soils with few macropores. It has been shown that temperature and water inputs (e.g. precipitation, runoff, etc.) have the highest correlation with woody species distribution across the western United States. These conditions should be considered when choosing a species while still including soil conditions and ponding in considerations.

Short Term Goals

D. *Select the best adapted species/variety*

The decision of selecting a species is outlined above in the *Long Term Goals* section. The genera recommended for this restoration process are *Populus, Salix*, and *Acer*. These choices are based on research results of numerous studies on the distribution of different woody species across the western United States (Mcshane et al. 2015) and their abilities to survive the conditions present at the study site (Schrank et al. 2015).

E. *Amendment of soils to improve soil conditions for infiltration and root establishment.*

Different amendments have different effects on the soil they are added to. In the case of the Horse Creek tributary there are heavy clay soils that pond when large volumes of precipitation provide excess water inputs into the system. The two soil types of concern at the site are the Clear Lake series characterized as a poorly drained soil that pools and the Rincon series that is less likely to pool, have a higher rate of drainage and percolation, but have low infiltration rates. These dense soils may result in issues with root development for large, woody species growing in them (Douglas 2015).

F. *Site Selection*

Sites that are better suited to support woody species should be identified before restoration efforts begin. Those sites that require less effort to alter will increase the efficiency of the project. Project managers should consider soil series, intensity and frequency of ponding events, and other factors included in this report when selecting sites to be restored.

Restoration Plan

To effectively establish woody species on heavy soils that pond many factors must be considered including, but not limited to, the following: Genetic source of individuals for planting, genera of woody species to use, Seeding and/or transplanting seedlings, alteration of soils to promote woody species establishment and persistence, Average temperature and moisture conditions, and the frequency and intensity of ponding.

The recommended genera for restoration purposes are *Populus, Salix,* and *Acer*, all of which have been reported to be capable of establishing populations in ponding soils and high temperatures. However, it is important to select individuals that originate from a genetic population that has adapted to conditions similar to those of the project site. When choosing a genetic source one should search in populations that grow on heavy clay soils that pond. Having the genetic diversity to adapt to these conditions is a positive factor on the retention of the woody species community that will be established.

Based on a study by Ryan Mcshane (Mcshane et al. 2015) the genus *Populus* (Poplars) is a suitable candidate for establishment in this study. It has been shown to adapt well to warm temperatures and high moisture in its environment. These are similar conditions to the ones present at the Horse Creek restoration site. *Populus* presents a difficulty with physiological responses to environmental conditions because it is a fast growing species and some become large. For the purpose of establishing woody species on this site, *Populus* is a good choice. However, taking into account other factors present (e.g. beaver dam building) a fast growing species that grows large may be detrimental to the safety level of the site.

An alternative to the genus *Populus* may be the genus *Acer* (Maples). Studies on vernal pool communities have showed that Maples, a woody species, do well in flooded soils when the soil is flooded 60% of the time or less (Schrank et al. 2015). Maples grow to a lesser size than many Poplars and may be capable of establishing stable populations in heavy soils that pond. This implies that it may be less of a safety hazard in the case of beaver-implemented deforestation but may not be able to adapt its physiology as rapidly as *Populus* to unfavorable conditions.

A third option would be the reestablishment of the *Salix* (Willow) community in the riparian region of the tributary. Because the willows that were present on the site prior to beaver-implemented deforestation, they may be well adapted to the soil and hydrologic conditions present at the site. The risk of failed establishment could be lessened using these lineages that have previously adapted to the conditions detrimental to woody species establishment. However, the previous issue of beaver-deforestation will not be addressed.

Restoration managers should consider a combination of *Populus, Acer,* and *Salix* when deciding what species to plant for reestablishment of the woody community. Individuals should be chosen that originate from a lineage that has adapted to conditions similar to those present at the Horse Creek site to lessen the risk of failed establishment. Those concerned should also consider the need to defend those individuals from deforestation.

The likelihood that a population of woody individuals will survive may increase if they are more likely to survive juvenile stages. As such, planting methods of the genetically sourced individuals should be considered in the context of seeding the soil versus transplanting seedlings. Per individual introduced to the site the probability of survival through maturity increases for transplanting compared with seeding. However, it is also more costly to transplant seedlings than to incorporate direct seeding. Transplanting is recommended for the establishment of a woody plant community in the site (USNPS).

Allowing time for acclimation to growing conditions at the project site is an essential aspect of seedling germination and growth before transplanting. Once seeds are collected from populations with site conditions similar to Horse Creek tributary conditions they should be grown in containers with heavy clay soils and persistent standing water near the root zone. Although the genetic potential to survive these conditions may be present in individuals, allowing time for acclimation helps "trigger" desired genetic traits.

Before transplanting can occur, regions selected for planting that have particularly problematic soils should be amended or prepared. The two soil series that will be especially problematic for the project are the Clear Lake series and Rincon series; both tend to have persistent ponding of water and high clay content with few macropores.

Amending heavy clay soils can be difficult because of the effects amendments will have on infiltration, percolation, and water holding capacity. Because of the differences between the two soil types, each soil series that leads to ponding should be addressed individually when choosing amendments.

The Clear Lake series typically has more than 40% clay composition in some layers of the soil, which are concentrated in the upper horizons (USDA). Because the clay content is concentrated near the surface horizons the soil lacks a high percentage of macropores for water infiltration. When dry the soil cracks and forms prismatic pedons with large spaces between them, these tend to be sites with high levels of non-decomposed plant material. It is considered a poorly drained soil with slow permeability and potentially high runoff rates by the United States Department of Agriculture. Plants with a large volume of fine roots tend to colonize these soils while large, woody roots may have difficulty pushing through the dense soil.

Amendments for the Clear Lake series, if required, should increase infiltration rates, percolation rates, and drainage of the soil. In addition, amendments are needed to increase macropore space between clay aggregates. For a soil like those in the Clear Lake series it may be essential to decrease compaction before planting. High levels of compaction will decrease permeability and increase the duration and intensity of ponding while making it more difficult for roots to develop (Almquist 1993). A recommendation for amending Clear Lake soils is to add gypsum to the upper horizons with high clay percentages. Gypsum helps to break up clay aggregates and increase the total pore space and average pore size of the soil. This may help increase water infiltration rate and percolation rate through the soil to minimize ponding at the base of a woody plant (Almquist 1993). Gypsum should be added at levels between 40% and 60% to have the desired effects in the soil.

Rincon series soils tend to have better percolation and drainage than Clear Lake series soils. However, due to high levels of clay accumulation in the A horizon and B2t horizon in the upper layers of the soil (between 30% and 45% clay) infiltration of water is slow and runoff rates high for a Rincon soil. This series is more hospitable to woody roots of woody species; which can push through the middle and lower horizons while growing (USDA). Infiltration of water is the issue with Rincon soils that needs to be addressed to prevent ponding at the base of woody species.

Amendments will most likely do more harm than good in a Rincon soil, except at the very surface horizons. If amendments, like organic matter, are added they may increase water-holding capacity and decrease the already acceptable percolation rates and drainage of the soil. Gypsum added to the A and Bt horizons at levels between 40% and 60% may help increase pore space and average pore size to increase infiltration and decrease pooling intensity and duration (Almquist 1993). A recommendation for altering Rincon series soils is to decrease compaction and increase macropore space in the upper horizons through amending with gypsum in upper horizons at the sites targeted for planting of woody species.

Selection of sites for planting woody plants should be carefully chosen before restoration efforts commence. Including the variables in this article, factors related to the overall ecology of the site should be considered. Examples might be deforestation potential by beavers, herbaceous species already established, light intensity, and distance to water table from the surface of the soil.

Monitoring Plan

Monitoring is necessary for the preparation and success of the restoration project at the Horse Creek site. It may be accomplished through multiple measures of woody plant health and fecundity, soil characteristics, and interspecific fitness comparisons between individuals in each genus chosen for planting. To allow comparisons before and after restoration occurs consistent variables should be represented in monitoring trials before and after the project is implemented. In preparation for planting, measures for initial infiltration rate and soil texture should be taken at each planting site.

Plant health is a useful, aggregate measure that can be used in both the selection of genetic lineages and to assess the success of establishment after planting. Many factors of the individual can tell about the health of a plant including maximum height and diameter at breast height, area of the leaf, fertility and fecundity, and resprouting capacity following major disturbances (Pérez-Harguindeguy et al 2013). Plant height is measured as the distance between the shortest difference between the ground and the tallest photosynthetic tissue. Leaf area can be affected by environmental stresses and may be beneficial in measuring a woody plant's response to stationary water stress. It may also be used to assess the health of the parent plants in their native habitat. Fecundity is the reproductive potential of an individual while fertility represents the volume of offspring actually produced. These measures are highly correlated to the health of a plant and should be measured in the genetic source population as well as in the primary cohorts established through planned restoration. A higher level of fertility is common in healthier individuals. Following a major disturbance like flooding or beaver-assisted deforestation, the ability to resprout is a beneficial trait and should be assessed in individuals chosen as a seed source (Pérez-Harguindeguy et al 2013).

Not only is monitoring plant health after restoration an important practice to measure the success of the project, it is also an important aspect when identifying the source populations of the woody plants. The aspects of plant health chosen to be measured may be different from the ones presented in this proposal. Other suggestions are presented in Pérez-Harguindeguy et al 2013. And should be referenced when managers are deciding how to measure a plant's health.

Soil characteristics are an important factor that should be monitored before and after project implementation. Because the main barrier to establishing woody species on the project site is the soil's tendency to pond, ensuring that the soil is accurately prepared and maintained will be essential to success. According to the USDA Natural Resources Conservation Service, soils that are heavy in clay that create large cracks when dry tend to have high infiltration rates when dry. However when wet, infiltration rates in these soils can be very low. The Rincon and Clear Lake series present at the project site have characteristics similar to these and lead to ponding.

Soil infiltration rates should be measured before and after soil amendments are added to quantify the effects of amending clay soils. The single ring infiltrometer method can be used and is recommended by the USDANRC. A standard procedure should be established that could be used for infiltration tests before and after amending the soil. Infiltration rates at each site chosen for restoration should be measured to determine if the soil might be suitable for planting. While amending soils is a useful technique for preventing ponding at the base of woody plants it can also be costly. Choosing a woody plant species that is capable of surviving in heavy soils that pond would be more cost efficient and require less maintenance in the future.

While soil characteristics and plant health are important factors to consider, observations on the frequency and severity of ponding should be recorded before any actions are taken. Understanding how often an area ponds and for how long water is present on the soil surface are significant factors of this restoration plan. Sites with frequent and persistent ponding should be planted with species that can survive and grow in those conditions. While sites with infrequent and/or short-term ponding may require less attention.

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Native woody species

Arroyo Willow — *Salix lasiolepis*

The arroyo willow is a prominent and widespread riparian tree/shrub species native to California. It is commonly used for restoration projects due its tolerance of different soil types and flooding, as well as for the wildlife habitat it provides. Because it thrives in flood-prone areas and has deep roots, it can aid in bank-stabilization and erosion control; important aspects of many riparian restoration projects. As a riparian species, it has seen substantial decline since settlers first came to California, as it is estimated that 95% of historical riparian habitat has been destroyed or degraded (CA Wildlife Conservation Board, 2016). Such destruction has often come as a result of land conversion for agriculture or development and damming rivers that feed riparian habitats. Without water flow, hydrophilic species such as the arroyo willow cannot survive. However, in the last 10 years, riparian restoration efforts have been increasing, leading to an expanse of riparian habitat that is suitable for species such as the arroyo willow (River Partners, 2016).

Growth characteristics:

The arroyo willow grows as a tree/shrub with many trunks/stems, reaching a height of 23 feet, a width 15 feet, and a trunk diameter of 6 inches. (California Native Plant Society/Kershner et al, 2008).

It is fast growing (California Native Plant Society)

It is winter deciduous, meaning it will lose its leaves in the winter season (California Native Plant Society).

Leaves are from 1.5 to 4.5 inches long and are narrowly elliptical to obovate shaped. The leaves are most often a dark green on the top side, and paler beneath. They are also usually firm and leathery (Kershner et al, 2008).

Reproduction:

The arroyo willow flowers from February-May (CalFlora)

The flowers are yellowish-colored unisexual catkins, meaning each flower is either male or female, having either staminate or carpellate parts (California Native Plant Society)

The willows are dioecious, so each individual plant is either male or female.

Pollination can occur by wind or by insect, with insect pollination being the more successful and common form of pollination (Sacchi and Price, 1988).

Female flowers produce many small, non-dormant seeds towards the end of its flowering season. Because the seeds are non-dormant, seeds from a given year either survive in that year or die off, resulting in no seed bank. Therefore, conditions must be ideal at the time the seeds are released (Sacchi and Price, 1992).

Adequate soil moisture is the most important factor in seedling survival, as seedlings cannot tolerate drought well (Sacchi and Price, 1992).

Seedlings that survive 3 years are have a high likelihood of surviving until they reach their reproductive stage (Sacchi and Price, 1992).

Competition for sunlight and soil moisture force seedlings to become established in open areas along stream banks as opposed to vegetated areas (Sacchi and Price, 1992).

Arroyo willows often recruit on sand and gravel point bars along streams. A point bar is an area of newly exposed and deposited alluvium along a meandering stream (Stromberg and Patten, 1992).

Individuals can produce many clones vegetatively, allowing them to take advantage of moist and sunny areas nearby (Sacchi and Price, 1998).

Individuals can be easily propagated from cuttings (California Native Plant Society).

Habitat/Range:

Elevation 0-3070 meters (CalFlora)

It can be found in a number of states in the western United States, including Washington, Oregon, Idaho, Nevada, Utah, Arizona, New Mexico, and California. It is most prominent in California (Kershner et al, 2008).

The arroyo willow grows in and around a variety of California habitats, including coastal sage scrub, riparian, oak woodland, and yellow pine forest, in the southern, central, and northern regions of the state (California Native Plant Scoiety).

The arroyo willow requires areas of high water content, including marshes, wetlands, and along stream banks, all three which can be found in or adjacent to the various communities/habitats mentioned above (California Native Plant Society).

Environmental Preferences/Tolerances:

Prefers full sun exposure (CNPS)

Can tolerate temperatures down to -15 degrees Fahrenheit (California Native Plant Society).

Is most productive in soils with pH 5.1 to 8.2, with a minimum depth of 13 cm (Cal Flora).

Can tolerate a variety of soil textures, as long as they are moist and well-drained, but prefer gravel or sandy soils (California Native Plant Society).

As a riparian species, the arroyo willow prefers to have its roots have access to the water table, and can tolerate seasonal flooding (California Native Plant Society).

It can tolerate a wide range of precipitation, as it can rely on its roots in the water table in times of minimal rainfall (as long as water is present is the stream) and can endure flooding in times of high rainfall.

Arroyo willows have deep roots and flexible stems, allowing for flood toleration (Bendix, 1998).

Individuals prefer areas next to streams and rivers that are flat and occasionally flood. This is often in the form of newly exposed point bars (Stromberg and Patten, 1992).

Individuals survive and grow best along low-power streams, where meandering allows for alluvial deposition and the creation of point bars (Bendix, 1998).

High-power streams lead to erosion as opposed to deposition, and create deep, incised channels not suitable for the species as they can no longer reach the water table (Stromberg and Patten, 1992).

Excessive inundation can inhibit the success and survivorship of individual trees (Stromberg and Patten, 1992).

Biotic Interactions:

Catkin flowers attract, and are pollinated by, native bees.

Insects including wasps and sawflies commonly create galls on arroyo willows for nesting and reproduction. They are most often not harmful to the plant (California Native Plant Society/ Price and Craig, 1984).

Arroyo willows, and the thickets the create, provide habitat for numerous bird, mammal, amphibian, and insect species (California Native Plant Society).

Arroyo willow (*Salix lasiolepis*) coexists well with a number of other riparian species, including, but not limited to, Sycamore (*Platanus racemosa*), Fremont's Cottonwood (*Populus fremonti*), California wild rose (*Rosa californica*), White Alder (*Alnus rhombifolia*), and Cattail (*Typha sp.*) (California Native Plant Society).

Browsing may occur from grasshoppers, rabbits, deer, and cattle. (Sacchi and Price, 1992/Stromberg and Patten, 1992).

Disturbances:

Though flood tolerant to an extent, the arroyo willow can be removed and killed by flood flows that result in bank slumping and erosion (Stromberg and Patten, 1992).

- *Salix* species show high levels of mortality as a result of fire, but also show high levels of resprouting following fire events (Bendix, 2010).
- Young individual growth may be inhibited by herbivory or trampling by grazing cattle (Stromberg and Patten, 1992).
- Browsing by grasshoppers, rabbits, and deer may inhibit seedling survival (Sacchi and Price, 1992).
- Riparian habitat suitable for the arroyo willow has been degraded or destroyed in the past due to the damming of rivers, causing altered hydrology or insufficient water levels, and land conversion for agriculture and development (Natural Resource Conservation Service, 2007).

Goals, restoration, and monitoring plan for *Salix lasiolepis*

Project Goal

To establish numerous individuals of *Salix lasiolepis* along the riparian corridor so that they may survive and reproduce without human intervention after the initial establishment phase. A successful population will provide habitat for native fauna, facilitate bank stabilization and erosion control along the riparian corridor, and assist in filtering runoff flowing into the riparian area, keeping the waterway clean.

Restoration Plan

The arroyo willow is a prominent and widespread riparian tree/shrub species native to California. It is commonly used for restoration projects due its tolerance of different soil types and flooding, as well as for the wildlife habitat it provides. Because it thrives in flood-prone areas and has deep roots, it can aid in bank-stabilization and erosion control; important aspects of many riparian restoration projects. The first step in the restoration process of establishing thriving, self-sufficient arroyo willows is to map out the area suitable for planting and establishment. Such areas are riparian, and therefore need to be close enough to the stream or water source so that the willow tree roots can access the stream or water table. A very favorable place for this, and an area generally colonized by arroyo willows, is on sand and gravel point bars along streams (Stromberg and Patten, 1992). If no such areas are available, other areas close to streams, or on stream banks, are the next priority. Areas prone to seasonal flooding are acceptable as well, as the species can tolerate such flooding events (California Native Plant Society). However, it is critical to avoid banks that border streams that flow with high power as the continual effect of the water may lead to erosion, channel incision, and bank undercutting, resulting in the inability of the roots to access water and leading them to dry out (Stromberg and Patten, 1992). Also, though seasonal flooding is tolerated, flooding is a difficult phenomenon to predict, and excessive inundation can inhibit survivorship of individual trees (Stromberg and Patten, 1992). Therefore, it is recommended that planting sites be at least 1 meter up bank from the normal water level, but not far enough away that the roots cannot reach the water table. The exact distance will vary by site based on topography and hydrology, but nearer the stream is better than farther away. Individuals should be planted at varying distances from the water to account for uncertainties in the flooding regime. The arroyo willow can tolerate a wide variety of soil textures, but does best in gravel or sandy soils with a pH 5.1 to 8.2 and a minimum depth of 13 centimeters (Cal Flora/California Native Plant Society). Soil measurements for depth and pH, as well as observations of texture, should be taken to distinguish more and less favorable soil conditions within the restoration site.

Once suitable areas are recognized and mapped out, it will be necessary to remove, either physically or chemically, invasive species. A lack of competing invasive species will allow for the willows to have adequate sunlight and soil moisture; vital components of seedling survival and establishment (Sacchi and Price, 1992). Following site preparation, planting or seeding can take place. It is recommended that cuttings be taken from either nearby arroyo willows or those found in similar habitats to the site of restoration. Individuals are easily propagated from cuttings, and this may be the most efficient and cost-effective method for willow establishment (California Native Plant Society). If cuttings are taken, it is imperative that they be taken from both male and female trees, and planted somewhat alternately between the two sexes, as individual arroyo willows are dioecious. Alternate planting will increase the likelihood of successful pollination and reproduction between male and female individuals. Because individual trees/shrubs can grow up to 15 feet wide, spacing between planted cuttings should be a minimum of 10 feet (California Native Plant Society/Kershner et al, 2008). This spacing distance will allow the willows to grow into thickets, as healthy willow populations are often found, providing habitat for numerous bird, mammal, amphibian, and insect species (California

Native Plant Society).

Once the cuttings are planted in the ground, irrigation may be necessary to maintain an adequate soil moisture for the first few years, until the roots have grown deep enough to reach the water table. A drip irrigation system with emitters located within six inches of the main trunk/stem is ideal. Generally, seedlings that survive 3 years have a high likelihood of surviving until they reach their reproductive stage, so irrigation is recommended for these first three years (Sacchi and Price, 1992). If species such as grasshoppers, deer, cattle, or beavers are known to be present in the area, tree tubes may be beneficial for protecting young saplings and planted cuttings from browsing and trampling (Sacchi and Price, 1992).

Monitoring Plan

Pre-restoration site monitoring should closely parallel what was described in the first paragraph of the Restoration Plan, focusing on site characteristics including topography, hydrology, soil characteristics, and existing vegetative/biotic characteristics. Monitoring of the arroyo willows at the site following restoration is most critical during the first three years, as seedlings that survive three years have a high likelihood of surviving until they reach their reproductive stage (Sacchi and Price, 1992). Monitoring and management should entail assuring irrigation is functioning properly for the trees and adjusting irrigation levels based on observation of the health of the trees. Relatively stunted growth or browning of leaves probably means that more water is necessary. If tree tubes are employed during restoration, they should be monitored for breaks and cracks, and to confirm they are doing the job of protecting the trees from browsers and grazers. If tubes are degraded, replacement may be necessary. If tubes are not doing an ample job of protecting the planted cuttings, larger, more durable tubes should be utilized. Additionally, any invasive plants that have come up nearby the willow saplings should be removed to ensure that the trees are receiving the maximum levels of sunlight and soil moisture, and not being outcompeted by the invasive species. Monitoring during these first three years would ideally include bimonthly site visits, as long as irrigation is on an automatic and regular schedule. A one hundred percent success rate for the willow cuttings should not be expected, but if substantial failure occurs, site conditions including water availability, soil characteristics, and sunlight levels should be analyzed in an attempt to determine the underlying factors contributing to the lack of survival of the young arroyo willow trees. If observation reveals unfavorable conditions, plant cuttings in a new or adjusted area with more supportive conditions. If conditions seem satisfactory, cuttings can be planted again in the area in hope that the second round will have a higher survival rate.

If the arroyo willows experience success in the first three years, the more difficult part is accomplished. Irrigation will no longer be necessary if the trees have been planted where recommended and the riparian area still maintains a regular supply of water. Growth during the first three years should have resulted in a tree size that is no longer substantially susceptible to trampling or grazing, except by beavers or larger mammals. Fencing around the lower 3-5 feet may be necessary to turn such animals away (Beaver Solutions LLC). Wasps and sawflies may be observed creating galls for nesting and reproduction on the willow trees. They are most often not harmful to the plant, and should not be of concern (California Native Plant Society/ Price and

Craig, 1984). The focus of monitoring can now shift to reproduction of the trees and some of the services they provide. Monitoring can also take place at a less frequent rate than in the first three years. If male and female cuttings were planted nearby each other during restoration, the population should be able to successfully reproduce by wind or insect pollination. If lack of recruitment is observed, native honey bees can be introduced into the habitat, as bee pollination has been found to be more common and successful than wind pollination (Sacchi and Price, 1988). Often, sexual reproduction isn't completely necessary for a thriving willow thicket, as the trees can produce many clones vegetatively, filling in favorable and available habitat (Sacchi and Price, 1988).

Successful and thriving *Salix lasiolepis* can often be recognized by the services they provide within the riparian corridor. Such services include reducing bank slumping and erosion through the anchoring of the soil by the roots and reducing water pollution through the uptake and trapping of pollutants and sediments from runoff coming into the riparian corridor. Before and after photographs and data in the form of measurements can be compared to assess whether bank slumping has been reduced in areas where willows have successfully been established. Measurements of topsoil loss can reveal changes in erosion patterns. Water quality data from before and after establishment may provide insight to root health of the trees.

Research and information on the specifics of water table depth necessary for the arroyo willow, root growth rate, age of reproductive capability, and effect of contaminated water on the willow would be useful to know for both restoration and monitoring purposes. These topics, and others, including those related to riparian bank stabilization and erosion control, and benefits of using cuttings versus seeds or transplants, are research questions that could be answered by this restoration site, or by comparing this site to another similar project.

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Quercus douglasii

Blue Oak

Part I: Literature Review

Blue oak or *Quercus douglasii* is a medium-sized endemic oak tree species to California. It is primarily found in open stands of the foothills encircling the central valley where it's blue-green frosty leaves are a key identifier. Blue oak is important in restoration efforts as it provides habitat and food to many native species and its slow growth, relatively old stands, and many damaging diseases, insects, and animals make it more likely to become more scarce. Blue oak populations were severely affected in the 50s, 60s, and 70s when millions of acres were removed for livestock rangelands and have continually been declining since. Today blue oaks cover primarily private land with only 14% in National Forest lands and 11% on public lands, which makes it particularly important to public restoration projects (Fryer, 2007). Furthermore, the root system of the blue oak is excellent for erosion control and prevention. Overall, blue oak is an important species to many animals for food and habitat while providing ecosystem services.

A. Habitat and Range:

As mentioned above, blue oak is a native and endemic species to California which ranges within a narrow strip of foothills encircling the central valley and a small population on the southern California coast and the Channel Islands. It is believed that Native American settlements may have introduced blue oak to the south coast and Channel Islands. Blue oak primarily inhabits valleys and low slopes below 3,900 feet elevation (Fryer, 2007). It dominates most oak woodlands and frequently occurs with gray pine and other oak species. Blue oak has also occurred in low-elevation riparian areas along with Fremont cottonwood, black walnut, and other riparian species. Dispersal of acorns is carried out by various birds and mammals which often bury them allowing seedlings to establish (see more on reproduction below). Blue oak is drought-deciduous meaning it may retain its leaves all year in wet conditions and show flushes of new foliage after significant rains. Its drought tolerance is due to its extensive root system and depending on soil conditions its roots can tap down as far as 80 feet to groundwater. Climate requirements for blue oak are Mediterranean which include hot, dry summers and cool, wet winters. They can tolerate summer temperatures exceeding 100˚F and mean winter temperatures of 30˚F. Annual precipitation for blue oak populations range from 20-40 inches, though blue oak has been known to survive with little precipitation in extreme droughts (Fryer, 2007). A study on individual trees for drought tolerance found that blue oaks were only mildly stressed during summer drought conditions (Osuna, 2011). Though its natural habitat is relatively narrow and constrained to the foothills, blue oak has been introduced in the central valley with good results.

B. Reproduction:

Blue oak is wind pollinated and monoecious developing catkins from flower buds with acorns dispersed by animals. Acorns are produced in mass, known as masting, and mature in about 1 year with mast years occurring every 3 years depending on climate cycles (Fryer, 2007). Mast years usually occur after warm April and hot summer temperatures. According to McDonald, blue oak seeding development has been scarce over the past 60-80 years due to seedling damage from cattle, deer, insects, and especially gophers (McDonald). Germination of acorns occurs rapidly with initiation from the first rainfall continuing into spring and in some cases acorns begin germination before falling from the tree with 72% viability (Fryer, 2007). However, too much moisture in winter and spring can prevent seedling establishment due to fungal infection causing them to rot in woodland environments. On the other hand, above average rain in annual grassland environments can increase blue oak seedling establishment.

Seed banking of blue oaks is unlikely due the high palatability of acorns to predators. The filbert weevil and filbert worm larvae often destroy acorns before maturity. Acorns are eaten by many songbird species, small mammals such as rodents, and various large mammals (McDonald). With many acorns consumed by predators, a good amount is often dropped or lost allowing for seedling development. Furthermore, annual nonnative grasses can often damper seedling development. 10-30 year old sapling and pole-sized trees are relatively scarce due to herbivory by mammals, drought, and nonnative annual grasses (Fryer, 2007). A study in Shasta County found that the presence of nonnative Himalayan blackberry actually aided the production and growth of blue oak seedlings to saplings (Williams, 2006). The blackberry thickets prevented predators and grazers from reaching the young saplings. Typically, seedlings that can survive 10 or more years have a higher chance of surviving subsequent years. Blue oaks are susceptible to several diseases which attack the heartwood such as Inontus dryophylus, Laetiporus sulphureus, Hydnum erinaceum, and Ganoderma applanatum as well as Armillaria mellae which attacks the roots (McDonald). Many insects are known to infest blue oaks leaves, twigs, roots, bark, trunk, limbs, and acorns. Many of the insects occur in low numbers but epidemics can cause serious damage.

C. Ecosystem Requirements:

As blue oak is very drought tolerant it grows and adjusts root depth based on its soil conditions. In shallow soils with high water tables the root system is very spread out and shallow. In hard, rocky soils with little water blue oaks can develop a tap root to penetrate deep to the water table. Blue oak prefers shallow and well-drained gravel loam to clay soils in upland environments. Grazing typically has negative effects to seedlings and saplings as young foliage is generally consumed. However, the control of annual grasses will allow increased germination and success of seedlings. Blue oak bark is very thin and flaky making it particularly susceptible to fire. It is better adapted to quick understory grassland fires than slow hot chaparral fires and can lose all canopy leaves from a ground fire one year and replace them the next (McDonald). Low to moderate fires will generally top-kill blue oak seedlings and saplings but will regenerate the next year. New blue oaks will establish from acorns after fire. The effects of low intensity fire and prescribed burns is controversial as to whether or not it benefits blue oak health and dispersal. Some research shows that the control of annual nonnative grassland through fire is beneficial, however this allows for the invasion of nonnative forbs which outcompete seedlings.

Furthermore, fire exclusion can be disadvantageous to blue oak woodlands as it allows the invasion of other tree species which can overcrowd them.

D. Response to Change/Damage:

Overall climate change seems to have little impact on the growth and reproduction of blue oak as precipitation change was not found to be correlated to stem recruitment. A study of blue oak tree-rings from the 18^{th} through the 20^{th} century show that blue oak is capable of surviving decade long droughts as well as extreme wet periods (Fryer, 2007). Climate change may have an impact on the production of seedlings and saplings but it would appear well established trees are not severely effected. As discussed, grazing and fire can have both positive and negative effects. Positive effects would be for the easier development of seedlings and less competition with annual grasses. Negative effects are damages done by extreme fire and vegetation damage from grazing animals. Nearby plowing, if too close to the trunk of blue oak can damage the shallow root system promoting root rot and fungal spread.

E. Restoration and Conclusion:

Blue oak is often used for restoration projects of wildlife habitat, riparian, and watershed zones where its roots are used for erosion control on steep slopes and stream banks. Generally, they are established from acorns or nursery stock. Establishment from acorn is preferred as the tree will produce a tap root early on depending on soil type and water availability. Sites where blue oak had previously been removed and replaced by nonnative grasslands and grazing have proven to be more difficult to reestablish oak woodlands due to compaction and competition with grasses. Generally, it has been easier to establish blue oak on upper stream banks and riparian zones. Experiments have shown the most effective way of establishing blue oak seedlings is to plant them under shrub canopies or shade cloth with protection from herbivory and full sun (Muick, 1991). Furthermore, there is often difficulty in the success of seedlings due to herbivory by grasshoppers and gophers with nearly half of a sample restoration population being damaged by these (Tecklin, 1997). In establishing blue oak at a restoration site it is important to take these protective methods into consideration protecting both new foliage and roots, as well as being aware of soil type and compaction.

Part II:

Goal, Management, and Monitoring Plan

A. Goals

The overall goal for the restoration of Quercus douglasii is to reestablishment blue oak woodlands in areas that may have previously supported them or are within the range of suitable habitats. Long term focus will be focused on the establishment of saplings as blue oaks are more likely to survive after 10 years of growth. Blue oak is very slow growing and has a relatively low success rate for specimens less than 10 years (Fryer, 2007). Short term goals will be focused on seedling establishment and protection from predators. Along with the restoration of blue oak woodlands various other plant species should be introduced as well to contribute to natural soil development and long term health of the woodland. Once a blue oak woodland is semi-established the reintroduction of various birds and squirrels may be necessary to promote acorn dispersal. Because blue oak is slow growing with low success rates frequent monitoring would be necessary within the first 5 to 10 years or until saplings are well established (Bernhardt, 2001). With the establishment of blue oak it is important to also consider and maintain the oak woodland ecosystem as a whole once oaks are established.

B. Restoration Plan

Successful restoration of blue oak should be done by acorn establishment. Acorns should be locally sourced as they will be more likely to be adapted to climate and soil types. It is recommended that acorns come from the same watershed as far as 10 km away (Bernhardt, 2001). It is important to establish blue oak from acorn because the root system will be developed based on local conditions early on. A tap root will be developed early on if the water table is low or a shallow root system will develop if the water table is high. Its drought tolerance is due to its extensive root system and depending on soil conditions its roots can tap down as far as 80 feet to groundwater (Fryer, 2007). Furthermore, the establishment from container or bare root nursery stock causes tap roots to diminish or be underdeveloped. For planting acorns, it is important to be sure the acorn is viable and prepare the seedbed. The seedbed can best be prepared by breaking up the top 25-30 cm of soil and adding woodland soil with mycorrhizal fungi, and planting the acorn at about 5 cm depth (Bernhardt, 2001). Once planted it is important to apply an organic mulch across the site to hold in moisture, keep weeds down, and moderate soil temperature. For optimal growth performance it is best to manage invasive weeds across the entire restoration site and eliminate all vegetation directly around the seedlings.

Planting of acorns should be done immediately after the first autumn rains to ensure germination. Site selection is important for the overall success rate of seedlings. It is important to choose sites with minimal to no rodent activity for higher success rates. Tree shelters should be used around acorn seedlings to prevent herbivory destruction. Soil moisture and the avoidance of areas prone to drought and flooding is also very important. Planting of acorns should be avoided on south facing slopes and should be planted in areas with naturally occurring high soil moisture (Bernhardt, 2001). Success rates of blue oak seedlings can be significantly improved if the above measures are taken essentially improving success rates to between 75 and 88 percent (Tecklin, 1997). Supplemental irrigation is not necessary for the restoration of blue oaks as it can often lead to stress of seedlings when discontinued and it is not cost effective.

According to Standiford, Forest Management Specialist for the University of California, blue oaks most often occur where a water table is unavailable to trees with rainfall averaging at 10-60 inches a year (Standiford, 2016). Since blue oaks generally occur on hilly terrain it is best to locate seedlings away from flood prone areas in upland conditions. Seedlings will establish an extensive root system and tap root where necessary to tap into the water table.

More acorns should be planted than desired as it is unlikely all will survive. Furthermore, the acorns should be dispersed in such a way that grown trees can overlap to create a woodland. Because blue oak is slow growing it is recommended to plant acorns closer than within the full grown canopy size. It is possible that insects or fungi could damage seedlings in which case they should be removed. Because there is uncertainty with the preferred water table of blue oak it would be safe to plant acorns across several land types being sure to avoid potential flood prone sites. Oak woodlands typically consist of native grasses and very few shrubs, therefore it is important to locate acorns away from high vegetative areas to avoid competition.

C. Monitoring Plan

After the first winter acorns should be checked to ensure growth into seedlings. Any that show no signs of growth can be replaced the following autumn if desired otherwise tree shelters can be removed. It may be best to monitor the seedlings once a month for the first year. The average growth of shoots should increase by about 5 to 10 cm per year (Bernhardt, 2001). Those that have grown into seedlings should be monitored for damage by insects. Any insect or fungal damaged seedlings should be removed. Monitoring should continue for at least 5 to 10 years to ensure success of saplings into juvenile oaks where protection is no longer needed (Bernhardt, 2001). If it appears that seedlings show signs of stress during dry summer months it may be necessary to establish an irrigation plan, though this is not typically necessary. Tree shelters should remain for some time and tree cages should be added to prevent herbivory once the seedlings reach the top of the tree shelter tube. After the first few years monitoring can be scaled back to a couple times a year making sure there is no damage to saplings. Tree cages should be well enforced to prevent herbivory by deer and trunks shall be protected from rodent damage.

Oak woodlands are incomplete without various other species. California buckeye can be seeded with oaks in the initial restoration. Furthermore, other species such as perennials with slow reproduction introduced by root, corm, or bulb are good candidates for restoration with blue oaks (Bernhardt, 2001). Introduction of various other species common with oak woodland can help establish soil microorganisms at the restoration site creating better growing conditions and minimizing monitoring needs.

As blue oaks root system is relatively complicated and unknown this restoration plan can help determine the best location to plant blue oak acorns. This restoration can determine if blue oaks are best suited in riparian zones or upland conditions. Furthermore, given a particular restoration plan this data can help to determine the most suitable species to incorporate with blue oak. According to Bernhardt, few blue oak restorations are monitored past 3 to 5 years (Bernhardt, 2001). If monitoring continues past 5 years it could give much insight to the long term restoration of blue oak.

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Valley Oak (*Quercus lobata)* in the Central Valley

Background and Justification

The Valley Oak (*Quercus lobata*) is a winter deciduous tree that is endemic to California and is a dominant species in Oak Woodlands and Riparian Forests (fs.fed.us). It is a member of the White Oak subgenus, and it is the largest oak in Northern California and can grow a height of up to 30 meters. *Q. lobata*, like most oaks, is long-lived with an average lifespan of 100-200 years, but can live for upwards of 400 years (fs.fed.us). It is an integral component of many ecosystems in the California Central Valley, and has a wide array of ecosystem services and positive species interactions including soil stability in floodplains (USDA NRCS). Despite Valley Oaks' ability to tolerant a variety of conditions, we are seeing a strong decline in the number of Valley Oaks in the California Central Valley (Whipple et. al 2010). This is largely due to land conversion for urban, agricultural, and grazing uses. The diversion and control of water also affects Valley Oak populations in riparian areas, because when a river no longer floods, riparian forests suffer (Trowbridge et al. 2005). Additionally, oaks are a source of timber, so their numbers have been declining since industrialism reached California (Whipple et. al 2010). Even in areas where Valley Oak habitat is relatively intact, there has been a decline in successful recruitment (Whipple et. al 2010). This is due to a variety of factors including over-browsal, soil compaction, and invasive species (Trowbridge et al. 2005). There is already a very uneven distribution of age classes in living Valley Oaks as recruitment has been suffering for decades (Johnson et. al 2009). Their longevity has made it difficult to see that they are facing difficulties, but as the older trees die and there are no younger trees to replace them, it will become more apparent (Van Andel and Aronson 2012). Because Valley Oaks are a long-lived, slower growing tree, it takes decades for them to establish and reach their reproductive stage, so if we want to combat the recruitment issue, we don't have the luxury of waiting until the problem becomes obvious to the general public.

Required Growing Conditions

As a California endemic, Valley Oaks thrive in a Mediterranean climate of hot, dry summers and cool, wet winters (Jepson). They grow best in partial shade during earlier stages of their life, and are most successful on north-facing slopes (fs.fed.us). As its name implies, the Valley Oak thrives in the high quality soils of valley floodplains and on the surrounding slopes (Barbour et. al 1993). They can tolerate a wide range of soil textures from fine clay-rich soils to coarser alluvial deposits (Johnson et. al 2009). Despite being able to tolerate drought conditions, Valley Oaks need year-round access to the water table, preferably at an approximate depth of 10 meters. They are also equipped to handle soils that are poorly-drained, and as a component of riparian habitats are able to tolerate inundation with periodic flooding (Johnson et. al 2009). The average annual rainfall that *Q. lobata* receive in the California Central Valley is 8-30 inches (CalFlora).

Reproduction

The age at which Valley Oaks reach reproductive ability varies, but usually is at least 20-50 years (fs.fed.us). Valley Oaks rely on wind pollination and vary greatly in their acorn production from year to year. Fairly synchronized across the species, there are years of almost none to absolutely no acorn production and then years where they are produced in extreme excess, called mast years (Sánchez-Humanes et. al 2011). Valley Oaks flower between February and April and drop their acorns between August and October (USDA NRCS). Acorns do not survive in a seed bank, as they all germinate in the winter following being dropped (USDA NRCS). Germination is aided by the burial of acorns by species such as the California Ground Squirrel, as seeds that are at a soil depth of 2 to 4 inches are most likely to result in seedlings (fs.fed.us). However, the popularity of acorns as a food source for a variety of species also results in decreased number of seeds, and therefore, reduced seedlings. Despite this, herbivory is much more detrimental to Valley Oak regeneration in the seedling and sapling stages of its life. Browsal of the roots and stems by rodents and the leaves by deer greatly diminishes survival rates of young oaks (fs.fed.us). When damage occurs to a young Valley Oaks, they can resprout from the roots, an adaption known as coppicing (fs.fed.us).

Species interactions

Valley Oaks as a food source

Valley Oaks are a food source for many animals. Their acorns provide essential nutrition to black-tailed deer, California ground squirrels, acorn woodpeckers, and yellow-billed magpies (fs.fed.us). The soft new growth of oaks, especially young trees is also a food source for black-tailed deer and other herbivores. Additionally, the bark and roots of young Valley Oaks are eaten by rodents such as voles, pocket gophers, and California ground squirrels (USDA NRCS). Additionally, *Chionodes petalumensis* caterpillars rely on a diet solely comprised of Valley Oak leaves (CalFlora).

Valley Oaks as hosts

Two native species of wasps use Valley Oaks to house their larval stages in oak galls. *Andricus quercuscalifornicus* causes the oaks to produce galls along the branches, and *Andricus kingi* causes galls on the oak's leaves (USDA NRCS). Many butterfly species utilize the Valley Oak including Mournful Duskywings (Erynnis tristis), California Sister (Adelpha bredowi), Propertius Dusky-Wing (Erynnis propertius), and Gold-Hunter's Hairstreak (Satyrium auretorum) (CalFlora).

Valley Oaks as habitats

Valley Oaks in riparian forests are important nesting sites for many birds. At least 67 bird species including the Swainson's hawk use riparian forests and the Valley Oaks in them for nesting (fs.fed.us). In oak woodlands, Valley Oaks provide nesting sites for many birds as well (fs.fed.us).

Pests and Pathogens

Valley Oaks are susceptible to infection by the bacteria *Xylella fastidiosa*, which causes leaf scorch (Berkeley.edu).Glassy-winged sharpshooter (*Homalodisca vitripennis*) is a species of leafhopper that is a vector for Pierce's disease can cause infestations in Valley Oaks (Berkeley.edu). When Valley Oaks are not under especially stressful conditions, diseases rarely cause mortality, however very old or trees that are otherwise stressed can die from heart-rot caused by the fungus *Armillaria mellea* (fs.fed.us).

Hybridization (fs.fed.us)

Valley Oak can hybridize with:

Quercus douglasii (blue oak]

Q. turbinella ssp. *californica* (desert scrub oak):

Q. dumosa (California scrub oak)

Q. engelmannii (Engelmann oak]

Q. garryana (Oregon white oak)

Competitors

Very young Valley Oaks can be outcompeted by grasses and forbs, especially from annual grasses when soils are drier and water is limited. Once trees are no longer seedlings and reached the sapling stage, they are unlikely to experience much competition from other plant species (fs.fed.us).

Abiotic conditions

Environmental Conditions

Valley Oaks are found on slopes and in valleys in woodlands, savannas, and in riparian areas. In riparian areas, they are found in the highest parts of floodplains (Jepson Herbarium, fs.fed.us). Despite being present in riparian areas, they are tolerant of low water conditions, with annual precipitation in the California Central Valley being between 13 and 85 inches (CalFlora). Valley

Oaks are found at elevations between sea level and 1940 meters (CalFlora). The temperature range is 30-98 degrees Fahrenheit (CalFlora). Their growing season is 4-12 months depending on local conditions and annual fluctuation (CalFlora).

Soil (CalFlora)

pH: 5.2-8.2

maximum salinity: 3.7

minimum depth: 13 cm

can grow in fine, medium and coarse soils.

Moisture and Temperature Tolerances

The leaves of Valley Oaks are sclerophyllous, meaning that they are hard and small. They are energetically costly to make, but they are good for handling hot and dry conditions because they do not lose a lot of water via evapotranspiration (Johnson et. al 2009).

Spatial Scale

The spatial scale for Valley Oaks varies depending on the ecosystem. On drier slopes and valleys, trees are spaced farther apart, but they can be found in higher densities in riparian areas where water is less limiting. The higher the density, the greater the competition for resources, so when a resource like water is limited, lower density stands will do better (Johnson et. al 2009).

Disturbances

Grazing

Grazing has little to no negative effect on mature Valley Oaks, but it greatly hinder recruitment via direct herbivory and the soil compaction that herbivores cause (Barbour et. al 1993).

Fire (Holmes et. al 2011)

Mature Valley Oaks can tolerate low intensity fire but younger trees are less resistant. The historical fire regime of oak woodlands and valley oaks in riparian areas in not entirely known, but Native Americans burned oak woodlands and savannas to keep them from encroachment by woody species so they certainly experienced fire to some degree. If top killed, Valley Oaks can resprout (coppicing). Too frequent fire can hinder recruitment.

Climate Change

Climate change will negatively affect Valley Oaks because they need access to the water table. With increased temperatures and less rain, the water table will continue to drop, which will be a problem for survival. If the lack of water does not cause mortality directly, if can cause stress which makes the tree more vulnerable to disease and less likely to survive disturbances (Van Andel and Aronson).

Potential negative impacts on the ecosystem

Trees have higher water requirements than other vegetation types. In the face of drought, we may want to limit the number of trees in the park. However, once they become established, large trees are drawing water from a different depth than grasses, forbs and shrubs, the competition for water isn't as fierce. Additionally, the shade that a tree provides and the reduced evapotranspiration that goes along with it can be beneficial in a drought. Furthermore, complex root systems can also help retain water in the soils, so the benefits of having trees will most likely offset the possible costs as long as they aren't planted at extremely high densities.

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VALLEY OAK (*Quercus lobata*) Restoration in the California Central Valley

Jonah Weeks

RESTORATION GOALS

Valley Oaks are a long-lived species that takes decades to reach maturation, so the goals for restoring them to a landscape also have to be long-term. The initial goal is to have successful establishment of seeds and seedlings. There should be approximately 40 surviving individuals per acre in non-riparian areas (ucanr.edu). Once the trees are mature, this will translate to between 10 and 20% cover (Griggs and Golet 2002). In riparian areas, higher densities of Valley Oaks are possible, although the optimum cover varies. The main goal is to keep the young trees alive until they are no longer vulnerable to their main threats as seedlings and saplings: competition, herbivory, fire, flooding, and drought. In the first year, some mortality can be accepted due to lack of seed germination, or transplant stress. Initial planting at higher than goal density should alleviate this issue. After that initial decline, the goal is to keep the population stable. If an individual dies, replanting should occur. If a large disturbance occurs and results in wide spread mortality, the entire area should be replanted. This is assuming that the disturbance was an anomaly, not that the regime for a given disturbance is shifting/has shifted. For example, if flooding is becoming more extreme or more frequent in the area, the Valley Oaks will need to be replanted higher up in the floodplain. If fires are becoming more frequent, fire-breaks around the young trees must be put in place.

In the absence of a large disturbance, protecting against herbivory will be the main issue, but once the tree is large enough, those treats virtually disappear. If restoration efforts are successful in getting Valley Oaks to maturation (20-25 years) then the goals will be considered accomplished.

RESTORATION PLAN

Site Selection

Within a given site, care should be taken when choosing the location of Valley Oak plantings. If weed control has not been carried out prior to planting, Valley Oak seeds/seedlings should be planted where there is little cover of highly competitive species (USDA NRCS). When Valley Oaks are in the early stages of their lives they can be outcompeted by herbaceous plants and other woody species. Planting should be done in relatively open areas that receive ample sunlight. Soils should be well drained and of low salinity (<3.7), with a pH of between 5.2 and 8.2 (CalFlora). If possible, planting should be focused on north-facing slopes. In riparian areas, Valley Oak plantings should be done in the upland areas and higher areas of the floodplain (CalFlora).

Acquiring Seedlings

Using seedlings has the benefit of better survival possible. This increased chance of establishment is only likely if the seedlings are the offspring of trees from an area similar to the target location. However, Valley Oak seedlings are often hard to obtain and are expensive. Because very few nurseries grow Valley Oak seedlings, there is less choice in the genotypes available. If possible, obtain seedlings from a nursery that are from the same general area as the restoration project and not all from the same parent tree. Seedlings may not thrive in the local conditions of the restoration site, so it is important to have genetic diversity to increase the chances of successful recruitment.

Acquiring Seeds

Using acorns instead of seedlings gives land managers much greater customization of the genotypes that will be introduced into a restoration site. Collection of acorns involves relatively little labor as long as the desired trees produce adequate fruit that year. Primary collection should be from trees as close to restoration site as possible. If there are any healthy Valley Oaks within the restoration site, acorns should be collected from those individuals. If there are no mature, fruiting individuals in close proximity to the restoration site, acorns should be collected from areas with similar soil and climate conditions. Acorns should be collected directly from the tree to increase likelihood of seed viability. Acorns that fall to the ground can dry out and are less likely to successfully germinate.

Seed Storage

After collecting acorns directly from trees, remove caps and place in plastic bags and store in a refrigerator. If acorns are collected from the ground, they should be soaked for 24 hours. The acorns that float should be disposed of as they will not be viable. Acorns that sink should be dried and placed in slightly open plastic bags and stored in a refrigerator. The air flow will reduce the chance of the acorns molding (ucanr.edu).

Seed Planting

Acorns should be planted between November and March, depending on weather conditions of the planting year (ucanr.edu). Once the soil in the restoration site has been softened by rain, planting should commence. The earlier planting takes place, the bigger head start they can get on germinating and growing. Additionally, the earlier planting is done, the less time the acorns will have spent in storage.

For each acorn, a hole several inches deep should be dug. Soil should then be replaced until it is approximately two inches deep (fs.fed.us). The acorn should then be placed on its side in the hole, and the remaining soil returned to the hole (ucanr.edu). The extra depth of the hole refilled with dirt allows the roots of the young Valley Oak to more easily penetrate the soil beneath it.

Seedling Planting

There is more complexity to planting seedlings than there is with seeds. When transplanting seedlings there is a chance that they will experience transplant shock. Additionally, roots can easily be damaged in this process. Extreme care must be taken with the seedling while transferring it from its pot to the soil, as it is very easily damaged when so exposed. Follow basic protocol for planting: hole should be dug to a depth so that the pot soil attached to the roots is level with the ground, soil should be pressed in around plant to avoid soil cavitation, water area. As with the planting of the acorns, digging a hole deeper than the pot and refilling it with soil can help with root growth and establishment (fs.fed.us).

Spatial Arrangement of Seeds/Seedlings

In upland areas, shoot for 40 trees per acre . It is better to try and establish more individuals, especially if using seeds, because Valley Oaks are very vulnerable in the early stages of their life. It is almost guaranteed that a percentage of the seeds or seedlings planted will not survive to sapling age. If excess trees make it to a more stable life stage, they can be removed at a later time. Seeds or seedlings should be planted in a patchy distribution as opposed to evenly spaced in rows. A cluster of trees should contain 3-4 trees and these groups should be approximately 10-12 meters away from each other (ucanr.edu). If the Valley Oaks are being planted in riparian areas, seeds/seedlings should be plated in groups 5-7 meters apart. This higher density better represents the natural spatial arrangement of trees in wetter areas where water is less limiting (ucanr.edu).

Protection of Seeds/Seedlings from Herbivory

Seedlings should be purchased from a nursery or acorns can be collected. Benefit of planting seeds is that they are cheaper and they are exposed to local conditions from the beginning of their lives, so money won't be wasted on acquiring and planting seedlings only to have them be maladapted to some factor in the restoration site (ucanr.edu). If acorns are planted, precautions must be taken to ensure that they are not eaten by rodents, birds, or other animals before they germinate. If the restoration site is home to many of these acorn-eating animals, planting seeds deeper than one inch (2-4 inches) may reduce their chance of being excavated (fs.fed.us). Caution must be taken to ensure that they are not planted to deep however, as that could lead to acorn rot and loss of viability (ucanr.edu).

Once the seed germinates, or if seedlings have been planted, the threats on their survival do not disappear. For this stage, tree tubes can be helpful in deterring herbivory (fs.fed.us). Tree tubes can continue to be beneficial to the young tree to prevent browsing and girdling. In the very early stages of life, Valley Oaks are extremely susceptible to decimation by herbivory. As the trees grow, they become exponentially less vulnerable. When their bark is very thin, rodent girdling can be fatal, but as the bark hardens, it becomes less desirable and more immune (USDA NRCS). Additionally, new growth is the most sought after by herbivores. When the tree is young, all or most of its growth is new and more easily digested, leading to high mortality of young individuals. Mature Valley Oaks have sclerophyllous leaves that area hard and difficult to eat and digest, making them far less likely to be browsed upon (USDA NRCS).

Tree tubes should be inserted over the plant and into the soil approximately two inches to prevent rodents from entering the tube from the bottom (ucanr.edu). Tubes should be secured in the ground using stakes or posts. In addition to reducing herbivory, tree tubes can also protect the tree from herbicides that are being used to control surrounding unwanted vegetation (ucanr.edu). Tree tubes are the most effective way of reducing herbivory, but they can also restrict horizontal growth, negatively affecting tree structure, and reducing strength and stability.

Once the threat of girdling has decreased, tree tubes can be replaced with cages to allow unrestricted growth. The cage should be tall enough that the tree is out of reach by the largest herbivore present (fs.fed.us). A cage will protect the tree from deer and other larger herbivores, but smaller animals will still be able to enter the cage.

Protection of Seeds/Seedlings from other Threats

COMPETITION

Each planting site should be clear of vegetation prior to the introduction of the Valley Oak seed/seedling. Ideally, the 2-3 feet in every direction of the oak should be free of vegetation (ucanr.edu). Regardless of the method used to remove surrounding vegetation, there should be continued maintenance in the following spring and the next two years. Mulch can be used to reduce the chances that other vegetation will return.

FIRE

Young Valley Oaks should be protected from fire until the canopy of the tree is well above the surrounding vegetation layer (fs.fed.us). This height will be achieved at different ages depending on the growing conditions across space and time. Once trees are mature and have thicker bark and protected meristems, low-intensity fire can be used without causing death. If fire is going to be used in the early stages of the restoration process, Valley Oak seeds and seedlings should be planted post-fire.

FLOOD

Like fire, flooding can be very harmful to young Valley Oaks. If possible, flooding should be limited in the first decade at least (fs.fed.us). Because this may be difficult to control or detrimental to other restoration goals, planting seeds and young trees high enough in a floodplain is essential to avoid inundation during the early, vulnerable stage of their lives.

DROUGHT

Watering young Valley Oaks can help reduce the risk that they fall victim to drought. If there is adequate rainfall, this should not be a major concern, but in drier years, deep watering in the late spring/early summer can be beneficial (fs.fed.us). In order to make sure the soil is amply saturated, approximately two gallons of water should be used for each individual. Mulching the area around each seedling can reduce water loss from the soil.

MONITORING PLAN

The first task of monitoring is to note which and how many of the seeds have sprouted (if using seeds). This first stage will be considered a success if there are still more seedlings than the eventual goal density. It is crucial at this stage (late spring-early summer) that monitoring/managing is done as frequently as possible because the seedlings are highly vulnerable at this stage. After the surviving seedlings have tree tubes placed around them, monitoring can become less frequent. If there is a lack of germination from the acorns planted, or high mortality of seedlings, replanting must be done the following year. If acorns continue to be unsuccessful, seedlings should be planted instead. The next stage of monitoring is to make sure tree tubes are still in place and to decide when tree tubes should be removed and replaced with cages. This can be done biannually. If mortality is high at this stage, steps might have to be taken to reduce small herbivores before more seeds/seedlings are planted. Some possibilities include the introduction of a predator or the placement of traps. Once trees reach the top of their tubes, cages can be constructed around the trees and monitoring can become even less frequent. Trees can be checked on annually and cages adjusted if the tree's growth is being impeded by the cage. Managers can remove cages altogether after the crown of the tree is taller than the maximum herbivory height (10-15 years) and at that point the Valley Oaks will be rather resistant and resilient to their former threats (fs.fed.us).

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***Acer negundo* subsp. *californicum* (Box Elder)**

<u>Background and Justification</u>

Acer negundo subsp. *californicum* (Common name: California Box Elder), a dicot, is a native deciduous small to large tree with an irregular form. It often grows on flood plains and other disturbed areas with ample water supply, such as riparian habitats and wetlands. In California, box elder is one of many native species used for revegetating flood control basins, particularly in the Central Valley. Along riparian habitat, box elder is one of the favored flood-tolerant species recommended for recreation plantings (Knopf, Johnson, Rich, Samson, & Szaro, 1988). Box Elder has also demonstrated drought and cold hardiness, making it a popular tree in residential communities for street and ornamental plantings, in addition to windbreaks (Rosario, 1988).

Box elder species has been found to provide valuable environmental benefits. Box elder provides habitat for many wildlife species, particularly during temperature extremes in the summer and winter (Rosario, 1988). Swainson's Hawk, a California threatened species, is known to use the Box Elder as nesting habitat (Lee, 2012). Other birds and squirrels feed on the seeds of box elder assist in seed dispersal in the winter and spring (Rosario, 1988).

Because of such human influence, box elder species is not in known decline, however its habitat is increasingly diminished with the loss of riparian habitat and wetlands. The original California riparian forests covered several million acres, and in 1977, riparian habitat in the California Central Valley and Central Coast regions were observed to be in rapid decline due to land use change, streambank stabilization, channelization, reductions in water flow, and water pollution (Roberts, Howe, & Major, 1977). The recent drought may have affected the expanse of riparian habitat, which may have exacerbated these constraints on box elder species, despite its individual drought tolerance.

<u>Fact Sheet</u>

Project Goal

- To establish and sustain California box elder for wildlife interdependencies and ecosystem services in areas where riparian habitat has been degraded.

Growth Characteristics

- The trunk often divides near the ground into long, spreading, limbs, which branch irregularly to support a broad, uneven crown (Rosario, 1988).
- When growing among other trees, boxelder forms a high, open crown, with the undivided

portion of the trunk much longer and usually straighter than that of an open-grown tree (Rosario, 1988).

- Box elder may reach 70 feet (21 m) in height and 3 feet (0.92m) in diameter but is more often medium sized, from 40 to 50 feet (12-15m) high and from 1 to 2 feet (0.3-0.6 m) in diameter (Preston, 1976).
- Boxelder establishes in 2-3 years (Preston, 1976) and with a relatively short life span; it typically lives for 75 years, with 100 years maximum longevity (Loehle, 1988).
- Boxelder is the only maple with divided leaves. The three to seven leaflets are from 6 to 15 inches (15-38 cm) long, light green above and greyish green below, usually without hairs (Rosario, 1988).
- Seeds are 2 to 3 times as long as they are wide and are markedly wrinkled (Rosario, 1988).

Reproduction and Regeneration

- Box elder reproduces sexually and asexually (Preston, 1976).
- Vegetative reproduction is also common on damaged plants of this species. New shoots will appear on exposed or injured roots (Rosario, 1988).
- Box elder flowers from March through May with or before the appearance of the leaves.
- The fruit, a samara, ripens from September through October and is dispersed from September through March (Calflora, 2016).
- Seeds are dispersed by wind and wildlife that interacts with box elder (Rosario, 1988).

Range and Habitat

- Historically, box elder was observed in extensive surveys across California, occuring in riparian forest and wetlands across the California Central Valley, Central Coast (north from the Santa Ynez Mountains through the San Francisco Bay Area), and South Coast regions (Roberts et al., 1977)
- Box elder has been observed at elevations ranging from 0 to 1860 meters (Calflora, 2016)
- Box elder is able to tolerate a wide variety of soils but shows a strong preference for well-drained soils (Calflora, 2016; Rosario, 1988).
- Although box elder will grow on soils from gravel to clay, it grows best on deep, sandy loam, loam, or clay loam soils with a medium to rocky texture and a pH of 6.5 to 7.5 (Calflora, 2016).

Environmental Tolerances

- Box elder requires a minimum of 11 inches of annual precipitation, and can tolerate a maximum of 57 inches of annual precipitation (Calflora, 2016).
- Hardy to extremes of climate, boxelder is drought tolerant once well established and can also withstand short periods of flooding (Rosario, 1988).
- It is moderately shade tolerant but does not reproduce in its own shade (Rosario, 1988)
- Box elders are killed either by inundation (excessive soil moisture) for more than 85 days during the growing season or by shear stress (high flow regimes) that exceeds the critical

value for mobilization of the underlying sediment particles (Friedman & Auble, 1999).

Plant Interactions and Succession:

- Throughout its range, boxelder is most often associated with various species of cottonwood (*Populus spp.*) and willow (*Salix spp*.).
- In the Southwestern U.S., box elder is a dominant or codominant overstory species in several high-elevation riparian communities along with (*Alnus oblongifolia*) and coyote willow (*Salix exigua*) (Szaro & Patton, 1986).
- Across North America riparian forests, Boxelder may be replaced in the overstory by other more durable and shade-tolerant species that grow to greater heights. (Van Dersal, Mulford, & Thornthwaite, 1938).

Wildlife Interactions:

- Swainson's Hawk, a California threatened species, is known to use the Box Elder as nesting habitat (Lee, 2012).
- Other birds, squirrels , and box elder bugs feed on the seeds of box elder (Rosario, 1988).

Human Interactions:

- Epidemiological studies have suggested that urban green space within the living environment may ameliorate air pollution and the urban heat island effect, leading people to spend a greater deal of time outdoors engaging in physical activity (Tzoulas et al., 2007).
- Experimental studies have suggested urban green space lessens attention fatigue, psycho-physical stress, and stress-ameliorating effects that confer health benefits and personal fulfillment (Tzoulas et al., 2007).
- Survey studies have suggested people's favorite places indicate that people visit and live in particular neighborhood places, mainly natural settings, for regulation of their moods and feelings (Tzoulas et al., 2007).
- Expansive street trees, lawns/parks, urban forests, and wetlands generate a range of ecosystem services, including air filtration, microclimate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational values (Bolund & Hunhammar, 1999).

Management Recommendations:

- Prioritizing assessment and regular monitoring of riparian ecological communities for health and establishment can help in sustaining long-term project success (Hierl, Franklin, Deutschman, Regan, & Johnson, 2008). It is recommended box elder establishment be assessed in Early Spring (March), consistent with its bloom period.
- Riparian vegetation in combination with structural supports help reduce channel erosion and improve wildlife habitat (Griggs, 2009).

- Target areas with wide levee banks rather than deeply incised areas with minimal levee banks for revegetation (Pennino, 2000).
- Removal of conifers and undesirable overstory vegetation that encroaches riparian habitat can help the establishment and recruitment of riparian tree species (Griggs, 2009).
- Any seedlings of box elder planted should enact understory structural barriers to prevent small mammals from disrupting root establishment (Pennino, 2000).
- Where necessary, require fencing of riparian areas to limit adverse wildlife and human impacts to riparian habitats (Pennino, 2000).

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Restoration Plan for *Acer negundo* subsp. *californicum* (Box Elder)

The restoration of California box elder in Centennial Park will enhance local community benefits while improving long-term resilience of the riparian ecosystem at large. Below is a table summarizing the key goals relevant to native box elder introduction.

Table 1: Summary of Goals and Methodology for Restoring California Box Elder (*Acer negundo)*

Goal 1: Inventory existing patches of box elder and patches that can support introduced box elder.	Achieved through preliminary survey and soil assessment.
Goal 2: Modify habitat to support box elder in desired areas.	Achieved through irrigation mainline installation, and invasive species removal.
Goal 3: Transplant box elder to suitable habitat patches.	Implementation considerations and recommendations are detailed in this plan.
Goal 4: Engage partners and stakeholders in a long-term adaptive management program of box elder and its ecosystem.	Achieved through collaborative initiatives emphasizing timely monitoring, reporting, and evaluation of species and ecosystem.

These general goals, as presented, suggest the aforementioned order. Feasibility constraints may limit a holistic assessment of all suitable box elder patches, in which case targets for goal achievement need only be as comprehensive as possible. Goals 3 and 4 are the most important actions to achieve species establishment. Success will be measured by persistence and vigor of box elder species and annual improvements in canopy cover and habitat quality. By these measures, species establishment will increase resilience to floods, fire, and erosion while improvements in shaded area will contribute to ecosystem climate change adaptation efforts.

Restoration Plan:

The restoration plan, detailed below, describes implementation considerations and management recommendations for a land manager who has a site within the Central Valley at which we want box elder restored.

Revegetation Preparation:

Nursery seed stock of box elder species should be sourced from local ecotypes throughout the local watershed. This ensures species are adapted to similar water quality and soil moisture conditions, while preserving genetic integrity for the site (Harris, Hobbs, Higgs, & Aronson, 2006; Vacaville, 2013). Winter sowing of the seed (1/4-1/2 in. of soil depth) in outdoor beds (dusted with fungicide and mulched with sawdust) allows for the seedlings to emerge the following spring (Davis & Kujawski, 2002). During active growth, seedlings should be fertilized with granular 10-10-10 once a week from mid-April to Early June, then once every two weeks from Late June to Late August. Irrigation should occur after every fertilization, with the application rate to mimic 11 to 57 inches of annual precipitation (Calflora, 2016). Dormant bare root box elder is harvested for transplant two years from sowing. Proper propagation, fertilization, and irrigation can improve survival rate for box elder upon replanting.

Goal 1: Inventory existing patches of box elder and patches that can support introduced box elder.

In a recent vegetation mapping report in the greater California Central Valley, box elder was accurately mapped throughout 2,518.4 acres (CDFW & Center, 2013), suggesting existence of box elder across our project area. Developing a more descriptive inventory of box elder across our project area can help in assessing box elder health and the associated suitability of the habitat patch (Harris et al., 2006). As box elder is resilient to climate extremes and drought within its range, the major criteria to assess habitat suitability should include soil properties (grows best on deep, well-drained soils), soil pH (6.5-7.5), nearby plant species, and proximity to potential human or animal disturbance (Calflora, 2016).

For existing patches of box elder, management and monitoring should proceed as described in this report (see Goal 4). Special attention should be given to maintaining suitable habitat consistent with project objectives: along trails, and particular areas susceptible to reduced soil moisture, erosion, or flood risk (Vacaville, 2013).

Goal 2: Modify habitat to support box elder in desired areas

To restore Centennial Park habitat consistent with project objectives, it may be helpful to alter trailside habitat and new riparian habitat to better support box elder. Soil testing can assist in determining if soils are well drained with a pH between 6.5 and 7.5 – suitable for box elder. If habitat is suitable, then removal of invasive species and irrigation mainline installation may improve success of box elder in desired areas (Vacaville, 2013). Any involved changes should seek to minimize harm to native species and mitigate damage to the ecosystem consistent with CEQA permitting and Streambed Alteration permitting from the California Department of Fish and Wildlife.

Goal 3: Transplant box elder to suitable habitat patches.

Reintroduction of box elder should occur in late Fall or Winter, prior to precipitation events, prioritizing habitat along trails and particular areas susceptible to reduced soil moisture, erosion, and flood risk. Adjustments in the irrigation schedule should mimic annual precipitation between 11 and 57 inches per year (Calflora, 2016). Keeping roots moist, all bare root tree seedlings, including box elder, should be transplanted at 10-20 foot intervals along the drip lines into holes as deep as nursery depth and up to 3-feet wide to aid in root growth (Foundation, 2016; Vacaville, 2013). The soil should be firmed around the lower roots as it is replaced, along with a mulch berm around the base of the tree to assist in seasonal water retention. Watering should follow transplanting, and then the protective mulch can be spread in a 3-foot diameter around the base of the tree (Foundation, 2016). No additional fertilizer, potting soil, or chemicals should be used on seedlings as such products are dangerous to young growth (Foundation, 2016). A fence (0.5m in height) or other barrier should be placed around young seedlings for protection from small wildlife (Foundation, 2016).

Goal 4: Engage partners and stakeholders in a long-term adaptive management program of box elder and its ecosystem.

Efforts aimed at environmental restoration and species establishment require a monitoring and evaluation component. Monitoring and evaluation ensure that (1) program goals and objectives are achieved, (2) proper feedback and information about the actions are collected, and (3) ideas to improve the effectiveness of actions are considered (Salafsky, Margoluis, Redford, & Robinson, 2002).

The selected metrics should be feasible, cost-effective, and suitable in the context of evaluating program objectives. General monitoring requirements are touched on in the 2013 Centennial Park Urban Greening Proposal. Requirements are expanded with input from Section 3 of the Vineyard Creek Restoration Project vegetation monitoring report. Specifically, vegetation monitoring includes plant survivorship and vegetative cover as two measures of success, described in detail below.

a. Plant Survival

The performance criterion for plant survival is 85-90% survival of all plantings by the end of three years (May & Associates, 2011; Vacaville, 2013). Interim annual success criteria should be consistent with the above criterion. Following a complete inventory of all plantings across the project area, plant health and plant size should be assessed in the Fall of every year. The following standardized scale can be used (May & Associates, 2011):

For Plant Condition:		**For Plant Size:**	
Score	Condition	Score	Size
0	Dead	1	Less than 2 feet in height
1	Poor Health (alive, but with few green leaves and apical growth)	2	2 feet to 10 feet in height
2	Fair Health (alive with foliage but minimal apical growth)	3	Greater than 10 feet in height
3	Good Health (alive and growing vigorously)		

If average box elder survivorship falls below 85%, remedial plantings should occur in late Fall or Winter to compensate. The number of remedial plantings is contingent on the number initially planted (Vacaville, 2013).

b. Vegetative Cover

Assessing vegetative cover is less standardized, and should focus on whether or not vegetation provides erosion protection and increasing canopy cover on an annual basis (May & Associates, 2011). Documenting qualitative observations annually in the Fall can help assist in evaluating the effectiveness of box elder in providing bank stabilization and habitat value. Special attention should be given to canopy cover improvements near creekside routes and trails for community health benefits (Chiesura, 2004; Vacaville, 2013). Year-to-year comparisons can assist in evaluating progress in context of the previous year's erosion control and canopy cover baselines.

If erosion protection is spotty, remedial plantings of box elder or associated native cottonwood or willow species at increased density can assist in improved erosion control. Both species are associated with box elder throughout its range. If canopy cover decreases, first attempt to increase foliage by improving box elder health before conducting remedial plantings at increased density.

Adaptive Management Plan Considerations

Plant survival and vegetative cover is critical to the monitoring the establishment of box elder. Moving forward, research should pursue a comprehensive understanding of riparian plant, animal, bird, and invertebrate impacts related to box elder reintroduction. Early detection of invasive species introduction as a result of box elder establishment is important for managing restoration of native species. For modified habitat, management should include maintenance checks on functionality of irrigation mainlines, particularly during the first three years of box elder establishment. Given unforeseen climate and climate-induced impacts to the riparian ecosystem, more frequent assessments of box elder and general ecosystem health are recommended beyond the three year horizon of establishment (Harris et al., 2006) to inform progress on community health objectives and improve our understanding of the ecosystem's sensitivity.

It is suggested that the Solano RCD staff continue to expand on collaborative initiatives with partners and stakeholders to improve monitoring and evaluation, establishing clear definitions of commonly used terms, coordinating monitoring system components, and including qualitative and social metrics in future monitoring efforts.

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

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Magnoliopsida

Subclass: Rosidae

Order: Sapindales

Family: Sapindaceae

Genus: *Aesculus*

Species: *californica*

Mark W. Skinner, hosted by the USDA-NRCS PLANTS Database

California Buckeye (Aesculus californica) is a tree species native to oak woodlands, chaparral, and riparian habitats throughout much of California's central valley. California Buckeye is an important riparian species that provides stream and slope stabilization (USFS). Buckeye currently holds no federal legal status. It is considered a climax species in chaparral and mixed oak woodland communities. In addition to these communities Buckeye is found in grasslands and mixed evergreen forests in California (USFS). Buckeye possesses toxic glycosidal compounds in all vegetative and floral tissues. Buckeye was used by Native Americans as a seed crop, once the toxins were leached, when other seed sources were scarce. In addition to proving mostly unpalatable to many foragers, this toxic nature has important implications for pollinators. For this reason, Buckeye should not be heavily used in restoration sites close to apiaries (USDA).European Honey bees that create honey from buckeye nectar are poisoned and create toxic honey (Adler, 2000). However, Adler describes that toxic nectar may encourage specialist pollinators with higher fidelity. In a restoration system this may imply a decrease in generalist pollinators and an overall increase in pollinator species diversity (Adler, 2000). Buckeye has also been known to spread and serve as a host for *Phytophthoptera ramorum*, a pathogen that causes canker disease in many oak species (Rizzo et. al 2002).

Fact Sheet:

Growth Characteristics:

- At maturity California buckeye is 4-12 m tall perennial drought deciduous tree (Stone

2014)

- Buckeye experiences bud break between February and June, typically senescing its leaves shortly after heavy rains; by August the tree is leafless. (Newell 1991)
- California buckeye produces toxic vegetative and floral structures (Mendoza and Rodolpho, 2009)
- California buckeye has palmately compound opposite leaves. Its inflorescence is panicle like with staminate and perfect flowers. (Stone 2014)

Ranges:

- California buckeye is found in all counties in California with the exception of Del Norte, Modoc, Sierra, Lassen, Sutter, Alpine, Inyo, Mono, Kings, San Bernardino, Ventura, Riverside, Orange, San Diego, and Imperial counties. (USDA Plant Characteristics)
- California Buckeye has also been found in Jackson county, Oregon (USDA Plant Characteristics)

Reproduction:

- California buckeye reproduces by seed and produces about 100 seeds per year (Howard, Janet L. 1992.)

- Seeds are large dispersed poorly, mostly by gravity and water. (Howard, Janet L. 1992.)

- Seeds are viable for one year and shed from November to mid-February (Howard, Janet L. 1992.)
- Seeds will germinate if soil temperatures remain above 40□F (Howard, Janet L. 1992.)
- California buckeye can sprout from stump and root crowns (Howard, Janet L. 1992.)
- The fruit is pear shaped and light brown with one to six seeds that are 2-3cm in diameter(Howard, Janet L. 1992.)

Habitat:

- California buckeye grows in canyons, along slopes, and waterways; in the central valley it occurs on stream and river banks (Howard, Janet L. 1992.)
- Buckeye prefers sandy, sandy loam, or gravelly loam (Howard, Janet L. 1992.)
- Buckeye grows in a Mediterranean climate with cool wet winters and hot dry summers with mean annual rainfall below 14 in. California. (Howard, Janet L. 1992.)
- Buckeye grows below 4,000 ft in elevation (Howard, Janet L. 1992.)

Successional status:

- California Buckeye is widely scattered in grasslands and occurs as an understory shrub in mixed evergreen forests (Howard, Janet L. 1992.)
- California buckeye is a climax indicator in California buckeye woodlands, chaparral, and mixed oak woodland communities (Howard, Janet L. 1992.)

Tolerances:

- California buckeye is adapted to coarse and medium textured soils with a pH between 5.5-7.5 with low salinity (USDA Plant Characteristics)
- California buckeye is highly drought tolerant and somewhat fire and shade tolerant (USDA Plant Characteristics)
- Buckeye has a high tolerance to herbivory due to its toxic compounds (USDA Plant Characteristics)

Wildlife Interactions:

- California Buckeye produces toxic glycosidal compounds in all of its vegetative and floral structures and is toxic to animals (Howard, Janet L. 1992.)
- Although California Buckeye is toxic, it is slightly palatable to some animals including cattle and deer. (Howard, Janet L. 1992.)
- The palatability of California Buckeye seeds is fairly poor (Howard, Janet L. 1992.)
- California Buckeye produces toxic nectar which encourages specialized pollinators with high fidelity (Lynn S. Adler And Rebecca E. Irwin. 2005)
- California Buckeye nectar is toxic to honey bees (Lynn S. Adler And Rebecca E. Irwin. 2005)

Plant interactions

- California Buckeye is associated with Poison Oak in many communities that it occurs (Howard, Janet L. 1992.)
- California Buckeye is known to spread the bacteria *Phytophthoptera ramorum* which causes Canker diseases in many oak species (Rizzo et al. 2002)

Human interactions:

- Historically, Native Americans used Buckeye seeds for food after leaching toxins (Howard, Janet L. 1992.)
- When pregnant cattle forage on CA. Buckeye its toxins can induce abortions (Howard, Janet L. 1992.)

Threats

- California Buckeye has faced threats from habitat degradation. (Hogan, C., & Fund, W. 2014).
- 30% of historical Chaparral in California remains intact (Hogan, C., & Fund, W. 2014).
- Riparian Zones that are invaded with Arundo displace many native riparian species including California Buckeye (J. Hall Cushman and Karen A. Gaffney. 2010)

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Part II

Restoration of California Buckeye (*Aesculus californica*) in California’s Central Valley

A. Goals

California Buckeye (*Aesculus californica*) historically occurs along streams, rivers, dry canyons and slopes. Several pre- installation measures must be taken before introducing this species to a restoration site. In riparian settings, California buckeye usually occurs in the 'upland' zone that has a depth that is greater than four meters from the water table (Eviner, lect3). In California's central valley, riparian corridors are heavily invaded by woody and non woody species that displace naturally occurring vegetation (J. Hall Cushman and Karen A. Gaffney. 2010). Before introducing California buckeye to a riparian site, large invasive woody species and heavily competitive species would need to be mapped for removal. A few common invasive species that may heavily compete with native woody species found along California's Central Valley riparian corridors include: Chinese tallow tree (*Sapium sebiferum*), Common fig (*Ficus carica*), Giant Reed (*Arundo donax*), pampas grass (*Cortaderia selloana*), and American elm(*Ulmus Americana*) (Fessler, 2015). Regions that are heavily invaded should be treated for the removal of invasive species. Once these species have been removed, these areas will be seeded with California buckeye and have a drip irrigation system installed and closely monitored for two years. When seedlings have sprouted, shown significant growth, and have become saplings they must be wrapped with a protective tube to prevent herbivory (may take 1 to 2 years after seeding). Areas that are seeded should be monitored for the return of invasive species, particularly woody invasives that may be fast growing and compete with California buckeye.

B. Restoration Plan

1. Monitor for and map Invasive species for removal

Because of budget constraints it is unrealistic to aim to remove every invasive species that is present at a project site. To overcome this issue, management should monitor for areas that already have the highest amount of native plant species and focus on the eradication of encroaching invasives. This will work towards creating areas that have primarily native species forming habitat. When patches of invasive species are found interspersed among native species hand and tool removal may be implemented. When large patches of an invasive are found they may be sprayed with herbicide for removal. When woody invasive species are found they can be injected with an EZ-ject lance. If these individuals are found in areas that may not support buckeye, such as areas too close to the water table or areas with heavy clay soils, they should be left to provide habitat in the form of snags and logs.

2. Seed in California Buckeye and install drip irrigation

Access to a given seed source is often free from roadsides, other public access (parks),and willing land owners (Young and palmerlee, 2010). Seeds of California buckeye should be collected within a 50 mile range of the project site to encourage species with the genetic basis most adapted to the sites specific climate regimes. I suggest seeding in species rather than using nursery grown container stock because of the cost effectiveness of seeding. Although container stocks have proven to have higher survivorship rates, this gain is offset by the cost of producing nursery grown plants (Young and palmerlee, 2010). Seeds should be planted in groups of two or three. Due to the seeds large size of California buckeye, the seeds should be covered by approximately 1.3 to 2.5 cm of soil. After seeds have been places a drip irrigation system should be installed. Emitters should deliver 1gal/h at each direct seeded location. The irrigation system should be operated once every two weeks for three to five hours during the summer for at least one year. Once seedlings have grown and reach a height of 6 inches tall they should be protected by a plastic tube to protect them from herbivory (Tubex™, Aberdare, Mid Glamorgan).

C. Monitoring

After the site has been seeded, the area needs to be monitored for at least five years. During this period, plots that were seeded should be weeded during the growing season. If a plot where buckeye was seeded shows no survivorship after 2 years, the area can be replanted with a different woody species.

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Western Redbud: *Cercis occidentalis*

Elizabeth Ridolfi

Scientific Classification:

- Kingdom: Plantae
- Order: Fabales
- Family: Fabaceae
- Genus: *Cercis*
- Species*: C. occidentalis*

Back ground and Justification:

Cercis occidentalis or Western Redbud is a California native shrub known for its spectacular pink bloom during the spring. Among its historical and ethnobotanical uses, it is common to use it as a landscaping plant. It is a common plant found in the understory of California Oak Woodland, an ecosystem under threat by agricultural development and overgrazing (Holmes, 1990). The species Western Redbud is not threatened itself per say do to its horticultural interests and tendency to disperse, yet many of the ecosystems it occurs in are under threat. There are benefits to restoring Western Redbud in the environments where it could have once existed and has been destroyed to soil stability, pollination and for its esthetic value. It is an excellent stabilizer of soils and can even be used on road cuts where it is difficult to get even the sturdiest of vegetation to grow (USDA, Western Redbud). More recently, pollination and the current threats cause by lack of pollination to agriculture has been a dominant issue in ecology. Increasing the number of flowering plants like Western Redbud in areas adjacent to farmlands has been shown to increase and support pollinator populations (Kremen and Moradin, 2013). It is obvious that the environment of California is changing and due to the lack of historical records of certain plant populations, those changes will be difficult to estimate (Holl and Vasey, 2007). However, do to its adaptability, Western Redbud will be able to survive not only it its native areas but also in areas of restoration.

General Information:

- Scientific Name: Cercis occidentalis Common Names: Western Redbud, California Redbud (Gilman and Watson, 1993).
- Family: Fabaceae – symbiotic relationship with nitrogen fixing bacteria.
- Native to North America primarily California, Arizona and Utah.
- Concentrated populations In Northern California foothills below 4000 ft.
- Found in oak woodland, chaparral, mixed conifer forest, riparian woodland and closed cone forest (USDA, 2006).
- Not considered invasive.

Abiotic Requirements:

- Light Requirements: full sun, partial sun and partial shade (Gilman and Watson, 1993).

- Soil tolerances: clay, sand, loam, acidic, alkaline and well-drained (Gilman and Watson, 1993).
- Moderately drought tolerant (Gilman and Watson, 1993).
- Not tolerant of aerosol salts (Gilman and Watson, 1993).
- Requires temperatures to be below 28 degrees for flowering to be excessive (Gilman and Watson, 1993).
- Can grow in canyons, near streams, streambeds and rocky outcroppings (Gilman and Watson, 1993).
- Water table depth requirements are unknown.
- Often is found singly but can grow in clumps (Gilman and Watson, 1993).

Physical Characteristics:

- General form: height 15-25 ft, moderate growth rate, spread 15-25ft, moderately dense irregular crown. It will require pruning if it is near pedestrian walk ways because of its drooping growth form (Gilman and Watson, 1993).
- Flowers: pink, fuchsia and incredibly showy. Blooms for about two weeks at a time from February to April (USDA, 2006).
- Fruit: typical of legumes, attractive to birds and goats (USDA, 2006).
- Leaves: simple, cordate or ovate with entire margin, pinnate venation and alternate arrangement (USDA, 2006).
- Leaf color: green to yellow in fall. Leaves are deciduous, glabrous and leathery (Baldwin, Goldman, and Vorobik 753).
- Bark: The bark is very thin and easily damaged (USDA, 2006).
- Important nitrogen fixer (USDA, 2006).

General Habitat Information:

- Can withstand periodic flooding (USDA, Western Redbud).
- A good stabilizer of stream banks (USDA, Western Redbud).
- Key pollinators: bumblebees and mason orchard bees (USDA, Western Redbud).

Propagation:

- Redbud seeds require long periods of dry, cold weather in order to germinate correctly. They require pretreatment to germinate because of the thick seed coat and dormant embryo. The germination in the wild is catalyzed by fire but can also be done by pouring boiling water over the seeds and allowing them to soak overnight. This method might be beneficial in urban environments where fires are generally extinguished quickly. The greatest success rates seen and planting seedlings that are at least a year old and using cages to protect them from gophers. Give the plants summer water for at least three years without over watering them. While adapted to flooding, excessive water can cause crown rot. Liquid fertilizer can be used to induce growth (USDA, Western Redbud).

Notes on Pathogen Susceptibility:

- *Alternaria* sp. and *Botrytis* sp. can both affect Redbud by making its appearance less attractive but otherwise does not cause significant physiological harm. *Fusarium solani* and *Verticillium dahliae* can both cause root rot. Other fungi can be spread by older seed pods. These diseases do not kill the plants but can severely damage them. Fire is the natural preventive for these fungal infections by sterilizing the tissue (USDA, 2006).

Fire Regime:

- Research on the precise need for fire in the growth of Western Redbud is very limited. The plant can stump re-sprout after fire. Because of the lack of data on the fire regime of the central valley, determining the exact needs for Western Redbud will be difficult. It is historically noted that Native American tribes actively burned areas of the chaparral and valley to increase the availability of vegetation for animals. After the settlement of this area by Europeans, this regime changed. While the precise historical fire regime is unknown at this time, the estimate is somewhere between 35 to 100 years. Prescribed burns have been shown to have some positive health effects on Western Redbud (USDA, Western Redbud).

Successional Information:

- Western Redbud is found on areas frequented by disturbances like fires and can be present in several stages of succession. It can also stump re-sprout, making disturbance by fire less of a challenge. Seeds are dispersed to burned areas by animals. It is considered a good plant for rehabilitation because of its ability to stabilize soils and has been shown to be especially effective in revegetating road cuts (USDA, Western Redbud).

Livestock and Animal Needs:

- The information is fairly limited on this topic. Mule deer browse this plant as well as livestock on the young shoots. It is important for pollinators and is generally not grazed by cattle or sheep. It provides light coverage for smaller mammal species but does require pruning for the heavy flowering that is more attractive to pollinators (USDA, Western Redbud)(USDA, 2006).

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Restoration Recommendations for *Cercis occidentalis*, Western Redbud

Goals

- Determining the optimum species density for *Cercis occidentalis*
- Providing pollination services for endangered species
- Stabilizing soil and improving soil fertility to support growth of understory plant species.

Justification

Cercis occidentalis is an understudied species and the need for research before any formal restoration plans can commence is critical. Due to the lack of research, determining the historical species density has not yet occurred. While *Cercis occidentalis* is now a common horticultural plant in California, it is unknown if the species is threatened. The assumption can be made that due to the destruction of habitat, the species could be situationally threatened. Current observations suggest a patchy distribution and over a small area, *Cercis occidentalis* tends to grow singly (Gilman and Watson, 1993). It is unknown if this is the optimum density for this species but it is the only known growth habit that has been documented. It is also known that *Cercis occidentalis* is an important species for pollination, especially for bees, which was a great concern in the overall restoration goals for Centennial Park (Gilman and Watson, 1993). Central

Valley agriculture could also directly profit and benefit from the increase in pollinator availability due to *Cercis occidentalis* if prime blooming conditions are provided for. However, peak blooming occurs when winter temperatures fall below 28 degrees and due to the current climate in the Central Valley, those days can be rare (Gilman and Watson, 1993). It is still unknown as to the long term climate changes that could occur and it is a possibility that if the average winter temperature changes, there could be an increase in blooming which would lead to a possible increase in pollination if the insects survive the temperature change. Despite this speculation, it is probable that the restoration of *Cercis occidentalis* would provide an increase in pollinators and an overall increase in the level of pollination of other species. *Cercis occidentalis* is commonly used to stabilize soils in other restoration projects, primarily stream banks and road cuts (NRCS, Western Redbud). As the topography of Centennial Park is highly variable and there is a goal of restoring riparian vegetation, *Cercis occidentalis* would be successful in many areas. It could also add additional nitrogen to the soil, which could support native forbs that are threatened by invasive species. There is a significant risk of increasing the level of nitrogen in the soil to a level that would increase the growth of invasive annuals, particularly if restoration efforts for native forbs are not as successful. Based on this risk, a trade off must occur with the number of *Cercis occidentalis* individuals planted especially when the addition of nitrogen based fertilizer is highly recommended for up to three years after their planting (NRCS, Western Redbud). While this could have implications for the levels of pollinators and pollination that would occur, it would aid in the prevention of a further takeover by invasive annuals. *Cercis occidentalis* plants must then be carefully distributed throughout the site to ensure the successful stabilization of soil and to gain the maximum nitrogen fixation benefit without increasing the levels of invasive annuals. In regards to the restoration goals for this species, it is recommended that the determination of its historical range be placed in a long term category after years of observation of the restoration site. A tradeoff must be made between providing for pollination services and support for native forbs because while increasing the number of *Cercis occidentalis* plants would provide additional soil nitrogen and is favored by key pollinators, the nitrogen fertilizer used in the initial stages of its planting could increase the growth of invasive annuals if the native forbs are slow to colonize the understory.

Restoration Plan

Fall to Winter 1	Gather and treat seed pods. Sow seeds.
Winter 2 (onset of winter rains)	Plant year old seedlings, cage and fertilize
Late Spring/ Early Summer 2	Begin regular summer watering
Summer 3 and 4	Continue summer watering and fertilize as needed

Any restoration plans focusing specifically on *Cercis occidentalis* were not found through research so this plan is a composite of all known information on its observed behavior when planted. Spatially, it is found singly but can form dense patches (Gilman and Watson, 1993). Due to ease of maintenance, it would be advised to follow single distribution. If pollination support is critical, plantings should occur no more than 1 mile away from farmland (Morandin and Kremen, 2012). Because the exact historical spatial distribution is unknown, there is no effective way of predetermining a spatial scale for *Cercis occidentalis* restoration. Establishing a population of *Cercis occidentalis* takes approximately 4 years. Seed pods must be gathered from an area that is as close to the restoration site as possible, but this is not always achievable due to habitat destruction (NRCS, Western Redbud). The seedpods require a long period of dry and cold weather to germinate followed by fire. The latter is not achievable in many restoration sites because of the proximity to structures and property. Pouring boiling water over the seed pods and allowing them to soak overnight is an acceptable substitute (NRCS, Western Redbud). It is unknown if there are any additional benefits to fire germination that cannot be achieved with the boiling method. Seedlings can be raised using standard nursery methods and should be planted when they are at least 1 year old immediately before the onset of the winter rains (NRCS, Western Redbud). It is highly advised to use protective caging to protect from gopher damage and to fertilize with a nitrogen fertilizer to accelerate growth for 2 to 3 years (NRCS, Western Redbud). However, nitrogen fertilizer should be used with caution because of the risk of inadvertently contributing to the invasion of non-native species that thrive in high nitrogen environments. The precise need for fire in the life cycle of *Cercis occidentalis* is poorly understood. As previously mentioned, *Cercis occidentalis* germinates by fire when occurring naturally and the plant can stump regenerate after burning. Prescribed burns have been shown to have a positive health impact but no regime has been established (NRCS, Western Redbud). It is unlikely that prescribed burns will be able to occur near neighborhoods despite the positive health effects to this species due to safety concerns. The success of restoration is likely if the cultivation steps are followed as outlined above. However, the risks involved with nitrogen fertilizer use must be accounted. The temperature requirements for intense blooming can be replaced by pruning once the plants have reached reproductive age (USDA, 2006). Determining a natural distribution of *Cercis occidentalis* will require long term observation and will be difficult to establish without knowledge of its historical basis or fire regime.

Monitoring Plan

When deciding where to plant *Cercis occidentalis* plants, priority should be given to areas with lowest soil nitrogen content and high traffic from pollinators. It is recommended that soil nitrogen testing begins immediately so adequate base line data can be gathered and individuals are placed in areas where they will provide maximum benefit. The number of pollinators and their preference for *Cercis occidentalis* versus other natives versus invasive species should also be monitored in methods similar to Moradin and Kremen, 2012. Pollinators will be netted, identified and collected if they have had contact with the reproductive parts of the flower. This is to remove a level of error that exists from inadvertently counting insects multiple times if they visited multiple flowers. However, some level of error still exists (Moradin and Kremen, 2012). The data from Moradin and Kremen, 2012 indicates that pollinators prefer native vegetation (Moradin and Kremen, 2012). Nitrogen testing can occur any time of year but pollination studies can only occur during the blooming period which occurs approximately from February to April and for approximately two weeks per plant (USDA, 2006). If colonization of *Cercis occidentalis* is successful and pollination support is occurring, yearly monitoring will no longer be necessary. However, monitoring should occur as long as financially possible. As mentioned previously, the application of nitrogen based fertilizer can be used to aid in the growth and colonization of

Cercis occidentalis but should be used with caution as they can inadvertently contribute to the growth of invasive species. A combination of herbicides and mechanical removal should be used unless controlled fire is feasible in this location. If *Cercis occidentalis* bushes grow into pedestrian walkways, as needed trimming in the fall or winter is advisable. This restoration and monitoring plan allows for the satisfaction of the management goals with the exception of the research on determining the historical density and ideal growth form of *Cercis occidentalis*. The plan involves a relatively high level of human intervention via irrigation and fertilizing, effectively changing the survival rate of plants. The *Cercis occidentalis* will also not be planted in random areas but instead will be planted in areas in need of nitrogen and soil stabilization. There is also no effective way of measuring fertility and fecundity because of the alterations because of human management. It the application of herbicides to prevent the invasion of non-natives, *Cercis occidentalis* seedlings could be killed as well. Without a better understanding of the animal life surrounding the site, there is also no way of being able to predict the predation of seedlings either. *Cercis occidentalis* will stabilize the soil and improve the nitrogen availability in the local areas it is planted. Current research also suggests that it will provide support for pollination if flowering is moderate to intense. However, it is unclear as to whether or not it will be able to reach its historic level of distribution, mainly because it has not been determined as it's unlikely to be determined in this area.

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The California Blackberry (Rubus Usinus)

The California Blackberry (Rubus Ursinus) is an important species to consider for Central California restoration because it can bring many benefits to the ecosystem. The California Blackberry can provide food and habitat for many birds and other wildlife. It is also able to grow in low quality soil and help prevent erosion. It is also one of the first species to reestablish following fire. However, can also be very competitive and out compete other native species, thus reducing native diversity (Tirmenstein, 1989). For these reasons, it is an interesting species to manage because it's positive and negative effects. The California Blackberry can be found throughout the West coast all the way from British Columbia to Mexico and is particularly common from the Cascades to the Pacific Coast (Tirmenstein, 1989). It is found in a wide range of plant communities including many West Coast riparian communities dominated by willows or cottonwoods (Tirmenstein, 1989). It can also be found in yearlong aquatic habitats and seasonally saturated habitats. However, it is not commonly found within the central valley except for along riparian areas because the valley temperature exceeds their tolerance in the summer and there is not enough moisture. But overall the population isn't greatly declining and is still present in much of the California Coastal range along with much of the western United States (Calflora, 2016).

Fact Sheet

Distribution:

California blackberry occurs throughout the west coast all the way from British Columbia to Mexico, in canyons, coastal areas, disturbed areas, and in many West Coast riparian communities dominated by willows (Salix spp.) or cottonwoods (Populus spp.) (Tirmenstein, 1989).

Site characteristics:

California blackberry grows from sea level along the Pacific Coast to middle elevations farther inland. (Tirmenstein, 1989)

The California blackberry occurs across a wide range of sites from warm, open areas to dense woodlands. It is particularly common in prairies, clearings, waste places, and canyons. California blackberry frequently assumes prominence on sites which have been burned or logged and on river terraces or gravel bars dominated by red alder (Tirmenstein, 1989)

<u>TOLERANCES</u>

Shade tolerant

Elevation 0 to 1880 meters

Annual Precipitation: 12 to 159 inches

Wet Season 4 to 10 months

Temperature Range ≤ 64 ° F

December Low 28 ° F

July High 97 ° F

(Tirmenstein, 1989)

Soils: Blackberries grow well on a variety of barren, infertile soils. These shrubs tolerate a wide range of soil texture and pH but require adequate soil moisture for good growth. California blackberry appears to be tolerant of periodic flooding by brackish or fresh water (Tirmenstein, 1989)

SOIL

pH 5.2 to 8

Max Salinity 1.7 (non-saline)

Min Depth 13 cm

Texture(s): fine + medium + coarse

(Tirmenstein, 1989)

California blackberry typically increases rapidly on disturbed sites, persisting until suppressed by canopy closure. It occurs in stands of all ages but reaches greatest abundance in early seral communities (Tirmenstein, 1989)

The California Blackberry tolerates clay and seasonal flooding (Wilson & Wilson, 2014).

Importance to wildlife:

California blackberry provides food and cover for many wildlife species. (Tirmenstein, 1989)

Blackberries are eaten by numerous birds, including the ruffed grouse, northern bobwhite, sharp-tailed grouse, California quail, ring-necked pheasant, blue grouse, gray (Hungarian) partridge, band-tailed pigeon, American robin, yellow-breasted chat, pine grosbeak, gray catbird, and summer tanager (Tirmenstein, 1989)

Mammals, such as the coyote, common opossum, skunks, gray fox, red fox, raccoon, squirrels, chipmunks, and black bear, consume the fruit of blackberries (Tirmenstein, 1989)

In many areas California blackberry is particularly important to deer during the fall and winter (Tirmenstein, 1989)

Rabbits, porcupines, mountain beaver, and beaver occasionally consume the stems, leaves, and cambium of blackberries (Tirmenstein, 1989)

California blackberry provides important cover for a wide variety of wildlife species. Dense thickets of blackberries form good nesting sites for many small birds including, thrashers, jays, pigeons, northern mockingbird, sparrows, tanagers, and towhees (Tirmenstein, 1989)

Mammals such as rabbits, red squirrel, black bear, and beaver utilize blackberry thickets for cover in many areas (Tirmenstein, 1989)

Regeneration Process:

Fruit of the California blackberry is readily dispersed by many small birds and mammals (Tirmenstein, 1989)

California blackberry exhibits vigorous vegetative regeneration but also commonly reproduces through seed. (Tirmenstein, 1989)

California blackberry sprouts readily from "suckers" or "nonrhizomatous sprouts" after fire or mechanical disturbance. It is also capable of spreading rapidly from trailing stems which root at the nodes. These modes of vegetative spread occur even in the absence of disturbance. (Tirmenstein, 1989)

Most blackberries produce good seed crops nearly every year. (Tirmenstein, 1989)

Germination is often slow. Most blackberries require, as a minimum, warm stratification at 86 to 68 degrees F (30 to 20 degrees C) for 90 days, followed by cold stratification at 36 to 41 degrees F (2 to 5 degrees C) for an additional 90 days. These conditions are frequently encountered naturally as seeds mature in summer and remain in the soil throughout the cold winter months. (Tirmenstein, 1989)

The seeds of most blackberries remain viable for at least several years after being buried in the soil or duff. Although the precise length of viability has not been determined for the California blackberry (Tirmenstein, 1989)

Bloom Period: February – May (Calflora, 2016)

Management considerations:

Expected mortality was estimated at approximately 50 percent following plantings in southern California. Planting densities of 66 per acre (163/ha) were recommended for best results

(Tirmenstein, 1989)

Plants may be propagated vegetatively, transplanted, or seeded onto disturbed sites. Seed which has been scarified can be successfully planted in late summer or early fall (Tirmenstein, 1989)

California blackberry quickly assumes prominence on burned or logged sites. After disturbance it can compete aggressively with conifer seedlings in many locations (Tirmenstein, 1989)

Many chemicals including glyphosate, triclopyr, and roundup, have proven effective in controlling California blackberry. Fifty to 80 percent control has been achieved with roundup in some locations (Tirmenstein, 1989)

This California Blackberry can grow to 15 or 20 feet (5-6 m) in length (Tirmenstein, 1989)

Blackberries, because of their ability to grow well on infertile soils, may be valuable in preventing soil erosion on some sites (Tirmenstein, 1989)

In some locations, California blackberry is moderately grazed by domestic sheep but is rarely used by cattle (Tirmenstein, 1989)

Most effective in stabilizing a creek bank or the edges of a bioswale or banks of a flood basin. (Tirmenstein, 1989)

The stems of most blackberries are biennial. Sterile first-year stems, known as primocanes, develop from buds at or below the ground surface and produce only leaves. Lateral branches, or floricanes, develop in the axils of the primocanes during the second year and bear both leaves and flowers. (Tirmenstein, 1989)

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Restoration Plan for the California Blackberry

The restoration of the California Blackberry is important for the Central Valley in order to help support birds and other wild animals, along with preventing the erosion of top soil in poor soils. The California Blackberry is also an early successional species that can begin the recovery of disturbed habitats and help the reintroduction of later successional species (Tirmenstein, 1989). The first restoration goal of the California Blackberry should begin with a survey to determine where the California Blackberry currently exists. The next goal should be to determine that areas where the California Blackberry could be supported. The third goal should be to determine how potential sites would need to be altered to support the California Blackberry. Alterations may include the removal of existing vegetation and burning. The final goal should be to maintain the California Blackberry habitat. The California Blackberry is an early successional species and will be slowly encroached by other species (Tirmenstein, 1989). These goals can be accomplished through seeding disturbed sites and transplants in areas that have not recently been disturbed. Success will be measured in the prevention of erosion in top soils and the persistence of California Blackberry patches within the restored site.

Reintroduction preparation:

It is critical that the California Blackberries seeds are properly collected and if necessary, germinated in the correct conditions to ensure the maximum reintroduction potential for the project. Seeds can be collected from the California Blackberry around July and August when the shrubs are fruiting (Tirmenstein, 1989). Most Blackberries should produce a large amount of seeds every year. These seeds do the best when planted in a site in the late summer or early fall, the same time they would be introduced to the soil naturally (Tirmenstein, 1989). This ensures that the seeds will be germinated in time for the normal February to May blooming season (Calflora, 2016). If it is determined that transplants will be needed for the restoration of the site, the seeds will have to be germinated in specific conditions. The process of germination for these seeds is lengthy and requires about 180 days. Most blackberries require, as a minimum, warm stratification at 86 to 68 degrees F for 90 days, followed by cold stratification at 36 to 41 degrees F for an additional 90 days (Tirmenstein, 1989). This simulates the fall and winter months that the seeds would naturally have to wait through before germinating in the spring. Once the transplants have been grown and are ready to be planted in the restoration site, the expected mortality rate is estimated to be around 50% for the transplant (Tirmenstein, 1989). This estimate was calculated using a restoration site in Southern California, so the expected mortality rate for the Central Valley may vary.

Conservation:

The California Blackberry can grow in a wide variety of conditions. It also occurs in many West Coast riparian communities dominated by willows or cottonwoods. It is typically an understory shrub and is able to tolerate low light conditions (Tirmenstein, 1989). It is able to grow in poor acidic soil of varying textures (Tirmenstein, 1989). It is also able to tolerate seasonal flooding and clay (Wilson & Wilson, 2014). This is important especially around the riparian areas it can be found by. Because it can tolerate a wide range of conditions, there are many different habitats it can be found in. The best sites to restore the California Blackberry is one where the blackberry already exists. This decreases worry about unforeseen consequences of introducing a species to a site it wasn’t previously found in. If the California Blackberry is already present in the site of interest, but is not doing as well as desired, there are several methods that could be used to help promote and conserve the. The existing blackberry plants are able to quickly sprout vegetatively after a disturbance, such as a fire or logging (Tirmenstein, 1989). These disturbances would destroy the blackberries along with any other competing vegetation. However, the blackberries aren’t completely killed and would are able to quickly sprout back and become very competitive in the area again following a disturbance (Tirmenstein, 1989). This would reset the successional stages, which would favor the California Blackberry over other plants that do well in later successional stages. Canopy vegetation can also be trimmed back to create a more open area, which is the condition where the California Blackberry is most abundant (Tirmenstein, 1989).

Reintroduction:

If conservation efforts of existing California Blackberry sites is insufficient, reintroductions can be made in the sites that may or may not already have a population of blackberries. The California Blackberry is a versatile plant that is able to regenerate in a few different ways. This flexibility in regeneration options makes it easier to fit into a broader scale restoration plan that includes a wide variety of species. The first option for a restoration plan would be to start with a disturbed habitat, such as a habitat that has been effected by fire or logging. The California Blackberry is an early successional species and does very well when its seeds reach an area that has been disturbed. If the area of interest for restoration is not currently disturbed, existing unwanted vegetation could be removed or burned and then seeded or transplanted with the California Blackberry. The California Blackberry seeds would be collected from existing plants in the area, if possible. If no existing plants exist, seeds can be taken from a similar habitat nearby. These seeds and can then be planted at the site during late summer and early fall or can be planted and germinated in a greenhouse during the same time period (Tirmenstein, 1989). Transplants can take place after the seeds have germinated and planted in the site after they have reached an appropriate size for the restoration project. The California Blackberry can be found in all successional stages, but are most abundant during the first stage where there is no canopy cover (Tirmenstein, 1989). Both the seeds and transplants should be placed in areas with little canopy cover and lots of light. If these areas do not exist in the habitat of interest, they can be created through habitat modification. Existing vegetation and canopy can be removed or reduced. If possible for the site, fire can also be used to create the ideal areas for the California Blackberry (Tirmenstein, 1989). There is little information on the minimum and maximum scale of transplants and seeing that is the most effective. However, if considering transplants, the planting densities of 66 per acre were recommended for best results during in sites in Southern California (Tirmenstein, 1989). This number may vary in central California, but should give a good estimate. Once the Blackberry seeds or transplants are set, there are some other issues that may affect the success of the site restoration. The California Blackberry is a very important food source for many birds and mammals (Tirmenstein, 1989). The stress of herbivory on young blackberries may affect how well they will do. Deer especially rely heavily on California Blackberry vegetation during the fall and winter when there are few other food sources (Tirmenstein, 1989). This could lead to a reduction in the survival in the young plants during their first year planted. If this becomes an issue, deer enclosures or other forms of fencing could be implemented to prevent the deer from eating the young plants. Another issue that could be encountered would be if the blackberry became too successful and overgrows other wanted species in the area. Typically, the California Blackberry can be controlled fairly efficiently with many chemicals including glyphosate, triclopyr, and roundup. Roundup has been shown to have about 50% to 80% control in some locations (Tirmenstein, 1989).

Management and Monitoring:

Management and monitoring of the California Blackberry will be necessary for many years after the site is restored. Due to the fact that the California Blackberry is an early successional species, it is constantly facing encroachment from species from higher successional stages (Tirmenstein, 1989). The blackberries in recently disturbed areas should not have to deal with much competition other than from other early successional species. However, once the later successional species start to gain a foothold in the area, there may have to be some removal of those species to prevent the California Blackberry from being mostly shaded out. If there is a decision to let the later successional species continue toward the climax system, the blackberries would have to be maintained in other patches within the area to account for the other patches lost to later successional species. So success for the maintaining of the California Blackberry in a site should be based off of the total percent coverage of the plant within the site restored to account for the natural process of succession. The percentage of cover for the California Blackberry should be monitored every year to determine if the overall coverage of the plant in the area is declining. It must be done fairly frequently because it takes some time to grow transplants and clear vegetation if necessary. This would help prevent there from ever being a huge drop in the California Blackberry population, which would help make sure that all the wildlife that need it for food and shelter wouldn't be too adversely affected. It may be declining due to other species succeeding it, lack of disturbed habitat to move to, or herbivory. If the California Blackberry is declining, steps would need to be taken to determine the cause of the decline. If the California Blackberry is not as abundant in the original sites they were restored in and there are latter successional species present, but the blackberry is also found in some new sites, it may be due to competition in the site. Steps could be taken to remove some of the competing vegetation if it is determined competition is the cause of the decline. If the California Blackberry is abundant in the sites it was originally placed in, but there is little spread of the plant to new areas, there may be an issue with lack of disturbed habitat for the plants to disperse to. Steps could be taken to increase the amount of disturbance in nearby areas through burning and logging in selected spots. Lastly, if the California Blackberry is declining in both old and new sites that doesn't have many competitors present, there may be decline due to herbivory. Herbivory could be reduced through the use of enclosures that prevent major blackberry predators like deer and beaver from getting to the shrubs (Tirmenstein, 1989). If the California Blackberry doesn't survive well in the site from the start of the restoration project, there may be issues with the site itself. Even though the California Blackberry can tolerate many harsh conditions like poor soil (Tirmenstein, 1989) and seasonal flooding (Wilson & Wilson, 2014), the conditions still might not be good enough for the California Blackberry to survive. The site should be reevaluated to determine if it exceeds any of the tolerances for the California Blackberry to see if it is an issue with the site itself. Management and monitoring will be very important for maintaining a species that is successful in the dynamic system that the California Blackberry thrives in.

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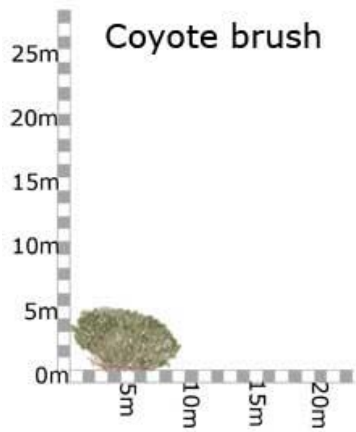
Coyote Brush *Baccharis pilularis*



Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Asterales

Family: Asteraceae

Baccharis pilularis is a shrubby plant which is commonly found throughout most of coastal California. *Baccharis pilularis* can act as a key part of the pioneer species used for this restoration project, predominately because of its ability to foster a large variety of herbivores, including some gal forming insects (Rudgers, 2006). Because it blooms later in the year after much of the surrounding vegetation has flowered and gone dormant for the winter, it attracts a large variety of pollinators (Steffan, 1997). In turn, these pollinators attract a large variety of other animals which can also take shelter in the wide, sweeping branches of *B. pilularis*. Overall, this species can act as a haven for a large assortment of beneficial wildlife, creating an ecosystem that may be more resilient to disease, invasion and infestation (Downing, 2012). The overall population of this species been largely diminished due to only 15% of coastal sage scrub habitat remaining (Stephenson, 1999). However, there is a large amount of literature present on its invasion onto grasslands around California which speaks volumes of the resilience of this species. There was a study done in Santa Barbara on the shifts from coastal sage scrub, grassland, and oak woodland (Callaway 1993). It revealed that there was a very slight shift from grassland systems into coastal sage scrub (0.69%/yr.) It is known to invade grasslands in the absence of fire and grazing, a highly relevant characteristic (Williams, 1989) and may not be a negative one depending on the mentality of the person leading the restoration project seeing how this would increase shrub cover and boost diversity with its ecosystem services. This species dominates northern coastal scrub regions and can be found amongst coastal beaches, coastal sage scrub, chaparral, foothill woodlands, closed-cone pine forests, and mixed-evergreen forests. Furthermore, it can live from 10-20 years or even longer if given the opportunity for basal sprouting and layering (Steinberg, 2002).

Fact Sheet:

Requirements:

- Water limitations are 250-750 mm rainfall (lower/upper limits) (Cabi.org).
- It is best adapted to medium-coarse-textured soils (U.S. Dpt. Ag, 2002) but can tolerate clay, loamy, sandy, rocky, infertile, saline, shallow, and sodic soils (Cabi.org)
- *B. pilularis* is highly drought tolerant, as a result of the waxy coating on its leaves. Furthermore, it is very intolerant of the shade and will do best in full sun (Cabi.org).
- Best establishment will occur during wet years, in the spring time. There will be high root growth as long as there is moisture (fs.fed.us).

Succession:

- Strong candidate for invading grasslands, especially in the absence of grazing and burning (Van Dyke, 2001).

Habitat:

- Prefers disturbed habitat and has a very broad range, from coastal sage scrub, to canyons to sandy coastal bluffs (Cabi.org).
- Because of its fondness of disturbance, it may respond well to colonization of plowed areas but more research is needed.

Reproduction:

- *B. pilularis* has a high reproductive potential due to being asexual (diecious) and fast growing. Its male flowers produce pollen and are yellowish, while the female flowers produce fruit and are white. The flowers are full of pappus which greatly aids in wind dispersal over long distances (Cabi.org).
- It has a bloom period from September – January (Calflora).
- Recommended to be planted near disturbed sites in a 1:5 male to female ratio (fs.fed.us). By planting the females around the male it will promote more of a radial distribution of the seed, thus allowing the seeds to find their most preferred niche.
- Many habitat features and reproductive characteristics of *B. pilularis* such as seed banking and inundation are currently unknown. Given that seed is not long lived (Cabi.org) it can be inferenced that seed storing from year to year is unlikely.

Propagation Requirements:

- Coyote brush germinates a under typical conditions found along its native range. It takes about 15-30 days for germination to occur. Although there is no temperature requirement it may have a facultative light requirement, it will grow best in mineral soil (Cabi.org).

Plant Interactions:

- Associates in Northern coastal scrub: San Diego bush monkeyflower (*Diplacus auranticus*), Monterey coast Indian paintbrush (*Castilleja lattifolia*), Pacific dewberry (*Rubus vitifolius*), open lupine (*Lupinus varicolor*), cow parsnip (*Heracleum lanatum*), seaside woollysunflower (*Eriophyllum staechadifolium*), salal (*Gaultheria shallon*), western pearlyeverlasting (*Anaphalis margaritacea*), coastal wormwood (*Artemisia suksdorfi*), and seaside fleabane (*Erigeron glaucus*) (Steffan, 1997).

Wildlife Interactions:

- Responds well to grazing because of asexual regeneration from root crown/roots and increased floral production upon grazing (Rudger, 2006).

- 55 insect species visit male and female flowers in late September and early October alone, given that this species flowers later than many of its neighbors in the scrubland Steffan, 1997).

- Good for increasing small mammal populations because of increased ground cover and shelter, provides food to many insects (Martinez, 1993).

Fire Regime:

- Tolerant to fire if it does not become too hot, low fire conditions on a grassland will allow for establishment of its population and it may outcompete other herbs (Van Dyke, 2001)

- If burned to reduce fuel loading, special care must be taken to conserve the endangered California gnat catcher which requires approximately 50% shrub cover and over 3.3 feet for its nesting territory. As a result, it is recommended that both mature and burned scrub lands are maintained (reducing fuel load) in order to mitigate impact to endangered sp. (Beyers, 1997).

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More references rated by importance:

Da Silva PG, Bartolome JW (1984) Interaction between a shrub, *Baccharis pilularis* subsp. *consanguinea* (Asteraceae) and annual grass, *Bromus mollis* (Poaceae) in coastal California. Madroño 31:93–101
This research takes a look at how Baccharis can deal with a common invasive plant of neighborhood bordering plots – Bromus mollis. It analyzes the relationships which can occur in the regions where grassland and brushland interact.
Importance: Medium

eSimone, S. A., & Zedler, P. H. (1999). Shrub seedling recruitment in unburned Californian coastal sage scrub and adjacent grassland. *Ecology*, *80*(6), 2018-2032.

This study examines the effectiveness of shrubs including baccharis in colonizing areas that were naturally disturbed, not including fires. There is interesting research regarding germination being fostered by animal (gopher) mounds.
Importance: Medium

Hobbs, R. J., & Mooney, H. A.. (1985). Vegetative Regrowth Following Cutting in the Shrub Baccharis pilularis ssp. Consanguinea (DC) C. B. Wolf. *American Journal of Botany*, *72*(4), 514–519. Retrieved from http://www.jstor.org/stable/2443583

Provides data to how Baccharis may respond to accidental mowing throughout its growth. Highlights that the prime age for resprouting is in shrubs aged to 3-4 years, data which can be used to promote more bushy coyote bush growth.
Importance: Medium-low

McBride, J., & Heady, H. F. (1968). Invasion of Grassland by Baccharis pilularis DC. *Journal of Range Management Archives*, *21*(2), 106-108.
Provides a dated but interesting perspective on invasion and does well to compare habitat dominated by baccharis to grasslands. Makes critical mention of species' population's resistance to fire and speculates that a change in fire regime is the reason for its spreading.
Importance: High

Williams, Kimberly, Richard J. Hobbs, and S. P. Hamburg. "Invasion of an annual grassland in Northern California by Baccharis pilularis ssp. consanguinea." *Oecologia* 72.3 (1987): 461-465.

This research looks at this shrub's rapid colonization of annual grasslands in California. Makes mention of various growth and establishment patterns of Baccharis and highlights its effectiveness of growing in a similar climate.
Importance: Medium

Goal and Reasoning	Spatial Scale	Temporal Scale
Increasing the amount/diversity of natural pollinators present – aids in pollination and helps sustain a healthy ecosystem	Creation of pollination routes throughout central valley for at least 55 various insects in Sept/Oct. (Steffan, 1997)	Such routes might be accomplished over the course of 1 decade due to the resilience of *Baccharis* and its efficiency at colonizing disturbed areas, however, it will take some time for pollinators to find their way.
Provide habitat for animals – birds perched in branches can drop seed, bringing in more diversity, small mammals can use this for shelter	The creation of cover and habitat for various wildlife to use the shrub-land provided by this species across the entire valley would be preferred	A corridor of this size could be achieved in a little more than a decade, providing that all of the small spp. of mammals can find their way
Add more green to the landscape – this evergreen plant can provide a nice option as a drought tolerant beneficial native	Depending on how individual farmers decide to treat this invasive native, it can be limited to hedgerows or sprinkled throughout the entire landscape	This would occur instantly given that this plant is an evergreen that looks quite distinct from the sky if compared to surrounding vegetation in the central valley, a drone at the right height could effectively monitor this distinct "greenness" under trained eyes
Groundcover form used to prevent erosion and help stabilize exposed slopes – keeping the fertile Central Valley soils from blowing away	This should be planted throughout any locations in the central valley susceptible to erosion, especially abandoned agricultural plots as this will quickly colonize disturbed areas	Erosion will likely never be stabilized within the central valley but given several decades, native shrub-land can act as a safety net for fertile soil that would otherwise float away as dust

I would propose three massive restoration plans across the central valley in order to get a better chance of having success because of the increased diversity provided by the three various cultivars. This would allow for the landscape to pick the fittest individuals of coyote brush and would also act as a safety net in case one of the cultivars is unable to become established. Seeds will be started indoors for higher germination success and sown early spring.

1.) Pigeon Point cultivar would be sowed en masse parallel into the many valleys and major slopes in order to establish a protective groundcover layer as well as to establish habitat (Standiford & Svihra, 1995). This dwarf, prostrate cultivar is just as hardy as the true *Baccharis* if not more, so its genetics (seed) can be sourced from any local plant nursery in central valley or collected from prime specimens in Central Valley. If the seed is sowed alongside slopes and develops then these plants can colonize more areas which inevitably become disturbed amongst the slopes, resulting in a positive feedback loop and allowing this plant to colonize and protect more land. This cultivar also has higher fitness due to it taking on a prostrate growth form

(Rudgers & Whitney, 2006).

2.) *Baccharis pilularis consanguinea* could be planted in patches 7 strong from seed sourced from local nurseries, 5 patches/100sq. km. These patches should be sprinkled across central valley in abandoned agricultural plots and along disturbed areas such as rarely used dirt roads. This will allow them to form a stable population and begin to spread along with the patterns of disturbance. The different height of branches would also supplement the hosting of a different suite of insects than that of the Pigeon Point due to a more pronounced architectural dimorphism dictating both the distribution and abundance of such various herbivores (Rudgers & Whitney, 2006). However, their research also showed that prostrate plants will provide more flowers and seed than erect plants like this one so the Pigeon Point cultivar may be hosting more biological activity than this and the subsequent erect variety.

3.) *Baccharis pilularis* this seed stock should be sourced from erect specimens throughout the Central Valley and coastline to obtain a rich genetic profile. The seed should be sown in patches 7 strong, in the same locations and at the same density as *Baccharis pilularis consanguinea*. This should provide a level playing field for these erect populations of *Baccharis* to take hold and begin to host less insects overall when compared to the Pigeon Point, yet their composition will be more diverse due to differing prey species, plant architecture and patterns of competition that arise (Gareau, 2008). It was also noted that parasitic wasp populations were flourishing around this plant even when it was not in bloom. It is also mentioned that a high abundance of parasitic wasps early on in the season can act to prevent buildup of pest populations around crop field, highly relevant to this CV scenario.

There truly are not that many problems/risks/uncertainties with this plan that I can think of given how hardy this plant has been described to be in literally all of the literature encounter so far. The largest being the formation of a corridor across such a large region. Given the birds and insects that can call this plant home are quite mobile, it would only be a matter of time for the patches of *Baccharis* to begin sharing activity with one another due to the large amount of insects that they can host. This lag period might last a year or two until its significant floral blooms attract enough beneficial wildlife for it to be considered a significant ecosystem service. This plant is resistant to deer grazing according to the National Gardening Association but any further information on herbivory by mammals on this specific species could not be found just yet. Although it is salt tolerant, the NGA states that it prefers a pH of 5.6-6.5 and the CV, the average pH for 125 sites in CV was measured out to be 7.10 in 2001 (DeClerck & Singer, 2003). Although the soil is likely not too alkaline for coyote brush, providing how hardy it has shown to be in its other characters such as with drought, heat, fire, and salt.

Theoretically a program could be designed that would analyze and compare imagery taken from this restoration project via drone(s) over the course of a decade or more or at least compile it into large panoramas of the entire central valley and how they change over time. A drone would be a relatively simple and inexpensive way for measuring the success (% cover) of such largescale projects, the ease of which arises from the evergreen foliage of this particular species looking distinctly different from most of its surrounding vegetation throughout the CV (Breckenridge, 2006). Monitoring could be done once a year during the dry points of the season

when the *Baccharis* should stand out the most from the surrounding vegetation. Interns could be sent out to study differences/patterns between the two different populations of erect *Baccharis.* If populations of this hardy species manage to fail completely then repopulation will occur out of both, seedlings that have been raised in beds of sand and then transplanted to native soil and, seedlings that are sown straight into the dirt in order to determine if germinating the seeds beforehand indoors causes the seedlings to be fatally shocked or stunted when they are planted outdoors. This will be done in small scale experiments first. If the death is sporadic then I will do another planting cycle in order to guarantee that this plant is able to become established in some areas where it will become a pioneer species. However, I am truly struggling to think of any thresholds of action for such a resilient species.
What should be answered:
Weaknesses of *Baccharis pilularis*, as well as the ease of identifying *Baccharis pilularis* from a certain height with a drone.

What this can answer:
How effective coyote brush is at being a companion plant in and around hedgerows and agricultural production by acting as a host plant for beneficial insects. This could be monitored by asking the organic farmers of the central valley to notice and report any reduction in pest/infestation patterns on their crops.

The efficacy of Pigeon Point as groundcover. This can be tested by comparing percent % over a period of time and by comparing the soil texture from before to after ~ 5 year establishment.

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CALIFORNIA FUCHSIA

Epilobium canum(Green)P.H.Raven
Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclasss: Rosidae
Order: Myrtales
Family: Onagraceae
Genus: Epilobium
Species: canum (USDA)

Background and Justification:

Epilobium canum, formerly, *Zulcherna californica*, (CALFLORA) is a perennial herb native to California Foothills and coastal areas. It is notable for its trumpet-shaped, bright scarlet flowers blooming in summer and autumn. (CNPS) Remarkably, it is the only California native flowering in the peak of summer. (CNPS). Although few research articles exist on this species it is worthwhile to mention in the context of restoration in the Central Valley.

E. canum versatile shrub. It is can be found in multiple environments of Riparian understories, ranging in elevation from 0 to 3530 meters. (CALFLORA) This perennial does best in full sun but has exceptional shade tolerance. It is also known for its moderate drought resistance. According to CNPS in the northern part of it's range *E. canum* requires no supplemental water after it has been established. It also survives in soil fine, medium, and coarse. (CALFORA)

Due to its tubular bright flowers and nectar *E. canum* attracts pollinators such as bees and humming birds. (Xerces). As another added benefit this perennial also serves as a host to White-lined sphinx, a species of moth. (CALFLORA)By bringing in a California native it will promote beneficial insects that ward away insect pests.(NPIN) The California Fuchsia provides a number of ecosystem services for a site with minimal resources.

<u>FACT SHEET:</u>

Project Goal:

- To introduce *Epilobium canum* into a restoration site in order for it to establish and attract beneficial insects as well hummingbirds. Ultimately, to diversify the area while not causing unbearable disturbance during the sites initial ecological stages.

Plant Characteristics:

- Phyllotaxis: opposite or alternate
- Leaves: small, lanceolate or ovate with short to inexistent stalks.
- Leaf color: green to nearly white
- Flowers: red to orange
- Flowering season: July to September
- Deciduous or Evergreen: summer is semi deciduous, winter season is as well. (CNPS)

Growth:

- Perennial herb, with spreading habit, 2-3 feet.(CNPS)
- Height: Low for a shrub .25 – 1.25 feet.(CNPS)
- Growth rate: Fast; 0 – 12 months of appropriate temperature.(CNPS)

Range:

- Elevation: species occurs between 0 – 3520 meters.
- Southwestern Oregon to Baja California; east to southwestern New Mexico (Wildflower Org)
- States: AZ, CA, ID, NM, NV, OR, UT, WY (Wildflower)

Plant Habitat:

- Communities include: Coastal Sage Scrub, Chaparral, Yellow Pine Forest, Red Fir Forest, Lodge Pole Forest, Subalpine forest. (CALFLORA)
- Habitat: Slopes and Ridges (Plant ID). Also found on bluffs or canyons. In more inland areas it is found on slightly damper slopes or flats as well as near seasonal creeks. (CNPS)
- Sun: Prefers full sun but tolerates partial shade.
- Precipitation: 9 – 117 inches per year. Flowers best at median
- Temperature Tolerance: Can tolerate cold to 0 degrees Fahrenheit. July high 98 degrees Fahrenheit, December 19 degrees Fahrenheit
- Drought Tolerance: Moderate (CALFLORA)

Soil:

- PH: 5.4- 8.2 (mostly basic) (CALFLORA)
- Salinity MAX: 0-1. Indicates no to low tolerance.
- Minimum Depth of soil must be between 15 cm – 250cm.
- Textures: Does well in fine, medium, coarse, and sandy soils.
- Drainage: Medium; soil must be well drained.
- Soil Toxicity Tolerance: tolerates serpentine soils (CNPS)

Landscaping Information:

- Max Summer Irrigation:1x/month
- Pruning: Cut or mow to base in fall or early winter to stimulate for new growth. Unwanted rhizomes can be pulled at any time.
- Propagation: Self-seeds readily. Rhizomes can be transplanted in winter or spring.
- Plant is not rhizomatous but still spreads through “rhizomes” nappy underground roots.
- Common uses: Butterfly Gardens, Hummingbird Gardens, Groundcovers
- Nursery Availability: Commonly Available. (CNPS)

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Establishment of the California Fuchsia

Project Goals:

- ➢ To introduce *Epilobium canum* into restoration site in the Central Valley.
- Assist to create an environment in which *E. canum* can become established.
- The plant must be able to thrive at its location; one indicator that would demonstrate that this is accomplished would be a successful flowering season of the plant.
- Since hummingbirds will provide pollination services for *Epilobium canum* they will

serve as another indicator that the plant is producing nectar.

- This California native has very little ecological literature available, other than on its pollinators and nectar production rate.
- *E. canum* is self-compatible; if it does not produce flowers with enough nectar or attract pollinators right away it can still produce seeds (Snow,1989)

➢ Ensure that *E. canum* is a successful competitor.

- It is often found growing with annual grasses such as *Bromus* and other perennial grasses such as *Agrostis*, *Carex*, *Elymus*, *Koleria*, and *Poa*. (CNPLE)
- Nonnative annual grasses and harsh growing conditions dominate the Central valley.

➢ Raise site's biological diversity.

- Attract more beneficial insects as well as wildlife.
- Reduce populations of aggressive annual grasses

Restoration Plan:

- Need area with water, as species is riparian. Although it is drought tolerant it would benefit being planted in between middle and high planting zone on a slope. Water passes through this zone but it not usually retained for long periods of time.
- Soil: Normally E. canum would be found on rocky hillsides. But it has various subspecies occurring at all elevations. What this species needs is good drainage. Clay soils will drown this plant it is better of on a slope. (USDI, 2012)
- Water: Considered riparian species but needs very little water it should be a good distance from water source.
- Space: Width is more important to consider when planting *E. canum* since it is low growing stems are also brittle and easily break off(Tree of Life, 1999). On average it expands about 4 feet. It should not be planted within such close proximity of other woody species (at least 5 foot gap), herbaceous and perennial species should be fine.
- To guarantee success it should be planted away from high traffic areas. Away from roads or walkways.
- Area in which we are planting these species needs to be big enough to welcome bird and insect species at the same time accommodate a plant community with a water source. Estimated 5-10 hectares?
- *E. canum* flowers during summer but should be planted during Fall through season.
- Seeds: Sowing seeds will require more time to grow as well as commitments to take care of. Most efficient method of reintroducing *E. Canum* would be to transplant the native using plugs. These should be purchased from a nursery that collects seeds locally so that they are preconditioned to the environment where they will be planted.
- Once established into the ground juveniles must be watered a few times monthly until roots are established.
- Blooming season usually last from 1 to 2 months.
- Plants should be pruned each year prior to raining season to encourage full growth after spring.
- Taller plants should also be pruned to encourage fuller growth. (Tree of Life,1999)

Monitoring Plan:

- Monitor growth and survival of plants.
- Pictures should be taken before and after plotting for visual record of data.
- Frequency: Every month to every week with the yard stick or measuring tape in the photo.
- Report: Number of flowers as well as flower color.
  -Visitation by insects: Bees, moths, etc.
  -Visitation of humming birds will be crucial. Record how often humming birds vist and how many times an individual flower gets jabbed.
  -This should be done during the flowering period, in the daytime, daily.
- Repeat process after the first year, 3rd and 5th year.
- Any growth of new seedlings as well as deaths of shrubs should be recorded.

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Heteromeles arbutifolia (Toyon)

Kingdom: Plantae

Order: Rosales

Family: Rosaceae

Subfamily: Amygdaloideae

Tribe: Maleae

Subtribe: Malinae

Genus: *Heteromeles*

Species: *H. arbutifolia*

BACKGROUND AND JUSTIFICATION

Toyon (*Heteromeles arbutifolia*) is a tall shrub that is located vastly throughout California in chaparral, woodland, and forest communities (McMurray, 1990). Toyon is observed from Coast Ranges in Humboldt County down to Baja California and from central California down to the Transverse Ranges in the foothills (McMurray, 1990). Toyon is a shrub that has a deep root system, which allows it to re-sprout quickly after a fire, making it drought tolerant (Meentemeyer et al., 2001). Although *H. arbutifolia* is fire resistant and has a high drought tolerance, studies done on Santa Catalina Island (off the southern coast of California), have shown that overgrazing of mule deer can lead to increased mortality when trying to regenerate after a fire (Ramirez et al., 2012). This is a good representation of how a species like *H. arbutifolia*, which is used to various environmental stressors, can have its characteristics be altered by other plants or animals in the environment. Because of its deep root systems, *H. arbutifolia* is widely used as an erosion control species and can be used to keep steep faces intact (McMurray, 1990). Species like these are important when discussing restoration because they can keep soil intact and allow for other species to populate and survive. Because of its broad leaves that provide a large cover area, *H. arbutifolia* is an important species to birds and small mammals that are looking for nesting area or a place to hide from potential predators (McMurray, 1990). It is also used for wildlife plantings because it possesses berries that are consumed by a variety of different bird species (Van Dersal, 1938). Populations of *H. arbutifolia* are still observed throughout the state of California and do not seem to be declining. However, there are areas like those discussed above where overgrazing has affected the local distribution and abundance of the species. Toyon brings many different values to the table when discussing restoration and should be beneficial to most habitats in Mediterranean climates.

FACT SHEET

Project Goal:

- To introduce *Heteromeles arbutifolia* (Toyon) for restoration in areas where soil erosion is an issue and where the ecosystem has been degraded.

Growth Characteristics:

- Toyon is a tall, broad-leaved shrub species that usually grows to be between 6 and 10 feet (McMurray, 1990).
- At some sites with appropriate nutrients and enough space toyon can become a tree and grow to be 33 feet tall (McMurray, 1990).
- Evergreen leaves are between 2 to 4 inches and are arranged alternately on the stem (McMurray, 1990).
- Red berries on the shrub are about .25 inches in diameter on average (Magill, 1974).

Growth Patterns:

- Active growing season from December – June. Stem growth stops after this due to the increased heat and summer droughts (McMurray, 1990).
- In spring, carbon is allocated to the development of the canopy. During periods of low stem growth, carbon is allocated to roots, fruits, and tannins that create protection against potential predators (Mooney & Chu, 1974).

Life form and age:

- Toyon is a phanerophyte (McMurray, 1990).
- Toyon can persist for as long as 100-200 years (Keeley, 1981).

Reproduction:

- Toyon can reproduce both sexually and asexually (McMurray, 1990).
- Fires can stimulate reproduction and increase both sexual rates of regeneration as well as asexual rates of regeneration (Arévalo et al., 2009)
- Seeds are able to germinate after being passed through coyote digestion, however this does not increase the likelihood of establishment (Silverstein, 2005).
- After a fire toyon is able to re-sprout quickly due to a pre-existing extensive root system (Cowan & Ackerly, 2010).
- Long periods without fire are necessary for seedling establishment/population expansion (McMurray, 1990).
- Seeds are dispersed mostly through various bird species (Dement & Mooney, 1974).
- Germination normally occurs between 10 and 40 days and no external stimulus is necessary for germination of seeds (McMurray, 1990).

Range:

- Toyon is widely dispersed throughout California's chaparral communities. It stretches from Humboldt County to Baja California in coastal ranges and from central California to the Transverse Ranges in the foothills (McMurray, 1990).
- It is also located on Santa Catalina island as well as the San Clemente islands in southern California; toyon is cultivated in Hawaii as well (McMurray, 1990).
- Toyon grows in the following ecosystem types: Douglas-fir, Ponderosa pine, Lodgepole pine, Redwood, Western hardwoods, Chaparral – mountain shrub (McMurray, 1990).

Habitat:

- *H. arbutifolia* resides in a Mediterranean climate that is often exposed to various environmental stresses such as heat stress (Valladares & Pearcy, 1997).
- Grows on semi dry, rocky slopes within foothills, mountains, and canyon bottoms. Typically at an elevation below 4,000 feet (McMurray, 1990).

Succession:

- It is a widespread species, however it is not typically abundant in a given ecosystem (McMurray, 1990).
- During fire free periods toyon is able to outlive and outlast other shorter lived species by spreading their shade cover and outcompeting other plants (Zedler, 1982).
- After fires toyon is one of the first species to emerge due to its vegetative propagation from existing roots (McMurray, 1990).

Requirements:

- Moderate water use requirements compared to other shrubs in the chaparral (McMurray, 1990).
- Soils are usually dry and well drained. Sometimes the soils are particularly saline (McMurray, 1990).

Tolerances:

- Toyon is extremely drought tolerant due to its deep roots which creates its ability to rebound quickly from fires (Cowan & Ackerly, 2010).
- Tolerates dry soils particularly well (McMurray, 1990).
- Toyon does not tolerate the following herbicides: 2, 4 – D and 2, 4, 5 – T (McMurray, 1990).

Wildlife Interactions:

- Not considered important to livestock because the plants grow out of their reach. However, birds eat the fruits and disperse the seeds. Other species known to consume the berries are California quail, band-tailed pigeon and raccoons. Deer populations can also help to disperse the seeds ((McMurray, 1990).

Human Interactions:

- Toyon has been referred to as “Christmas Berry” because of its bright red berries and has been used as a substitute for English holly. It is currently illegal in the state of California to collect the branches of toyon (McMurray, 1990).
- West Coast Native American tribes used the berries for food and medicinal purposes (McMurray, 1990).
- The Spanish used the berries to make a beverage (McMurray, 1990).
- Toyon bark has been used by fishermen to tan their fishing nets (Dale, 1986).

Propagation Requirements:

- Toyon can provide erosion control using its deep root system to stabilize steep slopes (McMurray, 1990).
- It can be propagated by both grafting and by cuttings (Magill, 1974).
- Two year old transplants produce seeds during the second season that follows the outplanting. Seed production does not decrease with age, but seed viability is short lived (McMurray, 1990).

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Restoration Plan for Toyon (*Heteromeles arbutifolia*)

The restoration of *Heteromeles arbutifolia*, commonly referred to as Toyon, in the Central Valley of California is important when discussing areas that experience soil erosion and where the ecosystem has been degraded. Restoring *H. arbutifolia* in the Central Valley will also support several native species of birds and small mammals that use the shrub both as a defense mechanism and a source of valuable nutrients. Specific species that consume the berries of *H. arbutifolia* include the California quail, band-tailed pigeon, and raccoons (McMurray, 1990). The first goal in restoration of *H. arbutifolia* should be to conduct a survey to determine where exactly existing population patches occur within California that share similar climatic characteristics as the Central Valley. In addition to this survey, we should also conduct a survey to determine the areas within California's Central Valley that lack *H. arbutifolia*, but contain some form of a soil erosion issue. After the survey stage we should have a better understanding of where we could introduce *H. arbutifolia* to have an immediate impact. The second goal of restoration should be to determine areas within California's Central Valley that show potential to support *H. arbutifolia*. The final goal would be to make physical changes to the areas determined in the second goal so that the areas will be able to support *H. arbutifolia*. Habitat modifications of these areas may include, but are not limited to: removal of invasive species, hydrological modifications, and topographical modifications. The goals listed above can be accomplished through the revegetation and transplanting of *H. arbutifolia* in sites that are suitable for growth of the species. Success of this particular management plan will be measured by the decrease of topsoil erosion and the persistence of *H. arbutifolia* populations over an extended period of time.

Revegetation:

In order to successfully revegetate populations of *H. arbutifolia* we will need to collect viable seeds during late fall and winter when the seeds are being dispersed (Keeley, 1987). Seeds must be collected from the berries in a careful manner either by hand or in a blender at a low setting, ensuring that the seeds are not damaged (Gordon, 2014). Germination of *H. arbutifolia* is completed in a fairly short amount of time, requiring only ten to forty days (Magill, 1974). Despite being a drought and fire tolerant species, extensive exposure to heat is lethal to seedlings (McMurray, 1990). Fresh seeds do not require stratification, however to increase germination stored seeds require stratification for three months in temperatures from 35 to 41 degrees Fahrenheit (Mirov and Kraebel, 1937). Initially *H. arbutifolia* seeds could be dispersed on the top layer of sifted potting soil in a two-inch deep plastic container (Gordon, 2014). After germination occurs the seed can be easily moved from the two-inch container to a small pot to grow (Gordon, 2014). After a couple months true leaves will start to emerge and the individual can be replanted into a one-gallon pot (Gordon, 2014). *H. arbutifolia* grow better in pots than in the ground during the course of winter because the pots stay at a warmer temperature (Gordon, 2014). Typically they are potted in fall and are ready to be planted in the ground by late winter or early spring (Gordon, 2014). If we follow these methods in the revegetative process, then *H. arbutifolia* will have a high likelihood of survival, as it establishes quickly and grows at a fast rate.

Transplanting:

Transplanting of *Heteromeles arbutifolia* would be most effective in late fall or early winter right before the rainy seasons in late winter and spring. If they were introduced in an area for erosion control, this would likely be on some sort of slope where they would aid in preventing erosion by rain, and would act to stabilize the hillsides they are situated on. Transplanted *H. arbutifolia* has a high rate of establishment and survival due to its drought tolerant characteristics, so irrigation is not an issue. Transplanting is more successful in areas not exposed to invasive species because of the complications they present (Ostertag et al., 2009). Closely monitoring areas surrounding *H. arbutifolia* is crucial due to the likelihood of repopulation of invasive species.

Conservation:

Heteromeles arbutifolia generally grows in scattered stands in chaparral and foothill woodland communities where the soil is usually dry and well drained (McMurray, 1990). By analyzing and gathering monitoring data from specific sites within these chaparral and woodland communities where *H. arbutifolia* is exceeding expectations or underperforming, we can get a sense of the factors that aid or inhibit growth. Looking at specific data such as soil temperature, soil moisture, precipitation, air temperature, and solar radiation will aid in determining the optimal conditions for *H. arbutifolia* to persist and control erosion. Other metrics that would be valuable to investigate could be competition between other plant species and the slope and aspect of the slopes in which *H. arbutifolia* is present.

Conservation of these identified areas should be at a high priority in order to conduct environmental monitoring. For the most part, *H. arbutifolia* can outcompete other plants during fire-free periods due to its widespread shade cover, which makes removal of other plant species unlikely or unnecessary. Restoration or management plans for other native species in the area could result in buffer zones being established to ensure the restoration of both species and not just one (Harris et al., 2006). If there are two native species seeking restoration in the same given area, then there is likely an issue with an invasive species that has taken hold in a community.

The existing communities of *H. arbutifolia* that are the largest and have the most community biodiversity should be the sites where the conservation priority is the highest. Conservation of these areas are important because they are areas that have seen successful growth of the species and make persistence of the species more likely going on into the future. It is likely that these large areas will not require restoration on a frequent basis, and the conservation effort could eventually be switched over to the smaller communities. Active restoration in the smaller communities could be achieved by introducing successful individuals from larger patches.

Reintroduction:

After conservation efforts are complete with areas that already contained *H. arbutifolia*, we can start to look at the areas within California's Central Valley that show potential to support the shrub and are not threatened by invasive species. These areas should be associated with those that are not exposed to a high rate of disturbance (anthropogenic or environmental), as that will significantly affect survival rates (Harris et al., 2006). As outlined in the second goal, surveys should be conducted throughout the Central Valley concerning environmental and physical characteristics of the land area, and use this information to determine which areas are the most ideal for *H. arbutifolia*. Reintroduction methods should mirror the conservation methods where we first establish large communities of *H. arbutifolia* and follow with the smaller surrounding areas. This ensures that we have areas with high genetic variability and gene flow, which can then be used to populate other areas.

Habitat Modification:

In order for some areas to become suitable for *Heteromeles arbutifolia* modifications must be made to the surrounding environment. Many areas in the Central Valley region of California have been significantly altered due to multiple agricultural practices, which make restoration efforts including habitat modification difficult (Allen-Diaz, 2000). *H. arbutifolia* is characterized by its ability to be drought and fire resistant, aid in slope stabilization, and erosion prevention (McMurray, 1990). Taking these qualities into consideration, the sites selected for habitat modification that are realistic should be areas within California's Central Valley that have been only slightly altered. For example, a site that other than a slight need for erosion control but otherwise contains all the necessary elements for growth would be an ideal site for habitat modification. Invasive species often pose a threat and usually must be removed in order for a more successful restoration (Ostertag et al., 2009).

Management and Monitoring

Close management of *Heteromeles arbutifolia* must occur with the individuals that have been revegetated, transplanted, or reintroduced in an area until they are able to grow and repopulate on their own. Researchers who are conducting monitoring at the sites can measure repopulation and increased abundance. Abundance or growth can be calculated by counting individuals within a quadrat via stratified random sampling, and reevaluating the same area using the same methods after a year or two to allow enough time for growth. Researchers can evaluate the effect that *H. arbutifolia* is having on erosion control by taking measurements of topsoil lost during a precipitation event before the introduction of the shrub and repeating the same measurements after the shrub has been introduced. A way to evaluate success in this aspect is to observe a decrease in topsoil lost after the introduction of *H. arbutifolia*, which would indicate positive erosion control. Monitoring of revegetated, transplanted, or reintroduced *H. arbutifolia* must occur frequently at the restoration sites for a duration of a few years to ensure that these populations will persist on their own. In years like this one where El Niño events brought heavy rainfall, careful monitoring and management would be crucial to ensure the survivability of the species. Climate change is likely to influence the environmental patterns in the near future, so more frequent monitoring will become much more important.

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Native herbaceous species

Native Bulbs: Triteleia, Brodiaea and Dichelostemma

Background: Native bulbs are perennial forbs that enhance the biodiversity of the landscape and therefor increase its ecological health. They provide aesthetic value to restoration sites, encourage ecotourism and generate income to communities that support their ecosystem by proxy. The three known bulb species found in the restoration sites are in the genera *Triteleia*, *Brodiaea,* and *Dichelostemma*. They are perennial herbs that are native to California and are also found outside of California, but confined to western North America (11). All three genera are currently classified in the family Themidaceae, but are still considered to be in the Liliacea family by some references, so their family status is somewhat unclear (9). Previously these three genera were lumped together under the Brodiaea complex, and were once considered part of the closely related onion family, Alliaceae (9). Many bulbs in families Themidaceae and other related families owe their wide distribution to Native American which historically cultivated and distributed them across the West Coast as food crops. These bulb species provide food for native honey bees, bee flies such as Bombylius facialis, butterflies and a host of other wild animals (10). Flowering time for all three genera occurs in spring, generally from March to April, with species in Brodiaea blooming all summer long until August (calflora). Furthermore, the common species found in California Grasslands are understudied and can provide a better understanding of grassland ecology (4).

***Triteleia hyacinthina* -Wild hyacinth**		***Dichelostemma capitatum* - Blue dicks**		***Brodiaea elegans* - Harvest Brodiaea**	
TOLERANCES		**TOLERANCES**		**TOLERANCES**	
Elevation	0 to 2330 meters	Elevation	0 to 2490 meters	Elevation	4 to 2640 meters
Annual Precipitation:	15 to 105 inches	Annual Precipitation:	7 to 103 inches	Annual Precipitation:	17 to 95 inches
Wet Season	4 to 10 months	Wet Season	0 to 8 months	Wet Season	4 to 9 months
Temperature Range	≤ 63 ° F	Temperature Range	≤ 65 ° F	Temperature Range	≤ 62 ° F
December Low	18 ° F	December Low	26 ° F	December Low	20 ° F
July High	97 ° F	July High	98 ° F	July High	98 ° F
Accumulated Temperature	0 to 212 ° F	Accumulated Temperature	79 to 264 ° F	Accumulated Temperature	32 to 212 ° F

Growing Season	0 to 9 months	Growing Season	4 to 12 months	Growing Season	2 to 10 months
Hardiness Zones	6a to 10a (-10 to 35 ° F)	Hardiness Zones	7b to 10b (5 to 40 ° F)	Hardiness Zones	7a to 10b (0 to 40 ° F)
SOIL:		**SOIL**:		**SOIL**:	
pH	5.2 to 7.2	pH	5.2 to 8.2	pH	5.5 to 6.9
Max Salinity	4.8 (slightly saline)	Max Salinity	2 (very slightly saline)	Max Salinity	1 (non-saline)
Min Depth	33 cm	Min Depth	13 cm	Min Depth	29 cm
Texture(s):	fine + medium	Texture(s):	fine + medium + coarse	Texture(s):	fine + medium + coarse
Max CaCO3 Equivalent	2 % (very low)	Max CaCO3 Equivalent	3 % (very low)	Max CaCO3 Equivalent	0 % (none)

Table 1: Tolerance comparison of three common bulb species found in Solano County (Calflora).

Range and Habitat

- Common Plant Communities: Valley grasslands, meadows, closed-cone pine forest, yellow pine woodland, foothill woodland and wetland riparian (Calflora)
- Found in areas that are wet in spring from northwest California and the Cascade Ranges to the Sierra Nevada, Great Central Valley and northern and central portions of central California and all the way to Canada and into Idaho. (Jepson)

Plant Characteristics

- The bulbs in the family Themidaceae are perennial monocots with geophytic growth (above ground death in winter with underground storage organs called corms). (1)
- Mature plants produce two leaves in fall rains with parallel veins and long slender blades characteristic of monocots, a new corm grows on top of the old one in spring and produce bluish purple or white flowers on a scape in spring. Above ground parts die after spring and seeds and corm persist through summer. (1)
- Seed germination occurs after about four weeks of watering, and reach maturity within 2-3 years after first growth. (6)

Plant interactions

- Invasive annual grasses are a known competitor for perennial forbs in California Grasslands where agricultural development has encouraged their take over (4)
- Further study on the relationship between the geophytic bulbs and invasive grasses is needed to determine the best management practices to encourage higher biodiversity of native species (5)
- It is suggested that presence of a healthy native perennial population discourages the growth of annual invasives by outcompeting them for soil space (5)

Human Interactions

- Historically the bulbs (or more accurately corms) of the three genera listed above were cultivated heavily by the Miwok tribe of Central Valley (13)
- The current wide distribution of these bulbs may be due to the consistent spread of the cormlets by the Native Peoples post harvest (3)
- The bulbs were harvested post seed production and their cormlets replanted immediately following retrieval to ensure future production in following years (3)
- The bulbs were eaten raw or cooked and were a main staple in the diet of many tribes in Western North America (14)

Animal Interactions

- Geophyte and animal interactions are yet to be fully understood and under studied in California Grasslands (13)
- It is thought that the corms of these monocots provide food sources for an array of wild animals including pocket gophers, hares and other vertebrates and their relationship possibly mutualistic; in exchange for sustenance the animals may aid in distribution of cormlets and discourage overpopulation by reducing plant density (13)
- The flowers of all three genera found in California Grasslands provide nectar for native pollinators as a primary or secondary food source (10).
- Grazing played an important role in the management of annual grasses and perennial grasses and forbs with moderate grazing providing the densest vegetative cover of favorable species and intense grazing favoring invasive annuals (4)

Fire

- It is suggested that fire and prescribed burns by Native Peoples played an important role in the life cycles of the common geophytes on the West Coast (12).
- There is evidence that the use of prescribed burns allowed Native Americans to harvest bulbs for consummation by removing grasses and other vegetation for easier access to the nutritious underground storage organs (14).
- The effects of fire on California Grasslands show similar results on invasive species as hand removal or grazing, which encourage the growth of perennial forbs and decreases the population sizes of annual grasses (4).

Effects of Disturbances

- Soil disturbance such as excavation, burial and simulated gopher mounds had an overall negative effect on native bulb populations and encouraged the growth of exotic annual grasses in California Grasslands (7)

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5. Effects of Established Perennial Grasses on Native Forbs in California

--Restoration techniques for grasslands using two-step method of reintroducing perennial grasses, herbicide, then planting of perennial forbs

6. http://plants.usda.gov/plantguide/pdf/cs_trhy3.pdf

--Distribution, habitat, uses, status, description and establishment of Brodiaea hyacinthia

7. Effects of Experiemental Soil Disturbance on Revegetation By Natives and Exotics in Coastal California Meadows, Peter M. Kotanen, *Journal of Applied Ecology*, Vol. 34, No. 3 (Jun., 1997), pp. 631-644 http://www.jstor.org/stable/2404912?seq=1#page_scan_tab_contents

--Effects of experimental excavation, burial and gopher mounds on native and exotic species in California meadows, ultimately soil disturbance favored invasive species

8. Flowering of three species of Brodiaea in relation to bulb size and source, Susan S. Han http://www.sciencedirect.com/science/article/pii/S0304423801002618?np=y

--Minimum corm size necessary for many species of Brodiaea to produce flowers

9. http://www.pacificbulbsociety.org/pbswiki/index.php/Triteleia
10. http://www.bioone.org/doi/abs/10.3120/0024-9637-61.1.87

-- The most important pollinator was a bee fly (Bombylius facialis, Bombyliidae), although native bees provided some pollination at higher sites. Ten-minute observation periods, during bee fly activity, showed up to 15 visits to plants in a square meter.

11. Calflora
12. http://www.wssajournals.org/doi/abs/10.1614/IPSM-08-087.1

-- The success of prescribed burning was correlated with biomass of annual grasses, excluding medusahead, preceding a burn treatment. It is hypothesized that greater production of combustible forage resulted in increased fire intensity and greater seed mortality in exposed inflorescences.

13. http://onlinelibrary.wiley.com/doi/10.1046/j.1526-100X.1999.72016.x/abstract;jsessionid=985030E1FB5672C36CA44D9EA96C4C46.f03t04?userIsAuthenticated=false&deniedAccessCustomisedMessage=

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-native americans, fire, geophytes

Restoration plan

One of the main appeals of Centennial Park is the beautiful blooms of the native bulbs that cover large expanses of the upland vegetation site. These perennial geophytes once covered the landscape of the California grasslands but their populations have since declined due to a several factors including but not limited to spread and introduction of invasive grasses, loss of fire regimes, and most importantly the loss of human assistance in propagation (2). The Miwok and other Native American tribes were known as stewards of the land and research in ethnobotany has uncovered a likely mutualistic relationship between native bulbs such as the ones present in Centennial Park and the tribes that facilitated their spread and population growth (2). In order to conserve these beautiful and historically fascinating flowers a hands-off approach would do more harm than good because of their developed relationship with human assistance. Prescribed burns, tilling and spreading of cormlets are highly recommended restoration practices that have shown to increase population size (2).

Goals

1. Manage, conserve and expand distribution of current populations of native perennial geophytes by employing a “hands-on” approach
    - Monitor percent cover of Brodiaea elegans, Dichelostemma capitatum and

Triteleia hyacinthina

- Introduce companion native species such as Allium, Chlorogalum, Calochortus, and Asclepias to achieve native plant cover including geophytes of at least 75%
- Use techniques such as tilling/digging and spreading of cormlets and measure density in experimental sites
- If approach hand separation shows positive results in population growth or distribution, continue this management strategy with volunteers, can be made into an educational opportunity for children with historic, botanical, and practical value
- Use prescribed burns to encourage new growth of bulbs**,** more research needed
- Percent cover desired should be achieved in approximately 4-5 years from beginning of management plan
- Possible conflict with ground nesting bird species
- Local regulations may make burning difficult to get approved

2. Decrease invasive grass species population to 0-10% cover in upland vegetation sites using prescribed burns and possibly grass-specific herbicide
    - Possible conflict with timing of seed production in native bulbs, though geophytes also triggered to grow by compounds released in smoke
    - Grazing annual grasses in early spring prior to bulb blooms has been shown to decease invasive grass seed bank and open up crown cover for perennial species. (1)
    - Grass-specific herbicides may harm native bulbs if the compounds that kill the grass are monocot specific, more research is needed to find an appropriate herbicide that is safe for use on bulbs
3. Increase biodiversity of grassland community by introducing ten new species of native perennial forbs
    - Need a curated list of species that were historically grown in communities of native geophytes found in site that wont compete and reduce population size
    - Should plant in fall when bulbs are dormant and can be disturbed and removed
    - Can coordinate planting of complimentary native forbs with spreading of cormlets to increase distribution while adding biodiversity
    - Could be costly in time and labor as well as the cost of the forbs needed, need more research to determine the percent cover goals for each species in new community

Restoration plan

Planting

- Seeds of geophyte species currently on the site can be purchased and planted for faster spread and expansion of current population if hand separating and transplanting is not feasible or too costly
- If transplanting cormlets from corms on site is possible, cormlets should be harvested in August during dormancy period and replanted immediately or saved and replanted

anytime after from the months of August-September (6).

- Locally adapted species of the native bulbs are best suited for this site and seeds should be sourced from local nurseries or collected from current populations on site in order to maintain genetic diversity (5).
    - If collecting seed from site, collection should occur in late summer or fall depending on species. The exact time of seed maturation varies by population and other contributing factors (abiotic and biotic) so an exact time should be determined by observation but should expect to do collection in early fall (5).
    - If seeds are purchased from local nursery, seeds should be planted before Octorber 1st and grown indoors in containers for three years before transplanting to site (5).
    - About 100 seeds should be planted in 6 inch pots so that corms can pull themselves down to the depth they require (5).
    - If purchasing bulbs/corms (instead of seeds), planting should be done in late August or early September when they are dormant (6).
    - Corms should be planted 2-4 inches apart at a depth of 4 inches (5).
    - If corms do not transplant successfully the above guidelines can be repeated the following year with adjustments depending on the situation.

Disturbance Regimes

- Fire has been shown to be an activator of bulb growth in the species found in the California Grasslands (2).
    - Historically fires were used to increase density, diversity and abundance of California native geophyte populations by the Native American peoples, but more research is needed to determine when and to what extent these fires should be lit (2).
    - Native geophytes of the California grasslands and chaparral are known fire followers and bloom in great numbers in the first spring following a fire (7).
    - When bulbs reach maturity they can become dormant and may only become activated again with the presence of the nitrile compounds in fire smoke that combine with rain water and soak (7).
    - Possibility of destroying seed bank if fire is lit at the wrong time, more research is needed to learn more about fire and the species of bulbs in the site.
- Fire has also been used to successfully kill invasive annual grasses in similar California Grassland restoration projects (3).
    - To reduce medusahead, brome, goat grass and most other annual invasive grass populations prescribed burns should be preformed in early summer and repeated yearly as necessary (3).
    - Most annual grass species should see close to 90% reduction after three consecutive yearly burns in early summer (3).
    - Possible conflict with timing of fires and life cycles of the native geophytes
    - If times conflict, a possible solution may be to use specific herbicides that only target invasive grasses
    - If grass-specific herbicide is not safe for monocots, removal of bulbs by hand or

plow followed by burning will allow for the conservation of the current population of geophytes

- After removal of bulbs and burning of invasive species, corms and cormlets can be stored until late summer before being separated from replanted using the techniques listed above
- Dormant bulbs may be stored indefinitely in a dark, dry space and should resprout upon replanting and watering (2).
- It is recommended that bulbs are replanted following fire in August (2).

Monitoring plan:

Pre-Restoration

Many of the techniques for pre-restoration monitoring have already been underway by our class such as measuring species diversity and percent cover, soil sampling and wildlife mapping. Additional information that would also be useful is the effect of fire, grazing, herbicide use, tilling, and separating on geophytic populations using experimental plots.

- Plots can be set up in different areas of the upland vegetation where bulbs are either absent or present with many more subplots within these two groups testing the effects of each type of disturbance
- These types of experiments can help to direct the restoration plan in determining when the best time to use these different disturbance regimes, to what extent, and to what frequency in order to maximize diversity, abundance and density of bulb population.
- Additionally, these experiment will answer many questions that can aid in future restoration of these bulb species and can provide another avenue for education using student volunteers.

Post-Restoration

If funding is available, restored areas in site should be monitored for percent cover of native species, indicators of geophyte health (size of scape, number of flowers per inflorescence etc.), and presence/percent cover of invasives remaining.

- Ideally, these restored sites should be managed by volunteers indefinitely using the "hands-on" approach introduced above (digging up corms, separating cormlets and replanting) with fires lit in the area periodically to keep invasive grasses at bay and to stimulate growth of geophytes.
  - If this is feasible, volunteer groups can be dispatched once a year in late summer to dig up and separate bulbs (3)
    - More research is needed to determine an appropriate fire regime post restoration, test plots can be used to better understand how the species on the site respond to periodic burns.
  - If this is not feasible, a minimum of three consecutive years of monitoring post restoration would be sufficient to at least determine the efficiency of invasive grass removal (8).
    - Monitoring should occur at least once a year to determine the percent

cover of invasive and native species with emphasis on the density and health of the native bulbs (8).
    - Monitoring should occur in spring when most species are flowering to better determine the survival of geophyte populations and remaining invasive grasses (8).
- If funding permits less monitoring or no monitoring, volunteers may still be able to assist in corm separation and distribution, with possible conflicts with native wildlife populations.
    - Conflict can be avoided if scheduled digging by volunteers occurred in late summer/early fall when most birds are not nesting and bulbs are dormant, more information is needed to determine which species are in the sites and when they are using it for nesting.
    - Cormlets may need up to five years to mature and store enough nutrients to flower, if percent cover is not at least 65% after this time replanting may be necessary (4)
    - If monitoring reveals the population of geophytes has declined or is less productive (via floral characteristics), reassessment of restoration regime must be taken into consideration with emphasis on tweaking timing of burns, use of herbicides and possible repetition of plan listed above.
    - If monitoring reveals no decrease or increase in invasive annual grasses, a fourth or fifth year burn may be necessary with a possible change in timing of burns or intensity of burns (8).

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Asclepias speciosa – Showy Milkweed

Chapter 5 Background and Importance

Rank	Scientific Name and Common Name
Kingdom	Plantae – Plants
Subkingdom	Tracheobionta – Vascular plants
Superdivision	Spermatophyta – Seed plants
Division	Magnoliophyta – Flowering plants
Class	Magnoliopsida – Dicotyledons
Subclass	Asteridae
Order	Gentianales
Family	Asclepiadaceae – Milkweed family
Genus	*Asclepias* L. – milkweed
Species	*Asclepias speciosa* Torr. – showy milkweed

Figure 9 Classification of *Asclepias speciosa* (NRCS 2011)

Showy milkweed, *Asclepias speciosa*, is an important plant species in California for preserving monarch butterfly breeding grounds as well as an important ethnobotanical resource. In the period from 1995 – 2013 there was an estimated 21% decline of milkweed abundance in the south eastern United States alone (Flockhart et al. 2015).

Monarch butterflies (*Danaus plexippus*), though not currently listed as threatened or endangered in the United States, are being considered for listing as a threatened species in the United States and are considered a species of concern in Ontario. *D. plexippus* larvae are known to only consume *Asclepias spp.* (Young-Mathews and Eldredge 2012), therefore maintaining populations of milkweed is necessary for monarch butterfly population maintenance. Caterpillars in danger of predation have been known to "play dead" and fall off of milkweed stems to avoid predation (Anderson 2006). For this reason, stands should be relatively dense so that a fallen caterpillar is near enough to another milkweed stem to continue to feed (Anderson 2006).

Historically *A. speciosa* has been used for many ethnobotanical purposes including rope, antiseptic, and treatment for several other issues including diarrhea, measles, and rheumatism (Ulev 2005, Anderson 2006, Young-Mathews and Eldredge 2012). It is still used in modern ~~m~~medicine as a way to control heart contractions (Ulev 2005). Preserving this cultural knowledge may prove important for combating disease in the future.

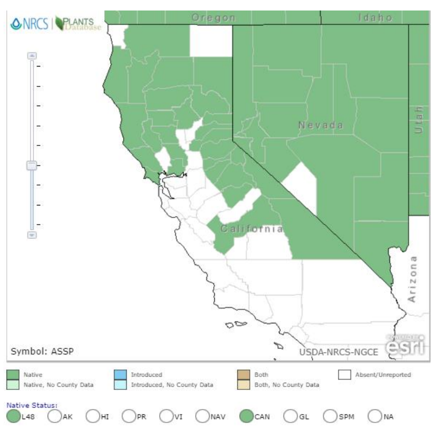


Figure 10 *Asclepias speciosa* range in California and Nevada (NRCS 2011)

Chapter 6 Plant Facts

Alternate Common Names

Showy butterfly weed, creek milkweed, Greek milkweed (Ulev 2005, Young-Mathews and Eldredge 2012)

Alternate Scientific Names

Asclepias giffordii Eastw., *Asclepias douglasii* Hook. (Young-Mathews and Eldredge 2012)

Legal Status

Listed as threatened in Iowa (NRCS 2011)

- Can be considered an agricultural pest (Ulev 2005)

~~Found in grasslands and occasionally in riparian areas in Oregon and Nebraska (Ulev 2005)~~

Identification

- Stems grow 50.0 – 119.9 cm in summer (Young-Mathews and Eldredge 2012)
- Leaves are opposite; ovate-lanceolate; 8 – 20 cm; grey-green; covered in velvety hairs (Ulev 2005, Young-Mathews and Eldredge 2012)
- Flower a large, showy umbelliform cyme; 15-28 mm; largest of all *Asclepias* species (Ulev 2005)
- Fruit a follicle; 2.4 – 4.7 inches (Ulev 2005)
- Seeds elliptic; 6 – 9 mm; with white hair-like tufts (Ulev 2005)

Figure 11 ©2004 Robert Sivinski

Figure 12 *©2006 Matt Below*

Figure 13 *©2008 Steve Matson*

Figure 14 *©2009 Neal Kramer*

General Characteristics

- Life Form: Forb (NRCS 2011)
- Warm Season (Ulev 2005)
- Perennial (NRCS 2011)
- Cardenolide concentration toxic to most animals (Ulev 2005, Anderson 2006, Young-Mathews and Eldredge 2012, Borders and Lee-Mäder 2014)
- Cardenolides found in all plant parts (Borders and Lee-Mäder 2014)

Habitat~~:~~

- General Distribution: Southern Manitoba west to British Columbia and south to Minnesota, to northwestern Texas, and California (Ulev 2005)
- Elevation Range: Sea level to 6,250 feet (Young-Mathews and Eldredge 2012)
- Elevation Range in California: 0 – 600 feet (Ulev 2005)
- Grows best in wet prairie habitats and moist, sandy soils (Ulev 2005)
- Grown in all soil textures (Ulev 2005)
- Can tolerate alkaline soil (Ulev 2005)

-
- ~~Legal Status: Listed as threatened in Iowa (NRCS 2011)~~
- ~~Weed Information: Can be weedy or invasive (NRCS 2011)~~
- ~~Found in grasslands and occasionally in riparian areas in Oregon and Nebraska (Ulev 2005)~~
- Good to stabilize and restore degraded sites because of its extensive root system, low nutrient requirements and drought tolerance (Young-Mathews and Eldredge 2012)
- Grows in well-drained soil in full or nearly full sun, in pastures, meadows, forest clearings, untilled fields, roadsides, and ditch banks (Young-Mathews and Eldredge 2012)
- Found in grasslands and occasionally in riparian areas in Oregon and Nebraska (Ulev 2005)

~~Propagation and Regeneration~~

- ~~Propagation by cuttings of rhizomes is easy and reliable, however the timing of propagation is important (See Plant Guide for ASSP) (Anderson 2006)~~

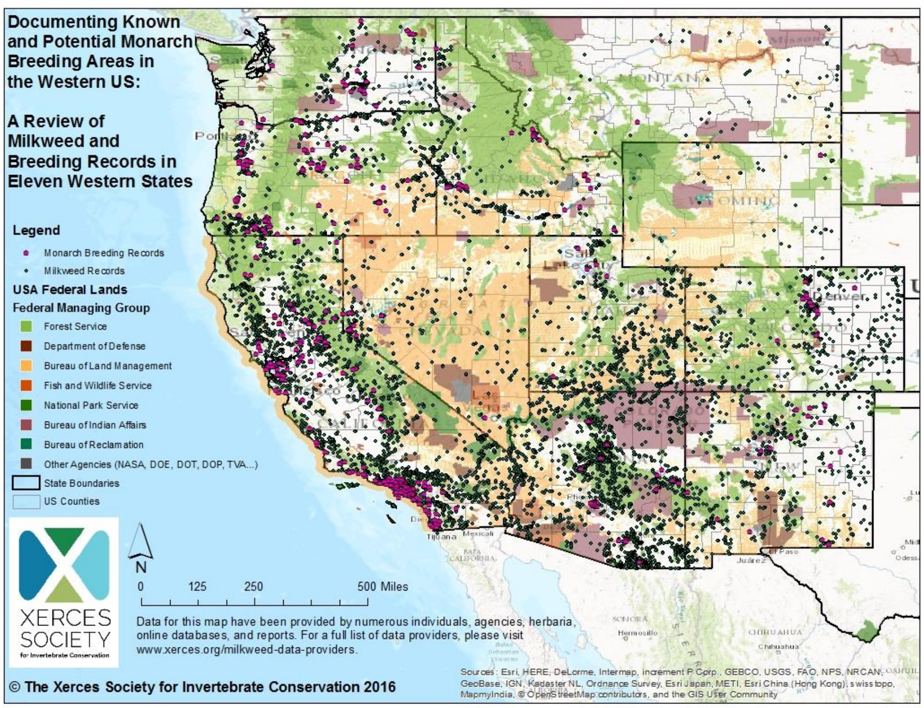
Pollination Ecology

- Also a host plant for the larval stages of queen butterflies (*Danaus gilippus*), dogbane tiger moths (*Cycnia tenera*), unexpected cycnia (*Cycnia inopinatus*), milkweed tussock moth (*Euchaetes egle*), and *Pygoctenucha terminalis* (no common name) (Borders and Lee-Mäder 2014)
- Many types of bees including bumble bees, carpenter bees, and solitary bees feed on milkweed nectar (Borders and Lee-Mäder 2014)
- Good for pollinators of all types including honeybees, butterflies, hummingbirds, native bees, and other beneficial insects (Anderson 2006, Young-Mathews and Eldredge 2012, Borders and Lee-Mäder 2014)
- In a study in Washington state, *A. speciosa* attracted more beneficial insects than any of the other species studied including mite-eating ladybeetles, minute pirates bugs, hover flies, and parasitic wasps (Borders and Lee-Mäder 2014)
- Natural hybridization of *Asclepias spp*. is rare, however common milkweed (*A. syriaca*) × showy milkweed hybrids have been found in the Midwest (Ulev 2005)
- Breeding System: Monoecious (Ulev 2005)
- In a study to determine the effect of pollination timing on fruit production in showy milkweed it was determined that afternoon pollination resulted in fewer mature seeds than morning or evening pollinations (Bookman 1983)
- Self-pollination reduces the success of outcrossing (Finer and Morgan 2003)
- Self-pollination can lower the instances of fruit abortion (Finer and Morgan 2003)
- Plants are largely self-incompatible and rely on a variety of diverse pollinators (Borders and Lee-Mäder 2014)

Milkweed and Monarch Butterflies

- *Asclepias spp*. Are the only host plants for the larval stage of monarch butterflies and monarch caterpillars require large, dense clumps (Young-Mathews and Eldredge 2012). When predated upon a monarch caterpillar will drop to the ground as if dead and will not find more stems unless they are densely spaced (Anderson 2006).

- Cardenolide uptake by butterflies is a logarithmic function of plant concentration and large concentrations do not seem to adversely impact monarch butterflies (Brower et al. 1984)
- Monarch butterfly population density is driven by conditions in breeding grounds, particularly influences on intraspecific larval competition and reduced egg laying, rather than overwintering grounds (Flockhart et al. 2015)
- Monarch larvae survival increases in planted patches with higher milkweed densities (Nail et al. 2015)
- A minimum of 29 milkweed plants is needed to raise a single Monarch butterfly to maturity (Nail et al. 2015)



Seed Production and Dispersal

- Showy milkweed is able to reproduce both vegetatively and by sexual reproduction (Ulev 2005)
- ~~Self-pollination can lower the instances of fruit abortion (Finer and Morgan 2003)~~

- Average 630 seeds per stem with a weight of 5.890 g per 1,000 seeds (Ulev 2005)
- Wind dispersed (Ulev 2005)
- Potentially water dispersed (Ulev 2005)
- Can spread clonally from rhizomes or root crown sprouting (Ulev 2005)
- For restoration:
  - Direct seeding preferred (Anderson 2006)
  - Cold treating seeds can increase germination (Anderson 2006)
  - Propagation by cuttings of rhizomes is easy and reliable, however the timing of propagation is important (See Plant Guide for ASSP for more information) (Anderson 2006)~~Can spread clonally from rhizomes or root crown sprouting (Ulev 2005)~~

Seed Bank

- Seeds able to germinate in fresh water, and can survive in fresh water for several months (Ulev 2005)
- Seeds generally not viable after two years (Ulev 2005)
- ~~Seeds able to germinate submerged in fresh water (Ulev 2005)~~

Seedling Establishment and Growth

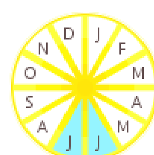


Figure 15 *Asclepias speciosa* bloom period (Calflora 2009)

- Seeds germinate in winter or spring once temperature and moisture requirements are met (Borders and Lee-Mäder 2014)
- Over its entire range may flower from May – August (Ulev 2005)
- In California flowers June – July (Calflora 2009)
- In California may flower and produce seed in its first year after germinating from seed (Borders and Lee-Mäder 2014)
- Don’t overwinter well in pots (high mortality) (Anderson 2006)
- While becoming established aboveground parts of the plant grow very slowly because the majority of the energy in the plant is spent growing roots (Ulev 2005)
- Relationship with arbuscular mycorrhizae is commensal where the milkweed receives the benefit of inoculation and the mycorrhizae have no apparent benefit (Busby et al. 2011)

~~Soil and Site Characteristics~~

- ~~Grows best in wet prairie habitats and moist, sandy soils (Ulev 2005)~~
- ~~Grown in all soil textures (Ulev 2005)~~
- ~~Can tolerate alkaline soil (Ulev 2005)~~

Successional Status

- Can quickly colonize disturbed sites (Ulev 2005)

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- Considered early to mid-successional weedy species (Ulev 2005)

~~Seasonal Development~~

- ~~Over its entire range may flower from May – August (Ulev 2005)~~
- ~~In California flowers June – July (Calflora 2009)~~

Fire Ecology

- Immediate effects are not known, but the top of the plant likely dies back (Ulev 2005)
- Studies conducted with other species of milkweed indicate that fire may benefit or have no effect on showy milkweed (Ulev 2005, Baum and Sharber 2012)
- ~~There is not much research **specifically** looking at the impact of fire on *Asclepias speciosa*, however its ability to resprout from rhizomes, prolific numbers of wind dispersed seeds, 2 year seedbank life, and ability of seeds to germinate after being submerged for months at a time indicate that it may tolerate fire (Ulev 2005)~~
- Fire is an important component of grassland maintenance in areas that support showy milkweed and fire return intervals in such areas may be 1 – 10 years (Ulev 2005)
- Riparian systems have a longer fire return interval (Ulev 2005)
- In California steppe and oak woodlands the fire return interval is less than 35 years, coast live oak communities 2 – 75 years, California black oak 5 – 30 years (Ulev 2005)

~~Fire Effects on the Plant~~

- ~~Immediate effects are not known, but the top of the plant likely dies back (Ulev 2005)~~
- ~~Studies conducted with other species of milkweed indicate that fire may benefit or have no effect on showy milkweed (Ulev 2005)~~
- Because no research has been conducted on showy milkweed specifically, if fire is used as a management tool small-scale burning and post fire monitoring are needed to assess plant response to burning (Ulev 2005)

Livestock

- Nutritionally comparable to alfalfa and corn, however not palatable to livestock (Ulev 2005)
- Milkweed plants are toxic to livestock, particularly sheep, cattle, horses, and goats, because of moderate levels of cardenolides, but animals will avoid them when other forage is available or unless included in hay (Ulev 2005, Anderson 2006, Young-Mathews and Eldredge 2012, Borders and Lee-Mäder 2014)

Wildlife

- ~~Not palatable to livestock (Ulev 2005)~~
- ~~Nutritionally comparable to alfalfa and corn (Ulev 2005)~~
- Poor cover for small mammals, upland game birds, waterfowl, and small nongame birds (Ulev 2005)

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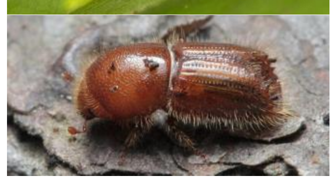
- Good habitat for man insects including nectar seeking bees, wasps, and butterflies; longhorn beetles; leaf beetles (Borders and Lee-Mäder 2014)
- Some birds may use milkweed floss as a nesting material (Borders and Lee-Mäder 2014)

Milkweed Pests and Diseases

- All insecticides have the capacity to kill beneficial insects as well as pests, therefore it is important to understand proper timing and application rates while minimizing their use (Borders and Lee-Mäder 2014)
- Information on the distribution, appearance, host plants, damage, biology, management, control, and related species of each of the following insects is detailed in Borders and Lee-Mäder (2014)

Pest	Damage	Management/Control	Photo
Aphids	• **Potential vector for sooty mold and phytoplasma** • **Feed on developing tissues**	• **Natural predators** • **Insecticides** • **Soaps – kill on contact and have no residue**	
Large Milkweed Bug	• **Suck the contents from milkweed seeds**	• **Avoid collecting pods that have milkweed bugs** • **Make sure there are no milkweed bugs in materials being processed** • **Insecticidal soap, neem oil, horticultural oil, or contact insecticides**	

Small Milkweed Bug	• **Suck the contents from milkweed seeds**	• **Avoid collecting pods that have milkweed bugs** • **Make sure there are no milkweed bugs in materials being processed** • **Insecticidal soap, neem oil, horticultural oil, or contact insecticides**	
Leaf Beetles	• **Severe localized defoliation** • **Larvae feed exclusively on roots which lowers overall plant fitness and can increase susceptibility to bacterial or fungal infection**	• **Can be removed by hand if labor is available** • **Spot treatment with contact herbicide**	
Swamp Milkweed Leaf Beetle	• **Adults and larvae eat leaves**	• **Can be removed by hand if labor is available** • **Spot treatment with contact herbicide**	

Longhorn Beetles	• **Adults eat leaves, buds, and flowers** • **Larvae feed exclusively on roots which lowers overall plant fitness and can increase susceptibility to bacterial or fungal infection** • **Adults feed on leaves from the tips inward, consuming a small percentage of each leaf**	• **Reducing the abundance of grasses near milkweed sites, particularly *Festuca* and *Bromus***	
Snout and Bark Beetles	• **Adults feed on young leaves, pedicels, petioles, immature fruits, and upper portions of the main stem and may damage apical meristems** • **Larvae feed on stem tissue and maturing seed pods**	• **Control adults early in the season before eggs are laid** • **Controlling adults late in the summer will prevent them from overwintering and reduce the number of emerging weevels in the spring** • **Adults tend to be nocturnal, therefore control may need to be implemented after dark** • **Pheromone lures are being researched**	

Generalist Herbivores	• **Mollusks – snails and slugs** • **Mammals – black-tailed jackrabbits, pocket gophers**	• **Species specific**	

Ethnobotany

WARNING: Milkweed can be toxic if not prepared properly – can induce vomiting or death

- Poisoning symptoms include: extreme dullness, depression, weakness, unsteady gait, diarrhea, loss of appetite, labored breathing, seizure (Borders and Lee-Mäder 2014)
- Used for food, medicine, and fiber across the United States and in Canada (Ulev 2005, Anderson 2006, Young-Mathews and Eldredge 2012)
- Fibers historically and currently used for rope, cord, bow strings (Ulev 2005, Young-

Mathews and Eldredge 2012)

- Latex used as an antiseptic as well as medicine for ring worm, calluses, and corns (Ulev 2005)
- Teas made from root material have been used for measles, coughs, diarrhea, and rheumatism (Ulev 2005)
- Have also been used as insulating material and as stuffing for flotation devices (Borders and Lee-Mäder 2014)
- Used in modern medicine to help control heart contractions (Ulev 2005)
- Processed residue can be useful as: pigments; natural rubber; tri-terpenoids, esters and related compounds; sucrose; inositol; polyphenolics; pectin; fibers; and livestock feed (Ulev 2005)
- Highly processed materials once deviod of poisonous compounds, are nutritionally equivalent to alfalfa hay (Adams 1983)
- Defatted seed meal can be used to deter army worms (Ulev 2005)

Figure 16 ©2005 Robert Sivinski

Chapter 7 RESTORATION PLAN

GOALS

Quantitative Goals

- Decrease cover of invasive plants outlined in Table 2 by at least 80% before planting
- Maintain invasive plant cover below 20%
- Patches of *A. speciosa* should contain no fewer than 29 plants in the second year and thereafter to be considered minimal adequate Monarch butterfly habitat

Project Timeline

***Any time restoration or monitoring activities are carried out at the site maintain a digital photographic record from permanent photo points.

- Year 1 – Site Preparation and Establishment Phase
    - Set up permanent photo points at several key points in the restored landscape
    - Photograph each location when plants are visible – timing photos and monitoring with the flowering of the plant (June/July) may aid1 identification, particularly during the establishment phase when vegetation is relatively slow growing
    - Baseline inventory: step-point method of vegetation cover to determine species composition and cover as well as potential hotspots to monitor for future weed control; determine soil types and general hydrology of the site using Web Soil Survey to aid in stratification and planting decisions
    - Prepare restoration site with herbicide application to remove undesirable vegetation
    - Plant seed or transplants in fall
    - At or immediately after planting, install long term monitoring stations, photo points, and irrigation in designated areas
- Year 2 – Establishment Phase
    - Maintain adequate irrigation for establishment
    - Conduct planned vegetation and arthropod monitoring and adapt management (primarily weed control) as needed
- Year 3 – Establishment Phase
    - Determine whether additional irrigation is required to help desired vegetation become established
    - Conduct planned vegetation and arthropod monitoring and adapt management as needed
- Year 4 – Establishment Phase
    - Conduct planned vegetation and arthropod monitoring and adapt management as needed
- Year 5, Year 10, etc. – Long-Term Monitoring Phase
    - Soil samples
    - If feasible, vegetation and arthropod monitoring should be conducted annually, however monitoring at the time other long-term monitoring is conducted may be

adequate

If the resources to hire qualified people to monitor the restoration area are not in place, consider reaching out to citizen scientists and local colleges and universities. Many people are interested in learning more about their local flora and fauna, and professors often seek out projects with long term research goals in mind. If neither of these options can be pursued, it may be useful to set up several permanent photo points in the restoration area and keep a visual record of vegetation changes in the same location over time. A surprising amount of information can be gleaned from photos, but only if they exist!

The Monarch Larva Monitoring Project (Kountoupes and Oberhauser 2008), overseen by the University of Minnesota, is one such citizen science group whose mission is to "better understand the distribution and abundance of breeding monarchs and to use that knowledge to inform and inspire monarch conservation."

Resources

- Natural Resource Conservation Service – Web Soil Survey (NRCS 2009)
- US Forest Service – Fire Effects Information System (http://feis-crs.org/feis/)
- Weeds of California and Other Western States (DiTomaso and Healy 2007)

Site Inventory

An initial site inventory should be conducted to determine what biotic and abiotic resources are available, as well as whether or not milkweed is already present at the site. This inventory should include detailed maps with all infrastructure and developments clearly labeled. When creating this inventory it is important to include short term and long term regional climate data, site-specific soil maps, water quality assessments, and vegetation and arthropod inventories to paint a clear picture of the site before the restoration project is initiated.

Because not all plants are easy to identify at the same time, vegetation inventories should be conducted several times over the course of a year to capture the entire flora of a site. Monitoring for *A. speciosa* should be conducted when the plant is flowering in June or July to aid in identification. There are many monitoring techniques available for vegetation analysis and choosing the proper monitoring technique will depend upon what you want to learn from the data collected. Like plants, arthropods are not always visible or active at the same time of day (or year). Because Monarch butterfly populations require milkweed species as nursery plants (Young-Mathews and Eldredge 2012), monitoring for Monarch larvae is a logical and feasible approach and can happen concurrently with milkweed monitoring. Once this baseline monitoring has been conducted, the restoration plan can be implemented and longer term monitoring can begin. Long-term monitoring should begin as soon as feasible during the establishment stage of the restoration project so that any problems that arise can be addressed in a timely manner. Included at the end of this document are examples of milkweed and Monarch data collection sheets used by the Xerces Society to document populations across the western United States.

The Natural Resource Conservation Service hosts Web Soil Survey for all members of the public to access detailed soil survey information where available. If you are not familiar with the site or how to interpret soil surveys, contact your local NRCS representative to guide you through the process or to request a custom soil report for your site.

Site Preparation and Selection of Plant Materials

Before plant materials can be introduced, the site must be prepared by removing undesirable plant biomass. Species of particular concern in California are listed in Table 2: Most Common Non-native Invasive Species in California Valley and Foothill Grasslands, Including their Growth Form and Cal-IPC Classification (DiTomaso et al. 2007).

Specific options and timing of management of invasive species will be site and species dependent, however there are several control methods to consider for each species. Mechanical control (hand removal, mowing or clipping, tillage, thatch removal) can sometimes have high rates of control, but are not cost effective to implement or maintain (DiTomaso et al. 2007). Biological control (insects or pathogens) spread beyond the point of release and have the potential to establish populations with densities adequate to decrease the cover of undesirable vegetation (DiTomaso et al. 2007). In certain instances this can have unforseen consequences, so it is important to use only researched, effective biological control agents such as listed in Table 1 (DiTomaso et al. 2007). Herbicides are an effective and reliable tool in managins invasive plants in grasslands, and are often considered the most economical option for large-scale restoration efforts (DiTomaso et al. 2007). It is important to choose herbicides that are registered for use in California and apply them at the specified rates and proper timing for effective control of each species of concern (DiTomaso et al. 2007). Herbicides may be applied locally from backpack units, sprayed via a broadcast application from a tractor or airplane, or tractor-mounted wick applicators to decrease herbicide drift (DiTomaso et al. 2007).Although herbicides can achieve high levels of control, their efffects are not often long lasting and patches may be re-invaded if more desirable vegetation is not established (DiTomaso et al. 2007). There are several methods of cultural control than can be effective when applied properly including grazing, prescribed burning, and revegetation (DiTomaso et al. 2007). As with other control options, it is important to determine the effectiveness of the control method before implementation.

It is important to recognize that control of invasive plants is not an overnight process and requires adaptive long-term management to be succesful (DiTomaso et al. 2007). Early detection and rapid response are increasingly being recognized as critical steps in achieving control of invasive annual grasses (DiTomaso et al. 2007). Assuming that populations of undesirable vegetation have been correctly identified, there may be practical or regulatory limitations on management tools available. These may include considerations oof neighbors when installing graing treatments near residential areas and regulations surrounding rare or endangered plants or animals that could share the same space as the undesirable vegetation (DiTomaso et al. 2007). Working in and around these hurdles is a substantial taks, but not impossible.

After site preparation, selecting plant materials is the most important step of the restoration process. It is important to seek out and include native, locally adapted ecotypes of the desired plant species whenever possible to avoid introducing potentially weedy exotic species. In the United States, it is particularly important to avoid introduced species of milkweed because they can disrupt Monarch butterfly migration cycles, increase Monarch disease, and disrupt future Monarch migration research (Borders and Lee-Mäder 2014). Hedgerow Farms, located in Winters, CA, specializes in growing locally adapted native seed and transplants for restoration projects. Contact them for more information about availability and pricing (info@hedgerowfarms.com).

Table 2 List of Biological Control Agents Against Grassland Weeds, Approved for use in California

Weed	Scientific name	Biological control agent	Distribution	Year of intro	Infestation	Control
Common St. Johnswort	*Hypericum perforatum*	*Agrilus hyperici*	Established widely	1950	Moderate	Unknown
		Chrysolina hyperici	Unknown	1945	Unknown	Unknown
		Chrysolina quadrigemina	Established widely	1946	Heavy	Excellent
		Chrysolina varians	No establishment	1952	Absent	Unknown
		Zeuxidiplosis giardi	Established limited	1950	Light	Poor
Diffuse knapweed	*Centaurea diffusa*	*Bangasternus fausti*	Established widely	1994	Moderate	Good
		Larinus minutus	Established widely	1995	Moderate	Good
		Sphenoptera jugoslavica	Established widely	1980	Heavy	Unknown
		Urophora affinis	Established widely	1976	Light	Poor
		Urophora quadrifasciata	Established limited	1990	Slight	Poor
Spotted knapweed	*Centaurea maculosa* (*C. biebersteinii*)	*Agapeta zoegana*	Established limited	1993	Light	Poor
		Cyphocleonus achates	Established limited	1993	Light	Poor
		Larinus minutus	Established limited	1995	Light	Good
		Terellia virens	Established limited	1995	Light	Poor
		Urophora affinis	Established widely	1976	Light	Poor
		Urophora quadrifasciata	Established limited	1990	Light	Poor
Squarrose knapweed	*Centaurea virgata* var. *squarrosa*	*Bangasternus fausti*	Established widely	1996	Moderate	Excellent
		Cyphocleonus achates	No establishment	1995	Absent	None
		Larinus minutus	Established widely	1997	Heavy	Excellent
		Sphenoptera jugoslavica	Established limited	1998	Moderate	Fair
		Terellia virens	No establishment	1998	Absent	None
		Urophora affinis	No establishment	1998	Absent	None
		Urophora quadrifasciata	Established widely	1998	Light	Poor
Puncturevine	*Tribulus terrestris*	*Microlarinus lareynii*	Established widely	1961	Heavy	Excellent
		Microlarinus lypriformis	Established widely	1961	Heavy	Excellent
Tansy ragwort	*Senecio jacobaea*	*Longitarsus jacobaea*	Established widely	1969	Heavy	Excellent
		Pegohylemyia seneciella	Established widely	1966	Light	Poor
		Tyria jacobaeae	Established widely	1959	Light	Good
Mediterranean sage	*Salvia aethiopis*	*Phrydiuchus tau*	Established limited	1976	Light	Unknown
Rush skeletonweed	*Chondrilla juncea*	*Cystiphora schmidti*	Established widely	1975	Moderate	Poor
		Eriophyes chondrillae	Established widely	1977	Moderate	Fair
		Puccinia chondrillina	Established widely	1976	Moderate	Good
Purple starthistle	*Centaurea calcitrapa*	*Bangasternus fausti*	No establishment	1999	Absent	None
		Larinus minutus	No establishment	1998	Absent	None
		Terellia virens	No establishment	1998	Absent	None
Yellow starthistle	*Centaurea solstitialis*	*Bangasternus orientalis*	Established widely	1985	Light	Poor
		Chaetorellia australis	Established widely	1988	Light	Poor
		Eustenopus villosus	Established widely	1990	Heavy	Good
		Larinus curtus	Established limited	1992	Light	Poor
		Puccinia jaceae var. *solstitialis*	Initial release	2003	Unknown	Unknown
		Urophora jaculata	No establishment	1969	Absent	None
		Urophora sirunaseva	Established widely	1984	Moderate	Poor
Slenderflower thistle	*Carduus tenuiflorus*	*Rhinocyllus conicus*	Established widely	1973	Moderate	Fair
Bull thistle	*Cirsium vulgare*	*Rhinocyllus conicus*	No establishment	1976	Absent	None
		Urophora stylata	Established limited	1993	Moderate	Unknown
Canada thistle	*Cirsium arvense*	*Altica carduorum*	No establishment	1966	Absent	None
		Ceutorhynchus litura	No establishment	1971	Absent	None
		Urophora cardui	Established limited	1977	Light	Poor
Italian thistle	*Carduus pycnocephalus*	*Rhinocyllus conicus*	Established widely	1976	Moderate	Fair
Blessed milk thistle	*Silybum marianum*	*Rhinocyllus conicus*	Established widely	1971	Light	Poor
Scotch thistle	*Onopordum acanthium*	*Rhinocyllus conicus*	No establishment	1976	Absent	None

NOTE: Further information on each of these agents is available in Coombs et al. (2004).

Table 3: Most Common Non-native Invasive Species in California Valley and Foothill Grasslands, Including their Growth Form and Cal-IPC Classification (DiTomaso et al. 2007)

Common name	*Scientific name*	*Family*	*Growth habit*	*Cal-IPC category*
Fennel	*Foeniculum vulgare*	Apiaceae	Perennial	High
Italian thistle	*Carduus pycnocephalus*	Asteraceae	Winter annual	Moderate
Slenderflower thistle	*Carduus tenuiflorus*	Asteraceae	Winter annual	Limited
Woolly distaff thistle	*Carthamus lanatus*	Asteraceae	Winter annual	Moderate alert
Purple starthistle	*Centaurea calcitrapa*	Asteraceae	Annual to perennial	Moderate
Malta starthistle (tocalote)	*Centaurea melitensis*	Asteraceae	Winter annual	Moderate
Yellow starthistle	*Centaurea solstitialis*	Asteraceae	Winter annual	High
Squarrose knapweed	*Centaurea virgata* var. *squarrosa*	Asteraceae	Perennial	Moderate
Rush skeletonweed	*Chondrilla juncea*	Asteraceae	Biennial	Moderate
Bull thistle	*Cirsium vulgare*	Asteraceae	Biennial	Moderate
Artichoke thistle	*Cynara cardunculus*	Asteraceae	Perennial	Moderate
Smooth catsear	*Hypochaeris glabra*	Asteraceae	Winter annual	Limited
Common catsear	*Hypochaeris radicata*	Asteraceae	Winter annual	Moderate
Scotch thistle	*Onopordum acanthium*	Asteraceae	Biennial	High
Bristly oxtongue	*Picris echioides*	Asteraceae	Annual or biennial	Limited
Tansy ragwort	*Senecio jacobaea*	Asteraceae	Biennial	Limited
Blessed milk thistle	*Silybum marianum*	Asteraceae	Winter annual	Limited
Dyer's woad	*Isatis tinctoria*	Brassicaceae	Biennial	Moderate
California burclover	*Medicago polymorpha*	Fabaceae	Winter annual	Limited
Rose clover	*Trifolium hirtum*	Fabaceae	Winter annual	Moderate
Broadleaf filaree	*Erodium botrys*	Geraniaceae	Winter annual	Not listed
Shortfruited filaree	*Erodium brachycarpum*	Geraniaceae	Winter annual	Not listed
Redstem filaree	*Erodium cicutarium*	Geraniaceae	Winter annual	Limited
Common St. Johnswort	*Hypericum perforatum*	Hypericaceae	Perennial	Moderate
Barb goatgrass	*Aegilops triuncialis*	Poaceae	Winter annual	High
Silver hairgrass	*Aira caryophyllea*	Poaceae	Winter annual	Not listed
Slender oat	*Avena barbata*	Poaceae	Winter annual	Moderate
Wild oat	*Avena fatua*	Poaceae	Winter annual	Moderate
Big quakinggrass	*Briza maxima*	Poaceae	Winter annual	Limited
Little quakinggrass	*Briza minor*	Poaceae	Winter annual	Not listed
Ripgut brome	*Bromus diandrus*	Poaceae	Winter annual	Moderate
Soft brome	*Bromus hordeaceus*	Poaceae	Winter annual	Limited
Red brome	*Bromus madritensis* ssp. *rubens*	Poaceae	Winter annual	High
Downy brome (cheatgrass)	*Bromus tectorum*	Poaceae	Winter annual	High
Hedgehog dogtailgrass	*Cynosurus echinatus*	Poaceae	Winter annual	Moderate
Orchardgrass	*Dactylis glomerata*	Poaceae	Perennial	Low
Tall fescue	*Festuca arundinacea*	Poaceae	Perennial	Moderate
Mediterranean barley	*Hordeum marinum*	Poaceae	Winter annual	Moderate
Hare, smooth and wall barley	*Hordeum murinum*	Poaceae	Winter annual	Moderate
Italian ryegrass	*Lolium multiflorum*	Poaceae	Winter annual	Moderate
Medusahead	*Taeniatherum caput-medusae*	Poaceae	Winter annual	High
Squirreltail fescue	*Vulpia bromoides*	Poaceae	Winter annual	Not listed
Rattail fescue	*Vulpia myuros*	Poaceae	Winter annual	Moderate
Bellardia	*Bellaria trixago*	Scrophulariaceae	Winter annual or biennial	Limited

Introduction and Establishment

Using the soil survey prepared by NRCS, determine the best places to plant within your restoration area. *Asclepias speciosa* grows in all soil textures and can tolerate alkaline soils, however it grows best in wet prairie habitats with moist, sandy soils (Ulev 2005).

The preferred method of restoring milkweed to a site is by direct seeding (Anderson 2006). Although seeds can be broadcast across the soil surface, milkweed has better establishment rates when drill seeded (Borders and Lee-Mäder 2014).The drill seeder should be set to bury the seeds to a maximum depth of ½ inch (Borders and Lee-Mäder 2014). A wheel-guided Earthway seeder with a cucurbit or sunflower sized disc is an affordable and effective tool suited for this task (Borders and Lee-Mäder 2014). A seeding rate of 4 – 5 plants per linear foot should be enough to ensure adequate stand densities once established (Borders and Lee-Mäder 2014). Figure 9 Calculating seed orders (Borders and Lee-Mäder 2014). Figure 9 can be used to help determine proper amount of seed to order.

Calculating Your Potential Production Field Size

If you have a target seeding rate in mind, you can calculate how large of an area can be planted with your available seed. If your foundation seed has been professionally tested for purity and germination, you can base your calculations on pure live seed (PLS). PLS is the amount of seed in a bulk seed lot that is viable and has the potential to germinate. If a current seed test is unavailable, you can refer to existing estimates of bulk seeds per pound for your target species (some seed count data is presented in Table 4). You can also conduct your own seed count, and base your calculations on bulk seed.

Pure Live Seed (PLS) Calculations

The formula for calculating PLS is:

Percent (%) purity x percent (%) total germination / 100 = % PLS

Sample pure live seed calculation:

If you have a seed lot with 95% purity and 85% germination -> 95 x 85 / 100 = 80.75% PLS

If your seed lot weighs two pounds and there are an estimated 75,000 bulk seeds per pound, you have 150,000 bulk seeds on hand. Since you know the PLS for the lot, you can calculate that 121,125 (150,000 x 0.8075) of the seeds are viable and will potentially germinate.

If your target seeding rate is 4 live seeds per linear foot, you can determine the rate at which bulk seed needs to be sown by dividing the target PLS seeding rate by the percent PLS: 4 / .8075 = 4.95. Rounding up, if you will sow 5 bulk seeds per linear foot, you can plant 30,000 linear feet (150,000 / 5).

Due to a high level of seed dormancy in many native species, restoration practitioners sometimes calculate PLS based on the percent viability of a seed lot, rather than percent germination. If tetrazolium chloride (TZ) test results are available, the TZ value can be plugged into the formula above, in place of percent total germination. Alternatively, the sum of percent germination and percent dormancy (with the latter value derived from a TZ test) can be plugged into the formula.

For a more thorough discussion of PLS, please refer to Houck (2009).

Sample Bulk Seed Calculation

Borrowing from the sample PLS calculation above, if a two-pound seed lot has an estimated 75,000 bulk seeds per pound, there are approximately 150,000 bulk seeds. When seed lot viability is unknown, you may want to seed at a comparatively higher rate to increase the chance of sufficient germination and even stand establishment. If you were to seed at a rate of 12 bulk seeds per linear foot, for example, 12,500 linear feet (150,000 / 12) could be planted.

These sample calculations illustrate the benefits of having a professional seed test conducted on wild-collected foundation seed so that purity and germination data is available for performing these planting calculations.

Conducting In-house Seed Counts

If a professional seed count or a seed counting machine is unavailable, you can conduct your own seed count, using a digital scale with an accuracy of at least 0.1 grams. Counts will be most accurate for seed lots that have been finely cleaned and include minimal amounts of inert material. There are thousands of milkweed seeds per ounce, and it would be unreasonable to manually count a one-ounce quantity. Thus, to estimate the number of seeds per unit weight for any given seed lot, you can weigh at least five replicate samples of 1/10 of an ounce, count the total number of seeds in each sample, average the results, and then extrapolate the number of seeds per ounce or pound.

Figure 17 Calculating seed orders (Borders and Lee-Mäder

Irrigation

Although milkweed species are drought tolerant once they are established, at seeding they require constant moisture to germinate and as seedlings may require occasional light watering for at least the first year of establishment depending on local conditions and seed source (Ulev 2005, Borders and Lee-Mäder 2014). To achieve these conditions seed should be sewn in the fall to cold stratify the seeds in the field and allow for spring germination (Borders and Lee-Mäder 2014). Spring seeding is also possible, however requires artificial chilling to increase germination rates (Borders and Lee-Mäder 2014).

Potential Problems and Solutions

- *Asclepias speciosa* and other species of milkweed contain chemicals called cardenolides that are toxic to most animals (Ulev 2005, Anderson 2006, Young-Mathews and Eldredge 2012, Borders and Lee-Mäder 2014). Although visitors are asked to keep their dogs leashed, the reality is that dogs run off leash and could run the risk of ingesting toxic plant materials.

- Irrigation – Access to inexpensive irrigation water and supplies may be limited.
- Timing - Seeds have the best germination rates when planted early in the fall, however early spring plantings have also been successful (Anderson 2006).
- If seeds do not germinate at desired rates, future plantings may benefit from cold stratification for up to three months (Anderson 2006).

If seedlings do not establish in desired densities or are unable to outcompete weeds, consider propagating cuttings from other areas or acquiring plugs to transplant. In order to maximize your financial investment if this if the route pursued, it is important to remember that *A. speciosa* does not overwinter well in pots (Anderson 2006, Borders and Lee-Mäder 2014).

Chapter 8 MONITORING PLAN

Monitoring Techniques

There are several resources available for training Citizen Scientists how to monitor milkweed patches and Monarch butterflies and larvae. It is best to research several options and consider which best suits your restoration goals and record keeping style.

- **Documenting milkweed (*Asclepias* spp.) and monarch distribution across the western U.S.** – Xerces Society – http://www.xerces.org/milkweedsurvey/
- **Site Description and Measuring Milkweed Density (VIDEO)** – Monarch Lab – http://monarchlab.org/mlmp/training/online-training/mlmp-activities-site-description-and-measuring-milkweed-density
- **Milkweed Sampling for Monarchs: Pilot Project** – Monarch Joint Venture – http://monarchjointventure.org/news-events/news/milkweed-sampling-for-monarchs-pilot-project

Equipment

- Data forms(see below)
- Permanent location markers (photo plots can serve a dual purpose here)

Continued Monitoring

Once sampling locations are permanently marked they should be relatively easy to find and sample in subsequent years and long-term monitoring data is imperative for making management decisions.

- Annually in when showy milkweed is flowering (June/July)
  - Vegetation
    - Record observations on data sheets and note the presence and abundance
  - Arthropods

        - Monarch butterfly larvae can be counted on milkweed plants with relative ease
- Every 5 years
    - Comprehensive Soil Analysis
        - Maintaining long term records of changes in soil physical and chemical properties can provide data to inform future management decisions and avenues for research. Once long term data is collected, areas that *A. speciosa* has successfully established can be compared with areas that have not had successful establishment to determine whether there are soil properties precluding germination or establishment.

Long-Term Management

Using the data collected above management decisions can be made to maintain the health of the restored site. It is important to monitor the presence and abundance of invasive species as well as milkweed to determine whether any additional weed control measures may need to be taken. Milkweed population may be relatively competitive if soil conditions are right and invasive plant populations can be managed. Other declines in milkweed survivorship may be related to disease or predation by pests and can likely be determined with diligent note taking as annual monitoring takes place.

Thresholds for Management Actions

- Invasive plant cover
    - If any invasive species cover exceeds 20%, control actions should be taken to maintain milkweed's competitive advantage. Actions (timing, product choice, application technique and rate, etc.) taken should be determined carefully to ensure that pollinator populations are not adversely impacted by herbicide use.
- Showy milkweed cover
    - Monarch larvae will "play possum" when they are predated upon and fall to the ground. If milkweeds are not spaced closely enough, larvae are at risk of dying of starvation if new stems are not nearby (Anderson 2006)
    - Nail et al. (2015) determined that at least 29 milkweed plants must be present within a patch to rear a single Monarch caterpillar to adulthood. For this reason, if densities in any patch are lower than 30 individuals per patch the patch should be reseeded or additional plugs planted.

Research Questions to Improve Plan

- Does *Ascelpias speciosa* grow in relatively rare, clumped patterns once established? If so, it may be prudent to utilize adaptive cluster sampling techniques to more realistically map individuals and clusters. More information on adaptive cluster sampling in Thompson (2002)
- Can *A. speciosa* survive periods of periodic flooding in heavy soils? How long can it survive?

Research Questions Addressed by Restoration Plan

- What is the initial cover of *A. speciosa* in target areas? Is it present at all?
- Is *A. speciosa* able to maintain proper density for Monarch butterfly larvae nursery habitat?
- Does *A. speciosa* disperse and establish elsewhere on the site?
- Does *A. speciosa* alter soil physical or chemical properties?
- Long-term comparisons of all of the above with each planting treatment in each soil type

Chapter 9 Milkweed and Monarch Data Collection Sheets

Documenting milkweed (*Asclepias* spp.) and monarch distribution across the western U.S. – Xerces Society

Please fill out the following fields. When finished please enter the data into one of our digital reporting tools found at www.xerces.org/milkweedsurvey

Observer Information:

Observer(s):______________________ **Observer(s) E-mail Contact:** ___________________________

Observer(s) Affiliation (*Pick one*): Private Citizen, NGO, Land/Wildlife Management, University, Biologist/Researcher, Other

Affiliation Name: ____

Data Type: Visual Observation Photo Voucher Specimen Other:________________

Land Manager Type: Federal State County City/Town Private NGO Unknown

Geographic Information:

Site Name:____

State:____________ **County:**__________________ **Nearest City:**______________

Latitude(*In decimal degrees*)**:**_________________ **Longitude**(*In decimal degrees*)**:**______________________

Coordinate Derivation (*How were these coordinates derived*)**:**

Professional grade GPS	Recreational grade GPS	Topographic map	Google Earth	Other Web Map Viewer

Data Projection:

State Plane	Geographic (unprojected)	UTM 10	UTM 11	UTM 12

Datum:

WGS84	NAD83	NAD27

Coordinate Notes:

Locality Comments (*Example: Located 0.2 miles north of trail junction on Black Butte*):

Habitat Association and Management:

Habitat Type (*Select one dominant type*):

Mixed Forest	Cultivated Crop	Deciduous Forest	Emergent Herbaceous Wetlands	Evergreen Forest	Garden	Grassland/ Herbaceous
Park-Open Space	Pasture/Hay	Shrub/Scrub	Wood Wetlands	Developed-Low Intensity	Developed-Medium Intensity	Developed-High Intensity

Habitat Associations (*multi-select*):

Edge Habitat	Fencerow	Floodplain Habitat
Garden-Park	Irrigated Agriculture Fields	Irrigation Canals
Public Utility Corridors	Roadside	None of the Above Apply

Management Actions (*May affect milkweed plants positively or negatively*) – multi-select:

Brush Clearing	Grazing	Haying	Haying-Intense	Herbicide Application-Frequently
Herbicide Application-Infrequent	Insecticide Applications	Irrigation Ditch Maintenance	Mowing- Intense	Mowing-Light
Prescribed Burning	Road Grading	Timber Harvest	Watering-Indirect	Watering-Supplemental

Threats (*multi-select*):

Mowing	Flooding Regimes	Grazing
Haying	Herbicide Application	Insecticide Application
Invasive Species	Recreational Disturbance	Vegetation Encroachment
Pests/Disease	Drought Stress	Other:

Pests observed (*Especially oleander aphids - please list*):

Milkweed Observation :(*skip this page if no milkweed observed*)

Date of Observation (DD/MM/YYYY):____________________

Genus (*Asclepias*): ___________________ **Species (subspecies):**___________________________

Milkweed Structure (*of the patch*):

Linear	Clumped	Scattered

Plant Count:

1-5	6-10	11-20	21-50	51-75	76-100	101-500	501-1000	1001-1500	1501-2000	2000+

Count Type (*Select 'stem' for any single stalk or stem form or select 'plant' for bushy form*): Plant *or* Stem

Milkweed Patch Size (*in square meters*):

<1	1-3	3-5	5-7	7-10	10-15	15-20	20-30	30-50	50-100	100-200	>200

Average Height of Plants (inches)______________________

Percent of Vegetative Plants (*plants without buds, flowers, or pods*):

0%	10%	25%	50%	75%	100%

Percent of Flowering Plants (*plants with buds and open flowers*):

0%	10%	25%	50%	75%	100%

Percent of Plants with Pods (*includes young to mature pods*):

0%	10%	25%	50%	75%	100%

Ripe Pods: Yes *or* No **Seed Collected:** Yes *or* No

Evidence of Caterpillar Herbivory: Yes *or* No *or* Not Checked

Plant Count Method:

Complete plant/ stem count	Optical Estimation	Standardized Methodology	Other Methods

Comments regarding plant count methods or results:

Comments about the milkweed patch or site:

Monarch Observation: (*skip this page if no monarch observed*)

Date (*DD/MM/YYYY*):________________________

Monarch Count:

Total Adult Monarch Count:	**Total Female Count:**	**Total Male Count:**
Egg Count:	**Larval Count:**	**Pupae Count:**

Behavior Notes (*multi-select*):

Flying (Migrant)	Flying (Foraging)	Loafing/Perched	Nectaring	Night Roosting
Egg Laying	Eclosing	Mating	Other	None Present

Pupae Substrate (plant species or structure pupae was attached to):__________________________________

Comments related to monarchs observed (*Example: if a tagged monarch was observed, note that here*):

Nectaring Species (*Plant genus and/or species of nectar plant that monarch is using – Genus, Species*)

Other Flowering Plants at Site Monarchs May Use (*Genus,Species1; Genus,Species2; Genus, Species3*):

Environmental Conditions:

Temperature (*F*):______________

Observation Time (*24 hour clock*):______________

Windspeed (*MPH (Beaufort wind speed scale in parenthesis for reference)*):

<1 (0)	1-3 (1)	4-6 (2)	7-10 (3)	11-16 (4)	17-21 (5)	22-27 (6)	>27 (7)

Cloud Cover (*percentage*):

0	10	20	30	40	50	60	70	80	90	100

Precipitation:

None	Trace	Light	Moderate	Heavy

<u>Milkweed and Monarch Data Collection Sheet – Definitions:</u>

Habitat Type	**Habitat Description**
Cultivated Crops	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Deciduous Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Emergent Herbaceous Wetlands	areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Evergreen Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Garden	Garden
Grassland/Herbaceous	areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Mixed Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Park-Open Space	areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Pasture/Hay	areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Shrub/Scrub	areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Woody Wetlands	areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Developed-High Intensity	highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Developed-Medium Intensity	areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed-Low Intensity	areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.

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Soap Plant (*Chlorogalum spp*.)

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Liliopsida

Subclass: Lilidae

Order: Liliales

Family: Liliaceae

Genus: *Chlorogalum*

Species*: angustifolium*

Species*: parviflorum*

Species*: pomeridianum*

Background and Justification

Chlorogalum, or soap plant, is a perennial herb that is native to California. Chlorogalum grows in a Mediterranean climate with cool, wet winters, and warm, dry summers (Forest Service FEIS 2016). Chlorogalum is a geophyte according to Raunkiaer (Forest Service FEIS 2016). *Chlorogalum* means "green milk," referring to the green juice that a leaf of the plant exudes when broken (Forest Service 2016). There are five species of the genera Chlorogalum that are native to California, and three species, *angustifloium*, *parviflorum*, and *pomeridianum* occur in the central valley of California (Hickman 1993). *Chlorogalum angustifolium* is endemic to California (CalFlora 2016). *Angustifolium* means 'narrow-leaved,' referring to the species' thin leaves, *parviflorum* means small flowers, and *pomeridianum* is derived from the Latin phrase post meridian, meaning past mid -day, which refers to the fact that the flowers flower in the afternoon/early evening. *Pomeridianum* is the most abundant species in the genus (Forest Service 2016).

Soap plant is a very ethnobotanically important plant. Native Californians used the plant for many different uses. First of all, soap plant was used as food. Native Californians mostly ate *Chlorogalum pomeridianum* and *parvflorium*. Native Californians would roast the bulbs of the plant without removing the scales and fibers and place them in stone-lined pit ovens covered with leaves and a layer of dirt, overnight (Balls 1970). Soap plant was also used as a hand and laundry soap. For example, Native Californians removed the scales and fibers from the bulbs, and then rubbed the crushed bulbs on their hands or clothing for soap. Native Californians also used the brown fiber that can be stripped off of the bulb as brushes, boiled the bulb to be used as a glue and used the bulb to stupefy fish when fishing. (Balls 1970). The roasted bulbs were also used medicinally in a poultice used on sores (Balls 1970). Soap plant is not only culturally important, but is also important to pollinators like bumblebees, and moths, especially because *pomeridianum* flowers at night.

Fact Sheet

Characteristics

- Grows 2 feet tall by 2 feet wide (Watershed Nursery 2016).
- Light green, wavy-edged and linear leaves that are one to two feet long. Exposure to light increases wave patterns in leaf edges (Forest Service FEIS 2016).
- Flower parts occur in 3s, usually occurring with six tepals, 6 stamens with yellow anthers, and one stigma (Forest Service 2016).
- Tepals are white, each with a green mid-vein (Forest Service 2016).
- Flowers ½ to 1 inch wide with radial symmetry (Forest Service 2016).
- Bulbs are 3 to 6 inches long and 1 to 3 inches wide, and are buried 4 to 12 inches underground (Forest Service FEIS 2016).
- The bulbs of *pomeridianum* are covered with dense brown fibers, and in all three species, contractile roots at the base of the bulb pull the bulb downward so it becomes buried deeper throughout its lifetime (Forest Service FEIS 2016).

Growth Requirements

- All three species thrive in cool, wet winters and warm, dry summers (Plant Propagation Protocol 2016).
- *Pomeridianum*
    - 14 to 95 inches of annual precipitation (CalFlora 2016).
    - Shade tolerant (CalFlora 2016).
    - Low water tolerant (CalFlora 2016).
    - 4 to 8 month wet season (CalFlora 2016).
    - Gravelly clay soil (Plant Propagation Protocol 2016).
    - Shallow or deep soil (Plant Propagation Protocol 2016).
- *Parviflorum*
    - Low water tolerant (CalFlora 2016).
    - Snady clay soil (Plant Propagation Protocol 2016).
- *Angustifolium*
    - 22 to 63 inches of annual precipitation (CalFlora 2016).
    - 6 to 8 month wet season (CalFlora 2016).
    - 5 to 9 month growing season (CalFlora 2016).
    - Low water tolerant (CalFlora 2016).

Distribution/Habitat

- *Angustifolium*
    - Found in 21 counties in California (California Native Plant Link Exchange, 2016).
    - Found in from 65 to 2854 feet in elevation (CalFlora, 2016).

    - Found in valley grassland and foothill woodland (California Native Plant Link Exchange 2016).
- *Parviflorum*
    - Less widely distributed and is only found in 4 counties in California (California Native Plant Link Exchange 2016).
    - Found from 16 to 4101 feet in elevation (CalFlora 2016).
    - found in valley grassland and coastal sage scrub (California Native Plant Link Exchange 2016)
- *Pomeridianum*
    - Is distributed from the southwestern corner of Oregon down into Southern California (Forest Service, 2016). It is found in 47 of the 58 California counties. (CalFlora)
    - Is found from 0 to 1830 feet in elevation (California Native Plant Link Exchange, 2016).
    - Is found in valley grassland, coastal sage scrub, northern coastal scrub, foothill woodland, closed-cone pine forest, mixed evergreen forest, and chaparral (California Native Plant Link Exchange, 2016).
    - Grows on dry, open sites such as rocky hillsides, bluffs, and balds. It often occurs on south-facing slopes with drier and shallower soils. (Forest Service FEIS 2016).
    - Is most common in early and open communities because of the high light availability (Forest Service FEIS 2016).

Pollination
- *Pomeridianum*
    - Flowers only open for one afternoon and one evening, so there is a short window of opportunity for pollination to occur (Forest Service FEIS 2016).
    - Pollination is accomplished by bees such as honey bees, carpenter bees, and 2 species of bumble during the day, and sphingid moths in the evening (Forest Service FEIS 2016).
- Removal of a shrub layer, and subsequent increased light availability has been found to increase pollination rates in all 3 species (Forest Service FEIS 2016).

Reproduction
- All three species reproduce both vegetatively and sexually. Sexual reproduction is preferable for restoration though because it results in greater genetic diversity. (Forest Service 2016).
- *Pomeridianum*
    - Asexually, resprouts from the bulb. Harvesting, such as was done by Native Californians using digging sticks, splinters the bulbs creating offshoots and therefore increases asexual reproduction (Balls 1970 and Forest Service FEIS 2016).
    - Self-compatible, but usually relies on pollinators (Forest Service FEIS 2016).
    - Flowers open from the bottom to the top of the stalk (Forest Service FEIS 2016).
    - Seeds dispersed by gravity (Forest Service FEIS 2016).
    - It takes 5 to 7 years for the flowers to reach a reproductive age (Forest Service FEIS 2016).

- Does not produce flowers and seeds every year (Forest Service FEIS 2016).
- Blooms from May to August,

- *Angustifolium* blooms May through June (CalFlora, 2016)
- *Parviflorum* blooms May through August (CalFlora 2016)

Germination and Seedling Establishment

- *Pomeridanum*
  - The seed bank is short-lived, although limited studies have been done to determine exactly how long the seeds are viable (Forest Service FEIS 2016).
  - The seeds of *pomeridianum* are not dormant. They should, however be, be kept at 32 degrees Fahrenheit for 3 months before germination.
  - The seeds readily germinate under moderate temperatures, such as in the range of 70- 80 degrees Fahrenheit, once wet (Forest Service FEIS 2016).
  - Seedlings develop a large bulb and sufficient root system within the first year in order to survive summer drought (Forest Service FEIS 2016).
- One option for propagation: Seeds can be sown directly into 1.5" flats that contain a 1:1:1:2 mixture of sand, pumice, peat moss, and a fir bark mixture. After sowing, the flats should then be placed in an outdoor cold frame throughout late fall into spring. The seedlings can then be transplanted into pots using the same mixture of materials (Plant Propagation Protocol 2016).
- Second option: directly plant the seeds into containers in fall by October 1st. Using this method, the seeds should be wetted and then placed on top of sandy soil in one gallon containers. The seeds can then be covered with a light layer of soil and a ¼ inch layer of small gravel. The pots should be then set outside to be watered by winter rains. Pots should be in full sun during the early morning and late afternoon, and in the shade in the late afternoon (Plant Propagation Protocol 2016).
- All three species of soap plant establish easily, and grow like a weedy species (Watershed Nursery 2016).

Interactions

- Various species of soap plant act as a food source for small mammals such as ground squirrels, who eat both the bulb, and other parts of the plant (Watershed Nursery 2016).
- Top 12 species *pomeridianum* grows in association with:
  - *Lotus corniculatus* (Bird's foot trefoil), *Mimulus aurantiacus* (Sticky Monkeyflower), *Lupinus bicolor* (Lupine), *Solidago californica* (California Goldenrod), *Thysanocarpus curvipes* (Common Fringe Pod), *Lomatium utriculatum* (Hog Fennel), *Lupinus nanus* (Valley Sky Lupine), *Bromus laevipes* (Narrow-flowered Brome), *Lasthenia californica* (Goldfields) *Platystemon californicus* (California Cream Cups), *Poa secunda ssp. secunda* (Sandberg's Bluegrass) and *Eschscholzia californica* (California Poppy) (Plant Propogation Protocol 2016).
- Soap plant's biggest competitors are annual grasses, especially in oak woodlands and in grasslands (Kofron et al. 2013).
- High rates of leaf herbivory have been shown to be negatively associated with flower production (Forest Service FEIS 2016).

Relationship with Disturbance

- *Pomeridianum*
  - Seed and flower production increase after fire, and may increase after grazing (Forest Service 2016).
  - Occurs in a variety of fire regimes (Forest Service FEIS 2016).
- Fire increases light availability and allows better seedling establishment because it prepares the seedbed (Forest Service FEIS 2016).
- Grazing is not ideal because of the resultant soil compaction, which interferes with the ability of the bulbs to bury themselves (Kofron et al. 2013).

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Restoration of Soap Plant in California’s Central Valley

Goals

Soap plant is important for pollinators like native bees and moths, and its restoration would be beneficial to these insects. In addition, soap plant is culturally important to many Native Californian tribes, who still use parts of the plant in their daily lives’. The first goal for restoration of soap plant in the California Central Valley is to survey the existing communities of the different species. An important step is to determine what soils are present, the grade, aspect and elevation of the sites, how invaded the sites are, how densely populated the communities are, what pollinators are present, the disturbance regime present and to determine the hydrology of the sites in which each species of soap plant is growing, in order to determine what conditions are necessary for establishment of soap plant. A final goal is to increase the cover of soap plant in the restoration plots by 10%. Decreasing the cover of invasive annual grasses by at least 80%, although not a focus of this plan, is also important to ensure the continued success of the restoration of soap plant. The success of restoration of soap plant will be measured by the survival rates of plantings, density of soap plant measured, and degree of invasion by non-native species. Flowering is expected 3-4 years after planting for plants that have been transplanted, and after 12 years that are directly seeded into the site. A 10% increase in growth should be expected 10 years after flowering, according to a study that evaluated trends in population density of soap plant at Fort Hunter Liggett, California (Guretzky et al., 2005). The first of these goals is very feasible, although quite time consuming, and will be accomplished using GIS and GPS software. The feasibility of the second goal depends on factors like the degree of invasion of the site, and external factors like amount of precipitation and nutrient availability on the different sites, so the percent coverage for the last goal may have to be adjusted throughout the project or vary site by site.

Propagation and Transplanting

Although soap plant can reproduce through both sexual and vegetative means, to maximize genetic diversity, sexual reproduction is ideal (Kofron et al., 2013). The seeds of soap plant should be collected from existing populations that are located in conditions similar to those present at the desired site, usually in oak woodland, chaparral, and grassland, during June to July, and the seed can be retained on the flower head into the summer ("Plant Propagation Protocol," 2016). The species of soap plant that should be collected will depend on the type of plant community and the conditions that exist on the site. For example, *Chlorogalum purpureum* is suited for loamy soils underlain by clay, and with fine gravel on the surface, and has a narrow range, mostly being found in the rain shadow of the coast range in Central California. For grassland sites and sites located in chaparral or oak woodlands in the rest of the Central Valley, *C. pomeridianum*, *C. angustifolium,* and *C. parviflorum* are suitable. The seeds should be collected quickly by stripping the fruit capsules when the fruit capsules split open. The seeds usually occur in groups of three. Seeds do not need to be treated before planting, although they must be stored in a cold (32 degrees F) and dry environment prior to planting for 3 months ("Plant Propagation Protocol," 2016).

Seeds should be sown directly into 1.5" flats that contain a 1:1:1:2 mixture of sand, pumice, peat moss, and a fir bark mixture. After sowing, the flats should then be placed in an outdoor cold frame throughout late fall into spring. The seedlings can then be transplanted into pots using the same mixture of materials ("Plant Propagation Protocol," 2016). Another option for planting is to directly plant the seeds into containers in fall, preferably by October 1st. Using this method, the seeds should be wetted and then placed on top of sandy soil in one gallon containers. The seeds can then be covered with a light layer of soil and a ¼ inch layer of small gravel. The pots should be then set outside to be watered by winter rains ("Plant Propagation Protocol," 2016). In drought years, hand watering can supplement rainwater. To ensure survival and growth, the containers should be placed in sun in the early morning and late afternoon, and in shade during the hottest portion of the day (“Plant Propagation Protocol,” 2016). The active growth phase of soap plant is 6-8 months and hardening-off is not necessary (“Plant Propagation Protocol,” 2016). Both of these methods, seeds planted into flats and then transplanted into containers, and seeds planted directly into containers, are feasible and tested to be successful. A third option is to harvest bulbs from known populations of soap plant that occur in conditions similar to those found on site, making sure that the bulbs have healthy roots. The bulbs can then be planted in any soil types, but it is important to plant them shallowly, with the tops showing. (Anderson et al., 2006). If bulbs of soap plant are collected, it is vital that they are collected from sites that mimic local conditions (Anderson et al., 2006). Because of the greater genetic diversity that planting from seed provides, this plan will focus on restoring soap plant using seeds, although using bulbs is an easy option that can be utilized when resources for the restoration plan are scarce.

Before leaving the nursery, the individuals of soap plant will become dormant following spring, and will die back to the root. During this dormancy period the plants should be placed in 60-70 degree F dry storage, and stored for 3-5 months. Soap plant can be planted out in the field about 2 years after initial collection (“Plant Propagation Protocol,” 2016). Most species of soap plant should be planted in gravelly clay soil, although some species including *pomeridianum*, prefer soil that is slightly sandy (Kofron et al., 2013). Soap plant is able to grow in both shallow and deep soil (Kofron et al., 2013). The plants should be planted at least 2 inches away from each other. Soap plant becomes easily established once planted (Anderson et al., 2006). In studies, soap planted from seed on site flowered after 12 years, while soap plant that was planted in a screen house from seed flowered after 3-4 years, but most died 5-7 years after germination (Kofron et al., 2013).

Design

Because of an uncertainty in how successful restoration will be, and in order to determine the best method of reestablishing different species of soap plant, an experimental approach will be taken. In order to test which method of propagation results in the greatest level of success, and to test which species will do best in the specific conditions present at the site, different species of soap plant will be planted both straight from seed on site and by both methods of transplanting, planting seeds first in flats and then in one gallon containers, and planting seeds directly in one gallon containers. As a control, each species will be planted in their own conditions, including soil, hydrology, accompanying plant species, and light availability under which they were collected. Plots will be 10m by 10 m and will be distributed randomly throughout the larger site areas. In order to mimic the randomness of natural populations of soap plant, plantings should not be uniform as such a planting design would affect resource availability, which would affect how invasive species interact with the plantings. Within the plots, the transplanted bulbs should be planted 2 or more inches apart (Anderson et al., 2006). Because the most viable management practices for soap plant do not involve any machines, a non-uniform design should not be too unfeasible, although such a design will make hand management, including tilling, more cumbersome.

Conservation

Populations of soap plant, as well as other perennial bulbs, are threatened by annual invasive species, especially grasses that compete with soap plant for resources (Kofron et al., 2016). Conservation of existing populations of soap plant, in addition to restoration, is therefore important. Conservation is best accomplished by first mapping the distribution of the populations, including the sizes, densities, and frequency of the patches. Certain species of soap plant are more endangered than others. *Cholorogalum purpureum* is a listed endangered plant, and therefore mapping of the distribution of populations has been accomplished. It is found in very limited distribution in central California (Kofron et al., 2016). Close survey and monitoring of the populations of *purpureum* that remain is important to prevent further loss of the species.

Management

Fire can be used to manage the restoration of soap plant, especially because it is also beneficial in communities in which soap plant tends to be found such as oak woodland, chaparral, and grassland. As a perennial, soap plant persists during and after fire as a bulb. Observations, such as that soap plant populations increased the second year after the US army used a ball and chain to clear a patch of chaparral, and after a fire burned in a plot before the seeds matured, indicate that densities of certain species of soap plant increase after removal of competitors (Kofron et al., 2013). In addition, fires that burn during certain parts of the year, such as during summer, can result in plants with more reproductive vigor, such as increased numbers of flowers, fruits and seeds (Kofron et al., 2013). These results indicate that using fire as a management strategy will increase survival of soap plant, both through removal of invasive species, and through increased vigor of soap plant itself. According to studies done in California chaparral, species of soap plant flower the first year after a fire. The second year after a fire overall herbaceous cover dropped, and perennials, including soap plant, made up 30-80% of the cover, increasing from 3-13% of herbaceous cover. In the third year after a fire, annuals again dominate the herbaceous cover, but in the fourth year perennials dominate the cover (Keeley et al., 1981). Based on this information, fires to control invasive annuals should not be set more than every four years. Fire could be problematic, depending on how close the desired restoration site is to urban and suburban communities.

Another management option is tilling, either by hand or machine. Hand-tilling using tools is more easily controlled, and better suited for the small populations that soap plant exists in than is any mechanized tiling. Tilling using hand tools such as was done by Native Californians with digging sticks has been proven to result in higher density patches of soap plant populations because of the offshoots that are broken off in the process (Balls, 1970). It is important to identify the needs and weaknesses of the plants that commonly occur in communities with species of soap plant, because they can shape management needs including timing of fire and the viability of hand tilling. For example, hand tilling is not ideal in communities that contain easily disturbed and fragile species.

Although good in theory, grazing is not an ideal management strategy to increase populations of soap plant and control invasive species. Grazing compacts the soil, which is not ideal for soap plant, because in too compact of soil, it is more difficult for the bulb of soap plant to bury itself, which it does using contractile roots (Forest Service FEIS, 2016). Fire accomplishes the same goals as grazing, while also encouraging the growth of soap plant, especially because it can break off offshoots of the bulbs. Because of its growth requirements, it is important to compact the soil as little as possible, which limits management options, such as grazing.

Monitoring

Monitoring is very important in order to ensure the continued success of restoration efforts. With constant monitoring, adjustments to the plan can be made when the results are not as expected. The success of transplanted soap plants are important measurements, including mortality, growth, and reproductive health that should be taken incrementally throughout the restoration process. It is important that the pollinators of soap plant species are present on the sites in which soap plant is present, especially because the flowers of some soap plant species, including *pomeridianum* open for only one afternoon and evening (Forest Service FEIS, 2016). Pollinators include moths, honeybees, carpenter bees, and two species of bumble bee. Seed is not set in the absence of the correct pollinator ("Plant Propagation Protocol," 2016). Therefore, monitoring of pollinator species is an important aspect to determining the success of the restoration. The monitoring should include measuring whether the goals set at the beginning are being met, including whether the growth of soap plants in each plot have increased by 10%, and whether the cover of invasive species has decreased. Monitoring should continue for at least 22 years for the seeded plants, and at least 14 years for the transplanted plants, as that is enough time for the plants to flower, reproduce, and to ideally, increase in growth by 10% (Kofron et al., 2016). Monitoring for pollinators should occur every two weeks while the plants are flowering. Monitoring for survival, growth, and invasive plant cover should occur twice a week immediately after planting, and monthly later on. Monitoring for reproduction should occur a few times every year after the 12th year for the seeded plants, and after the 3rd to 4th year for the transplanted plants.

If there is complete failure of reestablishment of one or all of the populations, the plan will be re-evaluated, and aspects, such as how the seeds were collected, when the transplants were planted, in what site conditions the seeds were collected compared to the conditions the plants were planted in will be evaluated. In the case of difficulty of establishment in certain sites, the management techniques used will be examined and tested to determine the most appropriate one for different conditions. The restoration of soap plant will be considered successful if the growth of the plantings increase 10%, 13 to 14 years after planting for the transplanted plants, and after 22 years for the plants directly seeded onto the site. If this goal is not met after the initial monitoring period, the plan will have to be re-evaluated. Additional research on the effects of grazing on soap plant is required, as there is currently little literature on the subject. This restoration project should ask and attempt to answer what site conditions and management techniques are best for each species of soap plant, and in each type of plant community, including oak woodland, chaparral, and grassland.

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Eriophyllum lanatum

COMMON WOOLLY SUNFLOWER

Kingdom: Plantae

Order: Asterales

Family: Asteraceae

Genus: *Eriophyllum*

Species: *E. Lanatum*

BACKGROUND AND JUSTIFICATION

Woolly sunflowers are an annual, biennial, or short- or long-lived perennial herb or subshrub, depending on site conditions, though they are most frequently found as perennial herbs that flower from April to June (UCJEPS, 2016). Characteristic of their valley grassland habitat, woolly sunflowers are adapted to dry, rocky soils and are highly drought tolerant (Calflora, 2016). Despite their hardiness in regards to tolerating harsh soil and drought conditions, woolly sunflowers have a relatively delicate structure and, thus, are at risk to destruction from trampling via motor vehicles, cattle, or humans (USDA, 2016). This has not, however, been an intense threat to the persistence of woolly sunflowers on a global scale. Woolly sunflowers themselves are not endangered; they have a G5T1 conservation status, which means they are globally demonstrably secure but certain variants are critically imperiled (USDA. 2016). They do, nonetheless, provide a critical habitat for many pollinators, much of which has been otherwise lost to invasive grasses (Labar and Schultz, 2012). Because of its ability to establish and spread quickly and tolerate fairly harsh site conditions, woolly sunflowers are great plants for restoring invaded sites to a natural state (Labar and Schultz, 2012). During the establishment phase of seeds and seedlings, weeds pose a threat by shading out this shade-intolerant plant (Washington Native Plant Society, 2016). As long as weeds are controlled (via hand pulling or herbicides, which woolly sunflowers are tolerant to) for the first year until wooly sunflowers can establish, this plant is an ideal choice for a self-sustainable native plant and habitat for many pollinators essential for the ecosystem (Labar and Schultz, 2012).

FACT SHEET

Seasonality/Phenology

- The common woolly grows as a perennial herb in Central Valley conditions[1, 11, 12]
- This plant flowers in the spring and summer, over the months of May through July, with flowering peaking in June, but germination and growth will begin with Winter rains[11, 12]

Description

- The woolly sunflowers has a multi-branched, erect to spreading form, growing 10-60 cm tall[12]
- Stems and leave are covered with white hairs, which increases the plant's drought tolerance[12]
- Flowers are solitary and leaves are long and divide into narrow lobes[12]
- The flower head has a golden yellow disk flowers and 8-12 yellow ray flowers[12]

Habitat/ Range

- Woolly sunflowers are found in the following California Communities: Douglas-Fir Forest, Coastal Prairie, Redwood Forest, Yellow Pine Forest, Red Fir Forest, Lodgepole Forest, Subalpine Forest, Mixed Evergreen Forest, Foothill Woodland, Chaparral, Northern Juniper Woodland, Sagebrush Scrub, Northern Oak Woodland, Valley Grassland[1]
- Low to mid elevations are ideal for growth, with the growth range being from sea level to 3,050 m[12]
- The woolly sunflower is common on both sides of the Cascade Mountains from British Columbia south to Washington, Oregon, and California where most of its populations are found[12]

Environmental Tolerances and Preferences

- Plants tolerate rocky, dry, or sandy soils[12]
- Plants prefer nitrogen-medium soils[3]
- A minimum of 25 cm annual precipitation is required for woolly sunflower growth[12]
- Plants have a very high drought tolerance once established, which takes about 1 year[12, 7]
- Soil should be course and well drained, as inundation is intolerable[7]
- Woolly sunflowers prefer full sun exposure, but can tolerate partial shade[7]

Mutualists/ Competitors

- Wooly sunflowers attracts various pollinators, such as beetles, bees, moths, syrphid flies, and butterflies[12]
- Pollinators are required for plant production, as woolly sunflowers are self-incompatible[12]
- Weeds, especially grasses such as Medusahead and Italian Rye, present the biggest

challenge for establishment of woolly sunflowers. Weedy grasses have rapid above-ground growth and shade out woolly sunflower seedlings, hindering them from growing to a point where they can produce seeds and spread.[12]

- Woolly sunflowers grow well with the following plants: Sandberg's bluegrass, California poppy, California brome, Small head clover, Lupine, Narrow flowered brome, Big squirreltail grass, Giant mountain dandelion, Diego bent grass, Pale leaved serviceberry, Gold cup live oak, Yarrow, Hog fennel, Common fringe pod, Blue witch, Large flowered collomia, Snowberry, Tomcat clover, White flowered hawkweed, Sticky monkeyflower, Silver puffs, Poison oak, Purple sanicle, Goldfields, Cream cups, Pacific sanicle, Giant blazingstar, Prickly crytantha, Valley sky lupine, Chick lupine, Nightshade, Tongue clarkia, Few flowered blue eyed mary, Common phacelia, California brickellia, Chinese houses, Coyote brush, Vinegarweed, Rock lettuce, and Redberry[10]

Disturbances/ Disruptions

- Woolly sunflowers are sensitive to trampling and crushing by humans, cattle, and motor vehicles, especially during the first year while the plant is establishing itself [2, 5,13]
- Because of it's susceptibility to trampling, woolly sunflowers do not do well along trails or roads[5]
- Woolly sunflowers have been shown to do poorly at logged or burned sites. These sites often do not have ideal soil conditions, or soil conditions that woolly sunflowers cannot tolerate. Fires are also detrimental to this plant, regardless of the timing of the fire as woolly sunflowers are perennial[6]
- Trampled plants show a significant decrease in pollinator recruitment, which is crucial to the survival of this self-incompatible plant[5]

Germination/ Establishment

- Germination begins with winter rains, flowers bloom in late spring, and then after flowering, seeds are produced in June and July[12]
- Seeds ripen in July[12]
- Seeds should be collected in August[7]
- Seeds should be sewn in the fall[12, 5]
- For restoration purposes, woolly sunflowers can be established by seedlings or seed[12]
- "Seeds should be drilled into a weed-free seed bed in the fall at a rate of 3.4 kg PLS per ha and at a depth of 0.6 to 1.25 cm"[12]
- An extended cold moist stratification period (ideally 90 days) is needed to break seed dormancy and for ideal seed germination rates[12]
- When planting seedlings, plants should be spaced 15 to 45 cm apart[12]
- Woolly Sunflowers easily spread once established[12]
- If undisturbed by trampling, grazing, or weed competition, woolly sunflowers are exceptionally quick to establish, producing seed and flowers by the first year[12, 5]

Management Options

- Woolly sunflowers are best used in embankments and perennial borders.[12]
- "The Lady Bird Wildflower Center (2011) recommends selecting a local ecotype, planting several plants in a group, and pruning the dead branches"[12]
- Because of its quick establishment and ability to spread, woolly sunflowers are great for diversification and revegetation of rangeland of several habitats[12]
- Planting should be dense and patchy[5]

Restoration Plan for the Common Woolly Sunflower

Restoration Goals: Annual grasses have invaded much of California's Central Valley. The main goal of restoring woolly sunflowers to the Central Valley is to return these invaded lands to a natural state. The success of this goal will be measured as a dominance of native species after restoration has occurred. For the purposes of this restoration plan, the "50/20 rule" will be used to define dominance. As described by the USACE in their manual for wetland delineation, "dominants are the most abundant species that individually or collectively account for more than 50 percent of the total coverage of vegetation in the stratum, plus any other species that, by itself, accounts for at least 20 percent of the total" (USACE 2008). Because the woolly sunflower is relatively hardy, persistent, and easily spreads, they are ideal for creating a self-sustaining natural habitat once established (USDA 2016).

The second goal of restoring woolly sunflowers is to establish them to a level that they can sufficiently self-sustain a natural state and resist encroachment by non-native plants without human intervention. Success of this goal may be measured as a persistent native species dominance by the 50/20 rule, and hopefully increasingly dominant, 5 years after restoration has occurred. A 5-year period allows for establishment and seed production in the first year, and then 4 years to monitor changes and ensure woolly sunflower dominance persist. Because woolly sunflowers spread rapidly, this should be relatively easy once seed production begins about a year after planting (USDA 2016). Encroachment of invasive grasses may pose an obstacle to the persistence of woolly sunflower dominance (GOERT 2016). However, this obstacle will likely be negligible if weeds are manually contained during the first year after planting, or until the woolly sunflower seedlings have grown to the point where they produce their own seeds, which usually takes one year after planting. Once established, woolly sunflowers are usually persistent enough to keep weeds out (USDA 2016).

As a perennial flowering plant, the woolly sunflower also provides essential habitat for pollinators that have otherwise been lost to grasses (USDA 2016). Thus, a third goal of restoring the woolly sunflower to the Central Valley is to increase habitat for pollinators such as beetles, bees, and butterflies. In order to accomplish this, the woolly sunflower patch should be at least 6 m in diameter to promote optimal pollinator recruitment (Xerces Society 2016).

Currently, very limited literature exists regarding how woolly sunflowers affect soil quality. In hopes to expand on our knowledge of if or how woolly sunflowers affect the relatively poor soils they grow on, the final goal of restoring the woolly sunflower the

California’s Central Valley is to collect data on several aspects of the soils at the restoration beforehand and seasonally after restoration has occurred in plots with and without woolly sunflowers present and analyze that data to track soil quality trends over a 5 year period. While this goal is a lower priority, it may provide an interesting opportunity to gain incite on the potential for using woolly sunflower soil interactions as a model for planting other species on poor soils if the resources to perform this experimental monitoring exist.

Restoration Plan: Woolly sunflower seeds should be collected between July and August, or shortly after fruit ripening which occurs from June to July (GOERT, 2016). Seeds can be collected by hand picking entire dried flower heads and placing them in paper bags (Kruckeberg, 2016). After seed collection is completed, seeds should be planted in containers and placed in a greenhouse between October and November (USDA, 2016). After placed in containers, seeds should be stratified in moist and cold conditions for a 90-day period in the greenhouse for optimal germination (Skinner 2007). After this 90-day cold, wet period, prepare the plants for transplanting by hardening off seedlings for 2-4 weeks in a cold frame (Skinner 2007).

Before transplanting woolly sunflower seedlings, the site should be prepared by de-weeding the area. Any weeding technique should work as long as the seedbed is weed-free before transplantation occurs. This can be accomplished through mowing, cultivation, fumigating the soil prior to planting, herbicides, or hand weeding (Archibald 2006).

Once the seedlings and restoration sites are ready, seedlings can be planted in March(GOERT 2016). Plants should be spaced 15 to 45 cm apart; planting should be dense and patchy (USDA 2016). In order to support necessary pollinator populations, each woolly sunflower patch should be at least 6 m in diameter, or surrounded by other flowering plants to create a 6 m diameter minimum patch of native flowering plants (Xerces Society 2016). If the restoration site is in a high-traffic area, woolly sunflower patches should be planted away from roads or trails as much as possible to decrease trampling effects (U.S. Bureau of Land Management 2016). Patches should also be in direct sunlight and on coarse, well-drained soil for optimal growth (GOERT 2016).

If establishment by seedlings is not possible, woolly sunflowers may also be established by seed. Seeds, however, still require a 90-day cold and moist period after being planted. This cold, wet period may be harder to control at the outdoor site than in a greenhouse. To achieve optimal temperature and moisture during the initial 90-day period, seeds should be drilled into the seedbed in the fall—ideally at a rate of 3.4 kg PLS per ha and at a depth of 0.6-1.25 cm (USDA 2016). If seeds are planted in a dry year, moisture may need to be supplemented with a drip irrigation system for the initial 90-day cold and moist period. Patch size and placement should be the same for establishment by seed as the patches described above for establishment by seedlings.

Whether established by seed or seedlings, flowering and seed production should occur in the first year of growth (USDA 2016). If weeds come back within the first year of woolly sunflower growth, they may slow growth or kill woolly sunflower seedlings all together by shading them out (USDA 2016). To avoid this, weed control by hand weeding should be done until woolly sunflower plants are producing flowers and seeds. Once the initial 6 m wide seeded patch has established, woolly sunflowers should spread on their own fairly quickly. However, since they are self-incompatible, pollinators are necessary for plant production (USDA 2016). If pollinators do not naturally establish at the restoration site, then intervention may be necessary by manually introducing pollinators such as *Osmia* bees, orange sulfur butterflies, red admiral butterflies, comma butterflies, skipper butterflies, syrphid flies, or other native bees, moths, or beetles (USDA 2016). Once plants begin producing seeds and spreading on their own, management can focus on monitoring.

Purpose of Monitoring: By monitoring the % cover of woolly sunflowers and other native plants, as well as the % cover of invasive plants, the manager may determine how successfully a native state has been established, whether that native state is persisting, and if or when intervention is needed to contain invasive plants. Monitoring pollinator presence will allow the manager to determine whether or not goal 3 has been accomplished and if pollinators require aid to establish themselves at the restoration site—a crucial component to the persistence of the self-incompatible woolly sunflower. Measurements will be taken in the spring, as this is when flowering occurs and pollinator presence would be at its peak. For convenience, soil quality measurements will also be taken in the spring. It is important that soil measurements are taken at close to the same time each year to avoid variance from seasonal condition differences. All pre-planting measurements will provide a baseline of comparison for how restoration has altered the site. These initial measurements, as well as a dataset of 5 years worth of measurement on soil quality, will provide a great base for analyzing the ways in which woolly sunflowers alter soil quality if resources are available to give attention to the fourth goal. This data may provide some incite on how woolly sunflowers affect soil quality, which may be useful for future restoration on poor soils. Nitrogen content, infiltration, and pH are being used as indicators of general soil quality.

Monitoring- Before Planting: In the restoration site's current state—before clearing the site of invasive grasses or other weeds and before any woolly sunflower planting occurs—the following measurements should be collected:

*Nitrogen content of several different patches of soil across the site

*pH levels of the same patches of soil measured for nitrogen content

*Infiltration of the same patches of soil measured for nitrogen content and pH

*Across the entire restoration site, the %cover by native plants and the %cover by invasive plants

*The number of pollinators visiting the site (if any at all) and which pollinators are visiting the site

Monitoring- After Planting: After woolly sunflowers have been planted, the following measurements should be taken until 5 years of data has been collected:

*<u>Once every spring:</u> Nitrogen content at several patches, half with wooly sunflowers present and

half without woolly sunflowers

*Once every spring: pH levels of the same patches of soil measured for nitrogen content

* Once every spring: Infiltration of the same patches of soil measured for nitrogen content and pH

*Once every Winter, Fall, Spring, and Summer for the first year, then once every Spring: Across the entire restoration site, %cover by woolly sunflowers, %cover by other native plants, and %cover by invasive plants

-If %cover by invasive plants reaches more than 5% during the first year or until woolly sunflowers produce seeds, they should be removed as mentioned above by hand weeding. Weedy plants should cover a negligible amount of the restoration patch in order for woolly sunflowers to receive enough sunlight to establish and spread. If, at any point after woolly sunflower establishment, invasive plants begin to *dominate* by the 50/20 rule described above, action via weed control should be taken.

*Once every spring: The number of pollinators visiting the site and which pollinators are visiting

-If pollinators are not present at the site by the end of the first year, they should be manually introduced, as they are required every year for reproduction.

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Eschscholzia californica

The California Poppy (*Eschscholzia californica*), is an annual and/or perennial plant that occurs throughout the western United States and Mexico. Within California, the plant holds the title of being the state flower. While this species is not currently threated or endangered, it's existence has been reduced due to loss of native grasslands in California, as well as additional negative effects such as human disturbance (mowing, grading, pesticides, land development, commercial seeds, etc) and competition with faster growing exotic and invasive species (USDA, NRCS, 2016). Within the current populations of California Poppies, there is also a loss of diversity as commercially available seeds reduce the tolerance and natural adaptions of wild populations (Montalvo, Feist-Alvey, and Koehler, 2002). This loss of diversity contributes to decreased success in natural environments, in turn contributing to other issues such as loss of food source and habitat for bees and insects, as well as reduced adaptability to extreme events or conditions, and loss of erosion mitigation (USDA, NRCS, 2016). Further loss of native grasslands that include California Poppy populations leads to greater numbers of invasive grasses and species, in turn creating a chain reaction that effects native animals and other plants that can no longer coexist with their intended habitat. The encouragement of restoration using the California poppy is beneficial on many fronts. Restoration of natural California poppy populations helps increase biodiversity, increase bee populations, provide groundcover, and also allows for a plant that is easily adaptable to poor soils where other plants may not grow (USDA, NRCS, 2016).

Literature Review and Fact Sheet:

Project Objectives and Goals:

- Broad Goals: Creation of riparian trail system, decrease of invasive species, and restoration of native species.
- Class Goals: Site specific management guidelines, specific and woody species control
- Literature Review Goal: Provide specific information on the California Poppy to aid in efforts to reestablish this plant within the restoration

Characteristics:

- Brightly colored four petal flower (bright yellow to bright orange in color), dusty blue green foliage, and low and spreading growth habit. Can be an annual or perennial. (USDA, NRCS, 2016).
- Has become a highly variant species with the ability to grow in multiple types of habitats and displaying a wide range of morphologies (Cook, 1965; Montalvo, Feist-Alvey, and Koehler, 2002).
- Long taproot allows the poppy to survive in drought conditions and in multiple soil types with low water holding capacity (Cook, 1965).
- Requires minimal amounts of water (is drought tolerant) and requires minimal maintenance once established (O'Dell, Young, and Claassen, 2007).

Growth Requirements and Tolerances:

- Can withstand minimum temperatures up to 20° F and maximum temperatures up to 99° F (Calflora, 2016)
- Annual precipitation tolerated is a minimum of seven inches and a maximum of 71 inches (Calflora, 2016)
- Tolerable to a wide range of soils. Requires a minimum depth of 13 cm of soil to grow, in soil that maintains a pH between 5 to 8.2, is very slightly saline, and is tolerable of all soil textures. (Calflora, 2016; Cooks, 1965).
- Grows at elevations of 0 to 2450 meters (Calflora, 2016)
- Is generally able to recover well from extreme events, such as freezing, high temperatures, variable precipitation, soil types and textures (USDA, NRCS, 2016).
- Poppies do not do well in sites with pooled water or excessively moist soil (USDA, NRCS, 2016).

Habitat and Range:

- Grows in USDA hardiness zones 7a through 11a and below 7000 ft. (Calflora, 2016; USDA, NRCS, 2016).
- Growing season and bloom period ranges from February to September (Calflora, 2016)
- Native to California; range includes from southern Washington state to Baja California, Mexico. (Cook, 1965; Montalvo, Feist-Alvey, and Koehler, 2002).
- Is highly adaptable across a wide range of habitats and is able to establish on disturbed sites (USDA, NRCS, 2016).
- Poppies growing in areas of constant available water are frequently perennial and lack dormancy, while in areas of low water they can be a summer dormant perennial or annual (USDA, NRCS, 2016).
- For this project, the California poppy will do best in the Valle Floor Grassland Habitat, due to its preference for dry, well drained, and unsaturated soils.

Reproduction and Propagation:

- Germinate during rainy season during mid-winter (Montalvo, Feist-Alvey, and Koehler, 2002).
- The seed capsule is a cylindrical shape and reside at the base of the flower when ripe. The seed capsules burst and eject seeds within a 6 foot radius of origin. The seeds themselves are small, spherical, and brown in color (USDA, NRCS, 2016).
- Seed dormancy helps prevent against early germination; seeds remain dormant until winter rains to prevent blooming during dry or hot conditions. It is "unknown if poppy seeds have an annual cycle of summer dormancy followed by non or conditional winder dormancy A cycle of dormancy is suggested through the inconsistency of displays of poppies from year to year (Montalvo, Feist-Alvey, and Koehler, 2002).
- There is great variation in seeds of California poppy, throughout wild habitats and in commercial products. Across populations in the Montalv experiment, o, Feist-Alvey, and Koehler, both smoke (dry and liquid), and cold where successful at causing seed germination throughout different populations of poppy, although some fractions of wild

seed populations still did not germinate. Also, younger seeds have lower dormancy than that or older or ages seeds within the same populations. Overall, prescribed fire might be useful in restoration projects involving the poppy, although extreme heat can be detrimental (Montalvo, Feist-Alvey, and Koehler, 2002).

- For successful natural planting areas and reestablishments, selection of seeds from local populations or from populations with similar conditions is recommended Annual types are recommended for sites with shallow or sandy soils, while perennial types are recommended for moderate to deep soils (USDA, NRCS, 2016).

Interactions:

<u>Wildlife</u>:

- Beneficial to native bees for pollen. Poppies lack nectar and solely attract species with pollen, which provides food for the bees as well as help aid with plant reproduction. The inclusion of poppies alongside other native flowers is important for the encouragement of bee population growth and colony growth (Calflora, 2016; Storer, 2002)
- Minimally contributes to animal diets, provides cover for small birds, and supplies pollen for a range of insects such as bees, butterflies, beetles, and so on (USDA, NRCS, 2016).
- Can be potentially toxic to grazing animals, such as livestock, but also depends on the stage of poppy growth as well as the age and class of animal consuming the plant. Mowing or clipping poppies at various heights can encourage growth, suggesting that poppies will not be negatively affected by grazing (USDA, NRCS, 2016).

<u>Plant:</u>

- Certain grass plants (ex. Avena grasses) grow rapidly which reduce soil volume for the poppy to grow in, as well as gaining in height and breadth much quicker which will shade out the poppy. This trend attests to the poppy's preference for habitats that are unfavorable for other plants that would otherwise out compete those (Cooks, 1965).
- Establishing the California Poppy before the germination of invasive species or exotics within an area increases chances of survival and helps favor the poppy in competing with exotic species (Grman and Suding, 2010; O'Dell, Young, and Claassen, 2007).

<u>Human:</u>

- Can behave like a weed in areas disturbed by humans; can be found growing within gravel piles, roadway cracks, and other areas that have been disturbed by construction or excavation (Cook, 1965).
- Used frequently in California for restoration projects, seed mixtures used in

erosion controls, and roadside beautification (USDA, NRCS, 2016).

- Has some medicinal uses, including unique chemicals that have "anti-bacterial and cancer treating potential" (USDA, NRCS, 2016).
- Holds significance for many indigenous peoples, which have used poppies for food and drug purposes, such as a sedative, sweet candy, and also as eye shadow. The plant does hold a toxicity level (USDA, NRCS, 2016).

Threats and Succession:

- Exhibits ability to self-reestablish and successfully maintain self in an area post fire or burning, likely due to a reduction of competition with other plants that reduce soil volume or shade out poopy with quick height growth (Cook, 1965)
- Prior successful establishment of California poppy allows for greater chances of succession and continued establishment if preexisting before introduction of exotics/invasives (Grman and Suding, 2010; O'Dell, Young, and Claassen, 2007).
- Disturbances such as flooding lasting longer than two weeks, improper mowing, heavy grazing, and more reduce the poppy's ability to survive in an environment (O'Dell, Young, and Claassen, 2007).
- Pests of the California poppy include aphids, leafhoppers, Lepidopteran larvae, and the alfalfa looper. Diseases of the poppy ae phytoplam aster yellows, Tospoviruses tomato spotted wilt, necrotic spot, as well as diseases of the root, leaves, and flowers. Most commonly found on the poppy are powdery mildew and gray mold and are generally non-lethal (USDA, NRCS, 2016).

Restoration Efforts:

- The addition of mycorrhizal fungi to soils during restoration can greatly improve the effects of the restoration and help with reestablishment of native species, particularly when coupled with the removal of any exotic species. This allows for natives such as the California poppy to reestablish without competition, so when invasive plants do begin to grow they have a better chance of long term survival (Grman and Suding, 2010).
- Growth and potential of native species such as the poppy, and long term success of a project can be increased by deep soil ripping when seeding species (Montalvo, McMillan, and Allen, 2002).
- Flat or gently sloping areas should use seed imprinting; hydro-seeding should be restricted to steep or rocky areas due to lack of performance and higher associated costs; compacted soils should use deep ripping and soil amendments to increase success of seeding (Montalvo, McMillan, and Allen, 2002).
- Application of certain herbicides (ex. Broadleaf) shortly after planting can help reduce the appearance of invasive species that will outcompete native plantings (O'Dell, Young, and Claassen, 2007).
- While the poppy may benefit from exposure to smoke or cold to break seed dormancy, exposure to high heat treatments are harmful to most seeds (USDA, NRCS, 2016).
- Plantings should occur in the fall for Pacific regions to allow for favorable dormancy

condition exposure; pretreatment of seeds is not recommended for wildland reestablishment. Once established, populations become self-perpetuating (USDA, NRCS, 2016).

- Generally not tolerant to transplanting unless very young (USDA, NRCS, 2016).

Gaps in Knowledge:

- There is a lack of understanding of the germination cues of California poppies. While the Montalvo, Feist-Alvey, and Koehler study was able to cause germination via cold or smoke exposure, seeds in the wild and commercially grown seeds are able to germinate without these additional additives ((Montalvo, Feist-Alvey, and Koehler, 2002).

Other Information:

- Wild or native seed populations are expected to have greater success in a restoration project than commercially available seeds. This is likely due to commercial seeds' lack of dormancy, which has been selected against, and can lead to a die off of poppies in a restoration after a few year. Potentially, acquiring native seeds and smoking them before planting can help break dormancy, and then these seeds can be used in restorations to help contribute to greater success of the project (Montalvo, Feist-Alvey, and Koehler, 2002).

Restoration Goals, Plans, and Monitoring

Part A: Goals

The California Poppy plays a significant role in restoration projects throughout California's Central valley not only for its cultural significance as California's state flower, but also for the services it provides to wildlife and its surrounding environment. The goals for restoring the California Poppy (*Eschscholzia californica*) in the Central Valley shall aid in establishing viable, self-sustaining, populations that will work alongside other wildflowers to continue providing these services.

<u>Goal 1:</u> Examine existing populations of *Eschscholzia californica* to determine different adaptions within the species (soil type, microclimate effects, seed dormancy, etc.). (Short term, large scale)

As a highly adaptable species, there is great variation among populations of wild California poppies even within the Central Valley (Montalvo, Feist-Alvey, and Koehler, 2002). With this variance, different populations may have different seed dormancies and different exposures to cause germination. Therefore, examining populations of wild poppies that exist around the restoration site, or in areas with similar aspects (soil type, hydrology, microclimate, etc) to determine what will cause break in dormancy is necessary to have a successful restoration project (USDA, NRCS, 2016).

<u>Goal 2:</u> Enhance the presence of native wild populations of *Eschscholzia californica,*

with the selection and collection of appropriate wild populations' seeds for specific areas, and then planting using best method practices. (Long term, small scale)

Successful restorations will use seeds selected from local populations or from populations that come from areas with similar conditions of the projected restoration site (USDA, NRCS, 2016). This is due to the variance of seed dormancy within California poppies and what breaks dormancy. The age of seeds collected will also need to be considered, as younger seeds have lower dormancy thresholds than older seeds within the same population (Montalvo, Feist-Alvey, and Koehler, 2002). Commercially available seeds are not appropriate for restorations as these have been selected for their lack of dormancy, which can lead to a die-off in years after planting due to inability to cope with disturbances such as heat, cold, drought, and so on (Montalvo, Feist-Alvey, and Koehler, 2002).

<u>Goal 3:</u> Establishment of self-sustaining populations of *Eschscholzia californica* within the Central Valley. (Long term, large scale)

As previously mentioned in other goals, selection of seeds from the appropriate wild populations will help guarantee the long term success of establishing the California poppy within a restoration project. The appropriate seed selection will allow the plants to develop into a self-established component that requires little to no maintenance as it reseeds itself year after year (USDA, NRCS, 2016).

Part B: Restoration Plan

<u>Methodologies:</u>

- <u>Source of Seeds</u>: Seeds shall be collected from wild populations that are local to the restoration site (on or surrounding) or from populations that exist in areas with similar conditions to that of the restoration site (Montalvo, Feist-Alvey, and Koehler, 2002). Commercially available seeds are not appropriate for restorations and can contribute to failure of efforts (Montalvo, Feist-Alvey, and Koehler, 2002). Seeds shall be collected from the seed pods of these wild populations that exist under same or similar conditions. Research into the seed dormancy of these collected seeds shall also be done, as to understand what breaks dormancy and allows for germination.
- <u>Seeding Methods</u>: There are several methods of seeding available for the California poppy when taking on a restoration project. Seeding is the most appropriate method of establishing California poppy populations, as it is generally not tolerant of transplanting methods, although very young plants may have more success with being transplanted (USDA, NRCS, 2016). If the restoration site is a flat or gently sloping area, the best method for seeding is seed imprinting, where seed is distributed by machinery that also creates long furrows in the soil (Montalvo, McMillan, and Allen, 2002). A restoration project with steep sloping or rock filled areas is best suited for hydro-seeding due to difficulty with site

slopes and accessing such areas with other seeding methods may be more costly and less effective (Montalvo, McMillan, and Allen, 2002). Sites with poor and compacted soils best respond to deep ripping of the soils prior to broad seed distribution, and may also benefit with the addition of soil amendments such as mycorrhizal fungi which can greatly improve the success of restoration efforts and survival of reintroduced species (Grman and Suding, 2010; Montalvo, McMillan, and Allen, 2002). Overall, deep soil ripping when seeding has been shown to be the best method for increased and long term success with the California Poppy and restoration efforts (Montalvo, McMillan, and Allen, 2002).

- Manipulated Disturbance Regimes: Different populations of California Poppy will have different tolerances in response to disturbances that may occur. Due to the Central Valley's wide array of disturbances, intentional and unintentional, this includes instances of extreme cold and hot temperatures, fire, flooding, and grazing. For the purpose of intentional disturbances, the response of the California Poppy to such disturbances will highly depend on the local population it was collected from within the Central Valley. In studies, it has been shown that the poppy can benefit from exposure to cold breaks and smoke exposure from fire, but overall and across most populations of California Poppy, exposure to high heat such as direct fire or extreme high temperatures is detrimental to the plant and seeds, however prescribed fire without direct contact (smoke exposure only) may be beneficial (Montalvo, Feist-Alvey, and Koehler, 2002; USDA, NRCS, 2016). In terms of grazing, light to moderate grazing is not expected to harm growth of California Poppies, as suggested by research into mowing and clipping of poppies, which can encourage growth (USDA, NRCS, 2016). Heavy grazing, and other extreme disturbances such as long term flooding, extreme and extensive wildfires, will likely negatively affect the poppies' success (O'Dell, Young, and Claassen, 2007).
- Temporal, Short Term: Shortly after planting and seeding efforts of the restoration are completed, the addition of specific herbicides that affect and reduce the appearance and growth of invasive and exotic species within and surrounding the restoration site can help increase the success of native plants by preventing sources of competition (O'Dell, Young, and Claassen, 2007).
- Temporal, Long Term:

Potential Problems: how you might adjust the plan along the way if you encounter those problems

- Potential Problem 1: Pests or diseases such as aphids, leafhoppers, or necrotic spot begin affecting the success of the California Poppy within the restoration.
    - Response: Remove infected specimens and monitor others for spread of disease. If necessary, remove poppies and reseed in fall.
- Potential Problem 2: Natural disturbances occur such as flooding or wildfire occur and kill many of the poppies within the restoration site.
    - Response: Poppies are generally tolerant of wildfires and their seeds are likely to survive and reseed. In the case of flood, plants can withstand standing water that does not fully submerge the plant for up to two

weeks. If plants are killed by flooding, remove and reseed restoration site, with new seeds being planted in areas least likely to be affected by water levels.

- Potential Problem 3: The poppy seeds fail to break dormancy with no outside efforts.
    - Response: Based on the previous research into the adaptions of different poppies and the selection of seeds from wild populations under similar conditions, reexamination of the plants where the seeds where collected from can provide context as to what causes dormancy break, allowing one to understand if there needs to be controlled exposure to smoke or heat, or if the conditions needed for dormancy break are not appropriate during that time (seasonal cold or heat) or appropriate for the restoration site which would require reselection of a more appropriate population on California poppy seeds.

Risks and Uncertainties: Even with extensive research and efforts exerted for restoration projects, there are always risks and uncertainties that must be understood and accounted for. In the terms of the California Poppy, there is much uncertainty that lies with the variance of seed dormancy in populations, and seeds collected from a site with similar conditions may still not have the same factors to break seed dormancy, which can lead to little or no germination of these seeds in the restoration project.

Part C: Monitoring Plan

Pre-Restoration: Before restoration can begin, there must be extensive research of not only the current conditions of the site, but also research into the original conditions of the site, how it progressed to its current state, and the desired outcome of restoration, including research into the California Poppy (and other plant and animal species). This research is to help one not only understand the site and the species, but also how the poppy will react to being reestablished on a restoration site within California's Central Valley. Monitoring of the site shall include examination of any existing *Eschscholzia californica* currently located on the projected restoration site, or examination into why there is a lack of *Eschscholzia californica* on site, such as unfavorable soil conditions, out-competed by exotic species, and so on.

Post-Restoration:

- Failure of Reestablishment: If the restoration efforts fail, one shall reevaluate the entire restoration, from pre examination to post monitoring of the site. Specifics to look into in regards to the California Poppy include source of seeds, method of planting, soil type/quality/conditions, amount of water, temperature exposure, disturbances, and so on.
- Minimal Reestablishment:
- Successful Reestablishment: With successful reestablishment of the California Poppy, post restoration efforts should focus on regular monitoring at first that then can filter to periodical, and then no monitoring. Continuous checking for

invasive and exotic species in the first year of establishment is critical, as these generally faster growing species no only out compete the poppy for resources, but also eventually out shade the plant and causing die off of the species within the restoration (Cooks, 1965). Frequent monitoring of the poppy until it reaches full maturity and full establishment before the (eventual) arrival of invasive and exotic species can help increase chances of survival and success by pre-favoring the poppy when competing with other species (Grman and Suding, 2010; O'Dell, Young, and Claassen, 2007).

Research Questions:

- Can be Tested by Restoration:
  - After establishment and successful restoration efforts of a site occur and monitoring has stopped, can fully grown and established native species keep invasive and exotic species from returning?
  - Has the restoration of native California plant species within this site increased the population of bees compared with that previously present on site?
- Not Yet Answered:
  - Does the establishment of the California Poppy in this restoration have a detrimental effect on other native plants or wildlife species also being restored within the same site? Does this effect negatively outweigh the benefits of either the California Poppy or the other specie(s)?

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Juncus bufonius (toad rush)

Classification (NRCS, n.d.)
Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Liliopsida
Subclass: Commelinidae
Order: Juncales
Family: Juncaceae
Genus: *Juncus* L.
Species: *bufonius* L.

Background & Justification

Juncus bufonius (toad rush) is a native grass-like monocot usually found in wetlands (Calflora, 2016). There are three weakly delineated varieties of *Juncus bufonius* recognized in California including *bufonius*, *congestus*, and *occidentalis* (CNPS, 2014). The restoration of this rush has positive environmental impacts including controlling erosion, aiding in flood management, and providing habitat and food for wildlife (EPA, 2016). However, toad rush is often considered a weed in agriculture and can reduce crop yield (Pratley, 1983).

Although toad rush is common enough to be deemed a weed and is found worldwide, there is no information on its population or trends in its population (IUCN, 2013). In spite of this, information found on the degradation of its wet habitat indicates a 90 percent reduction of wetlands in California within the last century (Blankenbuehler, 2016). The decline in Central Valley is linked to mostly conversion of wetlands into agriculture along with channeling for flood control (Frayer, Peters, & Pywell, 1989). This trend is now starting to be reversed with projects utilizing toad rush to restore wetlands which will make these sites more productive and successful.

Fact Sheet

Growth Characteristics:

- Toad rush is an annual grass-like monocot (Calflora, 2016).
- It is unique compared to other rushes with its fibrous roots, annual life cycle, and relatively small size (SEINet, n.d.).
- The height can reach 1 foot tall with an upright form and has a fast growth rate (CNPS, 2014).

Range:

- Toad rush is native to California and has a recorded presence in every county except Kings County. It is not common in some desert areas of California since the temperature is too high and the amount of precipitation is too low (Calflora, 2016).
- It is distributed worldwide but less frequent in tropical and polar regions (Cope & Stace, 1978).

Habitat:

- Toad rush usually occurs in wetlands and prefers a high water table (Calflora, 2016).
- It is found in natural settings including streams, pond margins, ditches, and other wet places. The drainage from preferred sites is either slow or standing (CNPS, 2014).
- This rush is found often in wet sands or silty soils but can be found along paths with more compacted soils (SEINet, n.d.).
- A study at a California salt marsh found that toad rush is common in the landscape during the wetter years but absent in the driest. It is dependent on wet years or supplemental water (Callaway & Sabraw, 1994).

Reproduction:

- Toad rush has single, small flowers scattered along branches and have 6 greenish tepals. There are many yellow seeds that are "egg-shaped" with "short-pointed" tips (SEINet, n.d.).
- The flowering period listed on Calflora, a website based in California, is from March to May (Calflora, 2016). There is some variation in the flowering period since information based in Arizona and New Mexico stated it was from June to September (SEINet, n.d.).
- Seeds must be close to the soil surface in order to fulfill the light requirement for germination (Carta, Bedini, Müller, & Probert, 2013).
- A study by Cope and Stace found that the temperature is often too low in fall and winter for germination so it is usually delayed until spring (1978). However, another study determined that toad rush favors germination in winter but can germinate in spring if soil moisture is not limiting (Carta, Bedini, Müller, & Probert, 2013).
- The seeds rely on dormancy and are distributed throughout much of the soil depth. This study determined that 48 percent of toad rush seeds are deeper than 4 centimeters (Kotanen, 1997). Another study found that there were significantly more seeds germinating below 50 centimeters than above (Erkkila & Heli, 1998).
- A New Zealand study found that if there is a large seedbank, undisturbed and shallow cultivation of soil can suppress emergence of toad rush compared to deep cultivation (Popay, Cox, Ingle, & Kerr, 1994).

Dispersal:

- When seeds are wet, they become viscid and can attach to animals for travel. They could also be dispersed by wind or water and colonize on bare ground (Cope & Stace, 1978).
- Seeds are transported on the feet of wildlife including cattle, horses, and birds (Cope & Stace, 1978).
- Seeds are transported on feet as well as wheels of vehicles (Cope & Stace, 1978).
- The seeds of toad rush have been known to disperse by attaching to vehicles which then travel over 15,000 kilometers and germinate successfully (Cuba-Díaz, Troncoso, Cordero, Finot, & Rondanelli-Reyes, 2012).

Tolerances:

- Calflora lists the tolerances of toad rush as the following- elevation: 0 to 3010 meters, annual precipitation: 8 to 121 inches, wet season: 0 to 10 months, temperature range: less

than or equal to 66 degrees Fahrenheit, accumulated temperature: 8 to 253 degrees Fahrenheit, growing season: 0 to 12 months, hardiness zones: 6a to 11a (-10 to 45 degrees Fahrenheit), pH: 5.6 to 8.0, maximum salinity: 12 (moderately saline), minimum depth: 13 centimeters, textures: fine + medium + coarse, and maximum calcium carbonate: 3 percent (very low) (Calflora, 2016).
- It is not tolerant to shade or drought (CNPS, 2014).
- Toad rush is also intolerant to total submergence by salt-water (Cope & Stace, 1978).
- An Australia fire response database records over a 70 percent mortality when subject to 100 percent leaf scorch (NLM, 2011).
- The seed bank permits a quick recovery from unfavorable seasons and catastrophic mortalities caused by herbicide treatments, cultivation, and natural phenomena like flooding (Grime, Hodgson, & Hunt, 1988).

Threats:
- Toad rush faces no major threats to its population (IUCN, 2013).
- Other than aphids occasionally feeding on rushes, the genus is "fairly resilient" to insects and diseases that cause massive damage (GLANSIS, 2012).

Wildlife Interactions:
- Quail, muskrat, cottontail, songbirds, porcupines, waterfowl, and other small mammals feed on the seeds of rushes (GLANSIS, 2012).
- Horses, sheep, and cattle graze on rush (GLANSIS, 2012).
- The seed bank of toad rush is significantly reduced from grazing (Erkkila & Heli, 1998).
- Rush provides habitat for wetland birds and amphibians (GLANSIS, 2012).

Plant Interactions:
- Toad rush is often found with other wet area plants including bullrush (*Schoeoplectus* or *Scirpus* sp.), sedge (*Carex* or *Cyperus* sp.), cattail (*Typha* sp.), and spike-rush (*Eleocharis* sp.) (CNPS, 2014).
- Toleration for competition from other species or its own species is low (Cope & Stace, 1978).

Human Interactions:
- Toad rush is considered a weed in many areas and is rarely used for landscaping purposes. However, it is commonly available in nurseries (CNPS, 2014).
- While seedling numbers for most species declined with repeated deep cultivation in a New Zealand study, toad rush seedlings do not decline (Popay, Cox, Ingle, & Kerr, 1994).
- A study in Australia tried to eradicate toad rush from crop fields by using herbicides but they were not controlled by herbicides for grass. All herbicides tested, Bromoxynil, Bromoxynil + MCPA, Methabenzthiazuron + 2, 4-D, Dicamba + MCPA, and Terbutryne, reduced toad rush density but Terbutryne was very effective with a 97 percent reduction (Pratley, 1983).

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Restoration Plan for Toad Rush

Goals

Restoring toad rush to California's Central Valley would control erosion, aid in flood management, and provide habitat and food for wildlife. The process of restoring this environmentally beneficial plant can be achieved with the following goals:

1. Conserving any existing patches of toad rush

   Any successful establishment of toad rush should be conserved by preserving the current habitat indefinitely. These existing patches can also provide insight into what environmental conditions are favorable for the species.

2. Increasing the local population of toad rush by introducing the species after adjusting environmental conditions and removing invasive species

   Most of the Central Valley has conditions which fall within the species tolerances so most locations will not need any modifications other than possible irrigation since toad rush is drought intolerant (CNPS, 2014). The species also cannot tolerate competition with other species that are invasive (Cope & Stace, 1978).

3. Providing the habitat for a sustainable population that can produce positive environmental impacts while still providing adequate space for other beneficial species to establish and contribute for a more diverse community

   Toad rush can reproduce and spread without any human intention to do so, so much so that it is considered a weed in agriculture (Pratley, 1983). Considering this, it is important that toad rush does not crowd out other species which can positively contribute to the community.

Restoration Plan

These goals can be attained through a number of restoration plans. The following order begins with what is most feasible to more intensive plans which can be enacted if necessary for population growth or if resources permit:

1. Survey the site for existing establishment of toad rush

   If toad rush is already present on site, then the environmental conditions should be studied to determine what makes the species successful in that area. Some data that should be collected includes depth of water table, water availability throughout the year, soil pH, soil salinity, etc. This information could be helpful to conserve those existing plants and determine what areas without toad rush are similar and may do well with the introduction of the species. Since toad rush can be mostly self-sufficient in sustaining its population, conservation may be enough. However, if there is little to no existing population of the species, further action is required.

2. Determine areas with adequate existing conditions for toad rush to be introduced

   The introduction of toad rush is likely best done by seeding in versus transplanting because the seeds are persistent and successful at germinating with little or no human intervention (Kotanen, 1997). The seeds should be collected from June to September after the flowering period (Calflora, 2016). There is no known normal dormancy for toad rush's seeds although it is thought to be persistent. The seeds should be dispersed during spring so the temperature is high enough but there also must be ample water in order to germinate (Cope & Stace, 1978). It is also important that the seeds be close to the soil surface because light triggers germination (Carta, Bedini, Müller, & Probert, 2013).

   Since the species relies on seed dormancy, it does not require any specific planting configuration such as size of bare plots or the distance from edges of vegetation (Kotanen, 1997). Planting cannot be too dense because toad rush does not tolerate shade. However, the species can be mixed with companion plants including sedge, bulrush, cattail, and other wet habitat plants (CNPS, 2014).

3. Define sites that could be modified practically to support toad rush

   Out of all the environmental requirements for toad rush, the conditions that can be realistically altered include light and water availability. Sites with tall vegetation that provides few environmental benefits could be removed to provide direct light for better growth of toad rush. Water availability could also be improved by altering the banks of waterways into lower slopes that are closer to the water table. Before sites are adjusted, it is important to consider how these changes will affect other species already present.

Monitoring Plan

Pre-Restoration Monitoring

It would be beneficial to monitor the entire site for any existing population of toad rush. If the species is present, monitoring should be done over a few years to determine fluctuations in its population trends and the environmental conditions it is in. This would aid in achieving the goals of conserving existing patches and determining what sites could have toad rush introduced.

Post-Restoration Monitoring

Monitoring the population trend of toad rush by measuring the increase in size and number of patches will help determine if the species has established well. As these indicators of success improve, management can be reduced and the emphasis can be on monitoring. It is important that toad rush be monitored at least once every year since the species is an annual and, consequentially, has a shorter lifespan.

A large uncertainty for Central Valley's wetlands is how climate change will affect it. Most importantly, the water availability that is so vital for toad rush will change. Management and monitoring will become more important as this ecosystem adjusts to these environmental changes.

Thresholds

The most foreseeable threats to the goals listed previously is drought, an increase in toad rush that crowds out other species, and disturbances like flooding or fire. All require a planned threshold of action to prevent a continuation of these trajectories.

Drought

Toad rush's intolerance to drought is shown in a study where there was an absence of the species during dry years (6.6 inches) even if it was the most common species in the landscape during a wet year (26.9 inches) before (Callaway & Sabraw, 1994). Due to this relationship, it is important that the population size and water availability is compared. It is expected that toad rush will decline during drier years and intervention will not necessarily be needed since seeds persist and can restore the population once water availability increases again. However, if the population has decreased drastically, irrigation will be needed to sustain the remaining toad rush until there is more naturally available water.

Out-Competing Other Species

Due to toad rush's weed-like behavior, it may do too well and crowd out other species (Pratley, 1983). It is not only important to monitor its population every year but the population of other species that share toad rush's habitat as well. Toad rush may have fluctuations in its population from year to year such as when water is ample or scarce. However, if there is an increase in population for multiple consecutive years while other species decline, then some action will have to be taken. Grazing (Erkkila & Heli, 1998) and reducing that amount of soil disturbance (Popay, Cox, Ingle, & Kerr, 1994) should be enacted and repeated as necessary in order to significantly reduce the seed bank of toad rush and therefor reduce its future population.

Flooding or Fire

As a ruderal plant, disturbances are not as catastrophic to toad rush compared to other vegetation because it is one of the first species to colonize disturbed sites (Grime, Hodgson, & Hunt, 1988). If there was an existing strong presence of toad rush, the seed bank should provide a quick enough recovery from the natural disturbances of flooding or fire without any needed intervention. On the other hand, some seeding in will have to occur if there was little presence of the species before.

Research

Since there is little, if any, comprehensive information on the dormancy of toad rush seeds, it may be worth researching its persistence at the restoration site. This could be done by burying seeds in cloth bags that would then be excavated at different time periods such as every six months. The seeds would be examined to see if they are still viable to germinate. This would provide more understanding about how often the introduction of seeds is needed, how long to wait for the seed bank to restore a site after a disturbance, and many other actions that are affected by dormancy.

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Baltic rush (*Juncus balticus*)

Kingdom: *Plantae*
Subkingdom: *Virdiplantae*
Infrakingdom: *Streptophyta*
Superdivision: *Embryophyta*
Division: *Tracheophyta*
Subdivision: *Spermatophytina*
Class: *Magnoliopsida*
Superorder: *Lilianae*
Order: *Poales*
Family: *Juncaceae*
Genus: *Juncus L.*
Species: *Juncus balticus Willd*

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Background and justification

Baltic rush (*Juncus Balticus*), is a cool season perennial graminoid (DeFilipps 1964). It is a monecious plant that is a relatively widespread species rush that can be found on nearly every continent (Plant of the week). Baltic rush can reach up to three feet tall and can be identified by its brown flowering clusters, sturdy stems, and small scaly leaves located at the base (Plant of the week). The preferred environment is salt marshes and wetlands. Baltic rush can tolerate 2.5 - 8 cm of standing water as long as the level fluctuates over the growing season (USDA 2014). Baltic rush is not considered to be in decline. Baltic rush can be considered invasive in some areas; however, it can be used as an environmental control for out competing invasive species in areas that Baltic rush is considered native (Bard 2004). Baltic rush might be vulnerable to extended drought; Baltic rush can survive in saline soils, a wide range of pH, fires, and in flooded areas. Baltic rush can play a role in numerous ecological functions which can fix nitrogen (Tjepkema 1976), remove toxins in ground water, assist in erosion control and is also used by local wildlife. If plugs are used for restoration, the roots need to be thoroughly established. For plug propagation, roots need to be established before a flood, or the restoration may fail (Plants 2014). Baltic rush is a cool season species that reaches its maximum height by early summer and sets seed by mid- to late summer (Kinney 1994).

Project Goal

- To introduce Baltic rush or improve present communities in centennial park located in Vacaville CA. Baltic rush will be utilized to access its unique growth and restoration qualities with the intention of improving soil, maintaining ground moisture, removing potential toxins, and controlling invasive grasses.

Literature review

Habitat:

- Baltic rush can be found in mixed and deciduous forests, Shrub and grassland habitats, stream bank communities (Helms 1987), and salt marshes (Plants 2014).
- Wetland and damp soils. The environment does not necessarily have to wet all year (Plants 2014).
- Prefers poorly drained sandy clay loams to sandy loam soils (Svejcar 1998).
- Baltic rush is found in transition zones from salt to freshwater in the common river grass association (Looman 1981)

Growth characteristics:

- Baltic rush has a wide habitat tolerance, and can have very aggressive growth in wetland areas with the possible takeover of other species such as Basin Wildrye (Neuman 2006) (USDA 2014).
- Is efficient at pulling water from the ground, while maintaining a less negative pressure grasses (Svejcar 1998).
- Fine roots (<0.9 mm in diameter) often reach depths greater than 40 cm and the rhizomes never reached a depth greater than 4 inches 10 cm (Manning 1989)
- Optimal growth of Baltic rush plugs occurred when water levels were 3-5 cm below the soil surface (Beagle 1994)
- Hydrological planting zones range from 2-6 (Hoag 2011)

Reproduction:

- Bees have been known to pollinate Baltic rush, although it typically relies on the wind (Pojar 2006).
- Shoots of Baltic rush generally must grow on a 3 to 4 year old rhizome before they produce fruiting flowers. Baltic rush takes two to three years to attain maturity and is still incapable of flowering. Flowering does not occur in plants younger than four years (Stasiak 1994).
- Baltic rush can reproduce asexually from the youngest parts of the rhizome (Stasiak 1994).
- Manipulating the water level to rise and fall during the establishment period may speed spread (USDA)
- Small seeds at 7.5 million per pound, with a seedling rate of .3(lbs PLS/ac)
  PLS= Pounds of living seeds (Hoag 2011)
- Baltic rush has a persistent seed bank which can survive fire (WehKing 2002)

Tolerance:

- Can be found in a variety of settings but is most well-known for its saline soil resistances and the range of pH tolerance from 5.0 to 9.1 (Jeglum 1971).

- Both young and established communities have a limited drought tolerance, but can withstand seasonal droughts, but not prolonged droughts. (USDA 2014)
- Anoxic soils, floods, shade, moderate to mild soil salinity, and calcareous soils are all tolerable for Baltic rush, at least for a brief time (plants 2014)
- Requires a minimum of 90 days free of frost for growth (plants)
- Shade intolerant (Stasiak 1994).
- Moderately resilient to insect and disease problems. Aphids may feed on the stems, but rarely cause noticeable damage (USDA).
- High flood tolerance, however; roots must be established before the flood or the plants will fail (USDA)

Fire:

- Because Baltic rush is capable of growing back so quickly, it may have potential, prescribed fires may be used for enhancing growth (Baily 1979).
- Baltic Rush can grow back quickly after fires (Hargis 1986).
- Dormant Baltic rush is fire tolerant while it is dormant and the seeds in the soil can survive a fire (plants 2014).
- Baltic rush can adapt to a wide variety of fire regimes, ranging from every year to every hundreds of years (Payson 2000).

Propagation:

- Plants should be planted in the early fall before the rainy season, dormant plants and moist soil will lead to the highest success rate (Plants 2014). The flowering period in California is from May to August (Munz).
- Plug propagation is the most efficient way of incorporation Baltic rush to a new site; seeds are inefficient (Plants 2014).
- Plugs should be placed about 30 cm away from each other. The plugs should fill in the negative space within one growing season (Plants 2014).

Wildlife:

- Waterfowl and some songbirds use Baltic rush for cover from raptors as well as parts for constructing nests (Gilbert 1996).
- Cattle have been known to graze on the plant, but it will not be a significant portion of the diet and will typically be eaten last (Evans 2011).

Human uses:

- Baltic rush has been used historically by Native Americans for basket weaving. They also consumed the seeds and stems (Plants 2014).

Potential Benefits

Erosion:

- Baltic rush has been known to have moderate particle erosion, in comparison to conventional grasses that have a high amount of particle erosion (Dunaway 1994). Baltic Rush has also been known to have a lower overall erosion rate (Dunaway 1994).

Environment:

- Baltic rush has shown much promise in the removal of selenium in wetland settings. Up to 50% of the selenium from the inflow has been known to be removed by Baltic rush, as well as an 80% decrease in the selenium that can be found in the sediment (Gao 2003).
- Has a greater capacity to maintain moisture around its leaves, making its own microclimate and increasing moisture above the soil (Svejcar 1998).
- Has been used in the construction of wetlands ponds (USDA 1994).

Nutrients:

- Baltic rush is effective at the recycling of nutrients back into the soil. The litter from the rush contains large biomass percentages of both carbon and nitrogen. Approximately 43% of the litter biomass is carbon and over 1% is nitrogen. This can be almost double the percentage of other wetland grass species (Ray 2006). Although this percentage seems small, it's over 17 g/m2 of nitrogen added back into the soil. For a comparison, potato crops have 16 g/m2 of industrial fertilizer added (Gasser 2003)
- Baltic rush can also contribute significant amounts of organic matter through the litter that is deposited with these nutrients (Ray 2006).
- Phosphorus is found in the litter of Baltic rush at higher rates as well, at around .9 g/m2. (Ray 2006).
- Has a high affinity for fixing N2; however this comes at the cost of the creation of about three acetylene for every one nitrogen fixed, bacterial association accounts for the N fixation. (Tjepkema 1976)

Most research of Baltic rush has been done outside California with a few exceptions, and of those exceptions the studied areas are not in the central Valley. Most California studies on Baltic rush are done closer to the coast, in salt marshes.

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Restoration Plan for Baltic Rush

Restoration or introduction of Baltic rush is vital to improving present communities in Centennial Park located in Vacaville CA. Baltic rush can improve soil, maintaining ground moisture, removing potential toxins such as selenium and wastewater (USDA 2014), and controlling invasive grasses in areas where it is considered native (Bard 2004). Baltic rush works great in tandem with other wetland species, because of its ability to maintain moisture in the immediate area of the plant, which will assist in moisture availability for another plant (Svejcar 1998). Baltic rush has shown much promise in the removal of selenium in wetland settings. Baltic Rush not only has the potential to help other plant restoration projects but can also help local waterfowl and some songbirds, which use Baltic rush for cover from raptors as well as parts for constructing nests (Gilbert 1996).

The first goal should be determining if there is a preexisting populations of Baltic rush at the site, and determining the preferred habitat in which the present species thrives. If there is no Baltic Rush present, areas should be determined where there is potential to support Baltic Rush. The second goal is to alter the areas that could potentially support Baltic rush. The third goal involves Selenium surveys before initial propagation, to find where Baltic rush may be planted to have the greater effect when cleaning up Selenium, erosion surveys should also be done in areas where Baltic rush could be used to prevent possible erosion. The third goal highlights areas where Baltic rush could be best utilized but is not limited to those areas. The final goal should be to create a Baltic rush population that can sustain itself and have a slow outward spread that will be able to match or outcompete the invasive species present.

The success of Baltic rush introduction should be determined by the surviving plugs and total cover provided in a 1m x 1m square where Baltic rush has been planted. After one year the cover in that same square should be around 70-80% total cover as it is expected to cover space between plugs after a single growing season. A decrease in erosion or possible increase in stream bank topography by increased particulate buildup around the Baltic Rush is a success for erosion control. Selenium reduction of sediment around 70% per year should be considered a success, depending if there is a large amount of selenium present. A reduction of invasive species around the areas where Baltic Rush is planted, from the spread of Baltic Rush's rhizome at any rate should be considered a success.

Revegetation Preparation: Numerous surveys should be done including hydrology, soil, shade coverage, pH, and salinity, to establish ideal areas for Baltic rush to be planted. Baltic Rush can be found in a variety of settings but is most well-known for its resistance to higher salinity levels that have been measured as specific conductivity that ranges between .1 and 20.1 mS (Kantrud), for contrast sea water has a salinity of 53 mS. Baltic rush also has a broad range of pH tolerance from which can vary between 5.0 to 9.1 (Jeglum 1971). Anoxic soils, floods, shade, moderate to mild soil salinity, and calcareous soils are all tolerable for Baltic rush, at least for a brief time (PLANTS 2014). Baltic rush may be able to have a high tolerance for many of these factors; plugs should reproduce outward through its rhizome. Plugs would be the best option for restoration efforts through Baltic rush as seeds dispersal can be both expensive and inefficient. For plug propagation, roots need to be established before flooding occurs in the winter, or the restoration may fail (PLANTS 2014). The plugs should be placed about 30 cm away from each other. The plugs should fill in the negative space within one growing season (PLANTS 2014). Three to four years after the initial plug propagation the plant will be mature, which will allow the formation of fruiting flowers. When flowering occurs after maturation, Wind is the primary pollinator of Baltic rush (Richards 1941),bees have been known to pollinate also (Pojar 2006). After pollination occurs, there is germination, which primarily reliant on moisture, light and heat. (USDA 2014). Soil moisture can be difficult to maintain in the high temperatures that occur in the central valley, Baltic rush can hold onto moisture in it leaves and above the soil (Svejcar 1998). Baltic rush can reproduce asexually through the youngest part of the establish rhizome as well as natural seed dispersal (Stasiak). The seeds are typically transported through the wind, which will be beneficial to the spread of Baltic rush at the site due to the low tree population. However the average wind speed of the Vacaville area is around five mph (Vacaville), so it is not strong enough to remove the potential seeds entirely. Once a Baltic Rush population is established in the restoration area it should be able to self-perpetuate after maturation, through the plants ability to maintain moisture and the developed rhizome creating new plants. Any control burn that occurs at the site may prove beneficial as Baltic rush can have a persistent seed bank that is capable of surviving fire (PLANTS 2014). Relying primarily on seed dispersal after the initial plugs may not be the best way to carry out revegetation as the viability of the seeds can range widely between 28% and 96% (Shaw 1994). The gradual spread of the Baltic rush rhizome is the primary way that Baltic rush will spread, but this will make it difficult for new populations to arise elsewhere on the site.

Conservation: Baltic rush is found in a variety of environments, there is no need to conserve the species, as it is found in many locations. Baltic Rush does present an array of beneficial service to the environment which can have benefits for local human population, as well as local flora and fauna. Baltic rush has been known to have moderate particle erosion prevention, in comparison to conventional grasses that can be found in typical wetland setting that have high amounts of particle erosion Baltic Rush has also been known to have a lower overall erosion rate (Dunaway 1994). Baltic rush has shown much promise in the removal of toxins found in water such as selenium in wetland settings. Selenium has shown multitudes of adverse effects on waterfowl and other bird species. Up to 50% of the selenium from the inflow has been known to be removed by Baltic rush, as well as an 80% decrease in the selenium that can be found in the sediment (Gao 2003). Baltic rush has also been used in the construction of wetlands ponds (USDA 1994), which may assist with the concerns of flooding that have been presented on the site. The wetland ponds would also prove to be helpful for the rejuvenation of animals, in particular with the drought problems that come with being located in the central valley of California.

Habitat modification: Little to no modification may be needed to the site. Baltic rush is a very versatile plant that is capable of growing in a variety of areas such as deciduous forests, Shrub and grassland habitats, stream bank communities (Helms 1987), and salt marshes (Plants 204). Any modification that may be needed is a drip system in more water strained areas, and the initial removal of invasive to allow initial populations to grown.

Transplanting: Seedlings should be planted in the early fall before the rainy season to have the greatest success in establishing roots before any possible floods occur; however, optimal growth of Baltic rush plugs occurred when water levels were 3-5 cm below the soil surface, so some moisture is needed (Beagle 1994). It is important to remember that Baltic Rush requires a minimum of 90 days free of frost for growth in younger plants (plants), so monitoring frost protection, and proper transplanting times should be in place for the plug planting. The initial frost of the area typically occurs late November (Hardiness Zone), which would occur shortly after the plugs have been placed. Dormant plants and moist soil will lead to the highest success rate (PLANTS 2014). Creating dormant plants in a greenhouse may be difficult; it is recommended that seeds are soaked in water for 1- days to decrease the time it takes to sprout. The seeds should be kept in moist soil, with an air temperature around 32-38C. Germination should occur in approximately one week, and ready for transplant in 100-120 days (USDA 2014). Organization of how the plugs are spread out is very crucial, if they are too close you will have two competing plants, if they are too far away, it won't make use of the Baltic rushes impressive capabilities that allow it to hold onto moisture near its leaves and soil surface (Svejcar 1998). The flowering period in California is from May to August (Munz), and Seeds are released by mid- to late summer (Kirby).

Management & Monitoring: The initial planting of the plugs should be monitored, as well as a supply of adequate amounts of water through a drip system, especially in times of drought. The plant will be able to survive on its own through the perpetuation of its rhizome. Baltic rush is capable of surviving floods and drought; however is a drought or flood occurs there should be specialized follow-up surveys to see how the Baltic rush can handle the extreme conditions. A flood or severe drought shortly after propagation may kill the plants Baltic rush; however even young and established Baltic rush communities have a limited drought tolerance (USDA 2014). Selenium surveys should be conducted to monitor any change that has occurred in the fall to determine how the growing season has effected selenium concentrations. Erosion should be monitored before and after winter to get a perspective on the overall loss of topsoil and possible water bank expansion; surveys should also be conducted following heavy rain or a flooding events. After the plugs mature and are capable of reproduction, they should be monitored every spring, to measure the rate at which the Baltic rush spreads through cover surveys that measure percentage cover; because it is known to spread rather rapidly it may interfere with other restoration sites (Neuman 2006). If the Baltic rush doesn't grow quick enough further restoration efforts may be needed, by doing a second planting in the prescribed area. Monitoring and management plan is subject to change based on changing climate conditions.

More research should be done on how quickly the plants rhizome spreads, and how Baltic rush reacts to various pesticides and herbicides.

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Carex deweyana ssp. leptopoda

(Slender-footed sedge, taperfruit shortscale sedge)
Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Liliopsida
Subclass: Commelinidae
Order: Cyperales
Family: Cyperaceae
Genus: Carex L.
Species: Carex leptopoda Mack.
Alternate names: Carex deweyana, Carex deweyana var. leptopoda, Carex deweyana ssp. leptopoda, Carex leptopoda (CalFlora, 2016)

Background and Justification:

Carex deweyana ssp. leptopoda is a native sedge that is found in wetland habitats, riparian areas, and forests within California (USDA, 2016). While this sedge is not threatened in California, it is important to habitat restoration due to the fact that it is found in wetlands and riparian areas. Within California, over 90 percent of the wetlands have been lost due to human alterations (NOAA, 2016). These alterations include diverting water, draining the wetlands, dredging the wetlands for development purposes, and many other activities (NOAA, 2016). Groups such as governmental agencies and restoration teams have been actively working to protect and restore wetlands in California as they provide many ecosystem services, such as flood control and shoreline maintenance (NOAA, 2016). Moreover, riparian areas serve many of the same functions as wetlands, and they have been increasingly altered and destroyed by human interference (Human Alterations of Riparian Areas, 2002). Thus, Carex leptopoda, along with other core wetland and riparian species, is important for restoration because it is present in two habitat types that are currently a major concern and focus for restoration groups. While Carex leptopoda is not currently threatened, its status could worsen if riparian and wetland areas continue to be altered and degraded. In addition, studies have been conducted showing that Carex leptopoda grows in lower densities in the presence of certain invasive species, such as reed canarygrass (Fierke & Kauffman, 2006). Therefore, it has multiple threats that are currently affecting its presence within habitats. Ultimately, Carex leptopoda should be restored and reinstated in ecosystems because it has a great amount of conservation value. Specifically, the sedge provides erosion control for the area in which it is planted, especially when it is established on slopes (Weeks, 2012). It is also adapted to natural levels of grazing, which is an interaction that frequently occurs in California (Schwartz & Mitchell, 1945). Moreover, it is an ideal sedge to plant in meadows that are accessed by humans as it is resilient to foot traffic (Weeks, 2012). Carex leptopoda provides many beneficial services to the habitats in which it is found, and its presence can indicate a healthy wetland or riparian area. Thus, the restoration of Carex leptopoda should be a main focus during the project.

Fact Sheet
Project Goal: The goal for Carex leptopoda is to facilitate its growth in stream side areas that arecurrently dominated by invasive species. An additional goal is to restore the riparian areas backto healthy, natural conditions in order for riparian species, such as Carex leptopoda, to thrive.

Growth Characteristics:
• Carex leptopoda is a perennial, monocot sedge that exhibits characteristics similar to grasses (CalFlora, 2016).
• Carex leptopoda tends to grow in thick clumps (Jepson Herbarium, 2016).
• Its growing season within California ranges from 0 to 9 months, but the start and end months of the growing season in California were not specified by the CalFlora website. (CalFlora, 2016) (see gaps in knowledge). However, its growing season within nurseries starts in late April and ends in mid-October (Propagation Protocol, 2014).
• The mature height of the sedge ranges from 8 inches to 48 inches (Portland Plant List, 2011).
• Its stem ranges from 20 centimeters to 80 centimeters in length. Additionally, its leaf blade ranges from 2.4 millimeters to 5.9 millimeters in width (Jepson Herbarium, 2016).
• The only root information found is that it has a minimum root depth of 10 inches, and its roots form an upright rootstalk (Cannon Valley Nursery, 2016),
• Carex leptopoda grows extremely quickly and has no rhizomes (Sound Native Plants, 2016).
• It takes about 4 weeks for the sedge to become established, and its active growth phase lasts about 10 weeks after establishment (Propagation Protocol, 2014).
• Following germination, the roots and shoot develop extremely quickly (Propagation Protocol, 2014).
Reproduction:
• Carex leptopoda reproduces through seeds, which are created in bunches by the pistillate spikes within the fruit (Zukowski et al., 2010)(Minnesota Wildflowers, 2016). However, the number of seeds produced per sedge is unknown (see gaps in knowledge).
• The sedge can fruit within the months of May, June, July, and August (Jepson Herbarium, 2016).
• The sedge produces tiny, green fruit that have a pointy end and an oval shape (Jepson Herbarium, 2016).
• Around 40% of the seeds produced by the sedge successfully germinate. The soil needs to be damp in order for germination to occur (Propagation Protocol, 2014).
• Germination occurs at temperatures above or equal to 22° C (Propagation Protocol, 2014).
• Carex leptopoda can be successfully transplanted (Sound Native Plants, 2016).
• It must be noted that most of the propagation and reproduction details are found in reports from Washington and Minnesota. Thus, there may be some variability in propagation details within the Central Valley.

Range and Habitat:
• Carex leptopoda's native range includes California, Nevada, Oregon, Washington, Arizona, New Mexico, Colorado, Wyoming, Montana, Idaho, and the northwestern part of Canada (USDA, 2016).
• Within California, Carex leptopoda is found in many counties. These counties include: Alameda, Alpine, Amador, Butte, Calaveras, Del Norte, El Dorado, Fresno, Glenn, Humboldt,

Inyo, Lake, Madera, Mendocino, Mono, Monterey, Modoc, Mariposa, Marin, Napa, Nevada, Placer, Plumas, San Bernardino, Santa Cruz, Siskiyou, San Mateo, Sonoma, Tehama, Trinity, Tulare, and Yuba (CalFlora, 2016).

• Carex leptopoda thrives in wetlands, forests, and riparian areas (Portland Plant List, 2011). Throughout California, Carex leptopoda can be found in many different communities. These communities include coastal sage scrub areas, coastal prairies, red fir forests, yellow pine forests, Douglas fir forests, seasonal wetlands, and general riparian areas (CalFlora, 2016). Essentially, Carex leptopoda thrives in areas with damp soil and woody vegetation (Jepson Herbarium, 2016).

• Depending on the specific region, Carex leptopoda has a wetland status of either FAC or FACW. FACW means that the sedge is typically found in wetlands but can sometimes be found in non-wetland areas, while FAC means that it is commonly found in both wetland and nonwetland areas (USDA, 2016).

• It is commonly found in areas with a water table that frequently varies (Ceska and Sagel, 1995). However, the level of variation and the specific amount of water required from the water table is not known (see gaps in knowledge).

• Carex leptopoda's elevation range spans from 10 meters to 3,120 meters above sea level, and it grows well on slopes (CalFlora, 2016).

• Specific to the California Central Valley, Carex leptopoda is mainly found in the northern part of the valley as well as the foothills and coastal ranges that border it (Jepson Herbarium, 2016).

Requirements:

• The amount of annual precipitation that the sedge can endure ranges from 28 to 117 inches (CalFlora, 2016).

• Carex leptopoda is found in areas with a wet season that ranges from 7 to 10 months (CalFlora, 2016).

• Carex leptopoda can grow in moist soils as well as seasonally flooded areas (Christy, 2004). However, the specific depth of the water as well as the height from the water that it requires is not known (see gaps in knowledge).

• Carex leptopoda is a shade tolerant species and grows best in partial or full shade (Sound Native Plants, 2016).

• Carex leptopoda tolerates a "July High" of 88°F and a "December Low" of 14°F. According to CalFlora, the "July High" and "December Low" are calculated using "average minimum monthly data during the period 1981-2010" (CalFlora, 2016).

• Carex leptopoda has been recorded in sandy, loam, and clay loam soils (Christy, 2004) (Fonda, 1974).

• It is typically found in soils that are very rich in nitrogen (Ceska and Sagel, 1995).

Tolerances:

• Carex leptopoda populations remain stable during debris flow disturbances (Pabst & Spies, 2001). It must be noted that the study containing this information was conducted in Oregon.

• The sedge can tolerate and withstand foot traffic. It can also be kept in check by a lawn mower or string trimmer (Weeks, 2012).

• Once established, the sedge can tolerate periods of drought (Weeks, 2012). It takes about 4 weeks for the sedge to establish, but the general length of the drought period is unknown

(Propagation Protocol, 2014) (see gaps in knowledge).
• A study conducted in Washington found that the sedge could establish itself in gravel bars as well as in older areas covered by sand (Fonda, 1974).
• Carex leptopoda can tolerate and is adapted to grazing (Schwartz & Mitchell, 1945).

Wildlife Interactions:
• Species, such as the Roosevelt elk, consume the sedge. Specifically, the elk mainly feed on the leaves of Carex leptopoda during the spring (Schwartz & Mitchell, 1945).
• A study by Washington State recorded that Carex deweyana species act as host to eight different fungal species within the pacific northwest (PNW Fungal Database, 2016).

Wildlife Interactions- Threats:
• The abundance of Carex leptopoda decreases with the presence of invasive earthworm species (Corio et al., 2009).
• Because Carex leptopoda is a host to many fungal species, it is susceptible to fungal infections (PNW Fungal Database, 2016).

Plant Interactions:
• Carex leptopoda tends to grow alongside Carex hendersonii (Ceska & Scagel, 1995).
• In forests, the sedge grows alongside other herbaceous species in the understory layer. Specifically, it is the most commonly encountered sedge within understory vegetation of forests located in western Oregon and Washington (Fourth Corner Nurseries, 2016).
• There was no information found in regards to what species the sedge frequently associates with besides Carex hendersonii (see gaps in knowledge).

Plant Interactions- Threats:
• A study conducted in Oregon shows that the presence of Carex leptopoda is negatively correlated with the presence of reed canarygrass, an invasive species (Fierke & Kauffman, 2006).

Anthropogenic Threats:
• Human alterations to riparian areas are a huge threat to Carex leptopoda. These alterations include water diversion, groundwater removal, dam construction, urbanization, and changing the native species composition (Patten, 1998).
• Wetland loss caused by human activities is another major threat to all species found in wetlands (NOAA, 2016).

Ecosystem Services:
• People have planted Carex species within meadows due to the high amounts of foot traffic. This can be observed on the Cal Poly San Luis Obispo campus (Weeks, 2012).
• Because Carex species provide erosion control, people tend to plant them along slopes within their gardens (Weeks, 2012).

Management Practices:
• While this study was not conducted in California, it discusses how to go about restoring native sedge vegetation by eradicating invasive species through the use of herbicides (Simpson, 2009).

Gaps in Knowledge:

- Number of seeds produced per sedge
- The start and end months of the growing season in California
- Necessary level of variation of the water table
- Specific amount of water required from the water table
- Necessary depth of the water table
- Height/ distance of the sedge from the water table
- General length of the drought period that it can tolerate
- Other species that the sedge frequently associates with besides Carex herndersonii

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Restoration Plan

Carex leptopoda is an ideal sedge to plant in areas where both wildlife and humans are present. In addition to providing erosion control, the sedge acts as a food source for wildlife and can thrive in areas where foot traffic is prevalent (Weeks, 2012), (Schwartz & Mitchell, 1945). Moreover, the presence of Carex leptopoda in the Central Valley indicates the healthy state of both wetland and riparian areas, two habitats that are highly modified and degraded in California (NOAA, 2016). Thus, its restoration is important as its presence provides benefits to organisms around it and indicates the condition of critical native habitats.

Short-Term Goals

• **Identify areas within the Central Valley where Carex leptopoda currently grows:** There is little information available for the sedge that is specific to the Central Valley. While Carex leptopoda grows in a variety of habitats across California, it will be found in wetland and riparian areas within the Central Valley (CalFlora, 2016). One can essentially obtain an idea of the conditions in which Carex leptopoda thrives by identifying these specific areas.
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Additionally, knowing these habitat conditions and monitoring the success of the sedge in

certain areas is key to figuring out some of the current gaps in knowledge that exist.
• **Plant Carex leptopoda in suitable areas:** This is where the measurable goal for monitoring is defined. One should determine the specific coverage goal for the sedge within one year after planting. Carex leptopoda grows low to the ground in thick, dense clumps (Sound Native Plants, 2016). The specific coverage goal for the sedge simply depends on the size of the restoration area and how much space one wants the sedge to cover.

Long-Term Goals
• **Determine areas within the Central Valley in which Carex leptopoda could potentially grow and actively restore them to ensure future expansion and longevity of the sedge:** This goal is crucial for the restoration of wetland and riparian areas in the Central Valley. While Carex leptopoda is not a threatened species, wetlands and riparian areas have been lost due to human alteration or drastically modified (NOAA, 2016). Identifying and modifying areas where Carex leptopoda could potentially grow helps to restore critical native habitat in the Central Valley. It is expected that this long-term goal of restoring wetland and riparian areas will take up to 50 years (USGS, 2016).

Restoration Plan
Identify Areas and Conditions in which it Thrives: The first step of the restoration plan entails identifying areas within the valley where Carex leptopoda currently grows. This can be done by conducting a population survey and assessing the habitat conditions in which populations are present. This is an important first step in the plan because there are currently some essential gaps
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in knowledge that could be understood by identifying where it thrives in nature. The conditions that are not currently understood based on extensive literature reviews include:
• The location on slopes and proximity to the water source. It is known that Carex leptopoda grows well on slopes, and it is found in or close to the riparian zone (Sound Native Plants, 2016). It is also known that Carex leptopoda prefers moist soil and can tolerate seasonally flooded areas (Christy, 2004). Additionally, Carex leptopoda's close relative, Carex deweyana, thrives in swamps and wet meadows (Mount Pisgah, 2016). From this information, one can infer that Carex leptopoda would successfully grow close to the water source. However, directly observing the sedge in nature would give one a better understanding as to where to plant the sedge during restoration.
• The distance to and the variability of the water table. It is known that Carex leptopoda prefers a varying water table, but the degree of variability and the distance to the water table could not be found.
• Plant interactions common in the Central Valley. It is known that Carex letpopoda tends to grow alongside herbaceous species, specifically other Carex species (Fourth Corner Nurseries, 2016). It is also known that its presence decreases with the presence of reed canarygrass, an invasive species (Fierke & Kauffman, 2006). While this information is helpful, observing the sedge in nature could reveal any unknown competitors of the sedge. Additionally, understanding the species around which it is commonly found in the Central Valley helps one to identify suitable areas to plant the sedge.

Identify and modify potential areas within the Central Valley: Wetland and riparian areas have been drastically modified in the Central Valley due to human activity. Specifically, over 90 percent of the wetlands have been lost due to human alterations, and a majority of the riparian zones within the United States have been altered or damaged (NOAA, 2016) (Chapter 3, 2002). These alterations include water diversion, groundwater removal, dam construction, urbanization, and changing the native species composition (Patten, 1998). While these habitats have been highly altered, they still have the potential to support Carex leptopoda and other wetland species. In order to restore these ecosystems back to a more natural state, restoration teams must focus on eradicating invasive species, creating a more natural stream flow, and removing pollutants caused by agriculture and urbanization (Chapter 3, 2002). Once these habitat modifications are achieved, species such as Carex leptopoda can be introduced. The restoration of wetlands and riparian areas would ensure the the future success of Carex leptopoda. As mentioned above, this could take up to 50 years (USGS, 2016).

Planting Process

Seed Collection: Once the areas in which to plant the sedge are determined, seed collection is the first process for restoring Carex leptopoda. There are two ways in which seeds could be collected for Carex leptopoda. One way that seeds could be collected is by purchasing them from a nursery. There are three nurseries in California that contain seeds for Carex leptopoda. These nurseries include Bay Natives, East Bay Wilds, and Native Here Nursery (CNPLX, 2016). Another way that seeds could be collected is by collecting them from the sedge itself. The sedge flowers around late spring or early summer, and the seeds must be collected in late August when the perigynia can be removed from the sedge without difficulty (Propagation Protocol, 2014). This collection method is most convenient if sedges can be found in a nearby area. It would also be less costly than purchasing the seeds directly from a nursery.

Propagation Details- Preparing the Plugs: Once the seeds are collected, they must be placed in 160 milliliter plug containers within a nursery. It must first be noted that only 40 percent of the seeds are expected to successfully germinate (Propagation Protocol, 2014). Additionally, this process should take place a little over a year before one intends to plant (Propagation Protocol, 2014). The first step of the propagation process is to plant the seeds directly into the plug containers in the fall. Next, the seeds must endure a winter stratification period. Specifically, the seeds must be exposed to cold, damp soil for 5 months. The seeds must be kept outside during this period (Propagation Protocol, 2014). After stratification, the seeds enter their growth stage. This stage begins in late April and ends in mid-October (Propagation Protocol, 2014). Within the growth stage, the seeds first establish themselves through germination. This takes approximately 4 weeks and occurs at temperatures above or equal to 22° C . After establishment, the seeds enter their 10-week active growth phase. In this phase, the roots and shoots develop extremely quickly, and the roots should be fully developed at the end of the 10 weeks (Propagation Protocol, 2014). Finally, the plant enters the hardening phase, which lasts around 8 weeks (Propagation Protocol, 2014). The goal for the sedge at the end of the propagation process is the establishment of 6 to 10 leaves and a sedge height of 15 centimeters, which takes about 11 months in total (Propagation Protocol, 2014). Once this occurs, the sedges are ready to be transplanted from the nursery to the restoration site in the fall or winter.

Transplanting: If there is no established on-site irrigation system, the most ideal time to transplant plugs of Carex leptopoda is in December, January, or February (Hedgerow Farms, 2016). If there is an irrigation system, however, plugs can be transplanted up until May (Hedgerow Farms, 2016). Prior to transplanting, measures must be taken to ensure that the habitat is suitable for plugs. This entails making sure that the soil is moist and that the invasive weed species are eradicated prior to planting (Hedgerow Farms, 2016). The most effective way to eradicate weed species is by spraying them with herbicide. This must be done at least two days before planting occurs (Hedgerow Farms, 2016). Once weed eradication is accomplished, the plugs can be transplanted using a dibble stick. This stick creates a hole in the soil that is roughly the same size as the plug, and the plug can be inserted directly into the hole by hand. The bottom of the plug must hit the bottom of the hole, and the top of the plug should be compacted with soil to ensure that it is sealed in the ground (Hedgerow Farms, 2016). The distance between each plug ultimately depends on the desired density of Carex leptopoda. To meet the coverage goal within the first year, one should plant 9-27 plugs per every square yard in the area (Hedgerow Farms, 2016). After transplanting, monitoring and management techniques are implemented.

Potential Problems and Risks: There are some potential problems that could occur during the restoration of Carex leptopoda. First, because little information specific to the Central Valley is available, there could be unknown factors that might negatively affect the restoration of the sedge, such as an unforeseen competitor or pathogen of the sedge. Moreover, there are potential problems that could occur during the plugging stage. Specifically, moist plugs are susceptible to mildew, fungal species, and rust before they are planted (Hedgerow Farms, 2016). Fungicides can be used to avoid this problem (Hedgerow Farms, 2016). Additionally, it is possible that the current California drought could affect the success rate of the plugs on the restoration site. Carex leptopoda plugs require moist soil conditions for the first few months in order to survive on the site (Hedgerow Farms, 2016). In the case that a lack of precipitation severely limits soil moisture, the plugs would have a hard time surviving in the first few months after being planted. In the case that there is little precipitation, an irrigation system could be established to aid the plugs.

Monitoring Plan

In order to gauge the success of the restoration plan, multiple monitoring techniques can be implemented. First, prior to restoration of the sedge, one needs to ensure that the area is suitable for the sedge through weed eradication (Hedgerow Farms, 2016). Upon planting the plugs, management techniques can be used to maximize the chances of reaching the coverage goal within one year. This includes applying pre-emergent herbicides directly after planting the plugs in an attempt to prevent weed establishment as well as eradicating weeds with methods such as hand weeding every few weeks (Hedgerow Farms, 2016) (Bohnen et. al, 1997). Once it has reached one year since planting, the amount of Carex leptopoda should be assessed. In the case that only a few sporadic areas were covered by the sedge or all of the plugs failed to establish, one should replant plugs in the upcoming fall in the vacant areas. It would be suggested, however, to establish an irrigation line prior to the second round of planting so that the plugs have a greater success of surviving (Hedgerow Farms, 2016). In the case that the plugs do not survive after the second round of planting, this would indicate that the site is not conducive to supporting Carex leptopoda. This failure can be utilized as a learning experience to better understand the conditions in which Carex leptopoda cannot be supported.

One question that this monitoring plan can answer is when and how drastically the frequency of management practices can be reduced for Carex leptopoda. Ultimately, the necessary weed management of wetland species, including Carex leptopoda, will decrease the longer it survives on the site (Bohnen et. al, 1997). This will be determined in the monitoring stage through direct observation of how the weed establishment rate decreases as time progresses (Bohnen et. al, 1997). Additionally, one research question that needs to be answered in order to improve this plan is the effect of climate change on wetlands. Wetlands are currently experiencing a huge shift in ecosystem dynamics as a result of climate change. For example, water has been getting warmer and higher in some areas, causing a shift in species composition (NWF, 2016). Organisms that typically thrive in these ecosystems might not be able to survive. These new dynamics must be known to understand how and if Carex leptopoda could be actively restored in wetlands in the near future.

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*Typha laifolia (*Broadleaf cattail)

Background and Justification

The Common Cattail is important to manage for many reasons. It is the home of small animals the nesting ground for some birds like Red-winged blackbird and main food source for muskrats. They are also a possible option for grazing cattle and in some cases necessary for the success of neighboring plants(Gucker, 2008). The Common Cattail has a high tolerance for salinity, fire, floods and alkaline environments (Mason, 1957). This is because of its series of successive growth and seed dispersal. The Common Cattail communities in California can be found all along the wetlands of the central valley, San Francisco Bay, along the Sacramento and San Joaquin rivers and any area that is disturbed and wet. Due to their resilience to poor conditions Cattails can move into that wet and sunny area fairly quick. Typically the Cattails have quick regeneration from the presence rhizomes and developed lower stalks. If the wetland becomes dry for a long period of time, which is highly likely due to the current drought, the cattail are very susceptible to fire(Gucker, 2008). The risk of fire occurrences could be detrimental to neighboring plants and wildlife. So this needs to be taken into consideration when restoring and managing the growth of the Common Cattail.

Literature Review

Growth Characteristics

- The cattail is a perennial plant, meaning that it lives longer than 2 years. The cattail starts flowering after 2 years, they are fully mature (Gucker, 2008).
- Above ground the Common Cattails grow between 3 - 10 feet tall. Below ground, depending on the substrate conditions the rhizomes of the Broadleaf cattail can be as long as 28 inches horizontally with 0.2 to 1.2 inches of fibrous roots. Or they can be 3 -8 inches deep and branch out as they go down. (Gucker, 2008)
- Depending on the soil moisture and temperature of the region, some cattails can have over 50% of their total biomass underground. This biomass consists of shoot bases, rhizomes and roots. The shoot bases and rhizomes from the year prior decompose and the carbohydrates are stored for the next shoot growing period. This helps the Broadleaf cattail with vegetative regeneration. (Smith et al., 1988)
- In the first year the Rhizomes elongate in the begging of summer and the next year stem will shoot, growth annually can be up to 2 feet a year. (Sojda and Solberg, 1993)
- Usually the above ground shoot growth will start in late April and increase mid-May. Secondary shoots start growing in late July- early September. Below ground in the beginning of June new rhizomes start to grow, decomposed shoots from the last year which then makes up the underground carbohydrate storage over winter (Smith et al, 1988).

Reproductive Characteristics

- The cattail will regenerate asexually from sprouts rhizomes and sexually from seed germination. The cattail puts priority on developing rhizomes before establishing seeds. This makes them good competitors against non-natives, they will not be able to establish if cattail has developed dense rhizomes already (Gucker, 2008).
- Cross pollination between two flowers is possible because the female cattail flower will mature first. Flowering of the cattail is suggested to be most successful when there is little to no shade and the roots are not completely under the water. (Gucker, 2008)
- Seed production is done by the cattails that are in their second year of growth.(Gucker, 2008)
- Seed dispersal is done by water, wind and substrate movement. Cattails have many hairs at the base of their achenes, which help the fruits to be carried by the wind, float in water or to catch on to a moving animal walking by. The seeds may also not disperse until the next spring and some may not open and disperse at all. (Gucker, 2008)
- A single cattail can produce as many 250,000 seeds, and the dispersed seeds can remain viable for as long as 100 years, although this fact has not been fully studied, data suggest that the seed bank longevity is a very long time. (Sojda and Solberg, 1993)
- Rhizome growth lasts for 2 years and then it dies off after the 2nd summer, by this time the rhizome growth can make up over 50% of the Cattails entire biomass, depending on the environmental conditions. They will decompose, regenerate asexually, and then grow again for another 2 years (Gucker, 2008).

Habitat Requirements

- Seed germination ideal temperature is between 77 to 86 °F. Full light exposure and submerged seeds also increases germination (Gucker, 2008).
- Seeds can germinate in acidic, neutral or basic pH. Reduced oxygen through submersion has also been seen to increase germination success. So flooding is good for germination, under the right substrate and water quality conditions (Gucker, 2008).
- Broadleaf cattail will grow in many different types of soils. The most common are those that contain sand, silt, clay and loam (Gucker, 2008).
- Rates of Phosphorus uptake increase in early summer while the shoots grow the most (Smith et al. 1988).
- Continuous and/ or periodic flooding leads to an increase in biomass production (shoot height and photosynthesis increases) (Li et al., 2004).
- Tends to grow well in high nutrient available areas, as well as, low nutrient areas. Cattails grow well in newly disturbed areas (Gucker, 2008).
- Continuous Flooding is the best environment for cattails once they are established. A study shows that this environment over the control (normal

wetland), periodic flooding and periodic drought, the continuous flooding did not put too much stress on the plant and gave rise to the most photosynthetic activity, and the most shoot and roots biomass over the other areas of study (Li, 2003).

Succession

- Substrates that are new from volcanic or avalanche debris is favorable for Broadleaf cattail colonization in open water is considered its primary succession. (Gucker, 2008)
- In secondary succession Broadleaf cattails will take over an open and disturbed area. For example, it may take over a site that just had a fire (Gucker, 2008).

Tolerances and Restrictions

- Cattail germination decreases with increasing salinity, however; the seedlings and established stalks tolerated salinity just fine. (Gucker, 2008)
- Periodic drought significantly reduces root growth (Li et al., 2004)
- Cattails need at least 15 cm of water to germinate seedlings (Gucker, 2008).
- The ordinary water line necessary for cattails is not something I found much data on. I think it varies on the cattail (hybrid or not) and its adapted characteristics determined by its location and environment.
- Broadleaf cattails are shade intolerant. (Gucker, 2008)
- Cattails are prone to fires at the top of the stalks but can recover well due to the lower moist layers and regenerate quickly. Unless the fire burns down to the soil to where the Rhizomes cannot recover (Gucker, 2008). With the drought in the central valley and future climate change cattail fires are something we should be concerned with in the future.

Range

- Seeds estimated travel distance in wind that is 10km/h was 154 feet.(Gucker, 2008)
- Cattails occur in temperate Northern and Southern regions as well as in the tropics and subtropics. Most common in fresh water environments. In California the Broadleaf cattail is found below 6,500ft and California cattail is found above 3,000ft (Gucker, 2008).

Ecosystem Services

- Cattails are common habitats or food sources for small animals, like muskrats (Gucker, 2008).
- Cattails are habitats and nesting grounds for birds like: red-necked grebes, whooping cranes, marsh wrens, red-winged blackbirds, and ring-necked pheasants (Grucker, 2008).
- Provides erosion control and reclamation of industrial degraded sites. (Grucker, 2008)
- Cattails aerate the soil making it favorable for native plants to move in. (Grucker,

2008).

Management

- To keep cattail population down can help improve the success of other native plants that were outcompeted by them (Rahel et al., 2008).
  - A practice of lowering cattail density is burning it when the water table is low, this ensures the rhizomes burn as well (Kotze, 2013).
  - Livestock grazing is also another option to reduce Cattail abundance. It does not completely get rid of it, just manages its dominance.
  - Herbicide (Glyphosate) applied to the plant will reduce population as well. But it also carries uncertainties of how it may affect nearby native plants, water quality and the animals that rely on the cattails (Linz et al., 1996).
- To bring the population back up, this will provide sufficient nesting grounds and habitat for small animals and birds (Gucker, 2008).
  - Leaving the population to disperse naturally with continuous flooding and warm temperatures (77 degrees) the cattail population will grow on its own successfully, in doing so it will outcompete the invasive plants such as Star thistle and the Himalayan blackberry bush (my own assumption).
  - In the central valley, it is likely that the drought has caused a low abundance of cattails so to improve the range we will need to contour the stream bed to increase water holding capacity so the cattails get regular flooding. A benefit of keeping the Beavers in our site, although; this could cause potential problems for the nearby homes.

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RESTORATION GOALS

Short-Term

- We will increase the density of *Typhya latifolia*. The degree of density is dependent on what we plan on growing next to it and priority of our goals. For example, if want to plant 100sq ft of native plants that need plenty of shade we should establish cattails around this entire population to ensure shade is provided for these natives. However, if we are just concerned with the water quality of the wetland we should establish enough cattails so that it covers at least 60% of the wetland (Coon etal., 2000).
- Cattails will be planted in areas of the wetland that are greater than 15cm deep to ensure germination of seedlings. The cattails would best be planted near the entrance and middle of a wetland region. Their rhizomes will be beneficial in purifying water that comes in. This will meet a short term goal of first removing the excess nutrients and catching the excess sediments, pollutants and heavy metals that have already accumulated in the water. To finalize this short-term goal we will need to periodically dredge or harvest the Cattails to ensure the removal of the excess nutrients, sediments, pollutants and heavy metals. In California cattails begin to flower in June and July, since it is a perennial plant it will take at least 1 full growing season for this goal to be met, we would monitor the cattail each year and dredge every 2 years to remove the pre-restoration sediment, nutrients, pollutants and heavy metals. The rhizome structure of the cattail only lives for 2 years, removing them after this time ensures that the sediment and nutrients are not reintroduced into the water during decomposition. With the other areas around the wetlands being restored less debris and pollutants will runoff into the water, this makes it so we only would have to dredge or remove the cattails rhizomes for the first 2 or 3 growing periods.

Long-Term

- With the increase of coverage and density of *Typha latifolia,* the long-term goals of slowing the wetland's rate flow and decreasing nutrients like nitrogen and phosphorus through the Cattails nutrient uptake needs.
- We also expect the Cattail to out compete some of the invasive species around the wetland. Cattails are quick to claim disturbed areas and even better at balancing them out. This would also be checked on during the monitoring and dredge every 2- 3 years. A 90% reduction in exotics after 6 years would be considered successful, this would be after multiple dredging events and 6 years of established

populations.

- Since, cattails are very competitive and may even begin to take out compete the native species it would be in our best interest to monitor the cattails every 2 years to see their growth status. If we suspect that they are moving out some of the restored natives, we should do a controlled burn of the cattail shoots. This will keep the cattail density in balance with the natives and may also enhance the native plant's growth by allowing for secondary succession.

RESTORATION PLAN

The introduction of the cattails will be the same for both our short and long-term goals. To introduce the cattails we will want to use seeds that are collected in May- a study says that these seeds are 90% more successful in germination than any other seeds collected during another time. These seeds must be submerged in water, the reduced oxygen increases their germination success. The area must be well lit, with at least 80% light exposure and have optimum water temperatures of 77 to 86 °F. Also ash left in the soil from past fires increase seed germination success. Considering the requirements of the cattail seeds to germinate, specifically for the central valley it would be in our best interest to collect seeds in May and to disperse the seeds in May as well. The central valley climate conditions will be the most favorable during this time. The only problem with using seeds to germinate is that it may take longer to reach our restoration goals. Although, it will give us the most successful results(Gucker, 2008). We should check on the site July, mid-summer, to assess the site on cattail seedling success.

A 7 inch long shoot of a shoot of a cattail can produce an average of 222,000 seeds. It would be in our best interest to mix and use seeds from cattails that are currently living and thriving in similar conditions to our restoration site. This will increase genetic diversity and hopefully the adaptations necessary for the previous wetland are similar and helpful on our restoration site. We know that not all the seeds will take and that not all the cattails will grow flowers to continue reproduction once they develop(Gucker, 2008). This is one of our main uncertainties, there is not much research on exactly how much space each cattail will take up or how many of the seeds will take in a given season. There are so many factors that can determine the outcome that are highly determined by the site and chosen region of dispersal. Another problem is how the wetland will naturally disperse the seeds. The environmental conditions may move our seeds through the movement of water, soil or animals that walk through. So the cattails may not grow where we intended them too. A way we can adjust this is to concentrate the seeds in our intended area of growth.

We will want to plant and spread seeds in designated areas throughout the wetland and in alternate years. The first year we will clear and plant seeds in one half of all the sites we wish to grow cattails. The next year we will clear and plant cattails on the other half of each of the sites. This will ensure that when we dredge not all the cattails will be removed and that the cattails can recover well for the next growing season by having the established cattail shoots nearby. We will focus on regions at or near the wetland entrance as well as middle cells. We want the cattails early in the wetland to slow rate of flow and to purify the water before it reaches the sensitive native plants that we are trying to recover. If however, the water is too low or there is not enough of it present all year we should focus on planting in areas that we know to have these characteristics. It is also in our best interest to plant and disperse seeds in highly disturbed areas, cattails are very tolerant and grow better than other native plants in these areas. They can restore the soil and water quality and once we remove them we can have the option of expanding the native plants there as well. (Gucker, 2008).

Short-Term Actions

The short term plans main components are to introduce cattails to the wetland areas of our restoration site. Once this accumulation has occurred in the rhizomes we then will remove the cattails through dredging. By planting the cattails in alternate years the first dredging session will only take place on half of each of the growing sites. The half that we remove will be the 2 year old cattails that have dead rhizomes. The dredging depth will be determined on the site, surveying of the sediment and nutrient accumulation is necessary prior to dredging. Once dredging depth and scope is determined, we will scrape and set aside the surface soil around the cattails and reapply it to the area where we plan to removed the excess sediment. This layer of soil most likely has seeds of the surrounding plants and plant material that is beneficial for reapplication of the cattails and the surrounding native plants that may have been disturbed. The other half of the cattails that are still in their 2nd growing year will develop flowers and hopefully plant seed in the dredged area for regeneration of the cattail population. It also may be beneficial to do the dredging during the dormant season to further avoid native plant disruption. The only problem with this is the possibility of invasive plants moving in(EPA, 2009).

Long-Term Actions

We have three long term goals associated with the planting of the cattails in our restoration site. The first and second are met once the cattails germinate and grow in the specified regions of the wetland mentioned earlier in the management plan. The third and final goal of the long term restoration plan is to monitor and maintain the cattail population, we do not want them to outcompete or put stress on the success of our native plants. If their success starts to have this effect, we will do periodic burns on the top portion of the cattail shoots. Since cattails germinate and respond well to burning, this will ensure that the population will recover. This controlled burns should take place every 15 years, during April when there is plenty of moisture surrounding them so that the fire does not spread and to not damage the lower half of the cattails, the rhizomes. The rhizomes will be covered with water during this time so the fire should not affect them, they are necessary to regenerate the cattail population. (Gucker, 2008).

MONITORING PLAN

- After assessing our site in April, in the regions with water we will measure water depth and survey surrounding plants to determine if it is a suitable habitat for Cattails. Ideally the water will be about 15 cm deep and has plenty of sun exposure. If there are already cattails present that are successful we should pull from their flowers to set seed in other intended areas of growth. We will need to determine what the ideal cattail population for this wetland is first prior to spreading the seeds. For example, the surrounding plants could be recovering natives so we would want to avoid further planting. However; if the area is disturbed and covered in non-natives, we should remove those and continue with planned seedling dispersal. This will take place in early May(Gucker, 2008).

- In the first year the Rhizomes elongate in the beginning of summer in June and the next year stem will shoot, growth annually can be up to 2 feet a year(Sojda and Solberg, 1993). So our first monitoring day should take place in late June or early July to see if the Rhizomes have started growing. Fully grown and healthy rhizomes will average more than 50% of the total cattails biomass. They can be 3 to 8 inches deep and up to 28 inches long depending on the environment this element can vary (Gucker, 2008).

- We will then do the same for the 2nd half of the cattails the following year. Monitor in the beginning of May and plan to dredge at the end of the summer, September, before the rhizomes decompose. And to also reestablish the population that was just dredged (Gucker, 2008).

- Monitoring should continue each year for 2 more years around June to make sure the cattails are successful and to see if future dredging may be necessary. Monitoring the region in 15 years would also be wise considering the likelihood of cattail or grassland fires(Gucker, 2008). A controlled burn may also be necessary to keep the cattail population down if it looks to be disrupting the growth and success of the nearby native plants. This will be the other component to check during that 15th year monitoring day or days- depending on the size of the site.

- By taking water samples before dredging and a year after dredging will determine if the cattails are doing a good job in filtering the water of sediments and nutrients. This practice should be continued every 2 years (the lifetime of rhizomes) to determine if there is a need to dredge. TO prevent sediment and nutrient reentry.

- If there were non-natives in the area we reestablished the cattails and after 2 years that population decreased to less than 20% of what it was, then we would consider that successful. To further remove the invasive plants we should remove the rest and plant cattail seedlings in the disturbed area, and hopefully get 100% eradication.

Research Question

1. Would tissue samples of the rhizomes be a useful and feasible method in determining the sediment accumulation and how far to dredge?

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Purple Needle Grass (*Nassella pulchra*)

Kingdom: Plantae
Subkingdom: Viridiplantae
Superdivision: Embryophyta
Division: Tracheophyta
Class: Magnoliopsida
Superorder: Lilianae
Order: Poales
Family: Poaceae
Genus: Nassella
Species: pulchra

Background and Justification:

Nassella pulchra (Common name Purple Needle grass) is a native perennial bunch grass found across parts of California as well as southern Oregon and northern Baja California (USDA 2009. Purple needle grass is suited for the Mediterranean climate of California doing well in hot dry summers and is adapted to reproduce both sexually and asexually (USDA 2009). Purple needle grass once dominated the grasslands of the Central Valley as well as being found in numerous plant communities along the coast, in woodlands, and in serpentine soil areas (Porter 1996). However, due to numerous factors working in concert including drought, overgrazing, conversion of grassland to farmland, and invasive species, Purple needle grass has been pushed out of most of its native habitat with nearly all grassland in the central valley dominated by annual species (USDA 2009). European invasive annual grass species such as Italian rye (*Lolium multiflorum*) and weeds such a star thistle (*Centaurea melitensis*) are able to out compete Purple needlegrass in many areas (USDA 2009). Older, more established Purple Needle grass plants tend to do just find thriving in an area that they live in even when invasive species are present (Amme 2003). However, the plants take 2 to 3 years to reach mature size, and in that time annual species and weeds are able to grow much faster than the long-lived bunch grass and hinder the plants growth and survival rate (Abraham 2006). The species is particularly susceptible in areas where invasive species have been present for a few years allowing a seed bank to develop. When drought comes in, it kills off the mature plants and stimulating seeds to germinate. *Nassella pulchra* seedlings cannot compete with these annual invasive and their fast growth rates, and within years an area previously occupied by bunch grasses like *Nassella pulchra* can be covered in annual grasses and weeds (Abraham 2006).

Purple needle grass is an essential part of many ecosystems in California providing many services that are not fully satisfied by their annual counterparts that can take over. Parts of the Central Valley have always been subject to periodic flooding, something that can cause damage to agricultural products. When *Nassella pulchra* covers an area its deep rooting system helps prevent erosion throughout the year more so than annual species that have much more shallow root systems (Morghan 2006). The species is also quite palatable and nutritious for livestock though overgrazing of Purple Needle grass is one of the factors that contributed to its decline

(USDA 2009). It is also desirable grazing material for wildlife such as deer and elk and is home to forage for multiple species of native grasshopper as well. (USDA 2009, Porter 1996). Due to large swaths of grassland being converted to agriculture and invasive moving in, *Nassella pulchra* have vanished from most of the Central Valley and with it the ecosystem functions it was providing (USDA 2009).

Fact Sheet:

Project Goal: To reintroduce *Nassella Pulchra* to Central Valley disturbed grasslands that are currently dominated my invasive European annual grasses like Italian rye (*Lolium multiflorum*) and other weeds such as thistle (*Centaurea solstitialis*) and star thistle (*Centaurea melitensis*).

Growth characteristics:

- Densely tufted, long-lived, upright bunchgrass with long awns (USDA 2009)
- Purple needle grass is a monocot perennial grass species (Calflora 2016)
- Generally 2 to 3 feet tall with roots depth general 2 to 6 feet though roots have been known to grow 16 feet deep (USDA 2009)
- Plants go dormant following the production of seeds and begin growth again with rain in the fall (USDA 2009)
- Gets its name from distinct purple hue of its glume, turn from purple to pink with maturity (Amme 2003)
- Established plants can dominate plant communities however reaching the necessary size takes at least two years (USDA 2009)
- Bloom lasts 3 months from March to May (Calflora 2016)

Reproduction:

- Plants can reproduce asexually through tillering and bunch fragmentation, as well as sexually through seed dispersal via wind (USDA 2009)
- Quality of light, effected by a dense canopy and litter production from annuals, reaching the base of plants will impact tillering rates (Dyer 1996)
- High rates of self-pollination (USDA 2009)
- As the seeds dry, the points of the seeds as well as long awns that twist with drying drives seeds into soil (USDA 2009)
- Litter accumulation can suppress seedling establishment by reducing microclimate temperature and alters humidity (Dyer 1996)
- Purple Needle Grass has vigorous growth following fires and seed production is much greater (dyer 1996)
- Seeds (florets) range in size from 0.8-3.5 mm long with hairy lemma and twice bent awns that reach another 38-100 mm (USDA 2009)
- Depending on environmental conditions seed yields from cultivated plants ranges from 75-600 lbs/acre (USDA 2009)
- Fields can be harvested several times as seed matures using a seed stripper (USDA 2009)

Range:

- Can be found as far North as southern Oregon and as far south as northern Baja California as well as the Channel Islands (USDA 2009)
- Counties in California where Purple Needle grass can be found: Alameda, Amador, Butte, Calaveras, ContraCosta, Colusa, El Dorado, Fresno, Glenn, Humboldt, Inyo, Kern, Lake, Los Angeles, Madera, Mendocino, Merced, Mono, Monterey, Mariposa, Marin, Napa, Nevada, Orange, Placer, Riverside, Sacramento, Santa Barbara, San Bernardino, San Benito, Santa Clara, Santa Cruz, San Diego, San Francisco, Shasta, San Joaquin, San Luis Obispo, San Mateo, Solano, Sonoma, Sutter, Tehama, Trinity, Tuolumne, Ventura, Yolo, Yuba (USDA 2009)
- Conversion of grasslands in the Central Valley to grazing and farmland as well as invasive species and drought have pushed Purple Needle Grass to marginal edaphic habitats (Morghan 2006)

Habitat Requirements:

- Generally found in grasslands, oak and pine woodlands, mixed evergreen forest, chaparral, and coastal shrub though it many areas it has been replaced by annual grasses (USDA 2009)
- Occurs in a variety of soil types including serpentine and is particularly good with clayey soils (Porter 1996)
- Cannot be over shaded by nonnative annuals (USDA 2009)
- Young plants are susceptible to damping off in cold wet weather particularly in December and January (USDA 2009)
- Seedlings take 2 to 3 years to be able to establish themselves in a plant community (Amme 2003)
- Grows much better in deeper soils, does not do as well in shallow soils particularly in wet years (Morghan 2006)
- Generally grows in areas that receive 20-100 cm of precipitation annually (USDA 2009)

Tolerances:

- Can tolerate extreme summer heats as well as drought (USDA 2009)
- pH range of 5.5-8.2 (Calflora 2016)
- Wide range of elevations going from 0-2320 meters (Calflora 2016)
- Some ecotypes of the species have partial flood tolerance, depends where specimens are taken from (USDA 2009)
- Ranges from hardiness zone 8b to 11a (Calflora 2016)
- Well adapted to dry soils, as well as clay and serpentine soils (USDA 2009)
- Grows well in full sun as well as partial shade (USDA 2009)
- Very fire tolerant, producing more abundant seeds the year after a fire (USDA 2009)
    - Re-sprouts well after spring and fall fires, however plants burned by higher temperatures in summer fires do recover as well

Wildlife interactions:

- Valuable forage species providing food for deer, elk, and various other wildlife as it has moderate amounts of protein as well as being quite palatable (USDA 2009)
- Provides forage for insect species as particularly grasshoppers (Porter 1996)
- Can tolerate mind grazing from wildlife, however extensive year round grazing from cattle is a large part of lost Purple Needle Grass habitat (Buisson 2008)

Plant interactions:

- Frequently associated with Idaho fescue (*Festuca idahoensis*), praire junegrass (*Koeleria macrantha*), and bottlebrush squirreltail (*Elymus elymoides*) as well as various other species depending on location (USDA 2009)
- Has been pushed out of many native areas by invasive European annual grasses (Abraham 2006)

Human interactions:

- Purple Needle grass is often used in native and low water landscaping through the state (USDA 2009)
  The species was made the official state grass of California in 2004 (Amme 2003)

Threats:

- Overgrazing is a significant problem for Purple Needle grass particularly when it is eaten down to the base (USDA 2009)
- While Purple Needle grass used to dominate California, numerous invasive annual grasses such as have pushed it out of many areas and continue to threaten it in parts of the state (USDA 2009)
  - Primary annual grass competitors include *Lolium multiflorum* (Italian ryegrass), *Avena fatau* (wild oat), and *Bromus diandrus* (ripgut brome)
- Does not tolerate low nitrogen as well as many annual grasses and weeds such as thistle (Abraham 2006)

Propagation/Restoration requirements:

- Often times grown in fields with 20 to 30 inch spacing, as well as seedlings being grown in five foot bed with four rows per bed and 8 inch spacing (USDA 2009)
- Important to be able to determine when plants are mature enough to harvest (USDA 2009)
- Seeds should be sown on restoration sites ideally before first rains in late October early November, allows seeds to get water for initial growth (Buisson 2008)
- Seeds should be planted about a quarter inch below the soil (USDA 2009)
- When spreading live seed on a restoration site 9.5 lbs of seed are recommended per acre to provide roughly 25 seeds/ft^2 (USDA 2009)
- Competes better against exotic invasive in degraded habitats where topsoil has been lost

(Buisson 2008)
    - Lost topsoil removes exotic seed bank so there is less competitions
    - Topsoil loss also removes large amounts of N from the soil, lack of N in topsoil favors native grasses like Purple Needle grass
- Greatest determinant of plant success is topographic location (Dyer 1996)
    - Locations where plants aren't competing for light and moisture is abundant in early spring will do better.

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Restoration Plan for Purple Needle Grass

Restoring Purple Needle Grass in the Central Valley is critical to preserving native California grasslands and ensuring the species survival in the state. The first goal in restoring Purple Needling grass in Central Valley grasslands is determining where existing patches of the plant are to understand its current distribution. The second goal involves determining where the best areas are for reintroducing the species are and consequently where efforts should be concentrated. The final goal involves altering areas that could have potential for supporting Purple Needle Grass populations, but require habitat modification and improvement to be a viable site for restoration. These goals will involve both transplanting seedlings as well as spreading seed directly on habitats determined acceptable for restoration efforts. Success of restoration will be determined by persistence and overall health of Purple Needle Grass patches, increased resilience to invasive species, and ecosystem services provided such as erosion control.

Revegetation Preparation

Native grassland restoration is a growing practice and as such cultivating these grasses for different projects has been growing as well. Nurseries like Hedgerow Farms in Winters, California specialize in cultivating native plants with fields dedicated both to growing seedlings for transplant and seed production plants for spreading seed. The bunchgrass is grown in fields spaced 20 to 30 inches apart to provide sufficient room for growth or can be grown in five foot beds with four rows per bed and about 8 inches of spacing (USDA 2009). These seedlings typically require at least a year to reach suitable size for transplant however growth rates can fluctuate with environmental factors so they need to be monitored to determine the idea time to harvest (Amme 2003). Purple Needle grass bloom lasts 3 months from March to May, so fields where the plants are being grown for seed can be harvested during these months (USDA 2009). Furthermore, fields can be harvested several times as different seeds mature on the plant, depending on environmental conditions an acre of cultivated plants can yield 75-600 lbs/acre of seed. Collected seeds can be spread on restoration site the same year ideally in fall before the first rain (USDA 2009).

Conservation

While there are small native patches of Purple Needle thriving along the California coast and in the Sierra Nevada Mountains, in large part the species as been wiped out from the Central Valley (Calflora 2016). Within the Central Valley remaining Purple Needle Grass populations are for the most part along the edges of the valley in the woodland foothills and not generally in the Valley itself (Calflora 2016). That being said there are some remaining patches of Purple Needle Grass in the valley (Calflora 2016), so looking at the condition of these patches will provide crucial information on parts of the valley that could be suitable for conservation or as well as other areas with the potential for revegetation. Factors to consider when choosing sites for conservation are the soil and water chemistry of the area, competing species, herbivore abundance, water accessibility, as well as proximity to agriculture and ranching operations.

Greatest emphasis for conservation efforts in the Central Valley will need to focus on the biggest patches of the bunchgrass with the highest likelihood of continual survival and reproduction. Small patches can be surrounded for miles by invasive annual grass species that, even if conservation is attempted, will likely be whipped out when a drought comes along or some other kind of stress for the Purple Needle grass. While size of the patch is important it is also necessary to make sure conserved areas are healthy plant communities that will sustain populations of Purple Needle grass as well as its associated species. Status of other species as well as the Purple Needle grass is indicative of the habitats health overall which is important to consider for conservation. Some species commonly associated with Purple Needle grass include Idaho fescue (*Festuca idahoensis*), praire junegrass (*Koeleria macrantha*), and bottlebrush squirreltail (*Elymus elymoides*) as well as various other species depending on location (USDA 2009). When these areas are identified and chosen for conservation, efforts should be made to remove as many invasive from the areas as possible to reduce competition and enhance the likelihood of long term habitat conservation.

Reintroduction

Following conservation efforts made to preserving existing Purple Needle grass habitat, areas likely able to support the species should be identified for reintroduction. Surveys will be necessary to determine environmental factors such as soil quality, microclimate, current plant communities, and hydrology of the region. These will aide in deciding if an areas meets the species specification for ideal habitat. Ideal soil conditions are typically dry and the species favor more clayey soils as well as deep soils that allow for extensive root growth (Morghan 2006). Oddly enough, Purple Needle grass and other bunch grasses are also able to compete better in degraded areas where topsoil has been removed. When the topsoil is removed it takes with it the annual grass seedbank that threatens long-term revegetation efforts, as well as most of the nitrogen in the topsoil which would favor annuals if present (Buisson 2008). Purple Needle grass is very drought and heat tolerant, growing well in full sun as well as partial shade (USDA 2009). Litter accumulation and a dense canopy from other plants can alter microclimate temperature and alter humidity, so surveying the current plant community is crucial when determining ideal reintroduction habitat (Dyer 1996). Presence of wildlife and cattle is also important to consider when determining a site, as overgrazing is a significant problem for the species and will limit revegetation efforts (USDA 2009). Of all the factors that influence the success of these efforts, the greatest determinant of plant success is topographic location (Dyer 1996). While invasive species and grazing definitely impacts these plants in a large way, locations where plants aren't competing for light and moisture is abundant in early spring will do better (Dyer 1996).

When ideal habitat has been identified for a reintroduction of Purple Needle grass, similar techniques to conservation efforts should be implemented. Large patches should be developed with little presence of invasive species in order for the native bunchgrass to have the advantage when building up seeds in the seed bank. These large patches also protect growing seedlings from the threat of faster growing annual grasses. While established Purple Needle grass plants tend to dominate plant communities, getting established takes at least two years, during which time seedlings can be outcompeted and crowded out (USDA 2009). Depending on the area chosen for the site different cultivars of Purple Needle grass should also be considered. Some ecotypes are flood tolerant, as such if a site has a history of flooding it is important to have varieties that can survive and recover after flooding (USDA 2009). Overall when considering an area for reintroduction it important to remember habitats are not being modified for in reintroduction, so finding an ideal site means looking at the current state of habitat and determining whether it can support a Purple Needle grass population without intervention. These areas lack Purple Needle grass populations, but also do not have any present threats if a population of the species were present or introduced.

Habitat Modification

The final goal of Purple Needle Grass restoration is the hardest, as it requires altering habitat with the potential to be suitable before a population can be established. Historically, Purple Needle grass covered much of the grasslands of the Central Valley as well as parts of oak woodlands, chaparral, and coastal shrub ecosystems (USDA 2009). Annual grasses have almost entirely outcompeted Purple Needle grass in the Central Valley grasslands and a lot of restoration efforts there to bring the bunch grass back have proved unsuccessful in the long term. In areas where annual grasses such as *Lolium multiflorum* (Italian ryegrass), *Avena fatau* (wild oat), and *Bromus diandrus* (ripgut brome) have been present for decades and the seed bank is loaded with their seeds, it is all but impossible to establish a long term healthy plant community with Purple Needle grass . The habitats that should be looked at closely for potential habitat modification are the woodlands along the foothills of the valley as well as chaparral and coastal shrub ecosystems. Those areas where annual grasses are not as dominant and a more diverse plant community is present are better suited for habitat modification. In those areas, removing invasive annual grasses and hindering their future seedbank is a good way to give Purple Needle grass an advantage. Bringing in grazing animals or even controlled burns are great ways to destroy current seeds and prepare the land for the bunch grass (USDA 2009). Even after the plants are introduced to the community, controlled burns can greatly benefit the spread and proliferation of Purple Needle grass. The species has vigorous growth following fires and seed production is also drastically increased (Dyer 1996).

Seeding and Transplanting

Introducing Purple Needle grass to a habitat can either be done directly with seeds or with seedlings grown in a nursery like Hedgerow as mentioned above. Seeds should be introduced to a site in fall, preferably late October early November before the first rain so they can get that water for their initial growth (Buisson 2008). If there are annual grasses growing around where seeds are being scattered, efforts should be made to remove those grasses before they bloom and their seeds are added to the seedbank. If possible seeds should be planted about a quarter inch below the soil to help facilitate germination and prevent them from being blown away in the wind (USDA 2009). When spreading live seed on a restoration site 9.5 lbs of seed are recommended per acre to provide roughly 25 seeds/ft2 (USDA 2009). This quantity gives the species a viable chance of competing with other species that will germinate around the same time and will be competing for the same light, nutrients, and water.

Transplanting seedlings or plugs into restoration sites is the other option to directly seeding a restoration site. This requires the seedlings be grown in a nursery under the specification mentioned in the revegetation preparation section. Determining when the plants are mature enough for harvest is critical to a successful restoration because if they are transplanted too early they might not be able to successfully compete (USDA 2009). Spacing out the Purple Needle grass is important because those that grow too close together will hinder each other’s growth. The first two years are the most critical for the plant as they either establish themselves in the community at this time or are outcompeted by other plants. Monitoring is critical during this time to make sure plants are developing and are not being pushed out by other grasses.

Management and Monitoring

Management and monitoring of conserved and revegetated habitat should occur for at least two years following restoration. As mentioned about, Purple Needle grass requires at least two years to be able to establish themselves. During this time management in the form of weeding may be necessary to prevent annual grasses from outcompeting the young bunch grass. Grazing should also be limited on site as it heavily favors annual species that are able to recover much faster from grazing than the slow growing bunch grass. Growth can be measured not only in plant survival rates but also their rate of tillering and seed production. Once established in communities Purple Needle grass can spread out naturally over larger areas bringing with it the services it provides such as erosion control and increased resistance to wildfires. Annual grasses burn hotter and faster than the bunch grass and the prevalence of Purple Needle grass decreases the damaging effects of wildfire when it comes through. No irrigation is necessary on site however in the wet season monitoring should be conducted if there is the possibility of flooding as different cultivars of the species are more susceptible to flooding than others. On a similar note, when drought events occur, monitoring should be present to see how the stress is impacting Purple Needle grass populations as well as the species it is competing with. Even when established, monitoring should continue for several years to observe the growth of Purple Needle grass patches and how they fair in various plant communities even after management has ceased.

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Exotic plant species

***FICUS CARICA* (FIG)**

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass; Hemamelididae
Order: Urticales
Family: Moraceae
Genus: *Ficus*
Species: carica

Background and Justification

Ficus carica, commonly known as fig, is an invasive subcanopy fruiting deciduous tree that occurs normally around moist environments such as riparian forests, streamside habitats, levees, and canal banks in the Central Valley of California (Holmes et al., 2014). Unlike most invasive species the fig is able to establish itself in low-light, low-disturbance, and native plant dominated environments (Holmes et al., 2014). Due to these qualities, the fig is an extremely successful invader—it rapidly forms dense thickets and has proven difficult to eliminate (Bossard et al., 2000). The California Invasive Plant Inventory currently ranks it as having moderate impact capabilities with severe distribution levels (California Invasive Plant Council, 2006). If fig invasion is not controlled, it is likely that fig trees will dominate in the riparian forest ecosystem, pushing out native trees and understory shrubs that are vital for the ecological stability of California riparian forests (Bossard et al., 2000). Furthermore, riparian forests are extremely rare and endangered in California due to the conversion of over 95 percent of riparian forest lands into agricultural, pastoral, and other developed areas (Bossard et al., 2000). Very little research has been conducted on the fig's role as an invader. With the small percentage of riparian forests that still exist in California, further research is advisable in order to guarantee the future sustainability of these ecosystems.

The fig is native to southern Arabia, and was most likely domesticated in Mesopotamia, or what is known currently as Iraq. It was first introduced to California by Spanish missionaries in 1769; the spread of the fig was minor until the introduction of *Blastophaga psenes* in1899 (Bossard et al, 2000). Fig crop production was extensive in the 1930s, with more than 16,000 ha (39,536 ac) cultivated; current production stands at only 4,800 ha (Holmes et al., 2014). It is not clear how the fig spreads quickly into preserves and other wild areas, but most commercial fig cultivation occurs in the Central Valley (mid latitudes: 36°N to 38°N).

Fig trees grow to be approximately 10 meters tall (30 feet tall) and are characterized by multiple trunks, winter-deciduous leaves, and latex sap (Holmes et al., 2014). Figs spread via either root sprouts, which create dense thickets or broken off limbs which can also take root. The latter is a commonly occurring issue during storms or floods since the limbs that are broken off spread significant distances through streams and other waterways (Bossard et al., 2014). The fig is a unisexual gynodioecious plant consisting of the female tree, known as edible figs, and the hermaphroditic trees, known as caprifigs. Pollination is required to create the fruit—figs are only pollinated by the wasp *Blastophaga psenes*, a small creature which lives for only two days after emerging from the fruit (Holmes et al., 2014). The fig tree attracts the fig wasp through a unique combination of volatile compounds which allow the wasps to find the tree without visual aids (Holmes et al, 2014). *Blastophaga psenes* and the fig have a species-specific mutualism; as such *B. psenes* and the fig are highly interdependent. First, the adult wasps that survive the original cycle lay eggs in the male figs. The eggs then develop into larvae in autumn, and stays in the fig throughout the winter. In spring, the larvae leaves the fig and lays its eggs in the male fig. In the summer, adult wasps emerge from the male figs with pollen grains attached to it, and the female figs are ready to be pollinated by the adult wasps. The adult wasps enter the female figs, pollinate them, and then die in the female fig without laying the eggs. The cycle is able to continue due to some adult wasps leaving the male figs later enough in the summer to find new male figs during the autumn (Grison-Pigé et al., 2001). Fig seeds may also be dispersed by birds of deer that may eat the fruit (Bossard et al., 2000).

Fact Sheet

Project goal:

- To eradicate the fig from the remaining riparian communities in order to preserve the riparian communities and the native species that inhabit them.
- Research and develop methods for the eradication of figs, due to limited knowledge of fig eradication methods in riparian systems.

Growth characteristics:

- Fig is an invasive subcanopy fruiting deciduous tree that typically grows in moist environments such as riparian forests (Bossard et al., 2000). It can reach a height of approximately 10 meters.
- Leaves drop mid-to late autumn and emerge in early spring (Bossard et al., 2000).
- Figs have complex inflorescences called synconiums, which when pollinated, develop into multiple fruits. Synconiums are typically 1.5-3 inches long, and color varies (Bossard et al., 2000).
- Figs have root sprouts, so when the limbs of the fig are cut, broken, or fall off, it can root back into the ground and grow.

Reproduction:

- The fig reproduces through pollination and vegetative growth (Bossard et al., 2000).
- The environment it typically reproduces in is moist.
- Viable seeds usually are produced in late summer and autumn (Bossard et al., 2000).
- The fig reproduces through a species-specific mutualism with *Blastophaga psenes*. Other pollinators may include birds or deer (Grison-Pigé et al., 2001, Bossard et al., 2000). Fig

seeds may be washed away from the synconium after a storm.

- It is a unisexual gynodioecious plant consisting of the female tree, commonly known as edible figs, and the hermaphroditic trees, commonly known as caprifigs (Holmes et al, 2014).
- Seeds germinate between 50-85 degrees Fahrenheit (10-30 degrees Celcius) only if humidity is constant or the soil is completely wet (Bossard et al., 2000).

Range:

- It is commonly in these counties of California: Shasta, Tehama, Plumas, Butte, Glenn, Nevada, Sonoma, Napa, Yolo, Solano, Contra Costa, Stanislaus, Calaveras, Sacramento, San Joaquin, Kern, Los Angeles, Santa Barbara, and San Diego (USDA, 2016).
- In regards to fig production, California, Turkey, and Greece are major contributors (Bossard et al, 2000).
- It is also found in parts of Texas, Florida, Louisiana, Mississippi, Alabama, Georgia, Tennessee, North Carolina, South Carolina, Kentucky, Virginia, Pennsylvania, Maryland, New Jersey, New York, and Michigan (USDA, 2016).

Habitat:

- Figs normally inhabit riparian ecosystems or moist areas such as levees, canal banks, and stream side habitats (Holmes et al., 2014).
- It does not prefer a specific water depth; it has similar growth rates among river, slough, and terrace floodplain positions (Holmes et al., 2014).

Species Interaction:

- Figs are only pollinated by the wasp *Blastophaga psenes.*
- The fig tree attracts the fig wasp through a unique combination of volatile compounds (Holmes et al, 2014).
- The larvae of the wasp that was developed in autumn (adult wasps that originally survive have laid eggs in the male fig, and those eggs become larvae) stays in the fig throughout the winter, and then in spring, the larvae leaves the fig and lays its eggs in the male fig.
- In the summer, adult wasps emerge from the male figs with pollen grains attached to it, and the female figs are ready to be pollinated by the adult wasps.
- The adult wasps enter the female figs, pollinate them, and then die in the female fig without laying the eggs. The cycle is able to continue due to some adult wasps leaving the male figs later enough in the summer to find new male figs during the autumn (Grison-Pigé et al., 2001)

Human Interaction:

- Fig production is popular in California, Turkey, and Greece (Bossard et al., 2000).
- Varieties of figs were introduced to California for food and ornamental plantings after 1850 (Bossard et al, 2000).
- Commercial production of figs exploded when *Blastophaga psenes* was introduced in

1899 (Bossard et al., 2000).

- Although invasive, people are allowed to plant fig trees in their homes. Fig seeds from yards may be dispersed through the wasp, birds, wind, or other mobile animals that may feed on the fruit.

Tolerance:

- The fig is able to invade in low-light, low-disturbance, and native plant dominated environments (Holmes et al., 2014).
- It is usually not targeted by herbivores due to its dense thickets (USDA, 2016).
- Figs are subject to damage from nematodes, tree borers, and rust (Bossard, 2000).
- The fig wasp may carry fungal disease spores (Bossard, 2016).
- Little is known about controlling fig populations (Holmes et al., 2009).

Threats:

- The fig's ability to spread rapidly in riparian forests in California due to its ability to invade in low-light, low-disturbance, and native plant dominated environments is endangering riparian forests (Holmes et al., 2014)
- 95 percent of riparian forests have been converted to agricultural or developed areas
- As such, the biodiversity of riparian zones are extremely endangered by the invasive capabilities of the fig.

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Management Plan for the Fig

A. Goals

With 95% of riparian habitats destroyed and the fig's ability to expand quickly, it is essential that the fig is eradicated from riparian ecosystems. The preliminary goal is to identify various sectors of fig prevalence within the Central Valley riparian habitats while simultaneously making note of the specific habitations it prefers to invade in the ecosystem. By identifying these specific hot-zones and their geographical relevance, it may be possible to discover the dispersal rate and distance of the fig seeds. These discoveries may help prevent further seed dispersal, since management can regulate the amount of viable seeds that may enter a site. After categorizing these hot-zones the next goal would be to monitor the wasp *Blastophaga psenes*, the main pollinator of the fig plant, as well as the animals that may eat of its fruits at the site. This goal may prove to be difficult, due to the small size of the wasp and the lack of known fig-fruit consumers. There is also a need to consider that homeowners are allowed to plant fig trees in their backyard. This in turn gives birds that may consume the fig fruit access to a ready supply which may lead to the transportation of fig seeds to riparian ecosystems. Wind dispersal could also be a contributing factor in seed dispersal. The ultimate goal would be the prevention of fig seed dispersal in riparian habitats of the site, which would require extensive detailed observations of seed dispersal. As such, although ideal, these goals may not be fully attainable. Nevertheless, in order for the eradication of the fig from riparian ecosystems of a site to be successful, seed dispersal and root sprouting must be controlled.

B. Elimination Plan

Currently there are no known effective measures for the elimination of the fig from riparian ecosystems. Trees resprout quickly and are extremely difficult to control without the use of herbicides (Bossard et al., 2000). Because of this, herbicide and physical control are the ideal choices to consider presently. However, it is important to possibly consider the possible solutions below to understand what may or may not work for eradication.

Physical Control

Manual/mechanical: Before maturation fig trees have shallow root systems and are often located in heavy, wet soils; as such manual removal is simple. However, it is important to keep in mind that fig trees root-sprout which means the above-ground sapling that is pulled out could very well be linked to an extensive underground network of roots. Repetitive cutting of the resprouted saplings may eventually exhaust the network of roots, but this hypothesis has yet to be effectively demonstrated (Bossard et al., 2000). This method should most likely be applied once the fig groves are treated with herbicides.

Biological Control

The USDA has not approved any biological control species, but the fig tree can be damaged by nematodes, tree borers, and rust (Bossard et al., 2000).

Chemical Control

A study conducted at Consumnes River Preserve, located near Sacramento, California, called for thickets of fig trees to be cut between six and eighteen inches above the ground. These trimmed trees were then treated with a 100 percent solution of the herbicide amine formulation of triclopyr. The treatment was successful although the thickets had to be treated yearly due to resprouting (Bossard et al., 2000). The trees at times were retreated two to six months, which seemed to be more effective. Although successful in Consumnes River Preserve, this exact method was conducted at the Dye Creek Preserve, which also located near Sacramento, California (Bossard et al., 2000) and it was not successful there. Another viable method being researched is known as basal bark application, which involves the application of a herbicide in an eight-to-twelve inch-wide band around the trunk of uncut trees with diameters larger than two inches. In a study conducted by Holmes et al., basal bark treatment was used for the control of invasive fig trees in six different groves located in the Central Valley. The herbicide of choice was composed of 25% triclopyr herbicide and 75% methylated seed oil. During the experiment it was found that there was an over-application of the herbicide due to the high bio-density of the fig groves, which was an undesirable outcome. This is due to herbicides such as triclopyr having a slow degradation and absorption period which results in a higher than average soil leaching capacity. This in turn indirectly affects plant species which were not originally targeted such as natives (Holmes et al., 2009). Holmes et al.'s research found that native plant mortality was statistically greater in treated plots; however the mortality levels did not meet the criteria for restoration efforts and the levels were low (Holmes et al., 2009). This may have resulted in the herbicide contaminating the soil or extensive flooding that occurred in four sites. Herbicide treatment should be highly considered, due to its high success compared to others. Treatment is highly recommended before late summer and autumn, when viable seeds are produced; and retreatment should be every two-six months.

While long-term and effective solutions are still being researched, fig ecology is surprisingly well understood. This knowledge will likely prove critical in the development of a successful eradication plan. One significant source of this data comes via Holmes et al., in which the overlaying patterns and processes of the fig invasion at Caswell Memorial State Park, located in the Central Valley, were closely observed. The spatial location, diameter of the largest tree, reproductive status, total number of trees, and floodplain positions were recorded for each invasion site at the park (Holmes et al., 2009). After collecting the data, a chronosequence was created to examine the figs' rate of invasion; data collection consisted only of fig trees that were older than 10 years due to the discovery that figs do no expand laterally for the first 10-15 years of maturation. It was found that invasion sites with several older trees as well as sites that were closely compacted had significantly higher rates of lateral expansion when compared to invasion sites which were expanding from a single point. Intriguingly, even though the first fig tree invaded Caswell Memorial State Park in 1934, there was an 18-year lag before the fig population became fully established (Holmes et al., 2014). After this period, the fig population expanded at an exponential rate. On the topic of spread patterns, it was found that in the figs' early invasion period the distance between individuals were fairly scattered as the overall range of the figs increased. In recent years, the fig pattern of invasion has increased quickly due to new recruitment of reproductively mature fig groves (Holmes et al., 2014). Fig tree groves that were 30 years and older had hundreds of reproductive trees and saplings, due to short-distance dispersal that occurs from seeds from fruit falling near reproductive trees and root sprouting—this type of dispersal encourages high linear expansion rates (Holmes et al., 2014). Holmes et al. also found that figs are capable of long-distance dispersal through the various animals which consume the fruit as well as through its symbiotic relationship with the wasp *B. psenes.* It was found that in Caswell, the wasps had become naturalized in the population and increased local propagule production (Holmes et al., 2014). Through the presentation of similar growth rates among figs positioned within river, slough, and terrace floodplain positions it can be inferred that fig trees do not have a specific water table preference.

C. Monitoring Plan

Based on the Holmes et al. study of the overarching patterns and processes of the fig, tailoring eradication efforts according to the length of time a fig patch has been active will be a necessary step. Through a well-made monitoring plan information on root networks, invasion rates, and progression milestones could be discovered. This should in turn be combined with several other sources, which will require closer inspection. Seed production and dispersal is one such source. Of special interest would be the monitoring of dispersal distances and how they are affected by *B. psenes* and other species. If possible, data should be acquired on the gestation period and dispersal rate of seeds directly dropped from the tree. Multiple plots of the fig groves, including ones that are small, need to be monitored to ensure that all fig trees are covered. Observations of the fig's re-rooting capacity after storm situations would also be highly valuable, although there would be some difficulty in efficiently obtaining this data due to the natural variability of weather systems. As a result, this form of monitoring, depending on the amount of previous research available, may need to take place over the course of a year or two in order to ensure that all species-plant interactions are observed. However, the monitoring times may depend also on the site, due to the amount of available resources and niche space the fig may depend on (Holmes et al., 2014). Once comprehensive monitoring is accomplished within a zone of interest, eradication plans can be tailored to suit the affected ecosystems. Through the combination of previously known eradication techniques such as herbicidal treatments and manual removal of re-rooting branches with time-specific periods of maximal spread, managers could switch to an active-suppression tactic. For example, if the data shows that the fig trees within extensive storm zones spread the most after a storm with heavy winds management personnel could be deployed to manually remove broken branches. This would in turn reduce the need for herbicidal treatments which also damage native plant life. If however, figs are found to spread most during a period of germination then more precise applications of herbicides are needed in order to inflict a stress-state that limits total seed output would become the preferred course of action. Replicates and a control group should be in place to confirm that the treatment is actually working so that it may be applied to other sites in the future. Research on the effects orchards and home-grown figs have on the dispersal rates of figs, if any, would further inform development plans; this is of special import for suburban land managers within and around riparian ecosystems. Whether or not more effective manual or chemical eradication measures are found, the need for managerial intervention is clear due to the exponential spread of fig systems which has already been observed throughout several states and over many years (Holmes et al., 2014).

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Chinese tallow tree (*Sapium seiferum*)

Background and Justification

The Chinese tallow tree (*Sapium seiferum*) is an invasive, woody species that was introduced to the United States in 1776 from China. It is often planted as a shade tree and for its ornamental qualities and seed oil. The species has been so successful as an invasive species in the U.S. because of its reproductive potential and growing speed (Urbatsch, 1996). The Chinese tallow tree invades riparian habitats in the Central Valley. It was introduced to California in 1888 and became popular around 1970. It now occupies wetlands, prairies, woodlands, and forests (Aslan, 2009). However, it is very adaptable and can also survive in dry uplands. This species is important to keep track of because it has an effect on large-scale ecosystems by replacing native vegetation and reducing native diversity as well as the ability to take over the already limited riparian space in the Central Valley. It has the ability to become the dominant species in an open plot of land. Because it is very difficult to manage, it can cause animals to lose their habitat and alter ecosystem processes by displacing native vegetation and dominating riparian zones (Aslan, 2009). It is currently found in 7 counties in California, restricted by dry summers (USDA, 2016).

Literature Review

Growth characteristics:

- The Chinese tallow tree is most successful when it grows within 2 meters of the water's edge, but has been shown to survive 7 meters away (this study was done in Davis, CA) (Aslan, 2009).
- Roots develop shoots up to 16 feet that can regenerate the tree after damage (Urbatsch, 1996).
- It is considered a medium sized tree, reaching heights of around 30-50 feet. Leaves alternate with blades 1.5-3.5 inches long and 1.5-4 inches wide (Urbatsch, 1996).
- They are monoecious and the seeds can live on the tree for weeks. The flowers mature in April-June while the fruit ripens in September-October (Urbatsch, 1996).
- Seeds mature in late fall around October-November (Breitenbeck, 2009).
- It is a deciduous tree and loses its leaves in November-December (Cal-IPC).

Reproduction:

- The Chinese tallow tree's saplings produce seeds that are 95-160 mg starting as young as 3 years of age. The seeds are dispersed by birds and water (Aslan, 2009).
- Germination rates are highest with locally high salinity (2 ppt) and higher soil temperatures (slopes of land that receive afternoon light) (Aslan, 2009). Germination is also greater with variable temperatures rather than constant temperatures (Meyer, 2011).
- Germination is also increased when the seeds are buried. A study showed a 56% germination rate when the seeds were buried at a depth of 1cm (Meyer, 2011).
- In central California riparian zones, germination was greatest at elevations less than 7.5 feet above the water level (Meyer, 2011).

- It can remain reproductive for up to 100 years. A mature tree produces an average of 100,000 seeds a year (Urbatsch, 1996). The seeds can float for several weeks, which results in better dispersal over potentially long distances (Breitenbeck, 2009).
- Stumps and roots are able to re-sprout after the tree is cut down or burned (Urbatsch, 1996).

Range:

- The Chinese tallow tree is currently found in San Joaquin, Davis, Sacramento, Chico, Oroville, Roseville, and Folsom (Aslan, 2009).
- It is most likely being limited in California due to the lack of rainfall in the summer (Urbatsch, 1996).
- It is found mostly in the humid south-east, from North Carolina to Texas (Breitenbeck, 2009).

Habitat/Requirements:

- Chinese tallow trees grow in lowland riparian areas. Also, in the Gulf Coast the species is able to grow in wetlands, prairies, woodlands, and forests, so it has the capability to grow in various environments. However, because of California's common dry summers, the species mainly survives in riparian habitats (Aslan, 2009).
- It prefers to grow in sunlight, but has the ability to grow in shaded closed canopies (Urbatsch, 1996). A study showed that the Chinese tallow tree grew larger than American sycamore and Cherrybark oak over a period of time in shade (having twice the dry mass and basal diameter and three times the height) and equaled the growth of the sycamore in full sunlight (Jones, 1989).
- It is often found in ditches or canals where flooding occurs (Breitenbeck, 2009). It grows most successfully in wet, open areas, usually around the shores of bodies of water, swampy areas, or floodplains. It has been found in areas with average annual precipitation from 9.6-147 inches (Meyer, 2011).
- It cannot live in frigid or arid areas (Urbatsch, 1996). It is able to survive where the average minimum temperature is 5-25°F (Breitenbeck, 2009).
- Areas most at risk for invasion are poorly maintained pastures and farmland and clear cut forests (Breitenbeck, 2009).
- It is able to grow in clays, loams, and sandy soils with a pH of 3.9-8.5 (Meyer, 2011).

Tolerances:

- The Chinese tallow tree is shade tolerant and can tolerate temporary flooding. It can also grow with or without nutrient enrichment. However, lowered watering frequency, excessive soil moisture, very high soil salinity, or native plants can slow its growth (Aslan, 2009).
- It can invade dry uplands and can tolerate areas with some salinity around 2 ppt (Urbatsch, 1996).
- It cannot withstand severe winters and if frost persists into the flowering season the blooms will die (Breitenbeck, 2009).

- Its limbs are brittle and can snap in high winds (Breitenbeck, 2009).
- As temperature rises, due to climate change, the species will be able to expand its range northward (Simberloff, 2000).
- It tolerates flooding better than drought. Trees planted at water level were able to survive a summer drought in Davis. Those planted more than 3.7 feet above the water level did not survive the drought (Meyer, 2011).

Interactions:

- The Chinese tallow tree often displaces native plants as it becomes the dominant species in a community. It may alter bird migrations patterns (such as yellow-rumped warblers) by attracting them due to its fruit availability. It also competes with other plant species for avian dispersal (Aslan, 2009).
- It can affect ecosystem processes because their primary productivity is high, which changes the ion concentrations in the soil (Urbatsch, 1996).
- The species has very few pests, some of which include: bagworm, root-knot nematode, and fungi (Urbatsch, 1996).
- Its sap and berries are toxic to many animals and its decaying leaves can even leach toxins into the soil that makes it harder for native plants to grow (Simberloff, 2000).

Management considerations:

- Large Chinese tallow trees are able to re-sprout after cutting and fire (Aslan, 2009). Seedlings are more susceptible to fire and can be killed using controlled burns. Fully grown trees can survive fire or are top-killed and will re-sprout. Controlled burns cannot be used to control fully grown trees (Meyer, 2011).
- Any removal efforts should be monitored for at least 3 years in order to remove new seedlings (Aslan, 2009).
- Elimination of the species has been proven very difficult in most sites of research. The trees can be sawn down to remove the seed sources. Fruit from the tree must be removed. Also, because the stumps can re-sprout, they are often treated with herbicides. Basal bark treatment has been effective at controlling the species as well as spraying a 6-inch band of triclopyr herbicide around the trunk. A solution of Garlon 3A has also been a successful treatment (Urbatsch, 1996).
- If the tree is not yet established, then mowing once a year can control the species. Once it becomes established in an area, cutting it down can cause shoots to arise from the roots so plowing is not a long-term solution (Breitenbeck, 2009).
- Frequent mowing and prescribed burns have been successful at controlling the species. Smaller trees can be killed with foliar or basal spray treatment and larger trees can be killed with basal spray or injection. Large invaded areas can be managed with aerial applications of herbicides. However, the herbicides can harm the native species (Ernst).

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Management Plan for Chinese Tallow Tree

Goals:

The Chinese tallow tree (*Sapium seiferum*) is an invasive, woody species that is often found in riparian habitats in the Central Valley. The main restoration goal is to determine if the Chinese tallow tree should be controlled or completely eliminated from the area. This will mostly be based on the feasibility of removing the species. Ideally, because the species is so successfully invasive and can replace native vegetation, our goal should be to remove it completely from riparian habitats, especially since these habitats have become so limited in the Central Valley. Therefore, restoration goals should include:

- Completely eliminate the Chinese tallow tree from the area by managing fully grown trees, sprouting stumps, as well as seedlings (the methods of how this is done will be outlined in the restoration plan).

- After the trees are removed, the area should continue to be managed and monitored for at least 3 years in order to assure new seedlings do not sprout (the specifics of this management will be outlined in the monitoring plan).
- If the species cannot be completely eliminated, use long-term monitoring and preventative actions (such as mowing and controlled burns) to prevent the re-establishment of seedlings (this will be expanded on in the monitoring plan).
- Replace Chinese tallow tree with native species in the riparian habitats to ensure establishment of a native species and to prevent erosion and re-establishment of the Chinese tallow tree.

The goals are feasible if long-term monitoring is available at the site. Short-term monitoring for 3 years is a good start but will not ensure that the Chinese tallow tree will not re-invade the area.

The pre-restoration goals should be to survey the area:

- Survey the area to assess how many Chinese tallow trees there are. It is also important to note how many of them are fully grown, how many seedlings there are, and whether there are any stumps left from a tree that was cut down or damaged.
- Measure how many feet away the trees are from the riparian habitat and their elevations above the water level.
- Measure the soil temperatures and salinities that the Chinese tallow trees are growing in.
- Monitoring needs to be done near riparian zones, areas of high salinity, and areas of high soil temperatures, where the tree has its highest germination rates (the specific parameters are explained in the restoration plan).

Restoration Plan:

The Chinese tallow tree grows most successfully within 2 meters of the water's edge and has been shown to survive 7 meters away. Other than birds, water is the main mode of dispersal of the tree's seeds (Aslan, 2009). Therefore, eliminating the trees upstream and closest to the water in the riparian habitat will be crucial in order to prevent further spreading of the species downstream.

Elimination of the species is very difficult because it is fast-growing and has the ability to re-sprout after being cut down or burned. Fully grown trees can usually survive prescribed burns or are only top-killed (Meyer, 2011). Therefore, controlled burns cannot eliminate the species. The established trees should be sawn down to remove their seed source. The tree's fruit ripens in September-October (Urbatsch, 1996). The seeds mature around October-November and can live for several weeks before germination (Breitenbeck, 2009). The trees should be sawn down between February-September, after the seeds from the previous season are no longer viable and before the fruit from the next season start to ripen and produce seeds.

Additionally, the trees that are planted more than 3.7 feet above the water level cannot survive a summer drought in Davis, California (Meyer, 2011). Cutting down the trees that are above this water level can be done during the summer drought season when the seeds are not viable.

However, plowing alone is not a long-term solution. The stumps need to be treated with herbicides so they do not re-sprout. If cutting the trees down is not an option, herbicides can be used to kill the tree and prevent re-sprouting. Basal bark treatment is an effective herbicide for controlling the species (Urbatsch, 1996). A basal spray injection can also be used (Meyer, 2011). If the herbicide is not effective enough on its own, a solution of Garlon 3A can also be used to kill the tree or prevent a stump from re-sprouting. The roots of the Chinese tallow tree can develop shoots up to 16 feet that can regenerate after damage. Therefore, a band of triclopyr herbicide should be strayed around the trunk (with a diameter large enough to surround the roots) (Urbatsch, 1996).

For any surviving trees, all of the fruit needs to be collected in September-October when the fruit ripens to prevent spreading of the seeds (Urbatsch, 1996). After the seeds mature in late fall around October-November, the area should be mowed or (more effectively) burned to prevent establishment of the seeds (Breitenbeck, 2009). The species can start producing seeds at as young as 3 years of age (Aslan, 2009). Therefore, seedlings should be eliminated before they near this age. The seedlings can be pulled by hand. If the area is large and a safe distance away from people, controlled burns can be used. The seedlings, unlike the full-grown trees, are susceptible to fire (Meyer, 2001). During the first 3 years after the trees are removed, frequent mowing once a month or prescribed burns when seedlings are observed will eliminate the establishment of seedlings (Ernst).

If the invaded area is large enough to make applying herbicide to each tree, individually, impractical, aerial applications of herbicides can treat large areas (Ernst). However, this will affect the native species as well so it should be used as a last resort. Herbicides can harm the native species, so when treating the Chinese tallow tree, it is important to try to contain the herbicides. Using herbicide injections rather than spray could be beneficial if the tree is near native species that need to be preserved. The risk of damaging native species must be assessed at the site before herbicide use is decided on.

An additional problem that the restoration plan could face is the riparian zone's exposure to erosion. If the Chinese tallow trees are cut down the riparian zone could be exposed to erosion once the trees are gone and the roots die. Ideally, there would be native plants that could be planted in place of the Chinese tallow trees in order to conserve the state of the riparian habitat. These native species should be fast-growing so they can establish in the riparian and prevent tallow tree invasion. They should also be monitored to ensure their establishment. Ideally, the Chinese tallow would be replaced with another woody species, such as the willow, so as not to decrease the presence of woody species. Also, a species that grows in thickets could increase the site's resistance to re-invasion by the tallow tree by occupying a lot of space.

Monitoring Plan:

The Chinese tallow tree grows most successfully within 7 meters of the water's edge (in a study done in Davis, California). In central California riparian zones, germination is greatest at elevations less than 7.5 feet above the water level (Meyer, 2011). Its germination rates are also highest with locally high soil salinity of around 2 ppt and slopes of land that receive afternoon light, which have higher than average soil temperature (Aslan, 2009). Therefore, these areas, which should be determined in the pre-restoration surveying phase (outlined in the goals section), should be closely monitored for sprouts because it is where they are most likely to establish. Seedlings should be pulled by hand.

The tree's seeds can float for several weeks and are therefore dispersed effectively by water over potentially long distances (Breitenbeck, 2009). So, riparian areas need to be continuously monitored even after the established trees have been removed because seeds from upstream could invade the area. Any removal efforts need to be monitored for at least 3 years in order to remove new seedlings that resulted from re-sprouting stumps or seeds that were left from cut trees before they are able to start producing seeds (Aslan, 2009). If there are seedlings that re-sprouted from previous trees more triclopyr herbicide should be sprayed on the ground because the seedlings are most likely a result of sprouting from leftover roots (Urbatsch, 1996). Therefore, the area should be mowed once a month to help prevent sprouting and seedling establishment in the first 3 years after restoration (Aslan, 2009).

Also, continuous, long-term monitoring is important to control Chinese tallow tree growth because seeds can be transported by water and birds, so establishment is possible even after the trees in the restoration site are eliminated. After the first 3 years of intensive monitoring when there are no established Chinese tallow trees, mowing once a year can control the species by eliminating any seedlings (Breitenbeck, 2009).

In order to improve the plan, it is imperative to know whether there are desired native species that could take the place of the Chinese tallow tree, especially in the riparian zones where they are most likely to re-establish. This could be answered by seeing which native species grow in riparian habitats elsewhere in the Central Valley. It is also important to know if controlled burns are an option for the restoration site. Additionally, it is important to know if the necessary resources are available to provide continuous monitoring at the site. If continuous monitoring is not possible, monitoring for the first 3 years after the restoration project will ensure that seedlings are not sprouting from eliminated trees, which is the most likely way the Chinese tallow tree would re-invade the area.

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Rubus discolor (Himalayan Blackbeerry)

Background & Justification:

Rubus discolor commonly known as the Himalayan blackberry is native to Eurasia and was introduced to America for cultivation in the late 1800's (Caplan, & others, 2006)*. It escaped cultivation and rapidly spread throughout the Pacific Northwest and other parts of the country (Bennett & others, 2006)*. In California it is prevalent along the coast, central valley and the Sierra Nevada. Himalayan blackberry is easily identifiable by five green oval shaped leaves on long green canes which can grow to incredible lengths. The canes and undersides of the leaves are covered in sharp spines. The stems form dense mounds which are practically impenetrable. The Himalayan blackberry is often found along riparian areas and wetlands however, it can also tolerate very harsh soil conditions allowing it to adopt a wide range of habitats ("Cal-IPC: Invasive Plants of California's Wildland," n.d.). The blackberries ability to quickly spread into a wide range of ecosystems has resulted in many problems including smothering of existing native plant communities, providing a vector for diseases, as well as impeding movement of humans, livestock, and wildlife ("Wild Blackberries Management Guidelines--UC IPM," n.d.).

Fact Sheet:

Identification

- Long green spiny canes with branching clusters of five leaves coming off of the cane. Leaves are oval and serrated.
- Flowers are produced on the end of shoots in clusters. Flowers have white or pink petals and are around 1 inch across ripe
- Fruits are large and round clusters of drupelets which are black when ripe ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).

Growth

- The evergreen shrub can reach 10ft in height and in a single season a stem can grow over 20ft (Bennett & others, 2006)*.
- First year growth develops from buds underground and the stems only produce leaves. In the subsequent year the cane can produce leaves and flowers. After two years the cane dies and provides structure for the new growth (Bennett & others, 2006)*.
- Vines can grow from the crown or from the rhizomes. It quickly spreads laterally by first year canes developing roots when coming in contact with the ground ("Wild Blackberries Management Guidelines--UC IPM," n.d.).
- Roots have been found to grow down to 3 feet reaching lengths of 33 feet ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).

Reproduction

- It can reproduce both sexually and asexually ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).
- Flowering is usually between May and July ("Cal-IPC: Invasive Plants of California's

Wildland," n.d.). It is mainly pollinated by bees however, can self-pollinate ("Wild Blackberries Management Guidelines--UC IPM," n.d.).

- Fruits are produced starting in July and continue through September.
- Developed blackberry patches can produce up to 13,000 seeds per square meter.
- Seed dispersal is facilitated by many species of birds and mammals eating the succulent fruit.
- Seeds having a hard protective coating and are slow to germinate usually doing so in the spring.
- Seeds are best established in open areas such as stream sides, fallow fields, and eroded soils.
- The blackberry also reproduces by vegetative means often sprouting from large root crowns. It can also proliferate from just stem cuttings and root pieces. In just 2 years one cane cutting resulted in a thicket 16 feet in diameter ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).

Habitat requirements

- Riparian areas are prime habitat
- Himalayan blackberry prefers high sunlight exposure and greater than 29 inches of rain fall ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).
- Found in a wide array of disturbed areas such as farm land, roadsides, pasture, and wastelands (Hoshovsky, 1973).

Species tolerance

- Acidic and alkaline soils can support blackberries (Hoshovsky, 1973).
- Periodic flooding, even with brackish water inundation (Bennett & others, 2006)*.
- Up to 88% canopy cover.
- Wide range of soil textures and available nutrients. Can persist in areas with poor soil conditions giving it an advantage over other species (Caplan & others, 2006)*.

Home range

- Native to western Europe but has spread all over the U.S. West Coast and British Columbia and in experimental grounds in the East Coast and Ohio ("Cal-IPC: Invasive Plants of California's Wildland," n.d.).

Negative impacts

- Mass of blackberry thickets smothers most if not all other plant growth.
- Obstructs access to feeding areas and water for many mid to large size animals.
- Can harbor Piece's disease and provides a vector for pathogens to infect riparian areas and agricultural sites.
- Provides habitat and food for rats ("Wild Blackberries Management Guidelines--UC IPM," n.d.).

Management strategies

- It is a difficult task to eliminate the blackberry because of its resprouting capabilities and vast root system ("Wild Blackberries Management Guidelines--UC IPM," n.d.). For long term exclusion of the blackberry it is best to eliminate the blackberry and then introduce desired species that can provide a dense canopy to shade out blackberry invasion attempts (Bennett & others, 2006)*.

Methods

- Tillage
  - Repeated tillage may provide some control however, it can break up the roots and result in more new sprouts. Bulldozing can also have the same result("Wild Blackberries Management Guidelines--UC IPM," n.d.).
- Mowing
  - Only effective at temporarily reducing the vegetation cover. Promotes resprouting of suckers from the roots and encourages branching ("Wild Blackberries Management Guidelines--UC IPM," n.d.).
- Burning
  - Similar results to mowing, removes biomass but increases sprouting ("Wild Blackberries Management Guidelines--UC IPM," n.d.).
- Biological control
  - Blackberry leaf rust (*Phragmidium violaceum*) has been found to harm blackberries. It is not feasible in California because of several native *Rubus* species ("Wild Blackberries Management Guidelines--UC IPM," n.d.).
- Chemical control
  - Herbicides such as Glyphosate and Triclopyr when applied during late summer early fall are successful in killing the whole plant ("Wild Blackberries Management Guidelines--UC IPM," n.d.).

* Due to limited information on Himalayan Blackberries in California these sources come from studies conducted in Oregon and may not reflect the exact conditions in California.

***Rubus discolor* (Himalayan Blackberry) Management Plan**

Goals

The overall goal is to eliminate the presence of *Rubus discolor* in the given management area and to introduce species that will increase the community's resistance to blackberry invasion. Specifically no sprouts of the blackberry plant should be found on the site. The blackberry is a prolific sprouting plant even a very small amount can quickly grow and dominate the surrounding area thus it is important to eliminate the majority if not all it ("Wild Blackberries Management Guidelines--UC IPM," n.d.). This can be achieved by these four steps.

1. Prepare the site by getting rid of the plant biomass by means of mowing or burning.
2. Kill or remove the root crowns of the blackberry. This is an essential part of the process since blackberries can easily re-sprout from any root fragments.
3. Introduce native plants to repopulate the site.
4. Maintain the native vegetation by removing competing plants.

Management Plan

The most effective way of achieving goals 1 and 2 is by using a combination of mowing and herbicides. The site should be mowed or cut during the blackberries growing season (May-July). Once the canes are cut allow the blackberry to re-sprout and reach a height of around a foot and fully leaf out. Then apply herbicide in the fall (September-November) as the plant is actively sending energy stores to the roots at this time (Bennett & others, 2006).Two herbicides, triclopyr and glyphosate have been shown to be very effective on blackberries and should be applied by spaying onto the leaves of the blackberries where it will be absorbed and carried to the roots. After at least a week the remaining above ground vegetation can be cut or burned again. The remains left after mowing can be left on site to serve as mulch to retain soil moisture and add to soil organic matter (Bennett & others, 2006).

The use of herbicides in riparian and wetland areas where blackberries are commonly found in the Central Valley can be an issue. To insure no harm is done to aquatic species and other native plant species it is important to take adequate precautions. Triclopyr and glyphosate are preferred for riparian areas because both generally have small impacts on aquatic life (Bennett & others, 2006). Triclopyr is used for control of woody species and does not affect grasses making it appealing for a grassland ecosystem. At a 2% solution it is very effective on Himalayan blackberry however, can be harmful to fish at very high concentrations. Glyphosate is used for the control of most vegetation thus care must be taken when applying it as it will kill almost any plant. It is also nontoxic to fish and aquatic organisms as well as terrestrial animals. For best results using glyphosate on blackberries a 7.5% solution is recommended with as low as possible surfactant percentage as certain added surfactants can be detrimental to fish (Bennett & others, 2006). Herbicide use should be determined depending on the local conditions of the site and the opinion of a pesticide consultant.

An alternative to using herbicides, is to manually or mechanically dig out the blackberries. This is not as effective at controlling the growth of the blackberry but will adequately remove blackberries in areas sensitive to herbicides. For best results from mechanical removal of blackberries a tractor with a claw or bucket and thumb and a skilled operator is needed (Bennett & others, 2006). The idea being to pull out as much of the root system of the blackberry plant with the tractor. In order to have the best chance of not breaking the roots and pulling out the whole crowns this method should be implemented when the soil is loose and moist (Hoshovsky, 1973). This many cause access issues with a tractor if soils are too moist especially in wetland areas in the California Central Valley. The alternative to a tractor is to remove the roots and canes by hand which is a very labor intensive process and extremely difficult considering roots can be over a foot deep. This method of removal has its drawbacks as it disturbs the soil promoting the spread of weeds and re-sprouting of any blackberry root fragments left behind. Additionally erosion of the newly disturbed soil can be an issue. This can be remediated by use of erosion control cloths and the spreading of mulch of the area (Bennett & others, 2006).

Once the biomass of the Himalayan blackberry has been removed and root crowns have been treated or removed native plant species need to be introduced. For restoration of grasslands sowing the seeds of native grasses can help to eliminate the blackberry regrowth and recolonization. For riparian areas or wooded areas the best strategy is to shade out the site which was infested with blackberries, since blackberry growth is severely impacted without direct sun. Planting fast growing riparian species such as willows or other native woody shrubs or trees can greatly help in excluding blackberries (Bennett & others, 2006). Planting of woody species such as willow should be conducted in the spring after the initial removal of the blackberries. By planting in the prime growing season April to August the plants have the best conditions for rapid growth which is what is needed for them to out compete the blackberry.

Releasing current or introduced vegetation from the competition of blackberries is helpful in establishing a resilient community. This can be achieved by removing any encroaching blackberries from the desired woody plant species. By doing this it allows those desirable native species to grow and ultimately shade out the blackberries. Additionally stimulating root suckering of willows or other woody vigorous sprouting plants by removing any competition can give these fast growing species the opportunity to fully shade out the invading blackberries (Bennett & others, 2006).

Monitoring

Sites that have been treated for Himalayan blackberry should be closely monitored for several years after a treatment. Detailed observations of any changes in the number of blackberry plants or the presence of new sprouts in the site is important in determining the effectiveness of the treatment and when additional treatments are needed (Hoshovsky, 1973). Monitoring should take place every month during the main growing season of the blackberry from May through September. Observations should continue for at least 5 years after the initial treatment in order to be certain all new sprouts and new germinations from the leftover seeds have been addressed. Removal of any regrowth should be conducted as soon as the blackberry sprout is slightly over a foot long, by waiting until this point it depletes the blackberries energy stores as well as giving the opportunity for spot application of herbicides (Bennett & others, 2006).

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TAENIATHERUM CAPUT-MEDUSAE (MEDUSAHEAD)


Source:http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=10382

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Liliopsida
Subclass: Commelinidae
Order: Poales, Cyperales
Family: Poaceae
Genus: *Taeniatherum, Elymus*
Species: *caput-medusae*

Habitat types Medusahead tolerates:
Valley Floor Grassland

Background/Justification

Medusahead (*Taeniatherum caput-medusae*) is an exotic annual grass, that is categorized in California as a noxious weed. It is often found in low elevations near annual grasslands, oak woodlands, and chaparral communities (Kyser et. al. 2008). Medusahead is a winter annual characterized by late spring-early summer growth and mid-summer seeding. Because of this, it is often termed a late-season grass. Medusahead was first documented in the United States in Oregon in 1887 and spread North to Oregon, South to California, and East in to the Great Basin (Kyser et. al. 2008). After its likely introduction as a contamination in cereal seed grain (George 1992; Hilken and Miller 1980) Medusahead established itself as a competitive invader, spreading around 12% annually. Currently, the range is estimated at over 950,000 ha in the western 17 states only (Rice 2005). Medusahead is thought to spread particularly quickly in ecosystems with high nutrient levels due to the exaggerated differences in growth and vigor between Medusahead and the native annuals, this allows it to colonize early and take over the system. The distribution of Medusahead is thought to be strongly related with livestock production due to seed distribution though sticking. Also, in terms of forage quality, the high silica content does not lend itself to good forage quality; therefore for much of the summer, once its seeds are up, Medusahead is unpalatable and therefore can facilitate the next generation. This leads to colonization of vast areas despite a relatively small horizontal distribution (~10 cm) per generation (Kyser et. al. 2008).

Literature Review

Project Goals:

Removal of Medusahead to facilitate the reintroduction and recolonization of California native species.

Growth Characteristics:

-Winter annual (Kyser et. al. 2008)

-Stems grow 8-24 inches high (Kyser et. al. 2008)

-Seeds small with long awns barbs and silica scales (Kyser et. al. 2008)

-Above ground growth slow, root growth extensive during winter, vigorous aboveground growth during spring and summer (Kyser et. al. 2008)

-In colder temperatures, Medusahead roots grow much faster than native plants (Kyser et. al. 2008)

Reproduction:

-Seedbank: The Medusahead seeds are adapted to germinate in the thick thatch caused by the slow decomposition of the silica-dense Medusahead vegetation. Medusahead seeds send out aerial roots in order to penetrate the thatch and reach the soil. If the initial root dies, the seed can create more adventitious roots after rain or moistening events. (DiTomaso et. al 2008)
-Germination cues: Seeds have a dormancy period, thought to be temperature related. Due to the afterripening process, seeds must be exposed to cold temperatures for 90-120 days after maturity. Nelson and Wilson (1969) suggest that the after-ripening is caused by inhibitory substances contained within the awns of newly dropped seeds. (DiTomaso et. al. 2008
-Almost entirely self-pollinated, flowering in late spring-early summer, seeds mature by July (Kyser et. al. 2008)
-Long-distance dispersal through sticking to animal coats, short distance through wind (~10 cm) (Kyser et. al. 2008)

-Long-range dispersal by human activity or livestock tracking (Kyser et. al. 2008)

-Average of 8-15 seeds produced per seed head (California Invasive Plant Council)

-Optimal temperatures are around 20-25 C in the lab, however in the field optimum temperatures appear to be around 10-15 C (comparable to fall temperatures around the first precipitation event)and requires hot temperatures in summer for optimal growth (Kyser et. al. 2008 and DiTomaso et. al. 2008)

Succession:

-Due to rapid growth, in the event of soil disturbance Medusahead can replace slower growing native perennials quickly and form dense monocultures to keep them out. (Kyser et. al. 2008)

Range:

-Found statewide except for high Sierra and southern deserts. (Kyser et. al. 2008)

-Native to Mediterranean regions, but also does well in drier areas such as the Intermountain West and Great Basin (Kyser et. al. 2008)

-Often found in annual grasslands, oak woodlands and chaparral ecosystems (Kyser et. al. 2008)

Animal Interactions:

-Once seed has set, medusahead has little value as forage or wildlife habitat, however it is palatable (mostly to sheep) when green (Kyser et. al. 2008)

-Profoundly negative effects on Sage Grouse as a result of habitat and forage removal due to monocultures of Medusahead (Kyser et. al. 2008)

-Seeds not stashed by rodents (Longland 1994) or used by birds (Goebel and Berry 1976)

Plant Interactions:

-Often found in sites that are already invaded by cheatgrass (Dahl and Tisdale 1975)

-Sometimes borders sagebrush communities (Kyser et. al. 2008)

-Outcompetes native perennial plants due to increased vigor in spring months with increased moisture (Kyser et. al. 2008)

Habitat:

-Generally found with 30-61 cm rainfall, however can tolerate anywhere from 25-102 cm (Kyser et. al. 2008)

-Matures late in the season, able to thrive on infrequent precipitation events (Kyser et. al. 2008)

-Cannot tolerate inundation

-Little to no impact of slope or aspect on medusahead density (Kyser et. al 2008)

-Typically unable to colonize vernal pools/riparian areas

-Soil disturbance increases the potential for medusahead invasion (Miller 1996)

Responses to management

-Burning: Since medusahead seeds so late, most desirable grasses have already dropped seed. If you burn while medusahead is still actively growing, you can wipe out the medusahead while not harming the seeds that are already in the soil bank. Generally the best time to burn is mid May. (Becchetti 2013)

-Grazing: Around mid-April to the beginning of May is the best time to graze for maximum input. There is a short window during native grass senescence and before medusahead seed heads emerge where medusahead is selectively palatable. (Becchetti 2013)

-Herbicides: Selective herbicide use can be used to control weedy species such as medusahead on small plots with concentrations up to 0.22 lb/acre for no more than 50% of an acre. Therefore, though functional on a small scale this treatment is not viable on a large scale (Becchetti 2013) The herbicide that appears to work most effectively is Imazapic (a pre-emergent herbicide), however, other herbicides tested include Rimsulfuron, Chlorosulfuron+Sulfometuron (both pre-emergent herbicides), and Glyphosate (a post-emergence herbicide).

Negative Impacts:

-It is on the California C list – it is listed as a noxious weed (considered one of the worst)

-Competes for resources such a water and nutrients with more desirable species

-Changes ecosystem function to improve its own survival at the detriment of the rest of the ecosystem (Kyser et. al. 2008)

-Can lead to permanent nutrient changes, (including “reduced nitrogen mineralization, reduced total nitrogen, and significantly increased pH at the invaded site” [DiTomaso et. al. 2008]) increased erosion (Kyser et. al. 2008), and permanent changes in hydrologic cycles (the thatch layer acts as a mulch layer that slows water loss from the soil. [DiTomaso et. al. 2008])

-Alters the fire regime. Medusahead creates dense stands that form a continuous fuel layer and increase the fire return interval in the site. (Kyser et. al. 2008) For example invasion in the Great Basin, it changes the FRI in sagebrush steppe from ~200 years to 50-80 years. (DiTomaso et. al 2008)

-Thick thatch layer slows decomposition of other plants, reducing the soil nutrients and the penetration of other plants seeds into the soil. (Kyser et. al 2008)

-Limited grazing in early spring, in summer it can decrease forage value by 50-75% (fs.fed.org)

PART 2

A. Goals

The goal of this restoration plan is to minimize the amount of Medusahead and subsequent seed in the system. Consideration should be taken to minimize damage to desirable species. It is important to address Medusahead while the infestation is still relatively small, otherwise effective management will become significantly more difficult to achieve. Since Medusahead can spread up to 12% annually, any more than 20% cover can become a serious problem. If medusahead is in neighboring areas with a high risk of human or animal seed dispersal, rehabilitation efforts may be necessary in the neighboring areas to prevent introduction in the site.

Less Invaded → More invaded

Goal	Methods	Short/Long Term	Description
Prevention (<5% cover)	Increase biotic resistance	Long Term	Increasing the diversity at the site to allow native perennial species to dominate the site and keep Medusahead out
	Limit dispersal	Short Term	Such as signs asking people to check their shoes and pets for Medusahead seeds to minimize dispersal distance. Or physical/chemical barriers to spread.
Early Detection (5-20% cover)	Monitor for infestations	Short Term	Monitoring can help prevent the spread of an infestation or track the source of an infestation
	Eliminate small infestations	Short Term	Prevent widespread infestation of Medusahead
Rehabilitation (>20% cover)	Prescribed fire	Short Term	Use of prescribed fire to remove vegetation and render seeds unable to germinate.
	Herbicides	Short Term	The use of pre-emergence or post-emergence herbicides to kill the Medusahead and reduce seed viability.

	Grazing	Short Term	Use of grazing to remove vegetative Medusahead before seed head emergence

B. Restoration Plan

Prevention

Medusahead is exceptionally invasive in annual warm-winter grassland ecosystems with high nutrient clay soils. In terms of prevention, a disturbance regime is likely to do more damage to the surrounding desirable species than Medusahead, therefore in order to maximize the exclusion of Medusahead through biotic resistance, a more desirable, less invasive annual grass could be introduced to provide competition against Medusahead (Nafus and Davies 2014). Nafus and Davies suggest Crested Wheatgrass (*Agropyron cristatum)* as a buffer around the border of an infestation to prevent lateral seed dispersal. As Crested Wheatgrass is a species native to the Great Basin area, a possible California native that can be substituted is Purple Needlegrass (*Nasella pulchra*). Purple Needlegrass creates dense stands that can create a physical barrier to prevent the wind transportation of Medusahead seed. In terms of limited nutrients or water, Medusahead is still more competitive especially at the seedling stage (James et. al. 2011). Though medusahead is still more competitive despite limited nutrients, limiting the available nutrients does decrease the difference in vigor between native perennial bunchgrasses and Medusahead. The reduction in Medusahead vigor could allow perennial natives to reestablish while the biomass and seed production of Medusahead are negatively effected.

Early Detection

Early detection requires a monitoring plan set in place for the restoration site, specific attention should be paid to roads and animal trails, however random areas should be selected for monitoring in order to minimize small infestations of Medusahead growing unchecked. Small infestations can be controlled by the methods listed under “Rehabilitation”. After treatments have been applied to control the infestation, monitoring every three months for the first year should be conducted to ensure the successful eradication of the patch, and every six months for the second and third year in order to ensure that no regrowth has occurred and there are no new invasion sites. It is much more economically feasible to conduct preventative monitoring than it is to conduct large-scale elimination and restoration practices.

Rehabilitation

Prescribed Fire

Prescribed Fire is an effective and relatively efficient method of Medusahead removal, there are, however, limitations in terms of efficacy determined by the characteristics of the site. Without diverging too much, the best site types for effective prescribed burns are “low elevation, warm-winter areas with high grass biomass production” (Kyser et. al. 2008) due to large amounts of plant material that are susceptible to burning during late summer. The best time to burn is when the awns lose their purple color and the seeds are in the “early hard dough phase” i.e. still flexible) in order to maximize the fire intensity (generally around June 8 and June 15). There have been many studies (McKell et. al. 1962 and Young et. al. 1972 among others) that state that the affectivity of the burning treatment is dependent on the height of the flame, the time of season, the rate of advance of the fire, and humidity. The ideal fire conditions are slow moving, hot fires conducted at air temperatures around 26.7° C at midday with relative humidity around 45% and wind at 1 mile per hour. These fires should be conducted into the wind or downhill to prevent the fire from getting out of control. The seed mortality greatly decreases from 80% at 180° C to 15.5% at a temperature of around 200° C. Greater intensity slow moving fires are more likely to kill the viable seeds in the thatch layer and the new seeds in the inflorescence due to longer residence times and higher temperatures due to greater amounts of fuel. McKell et. al. 1962 and Young et. al. 1972 also state that that though there was an initial decrease in Medusahead population following the fire, following disturbance it had a competitive advantage in the system. However if an herbicide (see herbicide section) is applied in fall during the germination period, then a prescribed burn is conducted, surrounding plants may be able to suppress Medusahead at the site during the following spring (Young et. al 1972) and continue to suppress it for at least three years. If a competitive stand of perennial grasses is established following these treatments, the state will be relatively stable. Once Medusahead was removed from the system, the observed dominant species shift (for the Yolo county area) was toward *Vulpia myuros* and *Erodium brachycarpum* also observed was an increase in legumes and palatable forage species. Common mistakes that led to a less than complete removal of Medusahead include burning too early in the season which causes the fire to either burn poorly due to wetter conditions or kill the surrounding plants and allow Medusahead to produce additional growth with the nutrients and water left by the earlier-maturing species. Burning should also be paired with other management strategies such as grazing and reseeding. Multiple burns in consecutive years proved more detrimental than helpful especially in fire-suppressed systems (Young et. al. 1972).

Herbicide

In locations with healthy or at least relatively intact species diversity, the use of short-term management practices may be used to create a window for natives to re-establish. Herbicide use can greatly decrease the density of Medusahead over a short period of time. However, left to its own devices, Medusahead will repopulate the site. This method is best paired with some other method of rehabilitation, most often fire and reseeding to ensure maximum mortality for the seed heads and in order to build up a resistant plant community to prevent the re-establishment of Medusahead. Refer to the prevention methods for the re-establishment of native species such as Purple Needlegrass. This process often takes active re-seeding in order to cultivate sufficient densities to successfully keep out Medusahead. The table below shows four options for herbicides: three pre-emergence (Imazapic, Rimsulfuron, and Chlorsulfuron+Sulfometuron) and one post emergence (Glyphosate).

	Imazapic	Rimsulfuron	Chlorsulfuron+ Sulfometuron	Glyphosate
Concentration	240 g ae□L^{-1}	25%	50% + 25%	359 g ae□L^{-1}
Rate ($g*ha^{-1}$)	105 ae	70 ai	35 + 18 ai	420 ae
Timing	Fall applied (pre-emergence)	Fall applied (pre-emergence)	Fall applied (pre-emergence)	Spring applied (post-emergence)
Average residence time **in soil (half-life)**	120 days	2-55 days**	20-40 days***	N/A
Control of Medusahead Year 1	>93%	>93%	>93%	>94% at one site 61% at the other
Control Year 2+	78-88%	Not significantly different from untreated	Increased as compared to untreated plots	Not significantly different from untreated
Reduction in Seed Year 1	96-100%	96-100%	96-100%	48%
Impact on perennial grasses	No statistical difference	No statistical difference	No statistical difference	No statistical difference
Impact on Forbs	Increase in native forb cover. Decrease in introduced forbs.	Increased introduced forb cover and native forb cover.	Increased introduced forb cover.	Greatly increased introduced forb cover.
Seeding delay time*	12 months	7-12 months	3-6 months	None

Consistent overall control?	Consistent control. Medusahead only recovered 35-50%	Good initially however Medusahead increased in concentration when the treatment wore off. Not long term.	Good initially however Medusahead increased in concentration when the treatment wore off. Not long term.	Inconsistent control
Potential problems	Can bind to the litter layer and cannot be taken up by plants	Cover same as before treatment	Cover same as before treatment	Inconsistent reduction. Non-discerning herbicide
Positives	Consistent. Effective. No known negative effects on desirable associated species.	No significant outstanding feature	No significant outstanding feature	Inexpensive, low risk, environmentally safe.

Kyser et. al. 2007, Kyser et. al. 2013, Monaco et. al. 2005

*Amount of time that is suggested between herbicide application and seeding of new plants.

** Martins et. al. 2001

*** Washington State Department of Transportation

Grazing

Grazing as a management practice is not viable on its own on a large scale. However as a small-scale, short-term solution, mid-spring (April-May) grazing can reduce Medusahead cover by 86-100% (DiTomaso et. al. 2008). The grazing practices can increase forb cover, forb species richness, and ecosystem plant diversity. Intensive grazing practices (2.2 to 2.6 ha/500kg calf) (DiTomaso et. al. 2008) during the palatable growth period can reduce Medusahead cover from 45% to 10%. The timing of the grazing should be synchronized with the elongation of the stems but before the seed heads emerge. Grazing in late spring, early spring, or fall have no significant effects on Medusahead distribution. For sheep or goat grazing, there will need to be fences surrounding sensitive areas with plants that should not be grazed and nesting sites that should not be disturbed for example plant communities with showy milkweed, which is toxic to grazing species, or areas with ground nesting birds. DiTomaso et. al. (2008) used sheep grazed at a high stocking rate, 5-10 animals/100m^2 plot (goats may need slightly more animals per plot depending on differences in weight) for two to three days. The high stocking rate raises the grazing pressure on the Medusahead while avoiding catastrophic grazing on desirable species due to the higher level of Crude protein in Medusahead at that point in the season (Lusk et. al 1961) This resulted in a positive impact on species richness, diversity, and Medusahead reduction.

Risk and Uncertainty

As a result of management practices that use chemicals, there could be contamination of any nearby riparian or wetland areas due to leaching of herbicides through the ground water. The Glyphosate is a non-targeted herbicide and as such may have negative effects on surrounding vegetation. Grazing could cause habitat or vegetation destruction and erosion on stream banks. The utilization of prescribed fire can quickly get out of control if the wind shifts and the fire picks up. As with any endeavor, prepare ahead of time and contact the proper professionals for herbicide application and prescribed fire. There is no guarantee that these methods will completely eradicate the Medusahead population depending on the scale of the infestation, much more research needs to be done in this area of study in order to accurately determine the effects of and responses to management.

C. Monitoring and adjustment for Goals

Visit	**What to Observe**
Pre-Restoration Monitoring (up to a month before restoration)	Vegetation types, distribution of Medusahead (satellites or dense infestation), accessibility, relative plant available soil nutrients and water availability.
Follow up (6 months for herbicide; 1 month for grazing	Thatch should start to decay, population should be reduced around 60-100%
Management Implementation: Part 2	Prescribed burn, remove all thatch, should kill seeds and prevent germination during the next growing season.
1 year follow up	Observe Medusahead population density. Should still be 80-90% reduced from the initial population. If more than 20% cover, repeat chosen procedure (most effective is herbicide then burn)
2 year follow up	Medusahead population will likely have increased to about 50% of pre-treatment values. Are the perennial grasses pushed out of the system? May consider treating again.

Additional management if necessary	If treatment is necessary, continue with the management above. Consider setting monitoring for possible sources of infestation.

Monitor for medusahead populations or initial germination. Monitoring may be conducted by transects through previously invaded areas and by random walkthroughs or community monitoring for new growth and expanded invasion. 6 month follow up should be conducted during the winter (December-January) when medusahead is germinating, yearly follow-ups should be conducted during the early summer (June-July) in order to determine distribution during time near seed maturation.

D. Research Questions

- How do the management strategies work when integrated together?

-What is the distribution of Medusahead in the site?

-What are the interactions between wetland and riparian species and Medusahead?

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Festuca perennis

Festuca perennis (Italian Ryegrass) is an aggressive invasive species that is commonly found in many different native California ecosystems, from salt marsh and coastal prairies to shrub lands and chaparral. F. perennis often out competes native grasses (Pfeifer-Meister, et al., 2012) and inhibits succession of communities to native dominated landscapes (Zelnik, et al., 2010). F. perennis is also involved in the process called 'terrestrialization', in which a body of water transforms into a wetland and further into a terrestrial ecosystem (Lunt, et al., 2012). Populations of F. perennis do well in the Mediterranean climate (Lenssen, et al., 2004) and have contributed to the loss of wetland ecosystems coastal and inland (Power, et al., 2014). F. perennis is still used today as a ground cover plant for erosion control (Ahn and Dee, 2011; Zelnik, et al., 2010) and as a supplement to native perennial species to attract waterfowl in riparian habitats (Givens and Atkeson, 1952).

F. perennis Physiology:

- F. perennis is tolerant of Mediterranean wetland hydro periods, with winter growing seasons and dry hot summers and communities such as serpentine bunch grass and fresh water seep communities (Pfeifer-Meister, et al., 2012; U.S. Forest Service).
- F. perennis is a copious seed producer, but does not disperse far from the parent plants because of heavy seeds (1.3-2.6 g) (Beddows, 1973).
- F. perennis is believed to be distributed by animals (U.S. Forest Service), but may also disperse from seed drop.
- Self-pollination is possible in F. perennis but the resulting spikes have very few viable seeds (Beddows, 1973).
- It takes 10 days from pollination to achieve viable embryos, but 30 days until the caryopsis can be harvested (Beddows, 1973).
- Seeds may have up to a 6 month dormancy and may exhaust viable seeds in the seed bank through germination (U.S. Forest Service).

Interspecific Population Dynamics:

- Most native perennials can out compete F. perennis once established, but native seed mixture composition is important for maintaining species diversity and richness (Pfeifer-Meister, et al., 2012).
- Festuca perennis with high endophyte incidence (Neotyphodium) have increased recruitment and fitness when invading an ecosystem while increasing F. perennis biomass and reduced seed predation by granivorous rodents and birds, resulting in easier establishment of the invasive species (Uchitel, et al., 2011).
- F. perennis is subject to herbivory by water fowl and rodents (Beddows, 1973; Uchitel, et al., 2011).
- F. perennis is the host of the wheat yellow leaf virus (Lapierre and Signoret, 2004).

Benefits of F. perennis:

- In 1946, Festuca perennis was planted at Wheeler National Wildlife Refuge to attract waterfowl temporarily and at a cheap price by seed and labor (Givens and Atkeson, 1952).

- F. perennis are commonly planted at the beginning of revegetation efforts for erosion control, but can have adverse effects on establishment of stress tolerant, less competitive target species but can disappear completely with extended standing water durations (Zelnik, et al., 2010; Ahn and Dee, 2011).
- Total nitrogen in an urban plant uptake experiment was reduced 34.8% with an average N removal rate of 0.62 g m-2 d-1 in F. perennis (Above and below ground mass) and total phosphorus was reduced 35.8% with an average N removal rate of 0.1 g m-2 d-1 down to a concentration of .2-.3 mg L-1 for N and .01-.03 mg L-1 (Abe, et al., 1999).

Control Methods: Flooding

- Flooding during spring and summer months reduced exotic annual cover in general by 8%-30% with native perennials increasing in cover by 6%-26%, while flooding during any season would still reduce annual exotic cover by >2% (Lunt, et al., 2012).
- Controlled flooding should be timed after plant establishment (Lunt, et al., 2012)
- Long term inundation does not reduce seed viability, but does reduce emergence (Lunt, et al., 2012).
- Single short term event flooding may promote exotic annual cover because exotic annuals recover quickly from flooding. However, frequent, short duration floods are a practical method for controlling exotic annuals in consonance with the 'terrestrialization hypotheses' (Lunt, et al., 2012)
- Irregular flooding, and inundation of plant species appears to favor traits that increase competition, rather than flood tolerance in ecosystems that are naturally flooded (Lenssen et al., 2004).

Control Methods: Herbicides

- Herbicide application timing is critical to control Festuca perennis and must be applied during the early growth stages "(less than four leaf stage)" or just after seed bank germination to reduce abundance (Tucker, et al., 2006).
- F. perennis dry weight reduction decreased by >10% after mid-tiller life stages in response to triasulfuron (Tucker, et al., 2006).
- Triasulfuron reduced seven of 39 ecotypes' dry weight by <10%; two samples had no reduction in dry weight (Tucker, et al., 2006).
- Herbicide resistance in Festuca perennis is common and likely due to variation in herbicide metabolism, variation in acetolactate synthase (ALS) structure and expression and is propagated by cross-pollination (Tucker, et al., 2006).
- Diclofop, clodinafop, and metribuzin provide greater efficacy in controlling triasulfuron resistant ecotypes, though diclofop resistant ecotypes have been identified (Tucker, et al., 2006).

Control Methods: Other

- Solarization and herbicide treatments performed best at controlling exotic annuals in short term, but all treatments converged to native bunch grass dominated communities at the cost of species diversity and richness (Pfeifer-Meister, et al., 2012).
- Control and 'Till Only' treatments had lower native cover than other treatments, but all treatments resulted in reduction of F. perennis after 3 years of treatment (Pfeifer-Meister, et al., 2012).
- F. perennis was managed by "hand pulling, chemical application, and weed flame technology" and declined with changes in hydrology (Power, et al., 2014).
- Tilling and thermal treatments were ineffective at reducing exotic cover or seed banks (Pfeifer-Meister, et al., 2012).
- Grazing had no effect in controlling exotic annual species (Lunt, et al., 2012).
- Italian Ryegrass cover generally decreases after fires (Ahn and Dee,2011; U.S. Forest Service)

Needed Information:

- Ecotype variants.
- Pollination specifics.
- Buried seed viability duration and maximum dormancy.
- Exact flood duration required for cover reduction.

Invasive Control Plan for Italian Ryegrass

Removal and control of invasive populations is integral to restoring any ecosystem. Italian Ryegrass (*Festuca perennis*) is an annual or biennial invasive that is common in a large percentage of natural California ecosystems. While ryegrass has its uses in attracting water fowl (Givens and Atkeson, 1952) and erosion control (Zelnik, et al., 2010; Ahn and Dee, 2011), it has been known to displace desirable native species and is a proponent of 'terrestrialization' (Lunt, et al., 2012) which changes abiotic factors of the environment such that the area affected would no longer be suitable for desirable species.

Goal	**Short/Long Term**	**Description**
Identify plots with high *F. perennis* cover.	Short and long	Identify areas of plant growth where *F. perennis* contributes more than 20% of ground cover per 5 square meter.
Identify *F. perennis* dominated plots for treatment	short	5 Square meter plots with more than 50% *F. perennis* cover should be considered for treatment as 'high impact' plots.

F. Perennis treatment/removal from high impact plots.	Short and long	Reduction of *F. perennis* from 'high impact' plots through various control methods.
Establish desired species	Short	Introduce desired species of vegetation shortly after treatment through either transplant or seeding.
Monitor plots for *F. perennis* recovery	Long	Conduct periodic transects to monitor for *F. perennis* recovery or reestablishment.

Restoration Plan

This restoration plan was designed for Central Valley fresh water wetlands and uplands with hot and dry summer periods to facilitate prescribed burns and solarization treatments and controlled water sources to facilitate flooding treatments in the fall and spring. Other control methods may be applied anywhere, with sufficient precautions.

Identifying areas with high *F. perennis* cover

Patches of herbaceous cover can be identified using GIS technology and confirmed by an inspection of the patch. Cover percentage will have to be done in 2 meter transects over identified patches. Patches where transects indicate a 20% or less ground cover contribution by *F. perennis* should be monitored for changes *F. perennis* cover to prevent dominance of the invasive grass. Patches where *F. perennis* contributes 50% or more cover are considered 'high impact plots' and should be prioritized for invasive removal. Areas where *F. perennis* contributes less than 20% of the ground cover and is thus not dominant, may be suppressed by native plants (Pfeifer-Meister, et al., 2012).

Invasive removal and soil treatments

Hand pulling and mowing

Mowing is recommended for plots with a high percent cover of *F. perennis* while hand pulling may be useful in controlling *F. perennis* where it is not abundant. Mowing and pulling should be conducted during the blooming season, beginning in late January or once flowering has been noted, to prevent pollination of *F. perennis* flowers, halt seed development, and reduce the seed bank (Calflora, 2016; Power, et al., 2014; Pfeifer-Meister, et al., 2012). Mowing once every week to ever two weeks as needed to prevent flower bloom (U.S. Forest Service). Mowing and pulling is required to prepare for solarization in the summer (Stapleton & Parlier, 2008).

Solarization

Solarization is a weather dependent process, and the effectiveness of the treatment will depend largely on the average temperature and the duration that the treatment is applied (Stapleton & Parlier, 2008). Solarization should be done during the hottest months of the year, starting between June and July and lasting for 4-8 weeks depending on weather conditions. The primary objective of solarizing plots is to reduce, or remove, the seed bank of *F. perennis* (Pfeifer-Meister, et al., 2012; Power, et al., 2014). Solarization will also effect the seed banks of other plants and kill most nematodes, fungi and bacteria. Most beneficial soil organisms survive or recolonize shortly after the treatment (Stapleton & Parlier, 2008).

To prepare soil for solarization, litter and clods should be raked away such that the plastic will lie flat on the ground. Soil should be irrigated to about 12 inches to promote heat conduction through the soil. Irrigation should be done prior to applying the plastic covering. Plastic should be clear and thickness would depend on the terrain and wind. Thicker plastic for areas where the plastic is likely to be torn. Plastic of 1.5 to 2 mils would be preferred given the terrain, presence of wildlife, and wind shear of the park (Stapleton & Parlier, 2008). The covering should be applied immediately after irrigating to prevent water evaporation. Soil moisture should be checked once a week to make sure that the soil remains moist over the solarizing duration. Should the soil dry out, a hose can be placed under the plastic to rehydrate the soil in small plots. In larger plots, without the possibility of irrigation, use longer solarizing duration.

Herbicide use

Herbicide use should be limited to controlling small returning patches should other methods fail to control *F. perennis*. Herbicide application should occur during the early growth stages of *F. perennis*, after the first rains of the wet season, around September. Metribuzin is the preferred herbicide, though there are some metribuzin resistant ecotypes of *F. perennis* (Tucker, et al., 2006) as other herbicides are highly toxic to aquatic life at smaller concentrations than Metribuzin (National Center for Biotechnology Information, 2016).

It is important to note that all herbicides are acutely toxic to freshwater organisms and the organisms that use water sources contaminated with herbicides. Metribuzin is toxic to Rainbow trout at a concentration rates as low as 64 mg/l/96 hrs (National Center for Biotechnology Information, 2016) and is likely to be toxic to smaller fresh water organisms at much smaller concentration rates. Metribuzin is toxic to fresh water invertebrates at concentrations as low as 48 mg/l/96 hr but is non-toxic to bees (National Center for Biotechnology Information, 2016). Metribuzin will enter the environment under normal use, and should thus be used in small amounts, if at all, to control areas where other methods have failed. Metribuzin will photodegrade in water and has a half-life of approximately 4.3 hours in surface waters at a pH of 6.6 at 25 °C (National Center for Biotechnology Information, 2016).

Metribuzin is classified as a general use pesticide by the EPA. However, pesticide usage should be logged with dates and quantities dispersed.

Flooding

Flooding is an excellent way to remove *F. perennis* from low lying areas where desirable species are tolerant to inundation. Flooding should take place during the fall, beginning shortly after the first rains, or in late November/early December, as this is the period in which flooding is normal in California and what native plants are most certainly adapted to (Postel & Richter, 2003). Flooding should occur such that target areas are completely inundated for a period of four weeks at a constant water depth of at least two inches above the surface (Lunt, et al., 2012). This treatment should be conducted annually to prevent exotic annual cover, and promote target perennial species growth.

Establishing desirable species

Native species should be planted or transplanted the day after solarization plastics are removed. This will give the soil time to cool back to normal temperatures and allow beneficial soil biota to recolonize the area before planting (Stapleton & Parlier, 2008). The soil should be shifted as little as possible to prevent bringing any viable *F. perennis* seeds up to the surface.

Monitoring for *F. perennis*

Transects should be conducted in all the plots identified in step 1 between May and June annually. Percent cover should be compared to the previous year's cover to determine whether or not *F. perennis* populations are increasing in any given plot. Plots that exceed a 50% threshold should be treated as a 'high impact plot'. Plots that exceed a 25% threshold should be treated as a 'medium impact plot' and undergo targeted species removal through hand pulling or light pesticide usage. Plots that do not exceed 25% cover are considered 'low impact plots' and do not require treatment. A plot that is considered 'low impact' over a course of three years is considered to have recovered and should remain below the 25% threshold so long as there is not a significant disturbance event (Pfeifer-Meister, et al., 2012). Once native vegetation dominates a plot, that plot no longer needs to be monitored as it should converge to a more native species distribution (Pfeifer-Meister, et al., 2012).

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Phragmites australis

Note: Bolded citations indicate the source is specific to California.

A. Background and Justification

Phragmites australis is a perennial rhizomatous grass species which can attain heights of 15 feet and is found in areas adjacent to water bodies **(DiTomaso and Kyser 2013).** The species is native to California, however there is a nonnative haplotype that was introduced to the United States in the 18th or 19th century and has since spread (Hosier). When the nonnative haplotype forms a dense stand, there is a resultant decline in floral and faunal diversity (Mamolos et al. 2011).The presence of both native and nonnative haplotypes poses interesting management decisions. Restoration efforts will have to identify whether a particular population is nonnative and if so, use appropriate control efforts. Following its control, reintroduction of the native haplotype should be considered. With 95% of California's Central Valley riparian areas destroyed, the presence of the nonnative *Phragmites australis* haplotype threatens what remains **(Griggs 2009)**.

B. Literature Review

<u>Distinguishing Native Haplotype from Nonnative Haplotype</u>

- Native haplotype has a ligule length greater than 1 mm while the nonnative haplotype has a ligule length less than 1 mm **(DiTomaso and Kyser 2013)**
- Dead leaf sheaths fall off culms of native haplotype easily while they tightly cling to nonnative haplotype **(DiTomaso and Kyser 2013)**
- Genomic analysis can be used for confirmation

<u>Habitat Requirements</u>

- Considered the most widely distributed angiosperm in the world **(Smith and Allred)**
- Can tolerate an extremely wide range of pH: (2.9-9.2) (Gucker 2008)
- Tolerates a wide range of soil textures (Hosier)
- Can tolerate salinity levels of up to 45,000 ppm (Gucker 2008)
- Found in zones 7a-10a in California (minimum temperatures of 0-30 degrees Fahrenheit) **(Calflora)**

<u>Moisture Requirements and Tolerances</u>

- Typically found in moist or inundated areas in or along waterways (Gucker 2008)
- Capable of existing in areas with water tables over 3 feet deep and roots are capable of penetrating to 30 feet in depth (Gucker 2008)
- Inundation with greater than 3 feet of water during the growing season for a period of 4 months can kill rhizomes (Marks et al.)
- Roots have aerenchyma to cope with anaerobic conditions (Mamolos et al. 2011)
- 5-6 inch tall seedlings are able to withstand 3-4 inches of flooding (Gucker 2008)

- Prefers slow moving waterways (Marks et al.)
- Capable of tolerating variable hydroperiods, from inundation to prolonged periods of drought; this would permit it to live in seasonal wetlands (Pagter et al. 2005).

Life Span

- Plants require 3-4 years to reach maturity from seed in Utah; may be shorter in parts of California with longer growing seasons (Cross and Fleming 1989)
- Culms die following seed production (Cross and Fleming 1989)
- A colony may survive for 1000 years (Gucker 2008)

Asexual Reproduction

- Plants can asexually reproduce by rhizomes, stolons, and fragmentation (Gucker 2008)
- Fragmentation is disturbance mediated (i.e. by waves, disking, dredging) (Michigan DEQ)
- Rhizomes can grow as much as ten feet per year **(DiTomaso and Kyser 2013)**
- Greatest rhizome growth rate is observed in the fall (Cross and Fleming 1989)
- Fragmentation and subsequent establishment leads to the formation of new colonies

Sexual Reproduction

- More common than asexual reproduction, despite long held assumptions. (Hazelton et. al 2014)
- Flowering occurs between July-November **(Smith and Allred)**
- Staminate, pistillate, and perfect flowers are produced (Gucker 2008)
- Seed production can occur through cross pollination, self-pollination, or agamospermy (Gucker 2008)
- As many as 2000 seeds are produced per shoot (Hosier)
- Long hairs aid in wind dispersal of seeds (Saltonstall et. al 2010)
- Seeds can float on water in excess of 120 days (Gucker 2008)
- Seeds can be dispersed by red-winged blackbirds (Marks et al.)

Germination Controls

- A stratification period may be required (Gucker 2008)
- Germination rates are highest under high light (on the soil surface), warm temperatures (68-86 degrees Fahrenheit), and in a non-inundated area (Gucker 2008)
- Salinity levels greater than 5000 ppm can inhibit germination (Gucker 2008)

Seed Bank Dynamics

- There is no long-term seed bank; seeds remain viable for under two years **(DiTomaso and Kyser, 2013)**

Interactions with other Species

- *Arundo donax* colonies may halt spread and establishment of *Phragmites australis* in the Central Valley **(Lambert and Dudley 2008)**
- Native haplotypes are more prone to aphids, and have aphid caused fungal outbreaks and mortality, compared to the nonnative haplotype **(Lambert and Dudley 2008)**
- Found in association with *Spartina, Carex, Nymphaea, Typha, Glyceria, Juncus, Myrica, Triglochin, Calamagrostis*, *Galium,* and *Phalaris* (Marks et al.)

Response to Disturbances

- Fire typically only top kills plants; new growth can appear within 5 days of the fire (Gucker 2008)
- Disking the soil will break dormancy of subterranean buds and may fragment rhizomes leading to further spread (Cross and Fleming 1989)
- Nonnative haplotype will respond more positively to increased CO_2 levels than native haplotype (Strain 2013)

Factors that favor invasion

- More "flashy" hydrographs due to increased runoff from urban areas (Marks et al.)
- Alteration of stream banks (ex. dredging, erosion) (Marks et al.)
- Nutrient accumulation, particularly nitrates (Marks et al.)

Negative impacts

- Can outcompete native species, reducing floral diversity which consequently leads to a reduction in faunal diversity (Mamolos et al. 2011)
- Dense stands can impeded water flow resulting in accumulation of sediments which lead to decreased dissolved oxygen levels and higher nitrogen levels in water (Mamolos et al. 2011)
- Sediment accumulation increases flooding risk
- Accumulation of thatch increases fuel loads and could lead to an alteration in the fire regime

Benefits of its Presence

- Yuma skipper butterfly caterpillars (Ochlodes yuma) only feeds on *Phragmites australis*; unknown whether it will consume nonnative haplotype **(Shapiro)**
- Young growth is palatable to livestock (Tilley and St. John 2012)
- Can be used for erosion control (Tilley and St. John 2012)
- Can be used to filter nutrient laden runoff from urban areas (Mamolos et al. 2011)
- Provides cover for wildlife, nesting area for some bird species, and food in the form of seeds, stems, and rhizomes (Tilley and St. John 2012)

Management Options

- Multiple herbicide applications typically required for control; use herbicides that have approval in aquatic areas **(DiTomaso and Kyser 2013)**
- Cutting when carbohydrate reserves are concentrated in aboveground biomass can be effective (Marks et al.)
- Flooding for greater than four months during the growing season at a depth of greater than three feet (Marks et al.)
- Grazing can increase floral and faunal diversity in Phragmites australis stands (Hazelton et al. 2014)
- Draining and dredging can be used in non-natural areas (Marks et al.)
- Fire must heat the soil sufficiently to cause rhizome and root death in order for effective control (Marks et al.)
- Removal of thatch can increase floral diversity by increasing the quantity of sunlight which penetrates stands (Holdredge and Bertness 2011)
- Development of a biocontrol would have to be haplotype specific otherwise the native haplotype would be negatively impacted (Gucker 2008)

***Phragmites australis* Management and Monitoring Plan**

A. Goals

- The overarching goals are to control the nonnative haplotype of *Phragmites Australis* and following this control restore the site with the native haplotype
- In a Michigan study, *Phragmites australis* expanded at a rate of 21% per year. Based on this expansion rate, the baseline for management would be to reduce the population by 21% per year (Poyner et al. 2014).
- Quick detection and control of propagules and/or seedlings that come from offsite to avoid further spread
- Management of invasive haplotype will be permanent unless populations on site are eradicated.
- Introduction of native haplotype once the nonnative haplotype has been controlled.
- Establishment of native haplotype at the restoration site.
- Once established, yearly monitoring will be performed to determine health of population(s).

B. Restoration Plan

Management Options:

Fire

- Fire can take place as long as there is plant material capable of being ignited. A fire could occur in a year road wetland provided there is enough standing dry thatch present.

- Fire tends to only top kill plants. In order for effective control, fires must be intense enough and burn long enough to kill underground reserves: the roots and rhizomes. Such fires would be slow moving and smoldering leading to high temperatures deep enough below the soil surface to kill belowground material. (Marks et al.)
- Fire would have to occur at a time when fuels are dry enough to burn. A burn could take place in early fall, before the onset of the rainy season and while seeds are still developing.
- If fires are not severe enough to kill rhizomes, then fires could be used in successive years to deplete carbohydrate reserves in the plants. It is unclear how many burns this would take and could likely vary between stands.
- Consider proximity of restoration site to urban areas. Fire likely cannot be used in close proximity to urban areas given the perceived and real risks to homeowners.
- Consider potential negative effects fires could have on native species present.
- Air quality standards as well as weather conditions limit the days a burn can legally take place, making fire a less feasible management tool.

<u>Grazing</u>

- Young growth is considered palatable to livestock (Tilley and St. John 2012)
- Some sort of fencing would need to be installed to ensure livestock stay in desired areas. Fencing may be impractical in very steep, inaccessible areas as well as an added expense in management efforts.
- Goats can be used due to their smaller size and greater mobility than cattle.
- Set a stocking rate of 23.8 goats/acre (Silliman et. al 2014)
- Keep goats in enclosures until all *Phragmites australis* has been consumed (Silliman et. al 2014)
- Return goats to enclosure once plants have reached a height of 1.5 meters (Silliman et. al 2014)
- This particular protocol worked in this study, however stocking rates may have to be adjusted based on forage availability at particular restoration site. Based on this unknown, plant species diversity should be monitored; continuing grazing treatment if diversity is staying steady or increasing.

<u>Excavation</u>

- Large machinery can be used to physically remove *Phragmites australis* roots and rhizomes (Hazelton et al. 2014)
- Incomplete removal of belowground material will trigger bud break, stimulating plant growth (Cross and Fleming 1989)
- Removed plant material should be incinerated
- Access in some areas may be difficult due to steepness of banks, preventing use of this method.
- Use of large machinery can lead to soil compaction, disrupting the hydrology of the creek by increasing runoff rates.
- Excavation should occur when the soil is reasonably dry to reduce compaction.

- If all plant material is removed, excavation would only need to occur once in a particular spot.
- Following physical removal creek banks may be engineered to be more gently sloping; creating new riparian habitat and subsequent restoration opportunities.
- The soil disturbance creates an opportunity for other invasive plant species to establish at a site.

Thatch Removal

- Removing thatch from stands can increase native species diversity (Holdredge and Bertness 2011).
- This management technique would need little investment in terms of equipment; perhaps clippers to cut down dead culms.
- Unskilled volunteers could be used for thatch removal; freeing up paid staff for skilled and/or potentially dangerous activities.
- Removed thatch should be incinerated.
- Thatch removal would decrease vegetative debris that could make its way into the creek and thus reduce the risk of flooding.
- Thatch removal could take place yearly in early fall, before the commencement of fall rains. This would make conditions more favorable for other species in *Phragmites australis* stands once growth begins after rains.
- This may only be a short term solution; native species diversity may decline as new thatch accumulates in stands.
- This is not a means to control *Phragmites australis* but rather a way to make its presence less negatively impactful on native species.

Manipulation of Water Level

- Inundation with greater than 3 feet of water during the growing season for a period of 4 months can kill rhizomes (Marks et al.)
- This is an unlikely management option given this would require access to large amounts of water during the growing season; which corresponds with the dry part of the year. There would also need to be impoundment of water intended for this purpose.
- The restoration site would have to be in a large enough area in which it would be possible for water level manipulation to occur. This may require damming up a waterway.
- Inundation may also kill desirable species and lead to alterations in the plant communities.

Cutting

- Cutting can be effective if it occurs when carbohydrate reserves are concentrated in above ground biomass; this occurs towards the end of July (may be different in Central Valley) (Marks et al.).
- This technique would have to be used for several years in a row to result in stand death from nutrient depletion (Marks et al.)

- Cut material should be incinerated.

Tillage

- Disking causes subterranean buds to break dormancy and will lead to fragmentation of roots and rhizomes, aiding in asexual reproduction and spread (Cross and Fleming 1989).
- Tillage could also lead to erosion of soil into the creek, leading to sediment deposition and increasing flooding risk.

Herbicide

- Any herbicide used must be approved for use in aquatic areas **(DiTomaso and Kyser 2013)**.
- Removal of thatch and cutting of existing vegetative material may be needed to reduce the surface area that needs to be sprayed as well as to create a more uniform spraying surface **(DiTomaso and Ksyer 2013)**.
- Glyphosate and Imazapyr are recommended herbicides in California. They are post emergent herbicides **(DiTomaso and Kyser 2013)**.
- For greatest efficacy, herbicide application should occur after seed set (Marks et al.) At this time carbohydrates are being transferred to the roots and rhizomes.
- Phragmites releases its seeds November-January (Marks et al.)
- Multiple herbicide applications may be necessary.
- Care should be taken to avoid herbicide application on surrounding, desirable plants because they can be harmed or killed.
- Consideration must be made as to whether herbicide use is permitted at the restoration site.

Restoration of Native Haplotype:

- Ideally plant material should be collected within a reasonable distance (i.e within the same watershed, within a 10 mile radius). This value has been estimated because it is conceivable seeds/and or vegetative material could travel such a distance when in the same waterway. If such material cannot be sourced, seeds and or vegetative material should be used from plants present in the Central Valley.
- In order for germination to occur, seeds must be placed on the surface of a moist, but not inundated growing medium, under high light, and at temperatures of 68-86 degrees Fahrenheit. The upper limit for germination is saturated soil but it is unclear what the lower limit is. Based on this information, it would be best to keep germination media as close to saturation as possible (Gucker 2008).
- Transplants should be used rather than direct seeding because transplants can tolerate greater levels of inundation than germinating seedlings (Gucker 2008).
- Wire cages can placed around transplants both as a means to protect against herbivory as well as to mark their physical location. Additionally GPS points can be taken.
- Plants should be planted 5 feet apart. This is considering that rhizomes can grow up to 10 feet per year **(DiTomaso and Kyser 2013)**. Since these are small transplants it is unlikely they would grow that much in the first year. A 5 foot spacing should allow for reasonable

vegetative cover in the first year. This cover of native *Phragmites* can prevent the establishment of nonnative species. Focus should be placed on putting plants in prime planting grounds: such as areas consistently just at or above the water line which allow for seed germination of new propagules but still have high levels of soil moisture.

C. Monitoring Plan

Pre-Restoration:

- Conduct a population survey of existing *Phragmites australis* in the restoration area
- Upon location of individual(s), the individual or population's locations should be marked on a GPS in order to form a map of where plants are found
- Vegetative characteristics should be used to discern whether the given plant is a native or introduced haplotype
- If sufficient funding is available, genomic analysis may be used to verify identity

Post-Restoration

- Yearly surveys of *Phragmites australis* should be conducted in July or August to determine distribution and extent of populations of nonnative and native haplotypes. This timing will occur during the early part of the flowering season allowing time for management activities to occur. If cutting is desired, cutting could take place immediately. If herbicides are used, it would be best to wait until later in the season (i.e. September or October), when carbohydrates are being moved to the roots and rhizomes. If possible, herbicide should be applied before seeds become viable.
- Population extents and distributions should be compared to those of the previous year(s). New populations must be added to areas that require management. A shift to a different management practice (i.e. from grazing to herbicide) should occur when nonnative populations have expanded in size. An integration of management practices (i.e. fire and herbicide or grazing and herbicide) should be used when one management tool alone proves insufficient.
- Monitoring will continue indefinitely because in most cases, the nonnative population will be managed, rather than eradicated. Even in places where eradication occurs, propagules can disperse in from other areas.

Native Haplotype

- Survivorship of the native haplotypes planted should be taken in late fall, prior to the start of the rainy season. A survey earlier in the season would not account for drought related mortality that occurs later in the year. In the event of no establishment whatsoever or plants persisting but not spreading or reproducing, a re-evaluation of procedures must take place. For example, if mortality appears to be associated with a lack of moisture, a means of irrigation should be used and/or plants should be sited closer to the waterway/water table. In the event of competition induced mortality, a mulch or weed fabric can be placed around the transplant and/or weeding can occur weekly for the first year or two. Restoration will be considered a success when there is sexual and asexual reproduction occurring with populations remaining stable or increasing.

- Existing native haplotype (those occurring at the site before restoration efforts) populations should be analyzed and action should be taken if a decline is noted, by determining the cause of the decline.

Research Questions

1. Do larvae of Ochlodes yuma feed on the nonnative haplotype of *Phragmites australis* (Shapiro)?

2. How often are new propagules introduced into an area?

3. Are a greater diversity of plant and/or animal species found in native stands versus nonnative stands?

4. Is sexual or asexual reproduction more important at the particular restoration site?

5. What is the rate of spread at the particular restoration site?

6. How many successive burns are required to deplete carbohydrate reserves and lead to stand death?

How can they be resolved?

1. Surveys of Ochlodes yuma larvae can occur. If larvae are found consuming the nonnative haplotype, this issue is resolved. However, further study could be undertaken to determine whether larvae prefer one or the other. A more active method of research would be to place larvae on nonnative *Phragmites australis* and see if they feed on it.

2. This would be a difficult question to answer. First the site or plots within the site would have to be eradicated of *Phragmites australis*. Then the distance to the nearest plant/colony would have to be determined. This distance would be compared with the time it takes if/when a new propagule is introduced to the area and establishes. With different tests with different distances from a nearest population, a relationship between distance and time until reintroduction could be drawn.

3. Existing stands of nonnative and native haplotypes can be surveyed for plant and animal species. However, an experiment should also be considered in which plots are planted with native and nonnative haplotypes to help control for unknown variables effecting species composition in "natural" stands.

4. Propagation from seed, rather than from fragmentation appears to be the major mode of reproduction (Hazelton et al. 2014). However, as stands age, their diversity declines, possibly resulting in declined reproduction from seed (Hazelton 2014). To determine this at a particular site, it would have to be determined whether new individuals that appear in a population were from sexual or asexual reproduction. Genomic testing may be necessary, which would be quite costly.

5. Populations would be carefully mapped each year to determine rate of spread. Finding the onsite average would lead to a potential change in the threshold for action on how much the population should be reduced by each year.

6. Burned areas would be monitored for plant growth and would be burned yearly until there is stand death. This data would be averaged from multiple stands to determine typically how many years burns would have to take place.

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Perennial Pepperweed (*Lepidium latifolium*)

I. Background & Justification

Perrennial Pepperweed (*Lepidium latifolium*) is an invasive plant in the Brassicaceae family, native to western Asia and southeastern Europe. It has been found in North America on both the west and east coast, as well as in Canada and Mexico. It is most commonly found in wetland and riparian areas, especially coastal and brackish marshes. It grows in dense stands of shoots approximately 2 m tall, and spreads predominantly via root creeping. While shoots die off annually, a dense mass of roots remains are will re-sprout each year and in response to disturbance. In addition to root sprouts, *L. latifolium* is also a prolific seed producer. Due to its ability to spread very rapidly (a single plant can produce a population several meters wide with roots up to 3m deep in less than 5 years; Blank and Young 2002), *L. latifolium* is of high concern to conservationists, managers, and restoration practitioners, especially in wetland and riparian systems.

L. latifolium was likely introduced multiple times from contaminated sugar beet seed from Europe (Zouhar 2004) and is of high concern due to its ability to invade quickly and effectively, alter its environment and exclude native plants, including several rare and listed plants that occur in wetland and riparian systems in California (Renz 2002). It is a prolific invader on both the East and west coast, and in the Intermountain West region of the United States. Its prolific spread is in part due to a poor initial response resulting from hesitance to use herbicides in the wetland and riparian areas where infestations are the worst (Zouhar 2004). Control of *L.Latifolium* has been well studied, and additional herbicides have been developed and approved such that control of new infestations is now feasible. Even so, understanding the life history, invasive characteristics, and appropriate control measures offer the best chance of successful removal and prevention of additional infestations.

II. Fact Sheet

Habitat

- Requires moist soil at least seasonally, so it is most often found in wetland and riparian areas (Young et al. 1998).
- Most invasions have taken place in areas that were disturbed or in poor condition prior to colonization (Young et al. 1998).
- Plants can tolerate short-term drought periods once established, and are often found in upland irrigated areas such as ditches and roadsides, however they cannot withstand long-term drought or typical upland conditions (Young et al. 1998).
- Plants can tolerate flooding up to 50 days in duration (Jacobs and Mangold 2007).
- In California’s brackish marsh systems, infestations are most likely to occur 30 m from a channel or within 35 m of marshland/upland margin (Andrew and Ustin 2009).

Growth and reproduction

- New stalks grow in the early spring as a rosette from root stock that extends deep in the soil. (Zouhar 2004)

- Stems are typically 1-3 feet tall, but can be up to 8 feet in wet areas (Jacobs and Mangold 2007)
- Roots can extend ten feet or more into the soil but are concentrated in the top two feet of soil (Jacobs and Mangold 2007).
- Rosettes will bolt and send up a flowering stalk. Flowering occurs from May-August in California, depending on the habitat and weather (Zouhar 2004).
- New seedlings are rarely present in established stands, which indicates that despite prolific seed production, the importance of local dispersal via seed is minimal despite the high biomass of seeds produced (Zouhar 2004).
- Seed production has been measured as high as 1.6x10^10 seeds/ha (Young et al 1995), and seed viability has been reported to be very high (Jacobs and Mangold 2007).
- Seed germination is highest at fluctuating temperatures (hot day and cold night), and lower at more consistent temperatures, as may be seen if seed is deep in the soil (Miller et al. 1986).

Invasive Characteristics

- *L. Latifolium* spreads rapidly via root sprouts and by seed and forms dense stands that prevent establishment of other plants, and in cases blocks water drainage infrastructure (Young et al. 1998).
- Plants can grow from root fragments as small as two inches long, including fragments that have been dried and exposed to sunlight (Jacobs and Mangold 2007).
- In dense stands, *L. Latifolium* shades out most competitors, primarily other herbaceous species and grasses that are shorter statured (Young et al. 1998).
- The plant will form dense monocultures with stem densitites between 4 and 8 stems per 0.1m^2 (Young et al. 1998)
- The plant most commonly invades wetland and riparian systems, where soil moisture is high, but can establish in other disturbance driven systems and novel ecosystems (e.g. roadsides, agricultural fields, etc.) (Renz 2002).
- Isolated or satellite patches have the fastest rate of spread (Andrew and Ustin 2010).
- *L. Latifolium* spreads most commonly from the leading edge of the invasion, with a patch increasing between 49% and 129% in size over a 2 year period (Renz et al 2002).
- *L. latifolium* spreads fastest in years with a wet spring, especially in water-limited areas such as levees and roadsides (Andrew and Ustin 2010).

Plant/Soil/Nutrient Dynamics

- Tolerant of a wide range of salinities (Young et al. 1998).
- Acts as a “salt pump”, transporting salt from deep in the soil and depositing salts at the surface (Renz 2002).
- Alters Carbon/Nitrogen ratio in the soil by decreasing plant available phosphorus. (Renz 2002)
- Has the potential to loosen highly compacted or sodic soils (Blank and Young 2002),

however due to the risk of invasion and future soil degradation, the literature is mixed with regard to the use of *L. latifolium* as a restoration tool (Renz and Blank 2009).

- The plant is tolerant of flooding, and retains root starch content despite limited photosynthesis and loss of leaf carbohydrate (Chen et al. 2005).

Management and Control

- Herbicide application at the flower bud stage is the most effective at killing new growth and depleting root storage (Renz and Blank 2009, USDA 2014)
- In the West, including California, Control of existing invasions is highly unlikely. Control of new infestations and prevention by maintaining undisturbed ecosystems offers the best option for large-scale reduction of impacts (Zouhar 2004).
- Mechanical removal, such as mowing, disking, and burning alone are not sufficient to remove the root mass and prevent re-sprouting (Renz and Blank 2009).
- Cattle grazing can be used as an alternative to mowing or other mechanical methods. The most effective grazing strategy requires high stocking rates at a short duration within patches to encourage complete removal of aboveground biomass and damage to root stock via hoof punch (Wilson et al. 2008).
- Appropriate herbicides for control include glyphosate, chlorsulfuron, metsulfuron, 2,4-D, triclopyr, Imazapyr, and Imazapic (Renz and Blank 2009; USDA 2014).
- Following control, establishment of native plants is recommended to restore ecosystem function and resistance to future invasion. The use of a broadleaf-selective herbicide (e.g. chlorsulfuron, 2,4-D) and replanting with native grasses can provide a successful integrated management approach (Zouhar 2004).
- There is potential for the use of a native pathogen, white leaf rust (*Albugo candida*) as a potential control agent, but recommendations for its use have not yet been developed (Sullivan and Zink 2008).

Small infestations

- Isolated areas should be hand-pulled to avoid additional soil disturbance (Zouhar 2004).
- Small patches should be targeted due to their potentially fast rate of growth and potential to become large and dense (Young et al. 1998).
- Small, newer infestations are easier to control because the root mass has less accumulated energy and the canopy is more open to allow herbicide to cover a larger proportion of the leaf area. (Renz and Blank 2009).

Large infestations

- Early season (spring) mowing increases the effectiveness of glyphosate or chlorsulfuron application in control of dense infestations (Renz and DiTomaso 2004, Renz and DiTomaso 2006)
- Soil disturbance by disking or flooding may be necessary following control using

herbicides in order to restore pre-infestation soil conditions (Renz and Blank 2009).

- Mechanical removal or fire may be needed to remove litter following chemical control measures in order to access re-sprouts for future control (Renz and Blank 2009).

III. Management Plan for Perennial Pepperweed (*Lepidium latifolium*) in riparian and associated uplands of California's Central Valley

Introduction

Perennial Pepperweed (*Lepidium latifolium*) has been recognized as a noxious weed since the early 1980s (Young et. al. 1995) due to its ability to spread readily and rapidly and alter the soil chemistry in such a way that it decreases local plant diversity. Understanding the natural history and invasion ecology associated with this plant is vital to preventing invasion and eradicating populations that already exist on the site. The goals and methods for achieving them described in this plan are general, and may need to be modified based on site-specific information such as soil, hydrology, existing plant communities, or specific restoration goals that may conflict with the management of *Lepidium* on the site.

Goals

In sites where *Lepidium* has not invaded, the goal is to maintain resilient landscapes such that they are resistant to invasion and monitor vegetation to be able to detect colonization in the future. In restoration sites where *Lepidium* is already established, the primary goal is complete elimination within three years of project initiation (three years is due to the common length of time that has been used to study control methods; Young, Palmquist, and Blank 1998) and long term monitoring and adaptive management to prevent recolonization. There are many reasons why complete elimination of *Lepidium* may not be feasible, such as inability to deploy management tools (herbicides, mowing, etc.). In such cases the goals may be modified, and goals 3 and 4 (shown below) may be more feasible.

1. Prevent colonization and establishment of *Lepidium*.
2. Eliminate existing Infestations within three years of project initiation.
3. Eliminate existing infestations over a longer time horizon.
4. Prevent spread of existing infestation.

Management Plan:

1. Control of existing infestations

Existing site conditions prior to initiating a restoration project will determine the necessary management action to meet the goals of the project with respect to *Lepidium*. The following will describe the variety of tools that can be used, and in what cases they are appropriate.

A. Mechanical Control

Mechanical control includes hand removal, mowing, disking, grading, grazing, and burning. These actions are intended to remove above-ground vegetation and control the invasion without the use of chemical or biological control tools. Hand removal is the least disruptive tool, and may be appropriate where patches of *Lepidium* are small, or when small satellite patches emerge away from the main infestation. Hand removal is labor-intensive, and may be minimally successful when the infestation is mature enough to have established its elaborate system of deep rhizomes. Other mechanical methods such as mowing, disking, and burining,are less labor-intensive, but have the potential to disturb native wildlife species and disrupt other ecosystem functions

While mechanical removal alone has not been effective at controlling established infestations (Renz and Blank 2009), it may slow the spread of the invasion and can be used successfully as part of an integrated management plan. Mowing and burning are highly effective in removing the above-ground biomass (live and residual) that can interfere with the effectiveness of herbicide application. The application of herbicides in combination with mowing has been shown to increase the effectiveness of the herbicide (Renz and DiTomaso 2004).

Cattle grazing can also be used as an alternative to mowing to increase the effectiveness of herbicide application. Winter grazing, while plants are in the rosette stage, has been effective with short duration and high stocking rate such that there is near complete removal of above-ground biomass combined with trampling (Wilson et. al. 2008). Once plants enter the bolting stage, they are no longer palatable (Young et. al. 1995)

B. Chemical Control

Herbicides have been shown to be the most effective method for removal of established infestations of *Lepidium* since systemic herbicides can act upon the root mass as well as above-ground biomass. There are numerous herbicides that can be effective tools for control of *Lepidium* infestation. Selecting the appropriate herbicide depends on the location, goals, and existing site conditions. In general, there are two main classes of herbicides: Selective and non-selective. Non-selective herbicides, such as Glyphosate and Imazapyr, can be used successfully for large stands of *Lepidium* where the infestation has completely eliminated other plants from the area.

Broadleaf selective herbicides are a better choice than non-selective herbicides since they allow for establishment and recovery of grasses while *Lepidium* treatments continue. Examples of broadleaf selective herbicides are 2,4-D, Triclopyr, and Clorsulfuron. Since *Lepidium* infestations are common in wetland areas, it is important to make sure to use an herbicide that has been approved for use in the given habitat and to apply the herbicide with an approved surfactant (Hogle et al 2007). While Chlorsulfuron has shown the highest success rate, it is not approved for use near water bodies (USDA 2014); however, many herbicides have been approved for use in aquatic areas, including Triclopyr which is also an effective broadleaf selective herbicide.

Use of herbicides for control should be combined with mechanical control (mowing, hand removal, burning, grazing) for maximum effectiveness (Renz et al 2006). Furthermore, since there are so many herbicides available, it is also important to monitor the effectiveness of the control methods, and adjust the chemical and concentration if needed.

C. Biological Control

Biological Control is an important tool for invasive species control, however there is not yet an approved biological control agent for use on *Lepidium*. This is an area of opportunity that warrants additional study. There is potential for the use of a native pathogen, white leaf rust (*Albugo candida*) as a potential control agent (Young et. al. 1995), but the specific variety and recommendations for its use have not yet been developed (Sullivan and Zink 2008).

2. Restoration following removal

Lepidium typically invades areas that are already in a degraded condition or have undergone some amount of disturbance (Renz 2002). Once established, it is known to alter soil chemistry by increasing soil salinity, decreasing root available phosphorus, and increasing calcium ion concentration in the soil (Renz 2002, Blank and Young 2002). Because it is such an effective invader an ecosystem engineer, restoration actions following removal of *Lepidium* invasions will need to focus on restoring soil characteristics and creating a resilient community that is better able to resist further invasion.

Once the invasion has been managed, it is important to select specific plants for revegetation that can tolerate the new soil conditions. More research should be done to identify the best ways to reverse the effects of *Lepidium* on soil chemistry including plants that will uptake salts and increase available phosphorus. Alternatively, flooding the site can potentially help to restore pre-invasion soil characteristics as well as functioning as an alternative control mechanism (USDA 2014).

In order to prevent re-establishment of *Lepidium* or other invasive species, a comprehensive revegetation program should begin along with control measures. It is common to plant a mix of native grasses that can tolerate the use of a broadleaf-selective herbicide so that herbicide application can continue and the site can begin to recover. Selecting grasses will depend on site hydrology, degree of soil degradation, and project goals. After *Lepidium* has been completely eliminated, other broadleaf plants can be planted to restore diversity and ecosystem function.

3. Prevention of new infestation

The last step in managing a restoration site for *Lepidium* is preventing new infestation through monitoring and adaptive management, described below.

Monitoring Plan:

Part of preventing future establishment of invasive *Lepidium* is continual monitoring in order to detect establishment early, when it is easier to control. An equally important part is assuring that the system does not become so degraded that it is vulnerable to invasion. Monitoring for *Lepidium* can be done by ground survey, or using remote sensing (Andrew and Ustin 2009). It is most easily detected and identified when it is flowering, beginning in May and continuing through August.

During active control of *Lepidium*, the site should be monitored to prioritize sites for treatment, determine effectiveness of past control methods, and identify new areas where the weed has colonized. Once *Lepidium* has been removed, monitoring should focus on identifying new infestations and measuring local plant cover and diversity, as well as creating a self-sustaining landscape.

Adaptive management of *Lepidium* includes specific response measures based on available management actions (hand removal, selective herbicide application) that will be effective while minimally disrupting ecosystem functions. Annual vegetation monitoring should identify new patches of *Lepidium* while they can still be controlled using minimally invasive actions. Furthermore, frequent recolonization by invasive species such as *Lepidium* can be used as an indicator of poor ecosystem health and as such may drive additional actions on the landscape to improve overall ecosystem function.

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Poison Hemlock (Conium maculatum)

Kingdom: Plantae
Phylum: Magnoliophyta
Class: Magnoliopsida
Subclass: Rosidae
Order: Apiales
Family: Apiaceae
Genus: Conium
Other Common Names: poison hemlock, deadly hemlock, poison parsley

Category: Forbs/Herbs

Poison Hemlock has long been know for its acute toxicity. In ancient Greece, Socrates was famously executed with a poisonous hemlock tea. (Davis 2009). Poison Hemlock is an invasive species in the family Apiaceae. Poison Hemlock originated in Europe, Asia, and North Africa and was brought to the Americas as a decoration in the 1800's. (Drewitz 2016). Some of its close relatives include carrots, parsnips, celery, and a variety of herbs. It can be mistaken for some of these crop relatives at times. However, Poison Hemlock is quite poisonous and must not be ingested. It is most frequently present in highly disturbed areas but also has a high rate of success in invading native ecosystems. Poison Hemlock performs best in moist environments but can also survive in drier environments if necessary.

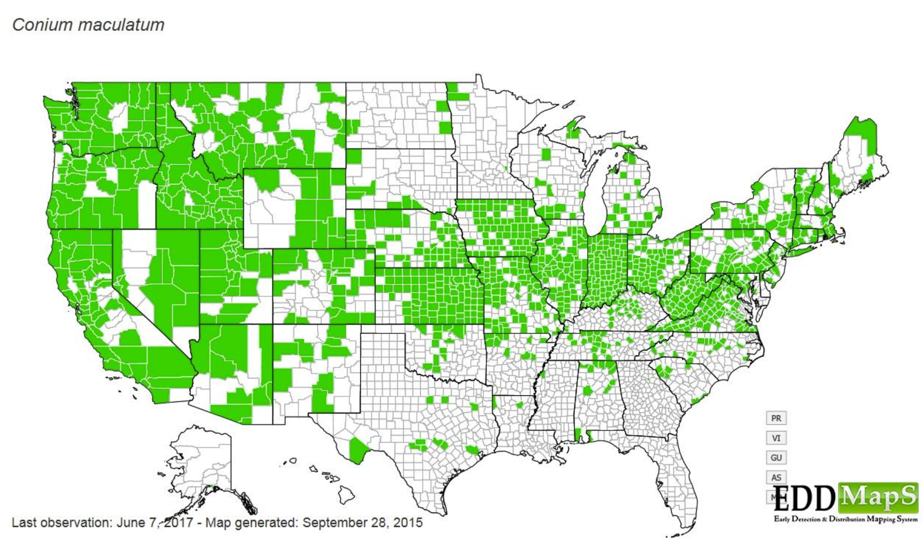
Poison Hemlock has been a wildly successful invader in various ecosystems in the central valley of California and across the United States. Poison Hemlock is a strong competitor and outcompetes many other native plants, both through shading and the release of toxins into the soil. Additionally, Poison Hemlock is toxic when ingested by almost every vertebrate and many invertebrates. Thus, this species is able to decrease plant diversity and destroy the palatability of grazing lands. This species is present in the project site and must be managed for other species, native and/or beneficial, to thrive. Historically, no convenient controls exist for management of hemlock populations. With a robust seed bank and high toxicity levels, it is not an easy target to eliminate. The information provided in the following fact sheet will help provide insight into Poison Hemlock's specific needs and thus shed light on possible means of control.

FACT SHEET:

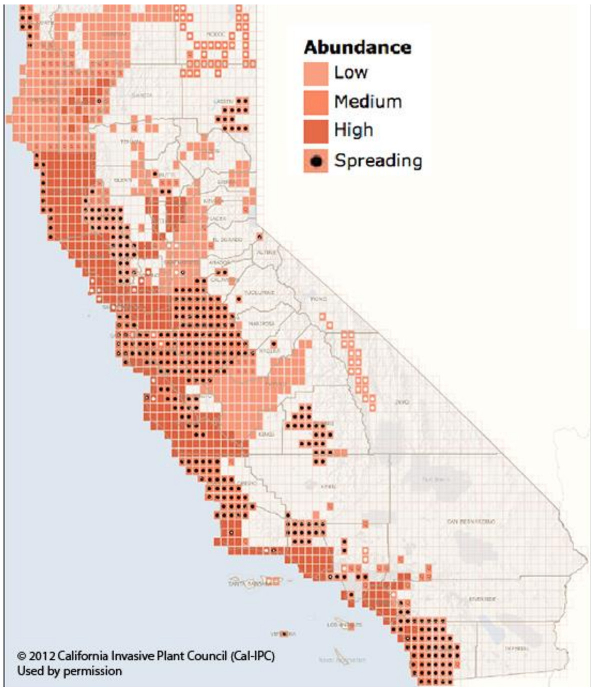
Goal: Ideally, complete eradication of Poison Hemlock from the site would be achieved. This is theoretically possible, but various logistics such as manpower, time and funds will likely limit the degree to which prevalence can be reduced.

Identification (Images from ipm.ucdavis.edu): Poison Hemlock is an herbaceous, biennial plant that is sometimes mistaken for other plants in its family. (Development takes place over a period of typically two years. As it nears maturation, it begins to generate stalks of 6-8 feet long that hold alternating leaves. These stalks are hollow, except at the nodes. A characteristic purple mottling marks the stems of mature Poison Hemlock plants. Flowers are small, white and clustered at the end of the stalk. (DiTomaso 2013).

Range:



http://www.invasive.org/browse/subinfo.cfm?sub=4365



http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pni74162-1a.html

Growth Characteristics

Germination: Non-specific germination preferences, making it quite difficult to limit or prevent germination in activated seeds. (Drewitz 2016). Germination preferable in cool moist soils but can also take place in dry soils, hot soils, and sand. High germination rates that can occur at any time of the year make control difficult.(Office of Water 2011). Poison Hemlock does not require light to germinate. (DiTomaso 2013). Temperatures of soil should not fall outside of the range of 4.9C-33.8C for germination to occur. (Drewitz 2016).

Temporal scale: Plant begins to grow successful reproductive at about 1 year of age. Seeds begin to be produced in April. Most seeds are fully mature and developed by June. 85-90% of seed dispersal takes place between July-February. (DiTomaso 2013). The long period of dispersal enhances the ability of the plant to germinate successfully in any environment. (Drewitz 2016). Plant dies after reproduction.

Seed bank dynamics: Non-dormant seeds will germinate almost immediately, but dormant seeds can remain inactive for 2-3 years while awaiting proper environmental cues.(DiTomaso et al., 2013). This is much shorter than most weedy plants. However, each plant can produce 30,000 seeds. (Office of Water 2011). These seeds can germinate at any point in the year and thus make the plant highly competitive. As soon as the mature seeds fall, 85% of them will be non-dormant and ready to germinate. The remaining 15% of seeds are either dormant on the ground or attached to the plant and will become non-dormant when conditions become suitable. Presence of dormant seeds ensures that those seeds can be left in the seed bank for the following season. (Drewitz 2016).

Reproduction: Exclusively reproduces through separated seeds. (DiTomaso 2013).

Habitat

Necessary quality: Quality is highly variable. Hemlock seems to dominate most in highly disturbed areas such as field edges. However, it can also take over native riparian areas quite easily. Its generalist nature makes it a fierce competitor.

Key mutualists and competitors, pathogens, competitors: Poison Hemlock likely possesses allelopathic chemicals, which are chemicals that inhibit the growth of neighboring plants. In our site, those plants being outcompeted are likely (or hopefully) natives. Unresolved concern exists regarding the possibility that killing the Poison Hemlock plants without physically removing the remaining plant material could allow for these inhibitory compounds to enter the soil for some time, even after the plant has died. (Hillman 1997). Poison Hemlock grows quickly and creates extensive shade cover which also allows it to outcompete many neighboring plants. (Drewitz 2016). Even after the plant dies, it leaves its large stalks that continue to overshade other plants in the area. There is a possibility that a singular species of caterpillar "self medicates" itself by consuming Poison Hemlock and thus making it undesirable for predators. If this is true, then there is also the possibility that these caterpillars (or another tolerating species) could be deployed to remove Poison Hemlock stands through consumption. (Gillis 1995). However, this possibility comes with two primary concerns. First, no conclusive studies exist that demonstrate a significant preference for Poison Hemlock by the caterpillars. Next, there are myriad issues that could occur with the mass introduction of caterpillars into the ecosystem. In the case of our site, I would advise against the introduction of species that could possibly consume the Poison Hemlock, due to the fact that this high level of consumption could transfer to other plant species and a whole new invasive species (the herbivorous invertebrate) could enter the equation.

Requirements

Specifics needed from ecosystem: Poison Hemlock tends to require moist soils with a water table for maximum growth efficiency.

Temperature: Soils need to be within 4.9C-33.8C for germination to occur.

Spatial scale needed (home range, dispersal distance, etc.): Spatial needs highly variable. Long tap root allows for water access even in clustered areas. Poison Hemlock's seeds fall freely from the plant once mature and have little to no dispersal ability so plants tend to grow in dense clumps. However, other factors such as animals and water movement can aid in seed dispersal. (Drewitz 2016).

Temporal scale needed (time to maturity, generation time, etc): Plant begins to grow successful reproductive at about 1 year of age. Seeds begin to be produced in April. Most seeds are fully mature and developed by June. 85-90% of seed dispersal takes place between July-February. (DiTomaso 2013). The long period of dispersal enhances the ability of the plant to germinate successfully in any environment. (Drewitz 2016).

Tolerances (Drewitz 2016; DiTomaso 2013)

Shade tolerant

Dry soils tolerant (very long tap root)

No foreseeable reaction to climate change
Resilient after fires
Tolerates poorly drained soils (Utah State University 2016).

Impact

Grazing areas: In the case of agricultural systems, Poison Hemlock has detrimental effects on the palatability of crops grown to support livestock. (Drewitz 2016). Can put livestock at risk if it begins to dominate within their grazing area. Silage does not reduce toxicity. (DiTomaso 2013). Closely associated with growing alfalfa. (Utah State University 2016).

Our site: Overshades native plants. Poisons native vertebrates. (DiTomaso 2013).

Control- One of the most vital tools in managing Poison Hemlock will be catching the plants early, before they seed.

Means of control: (Drewitz 2016).

Physical:

Hand pulling is highly effective, but labor must be considered when thinking about larger areas. Hoeing is also effective. Always wear gloves when dealing with this plant. Remove taproot.

Fire not a good means of physical control (DiTomaso 2013) due to the types of habitat in which hemlock is most likely to occur and possibility of making toxins airborne.

Possibility exists that caterpillar (Gillis 1995) or moth species A. alstroemeriana (Drewitz 2016) could serve as physical controls through their consumption of the plant, but their polyphagous/unspecialized nature could prevent them from being useful.

Mechanical- Wash mechanical device after control method performed to minimize risk of spread to other sites. (USDA FS 2015)

Repeated mowing (multiple times per year over the course of multiple years) can be successful (Drewitz 2016). In this site, it could be useful to take advantage of the fire breaks as “hemlock breaks” which would allow for the management of smaller individual areas of hemlock. The areas closest to the fire breaks would already be quite disturbed and could thus be controlled effectively via mowing.

Tillage can be highly effective. (USDA FS 2015). This could be very useful in firebreak areas.

Chemical

Spot treatment by herbicides very effective if plant has not put its seeds down yet. (DiTomaso 2013).

Herbicides usable by anyone: 2,4-D, triclopyr, and glyphosate (apply as soon as the plants reach the rosette stage of development) (DiTomaso 2013). Glyphosphate is not selective and thus must be used with additional caution.

Herbicides needing permit:chlorsulfuron, hexazinone, and imazapyr

Other, broader range of substances available for use listed on USDA Field Guide for hemlock management. (2015).

Note: chemical treatments will take a number of years to be effective, as the seed bank must be depleted over that period of time.

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PART II: C. maculatum (Poison Hemlock)

Goals: In an ideal world, the goal of this restoration project would end with the complete eradication of C. maculatum from the site. While this is possible in theory, it might not be feasible due to specific ecological conditions in our site, or because of a lack of funds or manpower. In the following section, the restoration plan will list protocol to achieve this ideal goal. However, performing the same strategies might lead to incomplete eradication which would be the secondary goal if complete eradication cannot be achieved. In order to be realistic, a temporal set of goals will be made known. In the first year of treatment, as much existing standing cover of C. maculatum as possible should be removed from the site. Put numerically, a minimum of 75% of the C. maculatum cover should be removed from the site in the first year. This will set the stage for the subsequent sequential removal of the plant from the area. It will also allow for other native species to begin to recover early on in the restoration process (Drewitz

2016). In the following two years, a noticeable decrease in C. maculatum sprouting should occur. As eradication efforts move forward, fewer and fewer sprouting individuals should occur. A significant decrease in developing flora (new sprouts, plants reaching sexual maturity) should take place. A 50% decrease in new sprouting events would be a good goal to aim for 2 years out from the initial cover removal. By this time, the population of C. maculatum at the site should be more manageable. Once most of the population is gone, it will be easier to manage new growth events. One of the most vital goals of this restoration project will be to make the C. maculatum in the site manageable to deal with. With the other reduction goals listed above, this should be possible. Potential issues arise when taking into account the other restoration goals that will be in place for other species at the site. The level of disturbance created by removal might be too much for other native plants or animals to deal with and thus less invasive methods would be implemented. However, the benefit of decreased shading for other plants and the removal of toxic vegetation, with respect to vertebrates, would provide support for the continued efforts in eradicating C. maculatum from the site. Because C. maculatum is an invasive plant, it has been difficult to determine what minimum population thresholds are required for its success (Annen 2007). It is also a generalist invader and so creating a management plan that can be followed and will help decrease C. maculatum numbers in any way should be taken seriously. The long term sustained reduction of C. maculatum density will be the first step in achieving a viable management regime. Today, some scientific gaps exist in terms of the environmental thresholds outside of which C. maculatum will perish. This would be beneficial information to gain in the long run.

Restoration Plan: Eradication of C. maculatum would be the most ideal restoration endpoint here. However, various aspects of C. maculatum ecology make it difficult to control. Each plant can create 30,000 seeds, 15% of which can remain dormant in the soil as a seed bank for up to 3 years (Office of Water 2011). Thus, many removal strategies will have to take place repeatedly over the course of at least 3 years to ensure that the living plants and the seed bank are gone from the landscape. Because the C. maculatum reproduces exclusively via separated seeds, controlling seed bank dynamics will be a great aid in the removal of the plant (DiTomaso 2013). A mixture of methodologies for eradication of the C. maculatum will be necessary. Due to the variety of habitats that C. maculatum has been known to exist in, it is not usually feasible or ideal to utilize fire regimes (DiTomaso 2013). Additionally, there is a fear that fires could make the toxins found in C. maculatum airborne which could compromise air quality in an unforeseeable manner. Thus, I recommend a series of treatments that would be ideal together, but can also stand alone if necessary. A mixture of mowing and tilling will aid in the lasting removal of C. maculatum. This method will also take a number of seasons (about 3) to yield optimal results. Mowing should take place before the mature C. maculatum drops its seeds is vital. Most of the seeds are dispersed from June- February so a small window during late winter and spring presents the most ideal opportunity for effective mowing (DiTomaso 2013). This method could also be limited by other restoration projects going on in the same area that might not allow for the level of disturbance that mowing and tilling create. Mowing and tilling should undoubtedly be used on and around manmade fire breaks, while other methodologies can be used in the interior of each section of the overall area. Here, "section" refers to the segments of habitat within manmade boundaries such as the fire breaks or housing developments. Each fire break can act as a "hemlock break" which would allow for the management of smaller individual areas of hemlock. The areas closest to the fire breaks would already be highly disturbed and could thus be controlled effectively via mowing. On a smaller scale (or large scale with larger manpower availability), the administration of hand weeding, hoeing, and chemical controls would be useful as well. These methods must battle the lasting seed bank for a number of years, as with mowing and tilling. Hand pulling is highly effective, but labor must be considered when thinking about larger areas (Drewitz 2016). Hoeing is also effective but faces the same constraint. In both of these strategies, the taproot must be effectively removed and gloves must be worn to reduce the risk of lethal exposures to C. maculatum's toxins. Hand pulling and hoeing can take place at any time of the year, but will be most effective before C. maculatum has dropped its seeds. Due to the proximity of other plants and animals, any chemical treatments will also have to take place on a small scale preferably in the form of spot treatments performed by a group of individuals (DiTomaso 2013). Some herbicides are usable by anyone, while others require permits for purchase and application. Herbicides usable by anyone include 2,4-D, triclopyr, and glyphosate (apply as soon as the plants reach the rosette stage of development) (DiTomaso 2013). Glyphosphate is not selective and thus must be used with additional caution. Herbicides requiring a permit include chlorsulfuron, hexazinone, and imazapyr. An additional, broader range of substances available for use is listed on USDA Field Guide for hemlock management. (2015). It is important to note that chemical treatments will take a number of years to be effective, as the seed bank must be depleted over that period of time. The integration of all of these strategies is possible, and would create the most effective eradication strategy. Initially, mowing and tilling would be done. This would be followed by the more small scale treatments (hand pulling, hoeing, herbicide spot treatments) for areas missed by the mechanical process or those areas unreachable by mechanized strategies. Individual "sections" can be taken care of sequentially to make the process more manageable to deal with. Many of the issues encountered with this line of eradication will have to deal with integrating the eradication strategies for C. maculatum with the restoration strategies for other species. In addition, funds and manpower will be the limiting factors once eradication measures are allowed to be taken. There are some risks with these strategies. Most importantly, proper personal protective equipment will be necessary when working with C. maculatum. In most cases this will be work gloves and possibly goggles. However, if the C. maculatum is able to become airborne, as in the case of a fire, face masks could be necessary. All equipment should be washed when moving between sites to avoid contamination (USDA FS 2015).

Monitoring Plan: Before restoration takes place, a general census should take place to estimate the amount of *C. maculatum* cover at the site. To do this, sampling techniques will be used either in the form of line transects or quadrant samples. With the line transects, 100m ropes or tape measures will be splayed on the ground in randomly selected areas. A census will be taken along the transect and then extrapolated to encompass the remainder of the area. Alternatively, quadrants 10m by 10m will be randomly selected and placed throughout the site. A census will be taken of the plants within the borders of the quadrant. This data will then be extrapolated to act as a representation for the whole site. These same tactics can be used to monitor and measure the progress of the reduction in *C. maculatum* density over the following years. These census events should take place every 6 months, to ensure that the plants are measured before and after their seed dropping season. If the census measurements reflect the desired percentages stipulated in the goals section, then progress will be occurring rapidly and effectively. As long as the numbers are steadily decreasing, though, improvement is occurring. If in any span of one year there is a significant increase in C. maculatum cover, then more aggressive removal techniques will need to be implemented. Monitoring should also occur during the season in which the adult plants drop their seeds. This monitoring should take place across the fire breaks. If furred vertebrates are creating a significant amount of traffic across the breaks, then there could be a threat of seed dispersal via transport in the fur. A correlative examination of both animal movements and differential seedling densities could be sufficient in determining whether or not dispersal by vertebrates is significant enough to develop additional management strategies for. If significant decreases have occurred after 3 years, as hoped, then census monitoring can be decreased to once per year for the next 5 years. If levels still remain in a comfortable range at that point, then less aggressive monitoring can begin.

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Milk Thistle (*Silybum marianum*)

Background & Justification:

Silybum marianum, also known as Milk thistle or Blessed Milk thistle, is usually a winter annual, but can be a biennial or even perennial, plant that has invaded a large majority of the Californian landscape (Calflora, 2016). It was introduced to California in the 1940's, and it quickly spread due to the favorable Mediterranean climate and ability to tolerate many types of habitats (Young, et.al, 1978). It is considered to have limited potential impact on native ecosystems, but is noxious due to its sharp thorns and aggressive growth. Large patches make use of land impossible, or even potentially hazardous to pets or children. Many efforts to control or eradicate milk thistle are currently underway in many counties all over California, with varying results. Due to its seven month germination window, and its ability to grow to over 8 feet, it has the ability to outcompete natives for nutrients, pollinators, and light resulting in a decrease in native plant diversity (Techline, 2013). The continue removal of milk thistle, and many other invasive plant species, are part of the ongoing efforts of many organizations to repair and restore damaged ecosystems throughout the state.

Literature Review Fact Sheet:

GOAL

To completely eradicate, or achieve a minimum of 99% control, of *Silybum marianum* in order to foster a more conducive environment for native plant species, while minimizing the impact on current ecosystem restoration projects.

LIFE CYCLE & PHSYIOLOGY

- Winter or summer annual, biennial, or perennial (Calflora, 2013; UC IPM, 2014).
- Germination period extends from October to May (winter), or April to July (summer) (UC IPM, 2014; Calflora, 2013).
- Begin as a rosette and develop a flowering stalk during germination (UC IPM, 2014).
- Leaves are known for the white variegation patterns and sharp thorns along leaf margin.
- Can grow prostrate or upright, depending on environmental conditions.
- Prefers coastal and moderately open land (Daehler, 2015).
- Optimum seed germination temperatures are around 10°C, but cannot germinate above 30°C (Young, 1978).
- Able to germinate from deeper soil layers with a maximum at approximately 8 cm deep (Young, 1978).
- Grows in thick stands that are highly competitive (UC IPM, 2014).
- Prefers pastures, crop fields, orchards, trail margins, chaparral and woodland areas, and any other damaged ecosystem (UC IPM, 2014).
- Resistant to mechanical controls and to current biological controls, i.e. thistle weevil (UC IPM, 2014).

VULNERABILITIES

- Low germination and seed success when exposed on the soil surface (Young, 1978).
- No vegetative propagation (Daehler, 2015).
- Susceptible to frost (Daehler, 2015).

- Low germination rates in sandy loam to clay soils, 6%-18% respectively (Young, 1978).
- Can be successfully controlled through herbicide applications (Calflora, 2013).

POTENTIAL IMPACTS & ENVIRONMENTAL INTERACTIONS

- Can become toxic to cattle and other grazing animals (Daehler, 2015).
- Shading from rosettes outcompetes natives, dense patches impede wildlife and reduce available grazing areas (UC IPM, 2014).
- Highly successful in disturbed areas, and in soils that significantly dry out (Daehler, 2015).

Eradication and Management Plan for Milk Thistle (*Silybum marianum*)

Milk thistle has been a consistent issue throughout the world since it's spread from Europe. It has established itself firmly throughout California, particularly in pasture and grazing land due to the lack of late season competitors (Arianoutsou & Groves, 1994). Despite milk thistle being a habitat for numerous "generalist" organisms—mainly insects—it causes more damage than it is worth to maintain. Removal of milk thistle will greatly increase the amount of available land for cattle and other human needs. The goal of this plan is to eradicate milk thistle from any ecological system where it causes detrimental effects, to a minimum of 99% effectiveness. Additionally, reducing and monitoring those high nitrogen soil areas that are conducive to milk thistle growth and development should assist in controlling further outbreaks. Through the combined use of herbicides, biological controls, and fervent monitoring, the eradication of milk thistle should be possible.

Preparation:

Locate and track populations of milk thistle in target areas. Each location will be marked using its GPS coordinates and a red marker flag for easy identification. Determine relative abundance of native species surrounding the milk thistle populations that are susceptible to Milestone®, glyphosate, or Garlon® 4 Ultra herbicides. Identification of any, and all, milk thistle populations or individuals is crucial to the success of this programs, as a single head of milk thistle can produce 20,000-25,000 viable seeds in a single flowering event (Nechols 1995).

Application:

Once areas have been identified and properly marked, then an applicator can begin going to each location and spot applying the required herbicide. This will begin with an early fall spray of Milestone®—when less grasses and vegetation are present to prevent the herbicide from reaching the soil effecting seedlings—at a rate of 6 fl. oz./A. Followed by spot application to emerging seedlings for the following two weeks. During May and June either a 5% solution of glyphosate or a 1% solution of Garlon® 4 Ultra will be applied to any remaining milk thistle plants.

In the event that individual plants manage to survive this treatment, then mechanical controls will be implemented. During late-spring the heads of any flowering plants will be removed and buried at a minimum of one foot in the ground to prevent the spread of seed, as well as sap the existing plant of depleting carbohydrate reserves.

Key things to ensure during this process are a consistent application of herbicide will result in the most effective control strategy, ensuring that mechanical controls are performed under stringent conditions to prevent accidental spread of either vegetative material, seeds, or other forms of propagules, and to quickly remove any emerging seedlings. Additionally, this program should be continued every year, and within 2-3 years, should see almost a complete removal of this species from the target areas.

Monitoring & Management:

To ensure that a reoccurring population can't continue to sustain itself in the target population, consistent and constant monitoring must be maintained. A minimum of Bi-weekly visits to previous infestation sites is recommended to remove any emerging seedlings—via herbicide or mechanical means—and to maintain the integrity of native vegetation after herbicide applications. Any deleterious effects from herbicide applications should be immediately reported, so the proper steps can be taken to minimize the impact.

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Native birds

Migratory Songbirds

<u>Part 1 - Literature Review</u>

Background and Justification

Migratory songbirds have been on an overall decline in population numbers in the Central Valley. In some cases, species of migratory songbirds no longer breed in the area due to decreased habitat quality and availability. A study conducted from 1979 to 1999 determined that of 31 songbird species captured in in the Western North America, 16 species declined significantly during those 20 years with an increase in decline during 1989 to 1999 (Ballard et al. 2003). Neotropical migrants demonstrated the greatest decline in addition to high-nesters and common cowbird host species (Ballard et al. 2003). A few songbird species are currently classified as threatened or near threatened according to the IUCN. However, this decline cannot be conclusively attributed to solely habitat degradation in the summer breeding habitat of the Central Valley (Ballard et al. 2003). It is possible that this decline may be more strongly correlated to causes in the species' wintering grounds. No matter the definite cause of migratory songbird decline, it is still worthwhile to focus on monitoring and restoring migratory songbird habitat in the Central Valley. Data from migratory songbird populations and individuals can indicate overall quality of restored riparian habitat (Latta et al. 2012). Migratory songbirds increase in mass after they arrive and stay at a functional migratory stop-over site for a few days (Cormier et al. 2013). Plant productivity of the habitat is marked by an increase in breeding success (Pillar et al. 2014). By monitoring easy to spot and easy to catch songbirds, managers are able to obtain an overall estimate of the health and effectiveness of a restored habitat.

Literature Review

The following list of migratory songbirds was determined by cross-referencing the Watchlist from the Yolo Audubon Society and the list generated from The Birds of North America Online when "migratory songbird" is searched with the All About Birds database with The Cornell Lab of Ornithology and the Audubon online Guide to North American Birds database. All of the information listed below is from either the All About Birds database, the Guide to North American Birds database, or the Watchlist. IUCN declarations found on All About Birds database. Citations can be found on the last page.

- Bank Swallow (*Riparia riparia*)
  - Species of Least Concern (IUCN) though it is on the list of "Common Birds in Steep Decline" and is on the California state list of threatened species
  - Colonial nester ranging from 10 to 2000 nests in size
  - Uses the Central Valley as mainly migratory stop-over sites
  - Forages on flying or jumping insects
  - Live in low areas near water and use vertical cliffs or banks as nests
  - Threatened by changes in nesting habitat and management practices that remove steep banks next to surface water, such as erosion control, flood control, and road

building. Construction projects that create mounds of dirt or gravel can provide suitable nesting habitat but the nests are destroyed if the material is moved or removed before the end of nesting season.

- Bell's Vireo (*Vireo bellii*)
    - Near Threatened (IUCN) with subspecies Least Bell's Vireo (*Vireo bellii pusillus*) as Endangered
    - Currently in California, they only breed in significant numbers in the south although a nesting pair was spotted in the Central Valley in 2005
    - Forages on insects and spiders
    - Live in low, shrubby vegetation in riparian areas, woodlands, or coastal chaparral but they are usually tied to water in arid regions
    - Nests are made of grass and long grass-shaped vegetation and are suspended low in small trees or shrubs, usually cottonwoods or willows
    - Threatened by loss of riparian habitat and cowbird parasitism. Riparian restoration projects focusing on cottonwoods and willows are underway to hopefully restore the species to the Central Valley.
- Yellow Warbler (*Setophaga petachia*)
    - Species of Least Concern (IUCN) although they are in slow decline
    - Summer breeders and migrants in the Central Valley
    - Forages on insects
    - Live in riparian forests and woodlands and nest in vertical forks of small trees or brush
    - Nests are made from grass, bark, and spiderwebs and are lined with soft fibers, deer hair, and feathers. If the nest is parasitized by a cowbird, the female will often build a new nest on top of the old one, abandoning all the eggs in the old nest. One brood can take anywhere from 23-29 days to complete, from nest building (4 days) to incubation (10-13 days) to the nestling period (9-12 days). Females may have 2 broods in one nesting season.
    - Some areas of the Central Valley no longer have a breeding population due to habitat loss although habitat restoration projects are attempting to fix that by rebuilding riparian forests along rivers.
    - Threatened by loss of habitat, degradation of habitat by grazing of rangelands near creeks, parasitism by Brown-headed Cowbirds, and collisions with buildings and TV towers while migrating at night.
- Little Willow Flycatcher (*Empidonax traillii brewsteri*) and Willow Flycatcher (*Empidonax traillii*)
    - Little Willow Flycatcher is a Threatened species in California while the Willow Flycatcher is of Least Concern (IUCN) but has marked declines over the last 50 years
    - Rare summer breeder and migrant in the Central Valley
    - Forages on insects
    - Nests in riparian areas with flowing water and populated by willows, cottonwoods, and alders
    - Nests are made from vegetation and lined with feathers and hair
    - Threatened by habitat destruction, degradation, and fragmentation. Stopping

water flow may also impact nesting. Affected by Brown-headed Cowbird parasitism.

- Western Wood-Pewee (*Contopus sordidulus*)
  - Species of Least Concern (IUCN) but have declined 51% in the last 50 years
  - Summer breeder in more sparsely forested areas such as open woodlands, forest edges, and in riparian woodlands
  - Forages on insects
  - Nests are made of grass and spider web and lined with hair or fine grass
  - Threatened by loss of tropical forest wintering grounds
- Cassin's Vireo (*Vireo cassinii*)
  - Species of Least Concern (IUCN) with a slight increase in population
  - Summer breeder and migrant in the Central Valley
  - Forages on arthropods
  - Nests in dry, open forests in the mountains and foothills
  - Nests are made of grasses, leaves, moss, and lined with grass, fibers and hair
  - Threatened by cowbird parasitism
- Black-chinned Sparrow (*Spizella atrogularis*)
  - Common species with a likely stable population
  - Uncommon summer breeder in the Central Valley with common breeding in Southern California
  - Forages on likely seeds and insects
  - Lives on arid, scrubby hillsides and nests in the dense low scrub
  - Incubation is likely around 13 days
  - Nests in small colonies and nests are made of grass, forbaceous stems, and lined with finer grass, fibers, feathers, and animal hair
  - Likely threatened by climate change
- Wilson's Warbler (*Cardellina pusilla*)
  - Species of Least Concern (IUCN) but have declined 61% in the last 50 years
  - Mainly uses the Central Valley for migration though summer breeding may also occur in select areas.
  - Forages on insects and berries
  - Nests in thick riparian shrubs at the edge of larger bodies of surface water, such as beaver ponds, lakes, and bogs
  - Nests are made of vegetation and lined with grass or hair and are usually placed on the ground, at a base of shrubs, or very low in a shrub
  - Threatened by habitat degradation and loss of their riparian breeding habitat in addition to brood parasitism by Brown-headed Cowbirds

Potential management actions

- Improve habitat
  - Many of the species listed above are dependent on riparian habitats. The restoration of shrubs and trees in riparian habitats should increase the chance of pairs to breed in areas where they had been extirpated. Restoration of the riparian habitat must also mean installing varying successional states as the various

songbird species need differing heights and types of vegetation. Cottonwood and willows should be planted as multiple songbirds prefer these two species of tree to nest in.
    - Private landowners should be encouraged to restore riparian forests on their land that is not in use (DiGaudio et al. 2015). In many areas of the Central Valley, there are not many large, unused plots of land that can be restored by the state. Instead, private landowners can be encouraged to restore the riparian areas next to surface water on their land to create habitat for songbirds and other waterfowl.
- Reduce Brown-headed Cowbird brood parasitism
    - Brown-headed Cowbirds have been observed to have contributed to 73% of the nest failures in Wilson's Warblers in a study site in the coastal riparian woodlands in Northern California (Michaud et al. 2004). Controlling Brown-headed Cowbird brood parasitism should increase the reproductive success of many of the above listed species of birds both by reducing the number of eggs destroyed by Cowbirds, but also by reducing the amount of effort individuals need to expend to raise a successful brood. In the species of songbirds that re-build a nest on top of nests parasitized by Cowbirds, the control of Cowbirds will allow the females to not build the second nest and utilize her time and energy more efficiently.

Gaps in Knowledge

Many of the species listed above have limited concrete information and details. This includes, but is not limited to, Cassin's Vireo, Black-chinned Sparrow, Little Willow Flycatcher, and Western Wood-Pewee. To best determine management decisions, having a detailed list of what each species needs is preferred. However, due to these gaps in knowledge, any decisions made will have to be done with the detailed knowledge that is available and with general knowledge about migratory songbirds. A large part of knowledge that is missing is the complete nesting season of many of these songbirds.

There have been studies done about the effect of climate change on songbirds and it has been published that climate change is affecting migrating songbirds so that they are arriving to their summer breeding sites in a slightly different timing (MacMynoswki et al. 2007). However, although we know of this phenomenon, we still do not know what can be done to aid the migrating songbirds so that they will not be negatively impacted by arriving at the wrong time.

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Part 2 - Goals, Management, and Monitoring Plan

A. Key Goals

- **Restore and improve habitat to increase the quality and quantity of nesting locations and stop-over sites**
  - For the eight songbird species we are focusing on, six use the Central Valley for nesting, one uses it as a stop-over site, and one uses it as both depending on where in California it ends up nesting. Five species nest mainly in riparian forests, and two species nest in drier open forests and scrubland in the uplands. The two upland species, Cassin's Vireo and Black-chinned Sparrow

have currently stable populations so we will not focus on restoring their upland habitat but instead monitor their populations to ensure they will not start to decline like the other six species we are focusing on. The other six, rely mainly on riparian forests for nesting and stop-over sites. Riparian forests are the most impactful and important habitat type for migratory songbirds (DiGaudio et al. 2015). A successful restoration site will have varying successional states because various songbirds need different heights and types of vegetation, while focusing on cottonwoods and willows and creating cover to help hide nests. Canopy cover should be varied because different species require differing percent cover. There is not a uniform suggested width to make these riparian areas. Different species of birds tolerate differing widths of habitat (Hawes, 2005). What can be done instead is to determine on a site-by-site basis which birds are present and what their preferences are (Hawes, 2005). To increase the amount of land we have to work with, private landowners along the riparian zone need to be communicated with and negotiated with to ensure their cooperation and participation in restoring the riparian forest (DiGaudio et al. 2015).

- **Reduce Brown-headed Cowbird parasitism of nests**
  - Brown-headed Cowbird parasitism impacts five of the eight species we are focusing on. For a few of the species, Cowbird parasitism is a greater threat than habitat degradation. To control the parasitism, we can either directly control the current Cowbird population or sabotage Cowbird eggs so their reproduction rate will lower. Controlling Cowbird parasitism is only a short-term solution for increasing migratory songbird populations (Siegle 2004). It should be done in conjunction to restoration of habitat. By restoring habitat to become larger, Cowbird effects decrease (Siegle 2004). This is due to an edge effect on songbird habitats. Cowbirds can only parasitize nests that are visible and nests are more visible in the thinner edge of a forest (Siegle 2004). To call this control a success, Cowbird populations will need to be on a statistically significant decline after the control takes place as a long-term goal. As a short-term goal, statistically significant fewer ratio of nests need to be parasitized by the Cowbirds.

B. Restoration Plan

- **Restore and improve habitat to increase the quality and quantity of nesting locations and stop-over sites**
  - **Restore riparian forests**
    - Before restoration begins, potential sites need to be determined and monitored to determine what species of songbirds are present, what their reproductive rate is currently, and the quality of their current habitat. Once this is determined, the details of the restoration end goals can be set based off of the characteristics of the present songbirds which are listed in the literature review (Part 1) of this project. To increase habitat quality for nesting, the riparian forest stands should be dense enough so that nests placed in low trees, where most of the species nest, are partially to completely concealed from predators. However, the stands cannot be too dense so that it is difficult for the

songbirds to fly through them easily to reach the water where there is a higher quantity of insects to feed on. If new trees need to be planted, it is best if small, around one year old trees are planted so there will be varying tree heights for a few years to accommodate those species that prefer shorter trees and shrubs. Any new trees should be planted in the fall as per usual restoration timing, so that they will have plenty of water in late fall and throughout winter and be ready to grow come spring after accustoming itself to its new conditions. Most of the birds favor cottonwood and willows to nest in so the focus should be on those two species of trees. If invasive salt tamarisk is in the system and is being used as critical nesting habitat, allow it to remain so that our management will not negatively impact reproduction rate (Siegle 2004). The single most important thing to do when restoring riparian forest is to create as much of it as possible in an unbroken strip (Hawes 2005). Private landowners need to be approached by someone personable and knowledgeable and given the chance to participate in the restoration, either by restoring their own land, or by allowing the government to restore their land. Creating larger areas of useable habitat increases the quality of the habitat, especially for the more shy bird species that would rather not nest in areas close to urbanization (Merenlender et al. 2009). In addition, some species are colonial nesters and would benefit from being able to have a higher population density. It also decreases the amount of Cowbird nest parasitism, which will be discussed next.

- **Reduce Brown-headed Cowbird parasitism of nests**
  - Before any control methods are put in place, pre-monitoring needs to be done to determine if there are any Cowbirds in the area, how large the population is, and how much it is impacting the reproductive success of the nearby migratory songbirds (Siegle 2004). This can be done with point counts to estimate population size of each species in the area, and nest monitoring to determine the frequency and ratio of parasitism (Siegle 2004). If Cowbirds are determined to be negatively impacting the reproduction and population size of the nearby species, control methods can then be put in place and executed the next year. First, habitat improvements as discussed above will help decrease Cowbird parasitism as Cowbirds prefer to nest in open areas and near the edges of forests (Siegle 2004). By creating more dense stands with more cover, Cowbirds will be unable to locate nests to parasitize. In addition, reducing grazing and human disturbance at the edges of the riparian habitat will also decrease Cowbird predation (Siegle 2004). While habitat restoration is ongoing, other methods can be used to control Cowbirds in the short-term. However, these methods are more labor intensive in the long run, which is why habitat improvements are still the ultimate goal to control Cowbirds. These methods include fertility control, egg removal/addling, shooting, and trapping. Fertility control is possible by spiking bait with specific chemical compounds that will prevent egg laying (Siegle 2004). However, this control method is difficult because the compound must be administered continuously

for one to two weeks for it to work (Siegle 2004). Therefore, it is more promising to use other methods of control. Egg removal/addling entails nest monitoring and when cowbird eggs are found in a nest, to remove the cowbird eggs or addle them by shaking. If the host species will desert their nest if eggs are removed, addle the Cowbird eggs. If the host species will desert their nest if eggs are removed, most of the host species eggs have been pushed out by the Cowbird, and there is still time in the breeding season for the host to restart her nest, remove the Cowbird eggs. If the host species will not desert their nest if eggs are removed, remove the Cowbird eggs. This method works well although it is labor intensive and some nests may not be able to be reached. Another drawback of this method is that there is no prevention for the female Cowbird's impact on the host species eggs (damaging or ejecting from nest). To decrease Cowbird population directly and therefore decrease the number of host nests impacted at all by Cowbirds, shooting and trapping can be done (Siegle 2004). These two methods may be unsavory to the public, but they are the simplest of the short-term methods and are effective. The shooting of the Cowbirds is easily done by attracting birds to the shotgun range during breeding season with taped recordings of female calls (Laymon 1987). It does not have to be done daily like nest monitoring and trapping, and it does not require trampling through large amounts of habitat and disturbing the migratory songbirds. The second direct control method, trapping, is widely used to control Cowbird populations (Siegle 2004). It does require going out daily to release any non-target species and therefore must be easily accessible. Also, trapping does not decrease population size, only controls it (Siegle 2004). Therefore, it must be done every year and in conjunction to other methods if we are to reach our goal of decreasing cowbird population.

C. Monitoring Plan

- **Citizen science to monitor key bird species during migration and breeding season**
  - Citizen scientists and landowners can be used to monitor the multiple sites and to conduct point counts. This will allow us to ensure reproduction rate of restored sites are not lower after restoration. Every few weeks, the restoration sites will need to be checked to ensure the planted species are taking well to their new location and are surviving well. If any of the plants die, if there is still time in the planting season, it should be replaced. If not, it will be replaced the year after.
  - Point counts must be emphasized as the key monitoring effort. They will be used to estimate population density of the eight migratory songbird species in addition to the Cowbirds.
- **Further research and improvement**
  - **Climate change**
    - There is almost nothing known about how we can manage for climate change and for migratory bird species that arrive to their breeding grounds in a slightly different time. More research needs to be done in that field so that we can incorporate new management techniques into this plan.

- **Details on lesser known species**
    - Some species of birds have relatively few known details about their specific nesting niches and preferred food. After more detailed monitoring of those species, we will be able to revise our management plans to fit any new information that is found that contradicts with the general knowledge about migratory songbirds that is currently being used.

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RAPTORS

Background and Justification

For many years, raptors and other large, predatory bird populations have dwindled after habitat change and pollution from chemicals entered their ranges. Raptors are extremely important because they have a strong ecological value. They help to control rodent, reptilian and bird populations (Scott). These species are also important indicators of how healthy the ecosystem is. Raptor populations see a greater impact from issues, like pollution, than species lower in the food chain would because they consume much more of the pollution from eating smaller species. The goal of this project is to maintain and support the population of raptors that are within the Central Valley by proving food, shelter, and safety from human disturbance. Raptors are a resilient group of birds but some species like the White-tailed Kite need extra assistance. Currently the White tailed kite is fully protected meaning that it is "provided additional protection to those animals that are rare or face possible extinction" (California Department of Fish and Wildlife). It cannot be taken or possessed at any time. The species that have large population sizes like the Red-tailed Hawk and Norther Harrier still need attention by managers to keep their habitats (Valley Floor Grassland and Riparian habitat) available for future generations. These species' populations fluctuate through the years but they have been slowly declining mainly because of habitat loss or degradation.

Literature Review

<u>White-tailed Kite</u>

<u>General Population information</u>

- The population size is at about 2 million worldwide but only 4% of that population is within the United States (Cornell Lab of Ornithology)
- This species is fully protected in California and has a concern score of 8 out of 20 (Moore and Cornell Lab of Ornithology)
- All white with very light brown or dirty white under the wings, dark or black shoulders and red eyes. They are often seen hovering with their wings held above their heads if they are not soaring or perching.
- California has the largest number of this species in North America (Moore)

<u>Diet and hunting strategy</u>

- Diet consists mostly of voles and other small mammals like house mice, harvest mice, shrews. Rats and pocket gophers while rarely eats birds, insects, reptiles and amphibians (Polite and National Audubon Society)
- Will soar, glide or hover less than 100 feet above the ground of "open grasslands, meadows, farmlands and emergent wetlands" (Polite)
- Before striking, it will hover over the prey with its legs extended out and wings held above its head like a helicopter to strike straight down on the prey (Polite)
- Specializes in rodents active during the day that live in open country (National Audubon Society)

<u>Breeding</u>

- It is a monogamous species that breeds between February and October peaking in May to August (Polite).
- The nest is made of sticks and twigs covered with grass and straw and hold 4 to

5 eggs where only the female will incubate the eggs for 26 to 32 days and the male will continually feed the female and young when hatched (Polite, Moore and National Audubon Society).

- The young will leave the nest after 35 to 40 days of hatching (Polite and National Audubon Society)

Environmental tolerances and needs

- Will live in wetlands although it is not its preference (Smith)
- Does not need a lot of water because most of its water requirements is satisfied through its prey (Polite)
- Found in coastal and valley lowlands and almost always found rear agricultural areas which makes this vital to their habitat (Polite)
- In lowlands, they live in herbaceous and open habitats (Polite)
- Also found in wetlands of the Central Valley of California where they can be found in “alfalfa, grassland, forage crops, fallow fields and wetlands”(Pandolfino et al. and Smith)
- The home range can be as big as 1.9 square miles but the foraging range decreases during breeding season to about half a mile (Polite).
- This bird is not very aggressive but it will defend its territory against “crows, other hawks and eagles” (Polite)
- Tolerate habitat change as long as the area is an open grassy area or agricultural field with a few trees around, otherwise they are affected by habitat destruction

Migration

- Does not migrate but will slightly follow prey where populations are abundant (Polite and National Audubon Society)

Roosting

- Will roost in saltgrass and Bermudagrass in southern California and uses dense trees for cover (Polite)

Nesting

- Dense, broad-leafed, deciduous trees for cover and twigs to use for a nesting (Polite)

Foraging

- Prefers agricultural or open areas near home range for hunting (Smith, Polite)

Ecosystem service

- Preys on rodents that are harmful to crops (Polite)

Red-Tailed Hawk

Physical features

- The population size is at about 500,000 worldwide. (Hawk Mountain Sanctuary Association)
- The red-tailed hawk has a maximum wing span of about 4.4 feet and maximum weight of 3.3 lbs. The western population has a darker morph than the eastern population while all individuals have fanned, red tails (Hawk Mountain Sanctuary Association)
- They are primarily seen soaring instead of perching (Hawk Mountain Sanctuary Association).

Diet and hunting strategy

- Often hunt near/along highways usually feeding on carrion especially road kill and sometimes steals food from other raptors (California Department of Fish and Wildlife and Hawk Mountain Sanctuary Association)
- Opportunistic hunters that feed on small reptiles, birds, and mammals up to jackrabbit size feeding on the species that are most abundant and their water requirements are met through their diet (Hawk Mountain Sanctuary Association and California Department of Fish and Wildlife)
- They primarily hunt from perches but may also hunt by "soaring, kiting, or powered flight." (Stout et al. and Hawk Mountain Sanctuary Association)

Breeding

- Have "elaborate aerial courtship displays" (Hawk Mountain Sanctuary Association)
- This is a monogamous species that will mate for life if possible. Pairs often nest in solitary trees with either new or reconstructed nests made of thin, three to four foot long sticks (California Department of Fish and Wildlife)
- They lay one to five eggs and incubate for 28 to 35 days and females will take care of the nestlings for 30 to 35 days. The males continually provide food for the nestlings and female (Hawk Mountain Sanctuary Association). The average number of eggs is two (Department of Fish and Wildlife)
- The young fledge after 44 to 46 days and will slowly move away from the nest and hunt nearby until they move into their own home range (Hawk Mountain Sanctuary Association)

Environmental tolerances and needs

- Have adapted to human landscapes well by utilizing isolated trees and agricultural fields (Stout et al. and Hawk Mountain Sanctuary Association)
- Can withstand many environments. Some individuals, especially the ones that live mostly in the northern United States, will live in their home ranges through harsh winters (Hawk Mountain Sanctuary Association).
- Winter tolerances range depending on where the population usually lives so population in northern habitat will withstand harsh winters while southern populations are much less tolerant and will migrate southward during winter (Stout et al.)
- Found from Central Alaska and Canada to Panama and found in all different altitudes (California Department of Fish and Wildlife)
- The population has started to replace Red-shouldered Hawk niches as forest destruction increases because the red-tailed hawks are able to better withstand the habitat loss than Red-shouldered Hawks (Hawk Mountain Sanctuary Association)
- There is not substantial enough evidence to show that red-tailed hawks are affected by organochlorines. The strongest threat to red-tailed hawks is "automobile collisions, nest interference, and shooting." (Hawk Mountain Sanctuary Association)

Migration

- Red-tailed hawks will either migrate south if they are in Alaska, Canada, or the northern Great Plains where populations in all other areas will usually not migrate at all (Cornell Lab of Ornithology)
- Migration is generally in October and November (Hawk Mountain Sanctuary

Association)
- Found throughout North America year round with some migrating to Canada in Summer (Cornell Lab of Ornithology)

Nesting
- Nests are placed in tall trees where they can have a large view of their habitat. Sometimes they will nest on cliff ledges or building ledges or platforms (Cornell Lab of Ornithology)
- Need trees that will lose long branches to help them find material for nests (Hawk Mountain Sanctuary Association)
- Elevated habitats are critical for the species for hunting and nesting because they have many nesting sites within their home ranges (Fitch et al.)

Foraging
- Open habitat with patches of trees to allow them to hunt from solitary trees and soar in search of food and nesting sites especially wetlands, grasslands, and rice fields (Stout et al., Hawk Mountain Sanctuary Association, California Department of Fish and Wildlife, and Smith)
- They have adapted well to human disturbance because it creates isolated trees for great nesting and hunting sites (California Department of Fish and Wildlife). Fire suppression and power lines also create great perching and hunting sites (Hawk Mountain Sanctuary Association).

Ecosystem service
- Pest control and removal or reduction of dead carcasses and a strong indicator of ecosystem interferences or issues (Stout et al.)

Northern Harrier

Physical features
- Has up to a four foot wing span and weights up to 1.3 lbs
- Long, narrow wings with a white rump at the base of the tail
- Females have brown plumage while males have a more gray plumage
- Females are usually 10-20% larger but 50% heavier than males
- This is the only Harrier in North America

Diet and hunting strategy
- Almost always hunt only by flight and flying close to the ground while it searches for food in open areas with mixed vegetation (Hawk Mountain Sanctuary Association)
- Their primary diet is small or medium rodents and birds but will also eat reptiles, amphibians, and insects

Breeding
- Breeding takes place in “freshwater and brackish marshes, lightly grazed meadows, old fields, tundra, dry upland prairies, drained marshlands, high-desert shrubsteppe, and riverside woodlands across Canada and the northern United States” with western populations often nesting in dry uplands (The Cornel Lab of Ornithology)
- Males can be monogamous or polygamous (Hawk Mountain Sanctuary Association and Cornell Lab of Ornithology)
- Ground nester in small colonies or solitary nests with each female having her

own nest (Cornell Lab of Ornithology and Hawk Mountain Sanctuary Association)

- Nests are located in open habitat near shrubby or grassy areas to help camouflage the nests from predators (Hawk Mountain Sanctuary Association)
- If a male fails to display or bring enough food, a female will leave the nest mid-build and new nests will be built each year but males often return to the same breeding site each year (Hawk Mountain Sanctuary Association)
- Incubation last up to 30 to 32 days and the offspring are cared for 12 to 14 days after hatching (Hawk Mountain Sanctuary Association and Cornell Lab of Ornithology)

<u>Environmental tolerances and needs</u>

- Needs dry open areas with less trees preferring grasslands and marshes (Smith and Hawk Mountain Sanctuary Association)
- needs a windy area to fly because it uses the wind currents to help it fly in its "V" form as it rocks back and forth to keep balance and direction (Hawk Mountain Sanctuary Association)
- The population originally took a major loss due to DDT in the 1970 but the population increased after the ban of the use of DDT (Hawk Mountain Sanctuary Association)
- Needs open habitat to search for food in open areas, breed on the ground, and communal ground roosting (Cornell Lab of Ornithology)

<u>Migration</u>

- As partial migrants, they migrate in autumn and spring. Their migration pattern is abnormal because they do not follow corridors and migrate along the coastline (Hawk Mountain Sanctuary Association)
- They migrate south usually during the day. Populations that breed further north with migrate further south than populations that breed in the south (Cornell Lab of Ornithology)
- The population has slowly been declining because of habitat degradation in breeding and feeding locations that has been taken over by agriculture and draining of wetlands (Hawk Mountain Sanctuary Association)
- The population originally took a major loss due to DDT in the 1970 but the population increased after the ban of the use of DDT (Hawk Mountain Sanctuary Association)

	Habitat preferences	Nesting habitat	Diet	Mortality concerns	Migration	Breeding Season
Red-tailed hawk	open areas for hunting (agricultural areas or grasslands). will utilize isolated trees to perch and hunt from. needs forest with layer canopies. like open woodlands	nest in solitary trees near open areas	opportunistic. will eat small mammals, birds, and reptiles	Predation on eggs. Can survive well in human inhabited areas	migrate as far as Canada and Panama	breed in summer (couldn't find specific months)
White-tailed Kite	will live in wetlands but prefer open habitats likes agricultural areas and grasslands for hunting. will roost in saltgrass and bermudagrass. uses dense trees for cover. found in the lowlands of the central valley.	dense, broad-leaefed, deciduous trees	needs voles. also eats mice, shrews, rats, pocket gophers. rarely eats birds, insects, reptiles and amphibians	Predation on eggs. Not a large enough vole population. Eggs being affected by insecticides or pesticides that break down egg shells	does not migrate	summer: peaking in May to August
Northern Harrier	prefer dry, open areas with less trees like grasslands and marshes. ground roosters.	ground nesters near shrubby and grassy areas. will nest along bunches of sedges, bulrushes, grasses, and shrubs	primarily eat small/medium rodents but also eat birds, reptiles, amphibians, and insects	Mowing during breeding season. Eggs predation.	migrate in autumn and spring along the coast	summer usually in Canada. ground nesters

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A) Goals:

	Short-term goal(s)	Long-term goal(s)
White-tailed Kite	Increase the population size in lowlands: 1) Increase habitat available like agricultural fields that are near available woodland areas 2) Stop or limit forest clearing 3) Increase prey abundance in those areas because the population fluctuates with the availability of prey 4) Use small fires in open areas before breeding season (February/March) to create nesting material. If being done in agricultural fields, allow a week before plowing the burnt fields to allow the birds to collect the material.	1) establish old growth woodlands for nesting, cover and roosting 2) as woodlands/forests are being created, create open area like agricultural fields or grasslands nearby to enhance the habitat and prey abundance
Red-tailed Hawk	Maintain population size: 1) Maintain open woodland areas 2) Increase open areas for small mammal prey species with scattered trees for prey like squirrels and for the hawks to perch on while hunting. There should be more open area than woodland. 3) Move carrion and road-kill off roads to keep the hawks from being struck by cars 4) Use small fires before breeding season in Spring to create nesting material	1) Increase the amount of open woodland areas 2) Need groupings of 8-20 trees with differing canopy height. Need two groupings per 300 meters to allow for the sedentary individuals or pairs of hawks.
Northern Harrier	Increase population size in open areas: 1) Protect the ground nests by creating open areas such as wetlands or grasslands away from disturbances like fires and mowing if that is part of the restoration. 2) Increase prey abundance two fold in open areas if there are less than four birds in the area initially.	1) Increase the amount of open area and maintain prey species within those areas 2) After monitoring the population with point counts, if breeding takes place on the site, do not mow or create fires within 200m of that area.

B) Restoration plan:

Increase habitat in the lowlands of the Central Valley

- increase open areas with woodlands near

These three species all need open habitat with large, small mammal populations. To maintain or increase population sizes of all these species there needs to be a mixture of open habitat or agricultural fields near dense woodlands with 30% tree cover and 70% open grassland. An individual white-tailed kite's (*Elanus leucurus*) home range is about 1.9 squares miles decreasing during breeding season which is between February and October peaking in May and August (Polite). With the white-tailed kite being of most concern between all three of these species, the area that should be covered should allow 1.9 square miles of habitat times the abundance of white-tailed kite that wants to be achieved. The trees near the open area are necessary for the white-tailed kite and the red-tailed hawk to nest in (Polite and Department of Fish and Wildlife). Red-tailed hawks (*Buteo Jamaicensis*) also use the trees to perch and hunt from (Stout et al.). If restoring around agricultural fields, 40% of the field should be lined with trees at least 5 meters tall for the raptors to hunt from (Cornell Lab of Ornithology). In natural areas without agriculture, patches of dense woodland and open woodland should be scattered throughout the area to allow for nesting and foraging. To increase woodland habitat, initially 10 to 20 year old trees should be brought in to allow for the first growth of the top story of trees because most oaks do not start to disperse seeds until about 40 to 50 years of age (Iowa Department of Natural Resources). Also, height of the trees is important for nesting because red-tailed hawks will not nest in tress any smaller than 3 meters (Cornell Lab of Ornithology). Varying tree height will create a variety of "edges" that the species can use for perching, hunting, and nesting (Iowa Department of Natural Resources).

- increase open areas that protect ground nests

Restoration should include the protection of ground nests for the northern harriers (*Circus cyaneus*) during breeding season. The nests will be in dense clumps of vegetation like willows, grasses, or bulrushes (Scirpoides holoschoenus) (Cornell Lab of Ornithology). Protection of these areas should occur during incubation, in summer, that is about 28-36 days through fledging that is 14 days after hatching (Cornell Lab of Ornithology). By protecting during breeding season it will increase the survival of each hatchling and help maintain the norther harrier population. Protection can be done through monitoring and controlling of predators that eat chicks or eggs. Examples of that would be coyotes (Canis latrans), Great Horned Owls (Bubo virginianus), raccoons (Procyon lotor) and striped skunks (Mephitis mephitis) (Cornell Lab of Ornithology). A common issue is livestock trampling nests (Cornell Lab or Ornithology).

Increase prey abundance in open areas and woodland areas

- attract small mammal prey

The species of least concern with food availability is the re-tailed hawk because they are opportunistic and will eat anything from birds to small mammals to reptiles (California Department of Fish and Wildlife). In the beginning of restoration with woodlands, trees that produce nuts like acorns should be planted to attract small mammals like squirrels that are great prey for red-tailed hawks (Iowa Department of Natural Resources and California Department of Fish and Wildlife). Voles are the main diet of Northern Harriers, but they will also eat other small mammals like mice, shrews, pocket gophers (Geomyidae) and rats (Polite). Mice and rats live in many different habitats and eat a variety of food. To attract them to restoration plan's grasslands and woodlands food, like insects, seeds and fruit, needs to be available (Bradford).

Mice and rats will be eaten by the other two species but voles are very important to northern harriers. Food like bulbs, shrubs, grasses and roots of many plants are important to attract meadow voles (*Microtus pennsylvanicus*) to the restoration area (Reich). For short-term goals, fire should be suppressed at the beginning of restoration to all the open habitat and woodland areas to establish large enough woodlands to maintain many small mammal populations. Suppressing fire especially from open areas will help to promote rodent populations because they tend to live in open areas with tall grass so predators cannot hunt them (Fennici). Once these populations have established, fires or mowing can occur as long as the burned material and clippings are left on the area for the small mammals to use for cover from the raptors (Fennici).

Increase nesting material

- use controlled fires and trimming of trees

Once an older woodland has been established, small controlled fires can be implemented to create dead trees which will in turn create more twigs available for nests of the red-tailed hawk and the white-tailed kite. The fires should be done in Fall after breeding season and fledging of offspring to reduce the risk of harm by fire but use the wet season to better control the fire. If fire is not a reasonable option for the project then cutting small branches before breeding season is a good option to increase the abundance of nesting material.

C) Monitoring plan:

For 2-3 years before the restoration project, the current populations white-tailed kites, red-tailed hawks, and northern harriers in the Central Valley should be monitored to establish the population size, fluctuations in the population, health, habitat range, migratory behavior and nesting locations of each these species. Also, the abundance of prey for the white-tailed kite, especially voles, should be monitored because the kites do not migrate but will move their range as their prey populations move (Polite and National Audubon Society). This will help to better narrow the options that are available for the project and will be great as comparison for future monitoring of the project. As the restoration occurs the raptor populations should continue to be monitored through banding to be sure that the goals of the species population size are successful. Biweekly monitoring of raptor and small mammal populations will show if the populations are actually using the restoration site and being maintained.

If some of the population goals are unsuccessful then restoration needs to reflect on the issues. Monitoring of prey species should start again if maintenance of the population goals are not met to be sure there is an abundance of prey available. If prey is not the issue then monitoring and maintenance of nesting area needs to be implemented to make sure that the offspring are surviving to adulthood. Protection of the nesting sites may be needed by controlling nest predation from mesopredators or creating larger woodlands.

A few research questions that are important before restoration can start are: What is the ideal population size for these species that can fit within the restoration site? Then, what prey population size is needed to sustain that population size? Once these questions have been answered, the questions for the site are: What is the current population size of each of these species? How many individuals can be maintained in the restoration area sustainably? The first question will be answered through the first stage of monitoring by banding and conducting bird counts of each species. The second question will have to be answered over time with the restoration project because the project needs to be capable of attracting and maintaining prey populations.

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Nest Boxes for Kestrels

Background and justification:

The American kestrel (*Falco sparverius*) is a small species of falcon, and the only kestrel found in the Americas. It is the most common falcon in North America, and is found in a wide variety of habitats, including grassland, woodlands and deserts. (Smallwood et. al. 2009). American kestrels are cavity nesters, but they are able to adapt to a wide variety of nesting situations. Kestrels occasionally nest in holes created by large woodpeckers or use the abandoned nests of other birds. They have been recorded nesting on cliff ledges and building tops (Hamerstrom et. al. 1973). Studies have shown that American Kestrels will readily utilize nesting boxes when available and may even prefer them to “natural” cavities (Bortolotti 1994). Over the past few decades Kestrel populations across North America have experienced noticeable declines (particularly in regions such as coastal California). The reason for these declines remain unknown. However, many believe that it is largely a result of shifting migration patterns, rather than habitat loss, interspecific completion, disease, etc. (Smallwood et. al. 2009). Studies have shown that the presence of nest boxes may help increase the number fledglings that a single breeding pair can produce (Toland and Elder 1987).

Characteristics of the American kestrel:

Migratory Patterns:

- The American kestrel’s northern breeding range extends from central Alaska across northern Canada to Nova Scotia. Most of these birds that breed in Canada and the northern United States migrate south in the winter to the Southern U.S., Mexico and Central America (Smallwood et. al. 2009).
- The American kestrel is found year-round throughout most of the continental United States, Mexico, Central America and the Caribbean. It is also widely distributed throughout South America (Smallwood et. al. 2009).
- Males typically arrive at nesting grounds before females within migratory populations (Ardia et. al. 1997).

Habitat Requirements and Preferences:

- Ideal kestrel habitat should include perches for spotting prey, open space for hunting, and cavities for nesting (Ardia et. al. 1997).
- Kestrels prefer open meadow habitat to densely forested areas (Ardia et. al. 1997).
- Females typically have preference over males when it comes to choosing optimal habitat locations (Ardia et. al. 1997).
- Kestrel population density has been shown to be directly proportional to the number of prey species such as voles in the area (Miller and Lanzone 2015, Toland and Elder 1987).
- On average kestrel home ranges vary from 4.5 to 5.2 square kilometers (Palmer 1988).

Predation Habits:

- A kestrel’s diet typically consists of grasshoppers, lizards, mice, voles and small birds (Toland and Elder 1987).
- The American kestrel's primary mode of hunting is by perching and waiting for prey to come near. The bird can often be spotted along roadsides or fields perched on objects

such as trees, overhead power lines, or fence posts for this reason (Rudolph 1987).
- If the success rate for catching prey decreases significantly in a particular area, birds will move to a different area (Rudolph 1987).

Nesting Habits:
- Kestrels typically nest in naturally occurring tree cavities, cliff sides or abandoned woodpecker holes. Kestrels have even been know nest in buildings (Bortolotti 1994).
- When given the option, kestrels willing prefer artificial nest boxes over natural cavities (Bortolotti 1994).
- When given options of different sized nest boxes, kestrels prefer larger boxes over smaller ones (Bortolotti 1994).
- Kestrels are typically territorial but in a few cases have been known to congregate in large numbers in habitats where food is abundant. This phenomenon is most apparent in migratory populations (Miller and Lanzone 2015).
- Kestrels very often return to the same nest site, year after year, and remain monogamous with the same partner (Bortolotti 1993).

Reproduction:
- American kestrels breed during early spring to late summer (Bortolotti 1993).
- American kestrels become sexually mature by their first spring (Hamerstrom et. al. 1973).
- Breeding pairs often form permanent lifelong bonds (Hamerstrom et. al. 1973).
- Most birds typically lay 3 to 7 eggs per clutch (Hamerstrom et. al. 1973).
- Incubation period is typically between 26 to 32 days (Hamerstrom et. al. 1973).
- Pairs usually produce either one, sometimes two broods per year. (Hamerstrom et. al. 1973).
- Nestlings are typically fledged within 28 to 31 days (Hamerstrom et. al. 1973).
- American kestrel nesting near areas of human development that experience high levels of traffic and other disturbances have been found to have elevated levels of stress hormones which can lead to reproductive failure (Strasser and Heath 2013).

Conservation Status:
- The American kestrel is classified as a species of least concern in the United States (Smallwood et. al. 2009).
- The number of American kestrels have been estimated at 1.2 million pairs in North America alone, with the Central and South American populations nearly equal in size (Smallwood et. al. 2009).
- Over the past few decades kestrel populations across North America have experienced noticeable declines. The reason for these declines remain unknown, however it is more likely the result of shifting migration patterns, rather than habitat loss, interspecific completion, disease, etc. (Smallwood et. al. 2009).
- Some regions such as New England, the American Southeast and coastal California have shown more rapid declines (Smallwood et. al. 2009).
- In the southeastern U.S. the species has declined 82% since 1940 due to a decrease in nest site availability. This decline is a result of longleaf pines forests being cleared from

agricultural fields (Hoffman and Collopy 1988).

- As a migratory raptor, American kestrels are protected by the Migratory Bird Treaty Act of 1918, and are illegal to capture, harm, kill or possess without a permit in the U.S.

Effect of nest box placement on species:

- Studies have shown that kestrels that inhabit artificial nest boxes produce a greater number of fledglings on average, birds that nest in "natural cavities" (Hamerstrom et. al. 1973, Toland and Elder 1987).
- Kestrels generally prefer larger boxes over smaller ones, however there is little evidence that the size of these boxes has any significant effect on the survivability of breeding pairs or their offspring (Bortolotti 1994).
- Nest boxes intended for use by kestrels should follow roughly these dimensions: Nest boxes should be have a floor roughly 25-30.5 cm^2, be 38 cm deep, and have an entrance hole of 7.6 cm diameter near the top. Boxes should be placed between 5 and 14 m above the ground (Toland and Elder 1987).
- Possible nest box sites locations can include buildings, silos, utility poles, and live trees (Toland and Elder 1987).

Gaps in knowledge

- Lack of data on local kestrel population characteristics unique to the Central Valley of California.
- Limited data on prey species abundance such as voles, mice, etc. in Central Valley and Solano County.

Goals:

1. **Provide suitable habitat for local kestrel populations and their prey**
   American kestrels are an adaptable species that can be found in a wide variety of habitats, including grassland, woodlands and deserts. (Smallwood et. al. 2009). Ideal kestrel habitat should include perches for spotting prey, open space for hunting, and cavities for nesting. The preferred habitat of these birds is generally an open-meadow type habitat (Ardia et. al. 1997).
   Kestrels typically nest in naturally occurring tree cavities, cliff sides or abandoned woodpecker holes and but have even been known to also nest in buildings and other man-made structures (Bortolotti 1994). Studies have shown, that kestrels willing prefer artificial nest boxes over natural cavities when they are available (Bortolotti 1994). Thus, nest boxes provide an effective means to encourage kestrel habitation.
2. **Increase the population of nesting birds in the Central Valley**
   Kestrels are typically territorial but in a few cases have been known to congregate in large numbers in habitats where food is abundant. However, this phenomenon is most apparent in migratory populations (Miller and Lanzone 2015). Kestrel population density has been shown to be directly proportional to the number of prey species such as voles in the area (Miller and Lanzone 2015, Toland and Elder 1987). If the success rate for catching prey decreases significantly in a particular area, birds will move to a different area (Rudolph 1987). We can increase the local density of these birds by providing optimal habitat for its preferred prey species: grasshoppers, lizards, mice, voles and small

birds (Toland and Elder 1987).

Restoration Plan:

1. **Restore grassland/meadow habitat**

   Historically, California's Central Valley was dominated by vast grasslands. Kestrels rely on the open spaces to that grasslands provide in order to spot its prey. The American kestrel's primary mode of hunting is by perching and scanning for prey before striking. These birds can often be spotted along roadsides or fields perched on objects such as trees, overhead power lines, or fence posts for this reason (Rudolph 1987). In areas with sparse tree cover, it would beneficial to plant large trees to provide such vantage points.

   In order to provide suitable habitat for kestrels, we must also provide suitable habitat for their prey. One particularly important prey species for the American kestrel in California's Central Valley is the California vole (*Microtus californicus*). This species of vole can be found throughout the state in habitats ranging from wetlands, to grasslands and oak savannas (Batzli ed. al. 1971). Preferred foods of this species includes wild oats (*Avena fatua*), ryegrass (*Lolium multiflorum*), and brome grass (*Bromus Spp.*) (Batzli ed. al. 1971). All of these species are introduced from Europe, which makes it difficult to determine what native grasses comprised animal's original diet. As a result our grassland restoration project should not be focused on restoring native grasses until further research is conducted.

   Kestrels are a highly adaptable species. And are able to tolerate habitats that have been altered by humans. Areas that would be good candidates for ecological restoration in the Central Valley would be abandoned farmland, or undeveloped parklands (Ardia et. al. 1997).
2. **Install nest boxes**
   a. Nest box dimensions

      Nest boxes intended for occupation by kestrels should be have the following dimensions: a floor roughly 25-30.5 cm^2, be 38 cm deep, and have an entrance hole of 7.6 cm diameter near the top. Boxes should be placed between 5 and 14 m above the ground (Toland and Elder 1987). While kestrels generally prefer larger boxes over smaller ones if given the option, there is little evidence that the size of these boxes has any significant effect on the survivability of breeding pairs or their offspring (Bortolotti 1994).
   b. Nest box placement

      Kestrels typically nest in naturally occurring tree cavities, cliff sides or abandoned woodpecker holes. Kestrels have even been know nest in buildings (Bortolotti 1994). For this reason, possible nest box sites locations can include buildings, silos, utility poles, and live trees (Toland and Elder 1987). When given the option, kestrels willing accept artificial nest boxes over natural cavities (Bortolotti 1994). Studies have shown that kestrels which inhabit artificial nest boxes produce a greater number of fledglings on average, birds that nest in "natural cavities" (Hamerstrom et. al. 1973, Toland and Elder 1987).

      Kestrels are typically territorial but in a few cases have been known to congregate in large numbers in habitats where food is abundant (Miller and Lanzone 2015). This phenomenon is most apparent in migratory populations, however the local Central Valley population is not migratory. This may be worth considering in when placing nest boxes. On average kestrel home ranges vary from 4.5 to 5.2 square kilometers (Palmer 1988).

Another potential concern in regards to the placement of nest boxes is their proximity to roads and other man-made disturbances. Kestrels nesting near areas of human development that experience high levels of traffic and other disturbances have been found to have elevated levels of stress hormones which can lead to reproductive failure (Strasser and Heath 2013).

Monitoring Plan:

In order to realize our goals of restoring suitable habitat for kestrels and increasing their numbers, we must possess the ability to measure all of the following: population density, average nest productivity, fledgling survival and prey abundance.

Monitoring should begin in the early spring when kestrels begin their breeding season (Bortolotti 1994). In each nest box occupied by kestrels, researchers should record the number of eggs per clutch for each pair. Pairs usually produce only one, but sometimes two broods per year. Most birds typically lay 3 to 7 eggs per clutch. Incubation period is typically between 26 to 32 days (Hamerstrom et. al. 1973). Once the eggs have hatched researches again should record the number of fledglings in each nest for once a week for several weeks until they leave the nest. Nestlings are typically fledged within 28 to 31 days (Hamerstrom et. al. 1973). A possible alternative to manual nest counts would be to install cameras in each nest box. The benefit of this method is that it allows continuous monitoring without the need for human researchers to disturb the birds and their nests. The downside is that this method would be more costly. If possible, another step would be to tag all fledglings before they leave the nest. This allows us to track these fledglings once they have left the nest and monitor their survival.

Average density of kestrel populations can be achieved by estimating the number of breeding pairs in a given area. This can be done by counting the number of occupied nest boxes, along with any “natural” nests found within the same area. Prey density can be estimated with the same area by setting traps for small mammals such as mice and voles. While not the entirety of the American kestrel’s diet, these two species constitute the most important prey items for this species and can provide a useful metric which may be useful to compare to population density measurements of the birds themselves. As mentioned earlier studies have shown that prey density can be correlated predator density in this species (Miller and Lanzone 2015, Toland and Elder 1987).

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<u>Tricolored Blackbird (*Agelaius tricolor*)</u>

Background

The Tricolored Blackbird (*Agelaius tricolor*) is a passerine bird in the family Icteridae. As its name suggests, these birds are distinguished by its three bold colors: a black body, red shoulder pads, and a white bar under the shoulder pads. The Tricolored Blackbirds are near endemic to California, particularly in Central Valley, and form large breeding colonies in over 46 counties (Tricolored Blackbird Portal, 2016). A study done in 1930s estimated that there were about 2-3 million birds all throughout California, based on nest counts (Neff, 1937). Then, in the early 1970s, DeHaven and other scientists conducted another study on bird abundance and estimated at there was at least 50% decline in species abundance since Neff's study (Tricolored Blackbird Portal, 2016). In more recent times, according to the National Audubon Society, the Tricolored Blackbird population has steadily been decreasing, 64% just over the last 6 years. By seeing these declining trends in the Tricolored Blackbird abundance, they were given as an emergency Endangered status within the California Endangered Species Act (Tricolored Blackbird Portal, 2016). While there are a variety of reasons for their decline, one of the main reasons is due to habitat loss, especially of wetland marshes and grasslands in the Central Valley where they breed and live (Center for Biological Diversity, 2016). Some agricultural farmers may consider them as pests; however, these birds are important for conservation because they increase the California native biodiversity as well as giving more of a reason to restore natural wetlands in California.

<u>Literature review: Characteristics of the Tricolored Blackbird</u>

Habitat use and requirements:

- Tricolored Blackbirds are social bird and live in high densities. They are not described as territorial. They only maintain territoriality at breeding nest during the nesting effort and not foraging areas. Most territories are between 2 and 6 square meters (Tricolored Blackbird Portal, 2016).
- Most Tricolored Blackbirds live primarily in the Central Valley through the breeding season; however, some were spotted in Washington, Oregon, and Nevada during the non-breeding season (Tricolored Blackbird Portal, 2016).
- Tricolored Blackbirds used to breed in freshwater cattail and bulrush marshes (Graves, et al., 2013). Now, they utilize Himalaya berries, grain fields, tamarisk trees, riparian scrublands, and wetlands (Beedy et al, 1997).
- Suitable habitat is extremely reliant on accessibility for water, protected nesting areas in flooded, thorny, or spiny vegetation, and foraging areas within 5-6 kilometers from the nesting colony (Beedy et al, 1997).
- Water accessibility means that the birds are able to utilize the fresh water for drinking purposes, at maximum of 500m from nesting habitat (Hamilton, 2004).
- Tricolored Blackbirds are able to live sympatrically with Red-winged and Yellow-headed Blackbirds as well as other waterfowl and songbird species (Tricolored Blackbird Working Group, 2009). They interact strongly in particular with Red-winged Blackbird and compete with them indirectly. The Red-winged Blackbirds inhabits nesting sites earlier in the winter as well as being aggressive to maintain their territories. Even though

the Red-winged Blackbirds are also native, they have been pushing out the Tricolored Blackbirds (Orians, 1963).

Foraging requirements:

- Tricolor Blackbirds forage within 5-6km radius of their breeding site. Within the area, they will forage on annual or perennial agricultural crops like sunflowers, alfalfa, rice, and grains as well as agricultural grasses for food. However, agricultural practices have shifted to other crops such as grapes and nut trees that are not utilized by tricolors (The Tricolored Blackbird Working Group, 2009).
- Other than agricultural crops, Tricolored Blackbirds mostly forage on invertebrate and animal matter. Adults will bring beetles, grasshoppers, caddisfly larvae, moth and butterfly larvae to their nestlings. (Desert Renewable Energy Conservation Plan, 2014).
- Tricolored Blackbirds adults also feed on invertebrates that include Coleopterans (beetles), Orthopterans (grasshoppers, locusts), Hemipterans (true bugs), Arachnids (spiders), and larval Lepidoptera (caterpillars) (The Tricolored Blackbird Working Group, 2009).
- Ideal conditions for foraging are shallow flood-irrigation, mowing, or grazing to keep the optimal height of <15cm in vegetation for the Tricolor Blackbirds (The Tricolored Blackbird Working Group, 2009).

Reproduction:

- A study from 1992-1994, 1997, trying to identify breeding season movements of Tricolored Blackbirds, found that birds are itinerant breeders, meaning that these birds travel from place to place. Some will start to breed earlier and move to a different location to breed again within the same season, usually in a more northern location (Hamilton, 1998).
- After the first egg laying is a failure, some birds may nest again 45 days later to produce a second brood either at the same site or a different site (Hamilton, 1998).
- The current breeding distribution of Tricolored Blackbird is in at least 46 counties in California, particularly in Central Valley (Tricolored Blackbird Portal, 2016).
- Initial breeding starts from mid-March through early April throughout California (Hamilton, 1998).
- Males reproduce at around 2 years old arrive before the females, usually 1 year old, 1-3 days earlier to breeding sites. Each male will mate with two females during the season (Tricolored Blackbird Portal, 2016).
- Nest are shaped as open cup with a variety of plant leaves and stems and placed about 1 or 2 meters above the ground or water (Tricolored Blackbird Portal, 2016).
- Eggs are laid one day after the nest is completed and one egg is laid each day. Nests typically have 4 eggs in each clutch, sometimes 3 eggs, but 5 eggs as are rare (Tricolored Blackbird Portal, 2016).
- Incubation begins with the first egg laid and occurs for about 12 days (Tricolored Blackbird Portal, 2016).

- Hatchlings are born blind and fed by the parents for typically 11-12 days. The young start to fledge at 10-14 days and are encouraged by the parents to fledge (Tricolored Blackbird Portal, 2016).
- Reproduction may fail due to agricultural harvest causing nest destruction and predation (Tricolored Blackbird Portal, 2016).
- There are no population size requirements known and no minimum space/ patch size requirements have been determined yet (Hamilton, 2004).

Threats

- Severe weather such as intense rainfall and strong winds can cause mortality to adult females, eggs, and young. During the summer, days that exceeds 38 degrees Celsius for 3 consecutive days, Tricolored Blackbirds will abandon their nests (Tricolored Blackbird Portal, 2016). Severe cold conditions or storms can cause reproductive failure in adult females. Some even succumb to hypothermia (Beedy et al, 1997).
- Habitat loss, especially wetlands, due to land use changes to agricultural lands eliminating suitable habitat (National Audubon Society, 2016).
- Most major predators include Black-crowned Night Herons, White-faced Ibis, and raccoons in wetlands while coyotes and cattle egrets in upland areas (Tricolored Blackbird Portal, 2016). In the Central Valley, coyotes are major predators in field colonies due to predation on eggs and young (Beedy et al. 1997).
- Agricultural harvest can cause nest destruction and mortality especially because crops may be ready for harvest before the young are fledged out of their nests (Beedy et al, 1997).

Potential Management Actions:

- Restore natural habitats, especially wetlands with cattails marshes with water accessibility. Water cannot flood to high levels because nest sites are not in high areas. Nests are typically 0.5-1.5m from the ground or initial water levels (Hamilton, 2004).
- If water levels get high than the 1.5m, the water can drown the eggs Thus, once nesting sites are found, it should be protected from rising or fluctuating water levels (Beedy et al, 1997).
- Foraging and nesting habitat must be in close proximity to each other, within 5 km or closer (The Tricolored Blackbird Working Group, 2009).
- Nesting habitats can be improved with naturally armored native plants such as California blackberries, nettles, and thistles (Beedy et al, 1997).
- Provide substrate with high abundance of invertebrate for foraging (The Tricolored Working Group, 2009)
- Monitoring the distribution and population trends of Tricolored Blackbirds (Beedy et al, 1997).
- If agricultural sites are around and are utilized by Tricolored Blackbirds, harvest should

be delayed until after nestlings fledge (Beedy et al, 1997).

Key Gaps in knowledge

- Tricolored Blackbird migration patterns during wintering season
- Habitat selection mechanisms used by Tricolored Blackbirds
- How large or small in wetland size are required by Tricolored Blackbirds

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Goals, Restoration/Management, and Monitoring Plan

Goals

A. Improve and restore suitable habitats for foraging and breeding Tri-colored Blackbirds populations

Tricolored Blackbirds have specific habitat requirements for their needs to reproduce and forage. These birds have 3 basic requirements when looking to settle in a colony, which are open access to water, protected nesting substrate, and foraging space within a few kilometers from the nesting colony (Beedy et al, 1997). This means that it is important to improve and restore habitat with open, fresh water bodies within 500 meters of dense armored vegetation. Tricolored Blackbirds utilize armored vegetation of native and nonnative species that are thorny, spiny, or flooded like cattail, bulrushes, nettles, thistles, and Himalayan blackberries, to provide protection to their nests from predators (Hamilton, 2004). Because Tricolored Blackbird will also nest in nonnative invasive plants like the Himalayan blackberries, if efforts are to remove these species, then there must also be efforts to replace the nonnatives with a suitable alterative such as the plants listed above (Campbell, 2016). Within these habitats, suitable foraging habitat must be within a minimum distance of 5 kilometers from the nesting colony (The Tricolored Blackbird Working Group, 2009). In ideal conditions, foraging habitat needs to have vegetation height of <15 cm (The Tricolored Blackbird Working Group, 2009). Suitable foraging habitat also means vegetation that supports a high availability of invertebrates such as annual and perennial grasses and crops (The Tricolored Blackbird Working Group, 2009). Thus, many of the types of habitats that meet these requirements include freshwater wetlands, riparian scrub habitat, wet marshes and shallow flooded agricultural lands.

In the Central Valley, freshwater marshes and wetlands may be one of the most valuable habitat types, but also the most threatened from land use changes over the years so the goal is to improve and restore these habitats that have characteristics of these basic requirements (Beedy et al, 1997). However, restoration of wetlands does not always benefit Tri-colored Blackbirds because most are primarily managed for waterfowl and other species. If management does not have Tricolored Blackbirds in mind, then the area may not provide suitable habitat for the Tricolored Blackbirds (Desert Renewable Energy Conservation Plan, 2014).

B. Water management

Water is an important contributing factor when Tricolored Blackbirds look for suitable habitat. Therefore, flooded wet habitats and/or agricultural areas such as rice fields are suitable habitat so Tricolored Blackbirds have been found colonizing them. Once they do colonize and build nests, Tricolored Blackbird nests are typically only about 1.5 m above the initial water level (Hamilton, 2004). Because of this, it is important to protect nests from rising water levels in order to reduce the risk of drowning nestlings or eggs (Beedy et al, 1997). Draining or mismanagement of water causing levels to drop for initial levels can also risks easy access of mammalian predators such coyotes and raccoons (Hamilton, 2004). Goals should be to maintain water levels constant from the time that nests are found in order to protect the nests from drowning and for avoidance of their natural predators.

Remove or reduce threats from agricultural practices to nesting populations

C. Harvest

One of the biggest threats to Tricolored Blackbird nesting population is from agricultural practices in the Central Valley. As many habitats change from, for example, a wetland to agricultural rice fields, certain agricultural practices such as harvest and disruptive water management increases mortality rates within nesting sites. As habitats change, many Tricolored Blackbird populations have been found to settle on these agricultural fields, especially on Triticale (hybrid of wheat and rye grown as silage) for nesting substrate (Graves et al, 2013). However, many colonies become destroyed due to crop harvest during the Tricolored Blackbird breeding season leading to high failure in reproductive effort. Not only will harvest destroy nests, it can also cause large disruptions leading to massive flushing of reproducing females (Hamilton, 2004). As such, the goals is to reduce this threat by delaying harvest until around mid-April to mid-July to ensure the greatest number of young has fledged from these agricultural nest sites (Beedy et al, 1997). Because harvest is important for farmers, more costs might be involved to incentive farmers to delay harvest (Tricolored Blackbird Portal, 2016).

Restoration Plan

I. To restore or enhance habitat

a. Habitat restoration

When planning a restoration site for suitable habitat for Tricolored Blackbirds, the main focus should be on the 3 characteristics of habitat structure that is needed by Tricolored Blackbirds. Breeding season of Tricolored Blackbirds are in the spring from mid-March could last through mid-July so at the restoration site, water must be managed during those times. Areas with low, shallow depressions of clay soils should be considered for shallow flooding. Shallow water levels can support vegetation of less than 15 cm such as cattail and bulrushes. To protect water quality, buffers from agricultural lands are useful in protecting the water against run-off containing nitrogenous fertilizers (Ducks Unlimited, 2014).

Not only is water management important, restoring native and upland vegetation plays critical roles in the restoration of habitat for Tricolored Blackbirds. They rely on high quality, dense vegetation so restoration should focus on naturally thorny or spiny vegetation. Bulrushes typically need to be planted in fall and/or early spring, taking 3-4 weeks to germinate, and should be planted densely to increase shoreline protection. Draw down water and plant the seeds were water, is expected to be about 6 inches deep, in moist soil. Once vegetation is established, water can be drawn back up. These can also be planted at the edge of the water 5-10 feet wide in saturated soils to get plants established (Jacobson, 2006). Cattail plants are also important for nesting sites and provide invertebrate food sources for foraging habitat, but cattails can quickly become invasive if not controlled. They will not germinate in standing water, but can germinate in mud flats leading to the water. Cattails can be managed by drawing water levels low to cut or burn the shoots and then flooded to essentially down the stem 2 or 3 inches above the stems (Jacobson, 2006). Another plant, the Himalayan blackberry, although invasive, provides suitable foraging and nesting habitat. These need moist soils with shade or less sunlight and grow in the spring (Soll, 2004). These plants can be managed by grazing from goats, prescribed burning, cutting, etc. (Ducks Unlimited, 2014). Other plants such as thistles and nettles can also be managed for restoring habitat structure. These plants should be planted in the spring also when Tricolored Blackbirds are breeding.

b. Water management

Water management can restore habitats for both wet marsh or wetlands and agricultural sites. Breaking tiles or plugging ditches can restore existing hydrology in wetlands naturally. Installing water pump stations can also work for a more reliable source for both wetland types and agricultural fields. Because the vegetation that Tricolored Blackbird utilize are mostly emergent plants, water levels must be maintained at 18 inches or below (Ducks Unlimited, 2005). Additionally, this level should remain constant throughout the breeding season because the risk of flooding can cause nest destruction and draining of water can risk the accessibility for natural predators to predate on the nesting females and her eggs (Hamilton, 2004).

II. Management of agriculture

In the Central Valley, agriculture is common, but harvest in nesting sites has destructive effects. In order to support Tricolored Blackbirds while still maintaining agriculture, on a large scale, farmers should plant agricultural crops that will be utilized by these birds such as rice and Triticale. Rice can be grown together in wetlands as a large-scale project to provide substantial benefits to wildlife. To enhancing foraging and nesting grounds opportunities, install islands of vegetation on the rice fields (Migratory Bird Conservation Partnership, 2014). Rice is best when planted in the springs so that the birds have foraging opportunities of insects in the winter (Migratory Bird Conservation Partnership, 2014). Rice needs to be grown in standing water of 2 to 3 cm for at least 3 days, or until the ground is soft. 60-80 kg of seeds per ha are required for direct seeding while 40 kg per ha are required for transplanting. Direct seeding may be appropriate in drier areas with limited resources and transplanting may be beneficial in wet fields, but do require nurseries for seedlings (International Rice Research Institute, 2016). On average, 1,432 liters of water is needed to produce 1 kg of rice so rice fields may not be the best strategy during droughts (International Rice Research Institute, 2016).

Another crop that are used by Tricolored Blackbirds is Triticale. Triticale is a hybrid of wheat and rye and need to be planted in well-drained soil with pH levels of about 5.5-6.0. It can be planted either in the spring or winter at the rate of 100 lbs. per acre (UVM Extension Crops and Soils Team, 2011). In the Central Valley, snow isn't much of problem so winter planting should not kill the plant. If the plant gets too cold and dies, it can regrow in the spring. Triticale harvest occurs later than wheat, so harvest can be delayed until end of July when breeding is finished for the season.

Monitoring Plan

Tricolored Blackbird should be monitored annually to estimate breeding adults, numbers of young produced, and to observe productivity. To monitor them, annual color banding of birds and young helps to identify the birds, estimate reproductive success, estimate life history, and site fidelity (Tricolored Blackbird Portal, 2016). This will help to document long-term spatial and temporal patterns.

For long-term trend, conduct a statewide population census every three years for population trends. Census can be done with area searches. Because Tricolored Blackbird colonies have dense amount of individuals, it would be acceptable to estimate the total number of adults at the site for 10-15 minute period. (The Tricolored Blackbird Working Group, 2009).

To estimate productivity by conducting plot or line transects of nest searches to collect data on number of nests and number of breeding females. This should be done after the breeding season is over to make sure the least amount to disturbance as possible.

From data collected from a census in 2005 estimated 260,000 Tricolored Blackbirds, which suggested a possible increase of a short-term trend (The Tricolored Blackbird Working Group, 2009). Thus, if estimates get lower than this estimate, then plans should be made for the restoration plan. Monitoring of these birds should remain until estimates of population indicate Tricolored Blackbird to have a self-sustaining population. This can be analyzed by the data and existing models for population goals.

In order to improve this plan, more research on habitat selection mechanism should be focused on. The relationship between how large or small wetland size should be and population size is also not very known. These questions should be answered to find make better restoration plans. Perhaps, more monitoring by site cameras and using population models can help to test these questions.

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Swainson's Hawk (*Buteo swainsoni*)

Swainson's Hawks are opportunistic generalist raptors that feed on a wide variety of animals including mammals, insects, snakes, lizards, birds, amphibians and even small invertebrates (England et al 1997). These birds are widely distributed across the United States and in recent years have suffered from large declines, especially in nestling survival and the number of breeding adults (Bloom 1980). In past years the size of the breeding population of Swainson's Hawks has decreased by ninety percent (Bloom 1980). The Swainson's Hawk is no longer listed though there has not been any increase in the population sizes (US Fish and Wildlife Service 2013). The species thrives in areas with mostly open grasslands or prairies that have trees suitable for nest sites and away from human disturbances (Bechard 1982). This species is an asset for maintaining insect populations as well as small mammals. By preying on insects especially around agricultural or urban areas it benefits the human population as well (England et al 2010). The target goal is to increase the overall population size of this species that has the potential to be an asset to agricultural practices in which insects are an issue that could potentially reduce or eliminate the use of toxic pesticides that negatively affect other bird species as well (Fleischli 2004). Furthermore, these fascinating raptors are important to the bird watching community, which furthers its appeal for conservation practices to be implicated (Holmes et al 1993).

Literature Review- Characteristics of Swainson's Hawk

Reproduction and Time Scales

- In recent past years, the overall size of the breeding population of Swainson's hawks has declined by approximately ninety percent (Bloom 1980).
- California has two populations, which comprise the breeding areas right now in California. These include the Great Basin as well as the other in the northeastern areas of California (Bloom 1980).
- The breeding grounds extend from Canada all the way down to Mexico. The eastern distribution of the breeding sites includes from California to Texas, Oklahoma, Nebraska and Minnesota as well. The range varies westerly between Washington, Oregon, and California (England et al 1997).
- Swainson's hawks tend to be monogamous where both parents defend the nest. In some instances they do exhibit polygyny (England et al 2010).
- Clutch size is usually two to three eggs with an incubation period of approximately thirty-five days. Female mostly incubates while the male hunts. After about forty-four days the young are able to fly on their own and stay with the parents until migration (Kaufman 2014).

Spatial Scales and Use

- Home ranges consisted both of cultivated and uncultivated fields. It was found that cultivated fields are the most abundant and support a large density of prey. Even though these fields supported such high densities, male Swainson's Hawks favored large areas of uncultivated land or cultivated lands after the crop harvest to use as its hunting grounds (Bechard 1982).
- Using radio tags, it was determined that the home ranges of Swainson's Hawks in the Sacramento area was approximately forty one square kilometers on average. (Babcock 1995).
- From the kernel method, areas of popular use by nesting hawks ranged between 0.26 square kilometers to 0.82 square kilometers (Babcock 1995). Additionally individuals were witnessed to travel up to twenty-three kilometers from its current nest site (Babcock 1995).
- Given that these measurements were among the Sacramento Valley the patterns of home, nesting, and foraging ranges have been found to be greatly influenced by agricultural practices and vegetative cover (Babcock 1995).
- Out of the birds that were caught, on average the males maintained larger home ranges than did females (Babcock 1995).
- Swainson's hawks travel long distances for migration between North America and Argentina. Migratory flocks begin to collaborate between August and September and they reach their wintering grounds in November (England et al. 1997).
- Swainson's hawks have an average migration distance of 13,500 km south and approximately 12,000 km northward (Fuller et al. 1998).
- Swainson's hawks utilize soaring flight while migrating in which they take advantage of rising air currents to conserve energy during the long migrations (Fuller et al. 1998).

Habitat Preferences and Requirements

- By utilizing radio telemetry techniques and observations it has been found that Swainson's Hawks prefer habitats with less vegetative canopy cover. Regardless of the prey density, in areas with high vegetative cover and high densities of prey the birds were much less likely to use the area to hunt in (Bechard 1982).
- Thus areas with reduced plant cover were favored as hunting areas for these foraging birds (Bechard 1982).
- Birds exhibited very large home ranges. These are thought to be large in order to compensate for the unavailable land due to farming or human use (Babcock 1995).
- During the breeding season, male hawks choose where to build the nest which requires groups of trees or solitary trees to be available to them. The types of trees usually used for nest sites include willow, oak, aspen, cottonwood and conifers as well (England et al. 2010).
- Usually found in or around dry grasslands, farmland, or prairie regions. Require areas with trees available to use as nest sites that are spread out far enough from other nest sites (Kaufman 2014).

Diet

- Swainson's hawks feed their chicks rodents, reptiles, and rabbits most commonly (England et al 2010).
- The adults during the non-breeding season consume a diet that mostly consists of insects (England et al 2010).
- During the breeding season the diet shifts from mostly insects to eating mammals and insects in order to meet the energetic demands of breeding (England et al 2010).
- Swainson's hawks are opportunistic generalists in which they consume a wide variety of animals. Some of these include birds, reptiles, insects, mammals, amphibians as well as invertebrates (Rudolph and Fisher 1993).
- When hunting these animals hunt by soaring overhead, running on the ground with wings flapping, or by perching and scanning the ground below them (Kaufman 2014).
- Water economy- Swainson's hawks acquire their water through their prey. Such that when nestlings are fed, prey with high fat content has low water content where the inverse is prey with low fat content has high water content. Additionally the birds received water from the metabolic water input and lost it through evaporation. Nestlings have a much higher rate of evaporative water loss as compared to adults expected by allometry (Kirkley and Gessamen 1990).

Threats

- In recent years mortality of Swainson's hawks has been attributed due to poisoning, habitat loss and other human related disturbances. Furthermore, egg-shell thinning, predation of young by Great horned owls, as well as being killed by traffic are also common causes of early mortality. The most frequent types of pesticides that have been poisoning the birds include famphur, carbofuran, diazinon, and fenthion (Fleischli et al 2004).
- Additionally, Swainson's hawks habitat loss has led them to become closer to human activities in which cause them to flush much more commonly as they would have before their habitat was lost. Flushing is energetically costly for the animals in which human disturbance including agricultural areas and urbanization have consequently led the hawks to be subjected to more disturbances (Holmes et al 1993).

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Photo: Swainson’s Hawk Google images

Part 2- Plan Version 1

Goals

The continuation of the presence and promotion of Swainson’s Hawks, Buteo swainsoni is a key factor in maintaining the balance among species in California and the surrounding areas. By improving the habitat and prey species abundance, eliminate the use of pesticides, and protect known migration sites the future of the species can be continued without the threat of extinction.

Improve habitat and prey species abundance

The Swainson’s Hawk thrives among the lowland grasslands as well as riparian communities throughout California in which home ranges varied tremendously based on presence or absence of farming practices, changes in plant and species distributions, and changes among prey densities (Babcock 1995). In past years there has been an estimated decline of 90% in the breeding community, which has significantly impacted the total abundance of the Swainson's Hawks (Babcock 1995). When the home range was under study, it was found that size of the home range usually varied between twenty-six to eighty-two hectares in size (Babcock 1995). This variation among ranges was greatly influenced by specific habitat types and qualities. Such that the poorer the quality of habitat in relation to amount of cover, prey availability, and nest sites was seen to be significantly larger than compared to the home ranges of the species among a much higher quality habitat (Babcock 1995). The species in particular is very well adjusted to living in areas affected by the human population, most specifically among crop fields. Home ranges consisted of varying amounts of cultivated and uncultivated areas. It was determined that although cultivated fields provided an abundant source of prey species, it was not until the field had been harvested when the Swainson's hawks frequented that section of the home range more (Bechard 1982). This was proposed as a result of the amount of plant canopy cover over the fields. Such that once harvested, the amount of canopy cover was reduced and the frequency of Swainson's hawks that utilized the area in its foraging areas increased (Bechard 1982). In further studies it was determined that in order of importance, the quality of habitat was more of a determining factor then the abundance of prey within a given area. Such that by improving the overall habitat quality as well as furnishing a larger abundance of prey species, the Swainson's hawk would have a greatly increased chance of augmenting its overall population size. Swainson's hawks prefer open areas of habitat in which have many available nest sites with low amounts of canopy cover (England et al 1997). The reduced amount of canopy cover allows the hawks to identify prey easier and with less interference when attacking (England et al 1997). As the human population has encroached on the open habitat type preferred by Swainson's hawks, the species has been able to adapt quite well in areas affected by farming practices in which they take advantage of the period after harvest where the vegetative cover is significantly reduced and the prey species are more readily available (England et al 1997). As complete restoration to a previous period is unreasonable the ultimate goal is to improve the habitat quality of frequented areas by decreasing the amount of vegetative cover, increasing the amount of suitable nest sites, and increasing the abundance of available and preferred prey species that altogether will support the success of the Swainson's hawks. As the ability to improve habitat and prey abundances takes time this would be a long term project in which can be monitored by evaluating correlations between changes in vegetative cover and Swainson's hawk presence, mark recapture methods to track populations and observations to record the number of individuals that utilize the area.

Eliminate the use of pesticides

A major factor causing high rates of mortality among adults and young birds is due to poisoning. Poisoning events were determined to be when more than fifty percent of inhibition of cholinesterase activity in the brain as well as the identification of poison among the gastrointestinal tract birds (Fleischli et al 2004). Some of the most common forms of poisoning events were directly the result of pesticide consummation (Fleischli et al 2004). The hawks as well as other birds are often exposed to pesticides through contaminated waters, farming additives, and through ingesting poisoned animals (Fleischli et al 2004). The most commonly ingested type of pesticides includes famphur, carbofuran, and diazinon types (Fleischli et al

2004). Once the birds are affected by the poison it often leads to death or serious impairments. The most common symptoms of poisonings include lethargy, incoordination, blindness, difficult breathing, tremors, feather fluffing, and convulsions (Fleischli et al 2004). Thus by significantly reducing the presence of pesticides or using alternative organic strategies, the detrimental effects on birds including the Swainson's hawk may be greatly reduced and lead to increases in the population size overall. This goal can be put into effect immediately such as through requiring use of organic pesticides only in which would not impact the birds so greatly. Monitoring the populations at designated locations may be possible through the use of observations and mark recapture to determine if the population sizes are affected. Also the collection of carcasses and tests for poisoning bouts may also reflect if there were any significant changes in the amount of birds poisoned. This can be put into effect immediately and be monitored for the near and distant future to track fluctuations.

Protect known stopover and migration sites

Swainson's Hawks are one of the many migratory species that utilize numerous stopover sites as well as migratory sites other than their usual home ranges. In general these hawks follow three broad basic routes south, meet up within central Mexico and make their way down to Argentina for an austral summer (England et al 2010). They spend extensive time migrating of which their southward migrations range from forty-two to ninety-eight days and their northbound migrations last anywhere from fifty-one to eighty-two days long (England et al 2010). These extensive migratory journeys take a significant toll on the birds, as they are extremely energetically expensive. As a result when the birds reach their migration sites they are often not as robust as they were when they began the journey and are not as able to hunt and defend themselves as efficiently (England et al 2010). Thus by establishing protected sites that are known migratory sites, these birds will have a better chance at being able to recover from the journey and store enough reserves for the migration back. As this would be a long-term project ranging from five to ten years monitoring through banding and recapture could be utilized to determine the percent of individuals returning as well as any changes in abundance.

Restoration Plan

Improve habitat quality and prey species abundance

In order to improve the overall habitat quality of an area to promote the Swainson's hawks three parts must be focused on. The first is to restore grasslands and open areas. As the Swainson's hawk prefer open grassy areas grass seed can be utilized to plant new native grasses that will not be an invasive species in the area. Some of these native grasses include Blue Grama, Sideoats Grama, and Buffalo grass in which require very little maintenance and are relatively hardy species (Kaufman 2014). The optimum time to plant the grass seed is around late spring to early summer to allow it to grow enough before the heat of the summer impacts it (Kaufman 2014). By planting a native, hardy species that is of the shorter variety it will allow the grassland to be improved as well as provide enough but not too dense of vegetative cover for the Swainson's hawk to preferentially choose the area for its home range. The second area of focus should be on promoting nest sites. Often nest sites are found in trees or large shrubs that are usually between fifteen to thirty feet above the ground and are well hidden among the foliage (Kaufman 2014). Thus to promote nest sites, the implantation of preferred trees and shrubs must be installed. The most used types of nest trees and shrubs include cottonwood, aspen, elm, Douglas fir, willow, saguaro cactus, poplar, and ponderosa pine (Kaufman 2014). This inevitably will be a longer process in which implantation of these species across known ranges usually spanning two to three square miles can be immediately planted though will take on the order of months to years to become mature enough to be an adequate nest site. As a result of planting short, fast-growing native grasses as well as planting desired shrubs and scattered trees for nest sites, there will be an increase in habitat availability for prey species among the grasses and under the cover of shrubs. So by improving the overall habitat quality for the Swainson's hawks it would attract a larger abundance of prey species and further support the hawk population among that area. Some potential problems with this plan involve the ability for the grasses, shrubs and trees to grow within such areas and be able to actually support the nests of such birds. If these species have difficulty growing it may be recommended that other species be planted or the current species be monitored and nurtured until it is capable of surviving on its own. This option does involve a considerable more amount of work over a longer period of time.

Eliminate the use of pesticides

A key factor that results in high mortality of Swainson's hawks is due to poisoning, primarily from pesticides used in farming and agricultural practices. Though mostly not intentional, these birds are poisoned through contaminated water supplies, consuming poisoned prey, and from farming additives (Fleischli 2004). To prevent such unintended poisonings the type of pesticides allowed should be organically based in which it will not have detrimental effects on birds such as the Swainson's hawk. To implement this plan farmers and agricultural workers should be educated on the matter and informed on the changes to organic based pesticides only. This would ensure that if the pesticides seeped into the environment such as through small invertebrates or vertebrates or within the water source for such species of animals the risk of poisoning would be minute (Kirkley and Gessaman 1990). This plan could be put into effect immediately over a short time scale (within weeks) and last long-term (years). The spatial distribution would have to be over a very large areas in which any agricultural areas or crops in which pesticides are used would switch to an organically based mixture. This would ensure that there would be no runoff into the water supply and smaller animals systems. The largest potential problem with this plan is the willingness of farmers and agricultural workers to only use organically based pesticides, as they may not be as effective over time as would be the toxic pesticides. Thus enforcement of this plan may be difficult and monitoring each farms pesticide use would be very time consuming.

Protect migration and stopover sites

Swainson's hawks have one of the longest migration lengths of birds and thus experience energetically costly consequences once at their migration destinations (Fuller et al 1998). Furthermore, once at stopover sites and migration destinations, these birds are often faced with high predation, low prey abundances and fatigue (Fuller et al 1998). In addition, often there are high amounts of human disturbance at these sites that often obliterate the potential for the birds to even stop at that site (Holmes et al 1993). To prevent increased losses due to migration emphasis can be focused on restoring stopover sites and migratory sites. This can be accomplished by increasing the available prey abundance at each site, restore the habitats at each site and prevent human disturbance from encroaching on such specified areas. As with the home ranges habitat restoration can be accomplished by planting native grasses, shrubs and trees dispersed over the stopover sites and migrations areas as well. By providing trees it may allow birds to avoid ground predators that may have a higher chance of being caught due to reduced vigilance from the journey (Rudolph and Fisher 1993). Again by improving the overall habitat for the birds can also provide more niche space for prey species suck as insects like dragonflies and small vertebrates (Rudolph and Fisher 1993). By providing increased abundances of prey species there is a greater likelihood that the offspring of the adults will be healthier as they do not suffer from malnourishment and fatigue for very long (US Fish and Wildlife Service 2013). Lastly, emphasis can be towards reducing the occurrence of human disturbance in the migration areas and stopover sites. Even though the Swainson's hawk has become well adapted with human disturbance such as agricultural practices, areas that are urbanized with buildings and other unnatural objects can severely limit the success of the birds if there is no where to reside without being additionally stressed by traffic, buildings, and aircrafts (Holmes et al 1993). This plan to improve and protect migration sites ranges from the wintering grounds in Argentina to the breeding grounds in the north to the stopover sites including the southern Great Plains, Arizona, new Mexico and central Mexico (Fuller 1998). This would be an extended restoration plan that could be implemented within months and last for many years if properly monitored and maintained. Potential problems with this plan include unwillingness from the local human population to conserve the areas and not urbanize them, the ability for the grasses, trees and shrubs to grow in different locations, and a lack in increase of prey species. As a result this plan would require extensive monitoring and be difficult to enforce.

Monitoring Plan

Improve habitat and prey species abundance

This plan requires the planting of grasses, trees and shrubs, which is, rather labor intensive. In order to monitor the effects of this plan the initial population size must be known or estimated. Then once the vegetation is planted it must be monitored to ensure that they are able to survive the environmental conditions and thrive on its own which depending on the age of the shrubs and trees can take months to years of monitoring. Once the vegetation is mature enough to provide nest sites for the Swainson's hawks over the following years population sizes should be sampled and estimated twice a year, once during the breeding season and once after the migration time. It would be ideal for this monitoring to last ten or more years after maturity of the vegetation in order to follow the fluctuations within the population. Overall, this plan is relatively feasible, as it requires the initial planting operation, then bi-annual sampling and monitoring of total population estimates. A key hole in knowledge is how to determine at what point the population is stable enough to no longer be monitored or concerned with.

Eliminate the use of pesticides

This plan includes the elimination of the use of toxic pesticides that are detrimental to wildlife including the Swainson's hawk. This could be put into effect by educating the public, specifically those that are farmers or agricultural workers on the devastating effects of such chemicals on wildlife populations. Afterwards, it would be looked down upon and eventually banned once the proper legislation is completed. To monitor this plan population estimates would be taken before the plan is put into effect and bi-annually afterwards specifically during harvest season and during non-harvest season. By maintaining monitoring over the course of multiple years before, after and during the implementation of the plan it could be observed whether there was any impact on the adult and fledgling populations. This plan is rather simplistic as it focuses on altering the type of pesticides used though to enforce this plan would be quite challenging. A key hole in knowledge that is present is the process and length of time to attempt to get a piece of legislation in regards to the use of organic pesticides.

Protect migration sites

Lastly, is the plan to improve migration and stopover sites. This could be done by improving the quality of habitat at these sites, increase abundance of prey species and prevent further human disturbances to the areas used by migratory birds. Once again the population size of the Swainson's hawk would be monitored through observation and mark-recapture methods. By monitoring the population size before, during and after the plan has been put into effect changes in population sizes could be seen if there were any at all. To monitor this plan estimates should be taken every year at specified stopover and migration sites. Due to the large span of area that this plan involves it may be difficult to accurately track the population sizes as well as involve other countries that support it. A key hole in knowledge is that not all of the stopover sites and migration sites are known thus an accurate sampling would be difficult.

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The California Quail (*Callipepla californica*)

Part I, Species Background and Justification

A. Why do we Care?

The California quails' scientific name means a California bird wearing a beautiful woven covering (Calli in Greek means beautiful and pepla means a woven covering) (Marianchild 2014). Because of its beauty and wide distribution in the state, the bird received the title of 'official state bird' in 1931 (Audubon). Native Americans prized the California quail for its meat and head plumes that were used as decoration on baskets and clothing (Marianchild 2014). Today, hunters value the California quail as an upland game species, with quail being the third most popular target for hunters (according to the 2000 Game Take Hunter Survey, (Mastrup 2002)). Though California quail are not considered 'special status' by state and federal agencies, their numbers are declining and they are referenced in the California State Wildlife Action Plan for their importance in riparian habitats of the central valley (*California State Wildlife Action Plan Volume II* 2015). Additionally, California quail are used by both California Department of Fish and Wildlife (CDFW) and United States Fish and Wildlife Service as indicator species because they are found in healthy systems, are an important part of the food web, and are easy to survey for (M. Meshriy, CDFW, personal communication, 4/29/16). As Leopold , the authority on California quail stated, "Quail habitat will be maintained only where a deliberate and planned effort is made to do so" (Leopold 1977, pg. 63).

B. Species Information

<u>Species Range:</u>

- From Baja California through southern Oregon and into parts of western Nevada. Absent from the Colorado and eastern Mojave deserts and the upper Sierra Nevada and Cascade Mountains. Has been introduced into northern Oregon, eastern Nevada, Utah, Washington, parts of Idaho, Hawaii, southern British Columbia, New Zealand, and parts of Chile and Argentina for its popularity as a game bird (Johnsgard 1973, Leopold 1977).
- Quail move about seasonally in their home range but are year round residents (Marianchild 2014).

<u>Habitat Needs:</u>

- Very diverse depending on regional conditions
- Cover in the form of woody vegetation (sage, juniper, atriplex, manzanita) or rock outcroppings is necessary (provides protection during the day from predators and connectivity between more open patches where quail food is located).
- Nighttime roosting areas off of the ground – dense trees, tall shrubs, elevated brush piles
- In more arid areas, precipitation and quail population size is positively correlated, in more northern wet/snowy areas, precipitation and quail population are negatively correlated. However, quail do require a drinking water source in close

proximity (within 400 yards of cover, though preferably closer) to their cover habitats (*How to Help Quail on Your Farm or Ranch*, Leopold 1977).

Diet:

- Seeds from forbs, including lupine, lotus, filaree, bur clover, clover, fiddleneck, California poppy
- Acorns, wild and cultivated fruits and berries, waste grain from harvested fields, and poison oak (Leopold 1977, Marianchild 2014).

Predators:

- Adult and young quail: Cooper Hawk, other hawk species, horned owl, coyote, dogs. To a lesser extent coyote, stray cat
- Nests: skunks, raccoons, stray cats, crows, ground squirrels, western scrub jay, long-tailed weasel, roadrunners, kingsnakes, (Leopold 1977, Marianchild 2014).

Behavior and Lifespan:

- Quail are mostly ground birds. They have heavy bodies and strong legs, but they do fly to flee and roost.
- They are cooperative, social birds and form coveys (made up of 30-70 birds, though a covey can be smaller or made up of as many as 1,400 individuals). Adult males will act as sentries for the covey, though usually only one guard will be on duty at one time.
- Multiple (10-14) California quail calls have been recorded and described including alarm calls, food calls, and parental calls.
- Quail generally have short lives. The average lifespan is between nine and ten months, however individuals that live much longer, such as a 6.5 year old male, have also been recorded. The average turnover rate (annual rate of replacement of individuals) was found to be between 59-77% in areas between central and northern California. (Leopold 1977).
- Leopold (1977) noted a relationship between reproduction and mortality in adult quail, finding that when no reproduction occurred for several years (due to poor environmental conditions, for example), mortality dropped to very low levels.

Reproduction:

- Though social birds, during breeding male quail become aggressive towards each other. In mating pairs, males will act as sentry and females construct the nest.
- Egg laying occurs between April and June. Females lay eggs (about 5 per week) with an average clutch size of 12 eggs. If one nest is destroyed, second clutches can occur, usually with fewer eggs than the first clutch. Nests are in depressions on the ground with some herbaceous cover (Johnsgard 1973, Ahlborn 1988). Quail are very secretive entering and leaving the nest. Females generally incubate, but males will take over if needed.
- Unmated males will often act as foster parents to young separated from their family unit. Adult males typically outnumber females (Leopold 1977).

Quail in Decline

Unlicensed hunting, loss of habitat due to agricultural and pastoral land conversion (loss of woody vegetative cover), and pesticide use all contribute to California quail population decline. (Leopold 1977).

Restoration:

- Some grazing can help open up dense grass growth in favor of the forbs that quail feed on (see above). Overgrazing, however, can remove cover and food that quail require.
- Invading non-native grasses can outcompete forbs and take over large areas, reducing the quails' food source.
- Fire control and suppression can lead to thickened woody vegetation that can lead to decreases in forb presence. Additionally, fires that do occur are now much hotter and larger and can remove woody cover altogether. Even when forbs return to the burned areas, quail can't use the habitat because of lack of cover and roosting areas (Leopold 1977).

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Part II: Goals, Management, and Monitoring Plan

A. Goals

a. Maintain and/or increase California quail populations (long term as quail populations fluctuate and seem to be dependent on precipitation during water year (mostly in the south range) or density dependent (mostly in the northern range), (Leopold 1977))

b. Improve habitat needs (large scale):
   i. Provide plants for food (within 50 ft. from cover), cover, and roosting. Relatedly, regulate grazing and leave wood piles or install brush piles on site to add to cover habitat (How to Help Quail on Your Farm or Ranch, Leopold 1977, Murphy 2014)
   ii. Provide water access, either in the form of cover (vegetation) around naturally occurring water or man-made water source (guzzler/other) with cover. A water source should be located within 400 yards of cover, nesting, and roosting habitat (How to Help Quail on Your Farm or Ranch). Guzzlers are a nice option as they collect rainwater for later dispersal and so after installation require little maintenance (Leopold 1977).
   iii. Reduce or stop use of herbicides (kills plants that act as cover or food for quail) and rodenticides/insecticides that can be harmful to California quail and other wildlife
   iv. Remove invasive plant species that can be harmful to California quail and other wildlife such as *Trifolium subterraneum* (subclover, contains phytoestrogens that have been shown to affect quail reproduction) (Leopold et al. 1976, Lowry 2007) and *Pyracantha* species (can cause birds to act inebriated and exposes them to elevated risk of predation) (Lowry 2007)

c. Feasibility:

   This list of goals for the improvement of quail habitat and population numbers is quite feasible, especially when implemented on a smaller scale such as a private ranch or public park. While carrying capacity of California quail at a particular site is highly dependent on the available habitat and year to year conditions, Leopold (1977) suggests that a population density of 1-2 quail per acre is good (occurring on a managed private property in Shandon, CA) and that densities less than this are found in nearby populations. Additionally, many more birds per acre can be sustained in Shandon on a good year. Unfortunately, more quantitative population density studies for California quail were not found. California Department of Fish and Wildlife regulates the hunting of California quail and so likely has regional data on population size, though this information was not readily found on their website ("California Department of Fish and Wildlife" 2016).

B. Restoration Plan

a. Maintain/Increase Population:
   i. Studies will be required to determine local California quail population densities and dynamics at specific sites/regions. This will require multiple years of data collection, though more simplified bird counts may be sufficient.

b. Improve Habitat Needs:
   i. Initial establishment of larger tree species for roosting habitat and shrub

species for cover will likely require protection against herbivory and possibly beavers at certain sites (tree guards), as well as prolonged maintenance and irrigation (at least 1-2 years or until plants are established). Regulation of grazing will be required, as quail will not nest in areas with less than 6” of vegetation and cover is essential for them. Similarly, in areas where managers do not want quail to nest, mow early and regularly to prevent nesting (Enhancing Coastal Scrub and Chaparral Habitat for Birds at Your Home or Ranch). Cattle can also trample nests and so should be fenced off from nesting habitat between April and June (How to Help Quail on Your Farm or Ranch, Leopold 1977). Where forbs are desired, plugs or seed covered with mulch are needed as quail and other wildlife may eat any exposed seeds (Lowry 2007).

ii. Water access in the form of guzzlers or other water delivery device may be useful, especially in more arid, southern habitats. Tradeoffs associated with potential disease spread and increased predation at water delivery sites should be taken into account. Vegetative cover is certainly needed at these water delivery sites (either natural delivery or man-made) and this cover could help with potential predation. Willow staking has been implemented with success for this purpose (Murphy 2014). Quail have been found to locate new water sources within 1-2 miles of their range, and Leopold (1977) suggests having water sources spread 1 mile apart or less.

iii. Targeted herbicide use will be necessary in some instances to control and/or remove invasive/unwanted plant species and herbicide type should be approved for the habitat it is being used in (i.e. riparian). 1st generation rodenticide, if needed, is a better option than 2nd generation as it takes repeated exposure to act on rodents and so lessens the instance of exposure to non-targeted wildlife (Williams 2013). Insecticides, if needed, should be researched and selected insecticides should minimize negative effects to wildlife.

iv. Removal of certain invasive plant species such as subclover or non-native grasses (to open up area for native herbaceous species that provide food for quail) will likely require targeted herbicide use that must be approved for use. Other species may need to be removed by hand, which, on smaller scale sites, is a feasible option, especially with the use of volunteers at publicly owned locations.

C. Monitoring Plan

a. Monitoring of bird populations may be aided with inclusion of historic trend data for specific areas, likely available in some form from CDFW. Additional data from state bird counts may also be helpful. Site-specific data may need to be collected, with trained birders surveying the site in the early morning to observe quail presence during hours with higher activity. Population numbers should be monitored pre-restoration, during restoration, and post restoration of specific site. In order to establish a trend, multiple years of data are needed. However, this must be balanced with funding availability.

b. Monitoring of habitat will include assessment of newly planted vegetation success. Survivorship, percent cover, method (either plug or mulched seed), etc. can be monitored and evaluated for success/cost/labor/resource tradeoffs. Since some plants are seasonal, monitoring should occur during a period when their presence/absence is visible, likely late spring. Additionally, with added brush piles, the use of the new piles can be monitored by birding surveys conducted in (a) above. Likewise, use of newly installed water delivery can be monitored with similar methods (bird surveys). Assessment of the site and the success of targeted invasive species removal will also need to be monitored. A survivorship rating of 50% for plants during the first year, with successive plantings scheduled for three following years, would be ideal to ensure vegetation succeeds at restoration sites. Managers should use adaptive techniques, so if one method consistently fails for two years in a row, another method should be implemented (for instance, if using dry water for new tree plantings does not sustain the tree, switch to irrigation.)

D. Research Needs:

a. A clear understanding of the amount of herbaceous vegetation needed to provide food for quail, the amount of water needed, and the amount of cover and roosting habitat needed is an essential question for each California quail population. Because all of these factors and more interact and account for quail population numbers, specific site by site knowledge is needed in order to assess the effectiveness of certain actions. In Walnut Creek, restoration efforts turned an area that had no quail (though historically they were present) to an area where quail were present. This shift from no quail to quail presence was enough for the Walnut Creek Open Space Foundation to warrant the restoration a success (Murphy 2014). Managers will need to decide if simple presence/absence of California quail is a sufficient measure of success. If not, more detailed population dynamic studies will need to be enacted.

b. The effectiveness of certain vegetative treatments could be studied here to see what planting methods work best in the Central Valley.

c. For larger sites, the benefits of guzzlers or other water delivery methods could be assessed by using a control site with no water delivery and another site with water delivery and equalizing (to the best possible) other environmental factors. The same could be done for installing or not installing brush piles. Quantitative information about the benefit of these man made improvements would be very helpful for restoration specialists.

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Killdeer (*Charadrius vociferous*).

Background

The killdeer *(Chardrius vociferous*) is a migratory shorebird that can be found from the Arctic all the way to the Caribbean and the northern areas of South America. During both the North American Breeding Bird Survey and the Christmas Bird Count, United States Geological Service have noted that population trends of killdeer have been negative since 1996, indicating population declines. Killdeer frequently use wetland and upland habitats during their migratory patterns as well as nesting sites (Sanzenbacher 2002). Given that the species retains residency in certain areas during the winter while others continue with migratory patterns and only use certain locations as stopovers, gathering accurate population and ecological information on the species can be very difficult.

Range and Population Trends:

- Found from the southern edge of the Artic circle to the northern seas of South America (Sanzenbacher 2002)
- Declines have been observed since 1966 in American populations (Breeding bird survery)
- Most severe population declines have occurred in Canada and the Western United States of America (Sanzenbacher 2002)

Habitat Use:

- Frequently utilize uplands and open wetlands (Sanzenbacher 2002)
- Year-round residents tend to have less overall movements and will travel smaller distances from nesting sites than do wintering residents (Sanzenbacher 2002)
- Site fidelity tends to vary among individuals and wintering versus year-round residents (Sanzenbacher 2002)
- During non-breeding stages individuals will travel and move greater distances (Demers et al.,)
- Require nesting habitat during May through mid-July (Wilcox 1986)
- Population declines are thought to be a product of decreased wetland and highly altered upland habitat (Sanzenbacher 2001)
- In agricultural lands such as rice fields, land usage by killdeer increases when straw is incorporated into the landscape prior to flooding and tend to avoid lands where straw has been removed prior to flooding (Elphick and Oring)
- Conversion of agricultural rowcrop into wetland and grassland habitat can have negative effects on population size (Fletcher and Koford 2003)
- Can inhabit agricultural lands (Lehnen and Krementz 2003)
- Local land use estimated to be about 6 hectares (Plissner et al., 2000)

Diet and Predation:

- Feed on arthropods and arthropod larvae (Fair et al., 1995)
- Nests are predated by species such as coyotes, California gulls, Ravens, small birds, badgers, and other small mammals (Johnson and Oring)
- Nest exclosures have been used to successfully exclude medium to large sized nest predators (Johnson and Oring)
- Following an increase of prey species (grasshopper) and then a decline, the species did not exhibit functional prey switching indicating that they may not be quick to adapt to changes in prey abundance (Fair et al., 1995)

Goals:

In order to help sustain current populations as well as foster success for future populations of Killdeer, the following goals have been set for management and restoration of the species. It should be noted that previous population studies have had difficulties estimating population sizes and overall rates of survival, mortality, and reproduction. Therefore, the following goals are based off of best inferences about minimum percentages needed to ensure success of the species. Thus, close monitoring should be conducted concurrently in order to allow for adjustments to these goals when necessary.

- Reduce nest destruction by predators by 20% within a 5-year period.
- Reduce predation of adults and hatchlings by 15% within a 5-year period
- Increase reproduction by increasing suitable ground nesting sites by 20% and monitoring reproduction and ground nest numbers in early Spring to determine efficacy of efforts within a 5-year period.
- Conduct a 10-year monitoring program to evaluate survival, mortality, and population growths or declines.

Restoration Plan:

- Reduce nest destruction: Parental defense of nests tends to be more active when predation occurs on the ground, meaning that the parents are more likely to resort to injury-feigning when protecting nests from ground predators versus sitting tight on the nest in response to aerial predators (Brunton 1990). In order to reduce nest destruction, and reduce the energetic costs of nest defense on adults, adequate habitat and materials must be present to allow the possibility of proper nest disguise by parental individuals. This should include adding pebbles near creeks and waterways. In order to further reduce nest destruction, nest enclosures should be used where small mammals and animals such as gulls, crows, and badgers live nearby and are known to prey on nests. By reducing the amount of nests destroyed, it is expected that survival into the next age class would be larger and thus there will be more breeding individuals in the future leading to overall greater population sizes.
- Reducing predation: Since crows have been identified as one of the main predators of hatchlings and nests, and crows are a common species in central California, efforts for restoring and retaining populations of killdeer should have some emphasis on reducing crow predations (Brunton 1990). In a study conducted by Hauser and Caffrey, it was found that crows fled in response to hearing the call of red-shouldered hawks, *Buteo*

lineatus (Hauser and Caffrey 1994). Therefore, during the breeding and nesting seasons calls of the red-shouldered hawk could be played at intervals throughout local sites to discourage crows from foraging for nests and smaller adults. However this method should be done under close observation as there is a risk of there being negative effects on nesting Killdeer and other bird species in the area. More research is needed to determine the effect of predator presence during breeding seasons to determine if this method of deterring crows would also deter killdeer from breeding or foraging due to predator avoidance.

- Increase reproduction: Increasing reproduction should focus mainly on providing adequate nesting sites and increasing overall hatchling survival rates. In order to improve nesting sites, pebbles can be added near flowing waters to provide camouflage and nesting materials for the species. In addition, agricultural areas that the species inhabit should have straw added prior to flooding and heavy rain events, or avoid the intentional removal of straw prior to flooding/heavy rain events to promote habitat preference. Since breeding occurs around early April for the populations found in the middle states (AllAboutBirds, 2015), it is vital to ensure that there is sufficient pebbles on the ground to allow proper nests. Killdeer are also known to feed on arthropods and arthropod larvae, so if there is a possibility to work in conjunction with projects that are attempting to aid arthropod development, it would be ideal to try and increase arthropod abundance prior to breeding seasons to allow more food availability for the energy demands of reproduction and around the time when hatchlings depart from the nest to allow an adequate food source. As outlined previously, crows should also be deterred from areas where there are nesting killdeer to avoid hatchling mortality (Jorgensen 2009). It has also been noted that average land use of killdeer is around six hectares, so this should be taken into consideration when altering habitats to fit the needs of the species and to ensure an adequate amount of high quality land is available to the species.

Monitoring Plan:

Most of the current population data on killdeer is based off of the Christmas Bird Count and the Breeding Bird Count. While this method has been criticized as non-ideal for a majority of shorebirds due to low detectability, it seems to be a valid method for C. vociferous due to their distinct calls and vigilant manners (Sanzenbacher 2001). However, even with the CBC and BBC population data, there is still a lack of knowledge as to the overall site fidelity and annual survival of *C. Vocerifus* populations. Therefore, I suggest the following monitoring techniques to determine the success of our management efforts as well as to gain a better understanding of the species as a whole.

- Pre-restoration monitoring: Prior to beginning restoration efforts, intense population studies should be conducted to determine site fidelity and year to year survival rates of the species. This study should include mark-recapture population estimates in which individuals are captured and marked prior to the breeding season. Juveniles born during the breeding season should also be captured and marked. The following year another set of capturing should be conducted to determine the proportion of individuals that return to the area, as well as the proportion of individuals born in the previous year that have survived a migration and returned to their nesting site. This monitoring would occur at specific sites to measure the probability of individuals to return to the sites at which they hatched. In addition to monitoring survival and population sizes, careful nest monitoring should occur as well to determine sources of mortality for yearly recruits. Given this information, management plans can then be altered to target eradication of key predatory species or to modify habitat types to favor *C. vociferous* over predator species. This monitoring should occur prior to the breeding season, and immediately following the breeding season every year. In total, monitoring should be conducted for a minimum of 10 years. During the first 5 years however, is when the goals outlined above should be reached. During the last 5 years, populations should be monitored to ensure that our methods are still effective and there is not a need for further changes in the way we manage the population.

- Post-restoration monitoring: Similar to pre-restoration monitoring, post-restoration monitoring should include mark-recapture methods at specific sites to determine site fidelity and population estimates. These should be conducted prior to migration and breeding, and post migration and breeding. This monitoring should occur once yearly for at least ten years in order to there to be a short-term population trend analysis similar to those conducted previously (Sanzenbacher 2001). Nest predation should also be monitored to determine mortality sources and rates of new recruits. All of the results from the pre-restoration and post-restoration data collection should be compared to determine if goals were met.

Following collection of data from both pre- and post-restoration, data analysis should be conducted so that comparisons can be made in order to determine the efficacy of management efforts and changes can be made as needed to ensure efficient use of funds and time. Once data is collected, management efforts should be adjusted as needed. For example, if data reveals that increasing survival of hatchlings has little to no effect on population sizes, but increasing survival of adults does have an effect on population size, restoration efforts should shift to reflect the importance in aiding adult survival rather than nest protection.

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Western Burrowing Owl

Justification For Restoration:

The Western Burrowing Owl is a species of ground dwelling owl that lives in the western regions of the United States. Populations of the Western Burrowing Owls have declined significantly in the last 50 years (Macias-Duarte 2015). Burrowing owls are the only owl that spends most of its life on the ground and in burrows (Trulio and Chromczak 2003). The species is also able to live near human settlement, which suggests that restoration plans based off of the concept of reconciliation will be possible (Hennessey 2015).

Burrowing owls are a charismatic species that are often popular residents of the communities they live next to. There are several organizations in the state of California that are looking to protect these owls. The main threat to burrowing owls is the development of short grass prairies (Macias-Duarte and Conway 2015). Burrowing owls help regulate populations of pests like grasshoppers and mice. This can be helpful in order to keep insect populations down in the areas they reside in. They also help upkeep vacated ground squirrel burrows and occasionally make their own. This makes them an ecosystem engineer (a species that alters it's environment in a way other species use). Their burrows can provide habitat for small reptiles, invertebrates, and other creatures, as well as affect the plant community above (Thomsen 1971, Sheffield 1997, Riding and Belthoff 2015). The combined threat to the owls, along with their importance to local communities and the benefit of the owls regulating pest numbers makes restoration of habitats for burrowing owls critical.

Literature Review:

Characteristics of the Burrowing Owl:

Feeding:

- Burrowing owls have a varied diet of small animal prey. These prey items include grasshoppers, beetles, Botta's pocket gopher, mice, and small reptiles (Chandler 2015).
- Insects are the majority of prey in terms of sheer numbers, making up 98% of their diet, however the majority of the owl's biomass is made up of rodents and other vertebrate prey (Chandler 2015).
- Burrowing owls are manly hunters, but also scavenge (Sheffield 1997).
- The owls mostly feed during late afternoon (usually after 4PM until sundown) (Thomsen 1971).

Reproduction:

- Burrowing owls can begin breeding at one year of age (Unknown 2016).
- Pairs are monogamous, but if one dies they will pair up again. Burrowing owls lay eggs in a nest created in their burrow (Sheffield 1997, Wellicome et al. 2014).
- Burrowing owls lay between 1-5 eggs. If they lose an egg they will replace it (Wade and Belthoff 2016).

- Burrowing owls breed between March and July (Riding and Belthoff 2015).
- Young fledge around four weeks of age and are capable of flight at five weeks old (Riding and Belthoff 2015).
- Burrowing owls will reuse nesting material. Removal of these materials reduces the likelihood a pair of owls will reuse a burrow (Riding and Belthoff 2015).

Interspecies Interactions:

- Like many other animals, burrowing owls get fleas. With fleas comes the possibility of plague, however plague was not found in the owls or their fleas, There is no evidence to suggest they can be infected or carry the plague (Belthoff et al. 2015).
- Burrowing owls are capable of making their own burrows, however usually steal their burrows from sciurid species (Sheffield 1997, Thomsen 1971). In California the primary species they take nests from in California ground squirrels. They will also take over abandoned badger dens (Sheffield 1997). Burrowing owls also maintain their burrows
- California ground squirrels might also provide the owls with protection. Burrowing owls are able to hear the calls of the squirrels in response to predators. This helps increase the survival of the owls (Hennessey 2015).

Space Use:

- Owls live relatively close to another, often around 200 meters away from one another (Riding and Belthoff 2015).
- Burrowing owls are sometimes migratory, and as such population restoration projects need to consider that both breeding and non-breeding habitat needs to be protected. In burrowing owls in different parts of the continent the non-breeding habitat seems to be more important in terms of survival. High levels of precipitation and storms on wintering habitat had a negative impact on the survival of these owls (Wellicome et al. 2014).
- Owls from urban areas display a bit more avoidance than those from rural areas. This suggests habitat can be close to humans, but not too close. (Carrete and Tella 2013). During the breeding season the distance between the owls and humans needs to be from 200-500 meters. In the late summer/early fall the owls need 200 meters. During the rest of the year activity can be as close as 50 meters from the burrow depending on the level of disturbance. At sites with higher disturbance it is best to aim for around 500-meter distance between the birds and people (D.F.G 2012).
- Burrowing owls spend most of their time near their burrows (Thomsen 1971).

Habitat Requirements and Preferences:

- Burrowing owls need short grasses (about 6 cm tall) so that they are able to see potential predators on the horizon as well as be able to see prey items either from the ground, or on a low perch (Sheffield 1997, Marsh et al 2014, Hennessey 2015). Getting rid of invasive species like wild oat and brome would help make the habitat better suited for the owls (Hennessey 2015).
- Burrowing owls need a healthy population of California ground squirrels or another ground dwelling animal of proportional size in order to have burrows to take over

(Sheffield 1997).
    - California ground squirrels may also be responsible for maintaining the short grass vegetation structures that the owls need (Hennessey 2015)
- While burrowing owls can live on farmed lands, they prefer uncultivated lands (Hennessey 2015).

Dangers to the Owls:

- The breeding habitat of burrowing owls has decreased significantly in the last half century due to development (Macias-Duarte and Conway 2015).
- Populations of the owls have decreased exponentially in California (Chandler 2015, Hennessey 2015).
- Vehicles often kill burrowing owls on roadways (Sheffield 1997).
- Feral domestic animals or outdoor pets can kill burrowing owls (Sheffield 1997).
- Climate change could also be affecting the burrowing owls by increasing storms and precipitation (Wellicome et al 2014, Macias-Duarte and Conway 2015). Increased precipitation leads to more burrow cave-ins and burrow flooding, two of the leading causes of nest failure (Wellicome et al 2014, Macias-Duarte and Conway 2015, Riding and Belthoff 2015). This may be part of the reason that the burrowing owl populations might have shifted south (Wellicome et al 2014, Macias-Duarte and Conway 2015).
- Certain invasive plants, particularly wild oat and brome ruin burrowing owl habitat because of their tall growth (Hennessey 2015).
- Populations of ground squirrels have dropped in some places due to the use of pesticides and invasive plant species (Hennessey 2015). Many farmers and developers will use anti-coagulant rodenticides such as brodifacoum or other rodenticides like strychnine. These chemicals are often strong enough to kill an owl through the ingestion of one infected prey item (Hegdal et al. 1986). Adding to this is that infected individuals are more easily predated upon by the burrowing owls (Sheffield 1997). Invasive Mediterranean grass species like Mediterranean grass have also lowered squirrel populations (Hennessey 2015).
- Flight Initiation Distance, which has been used to determine the effect that human presence have on the owls. There is a reasonably large amount of variation, with owls from urban areas displaying a bit more avoidance than those from rural areas, however the values are within a standard deviation of each other (Carrete and Tella 2013).

Management:

Habitat Protection:

- Spotting the owls is fairly easy as they are relatively distinctive and are crepuscular (Macias-Duarte, Conway 2015).
- Burrowing owl populations have shifted south, which decreases in the northern part of their range, and increases in the southern part (Macias-Duarte 2015, Conway 2015).

Habitat Restoration/Upkeep:

- Burrowing owls are hard to relocate, however they can respond well to "soft" releases. A "soft" release is when you acclimate an animal by creating an enclosure at its release site and having the animal live in the enclosure for a short period (Hennessey 2015).
- Artificial burrows have been used successfully with burrowing owls. This is one of the main management tools used with burrowing owls. However, these artificial burrows could become a problem because as owls get used to these burrows, they may end up depending on them, even if they are no longer good habitat. This forms what is called an "ecological trap", or a part of the environment which an organism might use thinking it is a good resource when it isn't (Hennessey 2015).
    - California ground squirrels are considered a pest, so these boxes can provide a good alternative. However it would be expense and time intensive in order to make the same amount of burrows that an established California Ground Squirrel population creates (Hennessey 2015).
- Areas without California ground squirrels or a viable replacement for them need to restore the populations of California ground squirrels. This can provide a problem as many people find these squirrels as a pest. In order to recover the habitat, it would be critically important to discuss with local leaders and community members and find compromises where the squirrels are returned to the habitat and the squirrels don't affect people living near by the site (Hennessey 2015). In some cases it may be beneficial to spend time restoring burrowing owl habitat in areas with healthy ground squirrel populations before those habitats without the squirrels.
- Keeping grasses short (under 6.5 cm) may be accomplished by returning the populations of ground squirrels back to healthy levels or mowing. Mowing may need to become a frequent activity, finding ways of getting the ecosystem to self-replicate will be critical for a restoration of the species (Hennessey 2015).
- Population monitoring would be helpful in order to determine if the population I stable (Hennessey 2015).

Information Gaps:

- What has been the effect on burrowing owls by California's drought?
- The effect of pesticides on burrowing owls specifically does not seem to have received a lot of study. Many of the species that that the owls eat and steal burrows from are frequently targeted for pest management regimes. The toxicity of the different poisons varies and their individual effects vary based on the species. Burrowing owls would also bioaccumulate these substances, and these chemicals may react with one another in the owls. This needs more research as this could have negative impacts on the reproductive success and survival of the owls. (Vyas 2013, Hennessey 2015)

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Burrowing Owl Restoration Plan

Introduction/Goals:

Burrowing Owls are a key element in the Central Valley's grassland habitats and their restoration is critical in order to help restore balance to the environment, as well as protect a species of cultural importance. The overarching goal of this restoration plan is to stabilize burrowing owl populations and return them to the population levels historically found at the site, while providing the opportunity for nearby sites to increase their owl populations. The first goal in restoring these populations is getting a current estimate of the number of burrowing owls at the site, their distribution on the site, and determining the minimum number of individuals needed in order to sustain a self sufficient population. The second goal is to have a population of California ground squirrels at the site for the burrowing owl's burrow needs. The goal should be at least 12 female ground squirrels (Hennessey 2015). This also will make artificial nest boxes unnecessary (Hennessey 2015). The third goal is to make sure that the vegetation is the right height for the owls, around 6.4 centimeters and there is prey available. Finally, the last goal is to bring in burrowing owls if they are not at the site and initiate a "soft release". The restoration will be defined as successful if populations at the site stabilize or increase.

Goal 1: Population Estimate:

Burrowing owls in California are listed as a "species of special concern", however data on the exact populations in California and specifically the Central Valley seems to be inconsistent (Macías-Duarte and Conway 2015, Sheffield 1997). While most burrowing owl restoration organizations and several scientific papers have expressed concern over burrowing owl populations and have shown evidence of decline, a few papers have shown no marked decline in owl populations (Macías-Duarte and Conway 2015, Sheffield 1997). The population dynamics at the site being restored need to be understood in order to know if the population needs to be restored.

Many sites have already had the numbers of burrowing owls and their distribution on the site documented. This information can usually be found on the U.S. Fish and Wildlife Services Mountain-Prairie region webpage (USFWS 2016). However currently the page on burrowing owls is down, so we should assume it has not been surveyed (USFWS 2016). If the site has not been surveyed then we can conduct surveying to determine if the population is increasing, decreasing or staying the same (C.O.B.C. 1993, D.F.G 2012). This should be done between

February 1st and August 31st, when the owls are breeding (C.O.B.C. 1993). The surveys need to be done four times on four different days during regular weather (not raining or foggy and winds not over 20 MPH) (C.O.B.C. 1993). They should be taken when the owls are most active, which is two hours before sunrise and two hours after sunset (C.O.B.C. 1993). Owl observations need to be taken from 500 meters from the burrow, so as to not disturb the owls (D.F.G. 2012).

Another option if an actual census is not possible is going off of the data from previous population counts and studies of burrowing owls and sorting this information based on when collected, and where specifically in the Central Valley this data was taken (Sheffield 1997). Since most of the discussion of burrowing owl decline suggests that most of the decline has been in the past 50 years, all literature from before then can be discounted from this data collection (D.F.G. 2012, Sheffield 1997). Once determined what the current state of burrowing owl populations are in California, we can go on to determine what parts of the Central Valley need the most restoration and are most endangered. The areas that can hold the biggest populations of burrowing owls and are in the most danger of development should be focused on as they are the most likely to be lost without action, and the populations are larger, so they of greater importance to the genetic diversity of the burrowing owls of the valley (D.F.G. 2012).

It is also important to know if the individuals are migratory, or non-migratory. This might be difficult to do as the owls do not have significant sexual dimorphism and it is hard to differentiate individuals (D.F.G. 2012). This step can be returned to after the lands being used are determined (see section on Land Determination).

Land Determination: Once areas with burrowing owls, or that could host owls have been surveyed and ranked, it is important to determine the different disturbances at the sites (D.F.G .2012). The first thing is to determine the impact of agriculture on the area. Areas that are disked are not the best habitat for owls as the disking can kill owls that are underground (D.F.G .2012). Burrowing owls also avoid most agricultural land, so placing them close to agriculture would be unsuccessful (D.F.G .2012). There also needs to be enough land for a sustainable population. This is defined as 10 breeding pairs with 30 acres each (300 acres total) (Trulio and Higgins 2012).

The habitat should also have limited vehicle presence and any artificial nest boxes need to be far from the road (D.F.G. 2012). The amount of space between human activity and the burrowing owl habitat differs from site to site, however there are basic parameters for the amount of distance needed per season and based on the level of disturbance (D.F.G. 2012). Between April 1st and August 15th their needs to be 200 meters between the owls and human activity on low disturbance sites and 500 meters for medium disturbance sites (D.F.G. 2012). August 16th to October 15th the owls need 200 meters at low and medium disturbance sites and between October 16th and March 3rd the owls need 50 meters for low disturbance sites and 100 for medium disturbance sites (D.F.G. 2012). Owls at high disturbance sites need 500 meters at all times (D.F.G. 2012). These numbers can be applied to both direct human exposure and vehicles (D.F.G. 2012). This also depends on the owls and their level of exposure to human activity (D.F.G. 2012). Burrowing Owls often exploit human structures, so certain human exposures such as old piping and drains can be in their habitat without problems (Botelho and Arrowood 1996). They also benefit from lighting, which can attract prey and the lower number of predators in human-altered habitats (Botelho and Arrowood 1996). Determining a balance between human disturbance and natural environment is key in restoring burrowing owl habitat (Botelho and Arrowood 1996).

There also needs to be limited domestic pet contact. If the site is in a public park, leash laws need to be enforced as the dogs could injure or kill an owl, or destroy their burrow (D.F.G. 2012). The sites also cannot have controlled burns as they can kill the owls (D.F.G. 2012).

Land parcels need to be able to support enough owls to have a breeding population (Rosier et al. 2006). A self-sustaining population is at least 10 pairs of owls, with each pair requiring approximately 30 acres of land (Trulio and Higgins 2012). A pair and their brood hold a territory around 100 meters (Rosier et al. 2006). Often the young will disperse and live within this habitat, however, others will disperse as much as 50 kilometers (Rosier et al. 2006).

When the pieces of land that are being used for burrowing owl restoration have been determined, it is important to take a full census of the number of owls on the site (D.F.G .2012). Owls should be captured and banded to determine sex and to differentiate individuals (D.F.G .2012). It is also important to mark where current nests are and set coordinates (D.F.G .2012). This is important so the existing owls can be monitored and the restoration team can give the owls space when working (D.F.G .2012).

Goal 2: Introduction of California Ground Squirrels

The most important consideration is the presence of ground-dwelling rodents, in particular California ground squirrels. The California ground squirrels are important because the burrowing owls that live in the Central Valley steal the squirrel's burrows to make their nests (Hennessey 2015). While artificial nest boxes can supplement California ground squirrels it is not a good idea to depend on man-made boxes that need maintenance (Hennessey 2015). It's best to pick sites with California ground squirrels or where there are plans to relocate squirrels that were deemed "nuisances" (Hennessey 2015). A female California ground squirrel's home range is around 27 meters, and overlaps other ground squirrels (Hennessey 2015). With a goal of 10 owls, we should expect to have at least 12 female squirrels (Hennessey 2015). Since it is best to relocate them with relatives for them to be successful we can have up to 50 individuals per 100 acres (Hennessey 2015). For the squirrels to be successful, the grasses need to be mowed to between 7.5 and 15 centimeters (Hennessey 2015). The squirrels do not need boxes in order to be successful at the site (Hennessey 2015). The squirrels also eliminate the need for artificial burrows for the burrowing owls, which can be expensive and require upkeep (Hennessey 2015).

Goal 3: Vegetation and Prey:

Vegetation:

Vegetation for burrowing owls needs to be short enough so they are easily able to see prey species, as well as predators on land and in the sky (Rosier et al., 2006). The length of the grass should be around 6.4 centimeters, which appears to be about the optimal height, so the owls are able to forage efficiently (Rosier et al., 2006). Plants that help stabilize soil well would be beneficial since one of the larger causes of natural mortality is burrow collapses, usually during heavy rain (Botelho and Arrowood 1996). The only information I found on invasive plants was that wild oat and brome caused issues for burrowing owls, however it seemed that it was mainly a problem because of its negative impact on California ground squirrels and the height of the plants (Hennessey 2015). It appears the main consideration for the owls is the height of the vegetation, followed by how well it holds the soil, and any impacts that it would have on its prey or the ground squirrels (Rosier et al., 2006).

Prey:

Burrowing owls need to have an ample supply of insects, small mammals, lizards, snakes, and small birds to feed on (Chandler 2015). A burrowing owl's diet is mainly composed of insects, but they need rodents or other vertebrates in their diet to get the right balance of nutrients (Chandler 2015).

Goal 4: Reintroduction:

Reintroduction of a bird is difficult as they are able to fly back to their home range. As such, it is best to work at sites with owls currently. If the site being restored doesn't have owls they can be brought in and released using a "soft release" (Mitchell et al. 2011). A soft release is a release where an animal is acclimated to a habitat by being put in a temporary enclosure (Mitchell et al. 2011, D.F.G. 2012). Moving a nesting pair into an enclosed part of your site and allowing them to nest would accomplish this (Mitchell et al. 2011). The owlets will imprint on the habitat and return to the site, even if the adults do not stay at the site (Mitchell et al. 2011). The success rate of soft released owls was 86% site fidelity compared to the 68% site fidelity from regular releases where the birds are just set on a site (Mitchell et al 2011). Reintroduction of burrowing owls is risky because many people have not studied relocation in burrowing owls (Mitchell et al 2011, D.F.G. 2012). The owls that are used for the reintroduction should be ones that are from habitats that are going to be developed because we do not want to move owls that are in good conditions away from what could be good habitat (D.F.G. 2012).

Monitoring:

When monitoring the burrowing owls it is important to use the bands that were used on the birds in order to determine which owls are at the site (D.F.G. 2012). New owls should be banded when seen. When being banded they should take different measurements, such as height and weight in order to determine fitness of the individual. Sex and age should be determined to determine what the sex and age ratios are (D.F.G. 2012). A population that has remained stable and/or has grown in population is a sign of short-term success for the project. After checking in for the first two years on the burrowing owls, the owls should be monitored after every two years during their breeding season (AECOM 2010). The crew doing the monitoring should document the ground squirrels, predators in the area, human activity, and any new or missing owls (AECOM 2010). If they are individuals that were relocated, success is if they return to the site the next year (AECOM 2010, D.F.G 2012). Overall success on relocation would be if the population on the plot is stable or has grown after the reintroduction of owls (D.F.G. 2012). If the population decreases, more restoration needs to be done and plan implementation needs to be looked at for ways to increase success (D.F.G. 2012).

Outside of those two years burrowing owl preservation organizations and citizens can help monitor populations in case something major happens between the monitoring periods. A wildlife biologist could work as an overseer on the project in order to make sure all data is accurate. This data should be sent into a central database on information on the owls so those working on the restoration plan can look at statistics (Sheffield 1997). This information can be compared to prior census counts (preferably those in the past few decades) (Sheffield 1997). It might be advantageous to also have the citizens enter any sightings onto inaturalist.org, a website that collects information on sightings of different biota. This can be shared with other scientists and provides documentation of where the owls are for other scientists and people interested in the owls.

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Other native wildlife

Restoration of Native Bee Habitat in California

California is home to nearly 90 different species of native bees, from the families Apidae, Colletidae, Andrenidae, Halictidae, and Megachilidae, (UC Berkeley, 2005) and there are over 4,000 species of bees worldwide (USDA, 2004). Bees function as key pollinators, a crucial component of agriculture and ecosystem services, and are responsible for the production of tomatoes, almonds, chocolate, apples, pears, citrus fruit, olives, and may other fruits, vegetables and nuts (UC Berkeley, 2005), and are also important parts of a successful restoration project by maintaining the reintroduced plant populations (Rhoades, 2014). Bees are abundant in temperate ecosystems around the world, although a national survey of their geographic distribution in the U.S is incomplete (Cameron et. al, 2010). However, bee populations worldwide are declining dramatically due to habitat destruction, increased pesticide use, climate change, invasive species, and disease (UC Berkeley, 2013). A study carried out by researchers from the University of California, which compared historical and current data on the geographic range and relative abundance of bees revealed a significant reduction in range as well as significant decreases in relative abundance throughout the United States in all of their target bee species (Cameron et. al, 2010). Researches at UC Davis studied the decline of wild bees in association with the conversion of natural habitat into intensive agriculture, and found a significant decline in wild bee populations since 2008 in California's Central Valley and an overall decline in 23% of the nation's wild bee habitats. These intensive agricultural projects, which are a very likely cause of this population decline, ironically have the most demand for these pollinators. Some of the conservation efforts for these bees may come from these agricultural stakeholders who rely on pollination services, but California bees need a concerted, united effort to preserve these important species.

Literature Review

Characteristics of Native Bees

Pollination and Plant preference

- Native bees are much more effective pollinators than honey bees. Instead of just focusing on the nectar, bees collect the pollen to take back to their colonies to help feed their young, meanwhile distributing the pollen amongst other flowers while foraging (Danforth et al, 2011)
- Bees prefer flowers that are full of nectar, brightly colored, aromatic, open in daytime, and often bilaterally symmetrical. (USDA, 2004). A table of plant preferences is provided below (Table 2 and Table 3).
- Native bees prefer native plants over exotic plants, and bees will also visit "unattractive" plants when they are in close proximity to bee-attractive flowers. Overall, when there is a wide variety of plants in a garden, every plant will receive more visits by the bees, whereas if each plant is isolated with low diversity, only the most attractive plants will be visited. (Frankie et. al, 2005)
- A study performed by UC Berkeley found that gardens with the highest diversity of bees

had the most plant diversity and availability of "bee-attractive plants" (Frankie et. al, 2005)

- Most bees are generalists, and can pollinate a wide variety of flowers, but others are specialists and are specifically suited to one type of flower (Frankie et. al, 2005)

Habitat requirements

- Bees have a wide variety of nesting behavior, typically categorized into ground nesting and cavity nesting, which include building nests in mud, building nests made of leaves and sand or plant fibers, using abandoned nests or burrows from other animals in the ground or in trees, tunnels in the ground, or living in colonies in beehives. Their nesting behavior is often used to identify the species of bee. (USDA 2004)
- Researchers at UC Berkeley found that urban areas with small gardens were suitable habitats for bees, especially ground nesting bees, and basic landscaping around urban areas provide enough resources for bee survival and reproduction (Frankie et. al, 2005).
- Wood-nesting bees need twigs and other wood debris, ground-nesting species need stable, loose soil on bare ground, and cavity-nesting bees, which are typically social, make use of small spaces in burrows or trees. (The Xerces Society)
- Some bees require floral resources as soon as the colony is established, as early as January, and until the colony dies out in late August or September. Some native California plants start flowering in January, so native habitat is critical for these species. (Greenleaf S. & Kremen C, 2006)

Reproduction

- The life cycle of the bee consists of the egg, larva, pupa, and adult. The bee lives within the "brood cell" of the nest until adulthood, and adult bees provide their offspring with pollen while they develop within the brood cell. (The Xerces Society)
- Males hatch from unfertilized eggs and females hatch from fertilized eggs (The Xerces Society)
- The egg typically hatches in April and grows and develops through August. When the adult is fully formed in September or October, it lays dormant in the nest until February or March, when it then emerges and becomes an active forager or reproducer until it dies at the end of the summer. (Bee Friendly, 2016)
- The adult male bee emerges from the nest in late March or early April before the female in order to acquire energy and resources for mating. After the male bee mates with a female, he dies. (Bee Friendly, 2016)
- The female bee then forages for nectar and pollen which she saves for her offspring. Most native bee species lay around 5-30 eggs throughout her 6-8 week adult life cycle. (Bee Friendly, 2016)

Ecosystem Services

- Bees strongly depend on the availability of natural habitat to provide pollination services, and a study found that crop pollination services are strongly correlated to the proportion of natural upland habitat within 1- 2.5 kilometers from the farm. (Walther-Hellwig &

Frankl 2000; Steffan-Dewenter *et al.* 2002)

- The most substantial service provided by bees is the pollination of a wide variety of native plants and agricultural crops.
- Tomato production significantly increases in the presence of native bee pollinators, although tomatoes are generally considered self-pollinators. Tomatoes that were pollinated by bees were also significantly larger. (Greenleaf S. & Kremen C, 2006)
- A study in California found that 100% of pollination needs can be met if 25-30% of the landscape is left as natural habitat (The Xerces Society)
- The most effective pollination services come from a community of bees with a variety of species that can pollinate a wider variety of plants in different environmental conditions. (Greenleaf S. & Kremen C, 2006)
- Bees are also key pollinators of native wildflowers, which hold an important aesthetic value for our society
- The use of insecticide on agricultural farms significantly reduces pollination rates by bees (Johansen & Mayer 1990)

Threats

- Bees are most threatened by habitat degradation and decline in floral abundance. The majority of this habitat loss is a result of the conversion of natural habitat into intensive agriculture
- Researches have also found a direct link between bee population decline and invasive pathogens (including *N. bombi*,) and nonnative parasites, which is severely affecting bee populations. This is most likely a result of the global trade of bumble bee colonies used for pollinating crops. (Cameron et al, 2010) (Goulson et. al, 2008)

Management of bees and Gaps in knowledge

- A Table of common bee species in California is provided below (Table 1) (Frankie 2009)
- The financial value of the ecosystem services that bees provide is generally unknown.
- The overall historical geographic distribution is unknown, with only limited data on the current overall geographic range and abundance of native bees.
- In order to preserve agricultural services provided by bees, a variety of strategies must be used to conserve both the native habitat of bees as well as smart on-farm management of bees that provide them with the resources and habitats they need, such as resources for building nests.
- Bee populations can be consistently maintained by providing a variety of native flowering plants. This can be done in urban gardens, natural habitats adjacent to farmlands, or wild habitat.
- A transition to organic farming without insecticide or pesticide use will also increase the health and abundance of native bees.

Reference Tables (Frankie 2009)

Table 1: Common Native Bee Species found in California

Common native bee species found in most (> 70%) California gardens surveyed

Common name	Scientific name
Andrenidae	
Mining bee	*Andrena angustitarsata*
Apidae (Including Anthophorinae)	
Small digger bee	*Anthophora curta*
Digger bee	*Anthophora urbana*
Honey bee*	*Apis mellifera**
California bumble bee	*Bombus californicus*
Black-tip bumble bee	*Bombus melanopygus*
Yellow-faced bumble bee	*Bombus vosnesenskii*
Small carpenter bee	*Ceratina acantha*
Small carpenter bee	*Ceratina nanula*
Gray digger bee	*Habropoda depressa*
Long-horn digger bee	*Melissodes lupina*
Long-horn digger bee	*Melissodes robustior*
Squash bee	*Peponapis pruinosa*
Cuckoo bee	*Xeromelecta californica*
Large carpenter bee	*Xylocopa tabaniformis orpifex*
Colletidae	
Masked bee	*Hylaeus polifolii*
Halictidae	
Ultra-green sweat bee	*Agapostemon texanus*
Large sweat bee	*Halictus farinosus*
Spined-cheek sweat bee	*Halictus ligatus*
Small sweat bee	*Halictus tripartitus*
Tiny sweat bee	*Lasioglossum incompletus*
Megachilidae	
Leafcutting bee	*Megachile angelarum*
Leafcutting bee	*Megachile fidelis*
Leafcutting bee	*Megachile montivaga*
Alfalfa leafcutting bee*	*Megachile rotundata**
Mason bee	*Osmia coloradensis*
Blue orchard bee (BOB)	*Osmia lignaria propinqua*

* Introduced.

Table 2: Common Bee- Attractive Plants with Flowering Season

Ornamental plants and their origins, flowering season and their visitor bee groups in seven California cities, 2005–2007

A. Plants with restricted visitor bee groups	Family	Origin*	Flowering season	Restricted bee groups†
Yarrow (*Achillea millefolium*)	Aster.	CA	Summer	Halictidae
Mexican daisy (*Erigeron karvinskianus*)	Aster.	NN	Spring/summer	Halictidae, Hb, Megachilidae
Pumpkins, squash (Cucurbitaceae)	Cucurb.	NN	Summer	*Peponapis pruinosa*‡, Hb
Manzanita (*Arctostaphylos* spp.)	Eric.	CA	Spring	*Bombus*§, Hb
Palo verde (*Parkinsonia aculeata*)	Fabac.	NN	Summer	Hb, *Xylocopa*§
Wisteria (*Wisteria sinensis*)	Fabac.	NN	Spring	*Xylocopa*§, Hb
Autumn sage (*Salvia greggii* cvs¶/ 'Hot Lips' *S. microphylla*)#	Lamiac.	NN	Summer	*Xylocopa*§, Hb
California poppy (*Eschscholzia californica*)	Papav.	CA	Spring	*Bombus*§, Halictidae, Hb
Sky flower (*Duranta erecta*)	Verben.	NN	Summer	*Bombus*§, Hb, *Anthophora urbana*§
B. Plants with diverse native bees and two or three prominent bee groups	**Family**	**Origin***	**Flowering season**	**Prominent bee groups**
Blanket flower (*Gaillardia* x *grandiflora* cvs)§	Aster.	NN	Summer	*Melissodes*§, Halictidae, Hb
Sunflower (*Helianthus annuus*)	Aster.	CA	Summer	*Melissodes*§, Hb
Goldenrod (*Solidago californica*)	Aster.	CA	Summer	Halictidae, Megachilidae, Hb, *Bombus*§
Pride of Madeira (*Echium candicans*)	Borag.	NN	Spring	Hb, *Bombus*§
Lavender (*Lavandula* spp.)/cvs¶	Lamiac.	NN	Spring/summer	Hb, *Bombus*§
Russian sage (*Perovskia atriplicifolia*)	Lamiac.	NN	Summer	Hb, Megachilidae
Salvia 'Indigo Spires'	Lamiac.	NN	Summer	*Bombus*§, Hb, *Xylocopa*§
Bog sage (*Salvia uliginosa*)	Lamiac.	NN	Summer	Hb, *Xylocopa*§, *Bombus*§
Chaste tree (*Vitex agnus-castus*)	Lamiac.	NN	Summer	Hb, Megachilidae

* Origin: CA = native to California; NN = nonnative in California.
† Bee taxa listed from left to right, more frequent to less frequent; Hb = honey bee (*Apis mellifera*) (fam. Apidae).
‡ Squash bee of the family Apidae.
§ Family Apidae.
¶ cvs = cultivars. These and S. 'Hot Lips' were listed together because of their similar floral structure and reward (nectar), and because they attracted the same bee taxa.
\# cv = cultivar 'Hot Lips'.

Table 3: Common Bee-Attractive Plants with daily Flowering periods

[illegible]. Selected plant types and periods of greatest daily bee attraction*

Plant type	Period of greatest attraction	Floral resource	Bee taxa
Goldenrod (*Solidago californica*)	11 a.m.–3 p.m.	Pollen/nectar	Halictidae, Megachilidae, Hb†, *Bombus*
Pumpkins, squash (Cucurbitaceae)	Before 9 a.m.	Pollen	*Peponapis pruinosa*, Hb
Palo verde (*Parkinsonia aculeata*)	Before 10 a.m.	Nectar	Hb, *Xylocopa*
California poppy (*Eschscholzia californica*)	Before 11 a.m.	Pollen	*Bombus*, Halictidae, Hb
Wild lilac (*Ceanothus* spp.)	Before noon	Pollen/nectar	Diverse native bees

* See also tables 1 and 2.
† Hb = honey bee (*Apis mellifera*) (fam. Apidae).

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A. Goals

Restore and improve habitat for native bees in urban and farmland areas

Bees depend on the availability of suitable habitat and a variety of flowering plants to maintain a healthy and sustainable population. 70% of California native bees are ground-nesting, meaning they dig vertical tunnels in the loose, dry top layer of soil and females deposit their eggs 6 to 12 inches below the surface where they remain during development (Vaughn et al 2015). Small patches of bare dirt or small piles of sand provide suitable habitat for ground-nesting bees, and ground disturbances must be limited. These bees may also utilize wood debris such as twigs or plant fibers to construct nests. Other species of bees nest in pre-existing cavities, such as small holes in trees, spaces between bricks, abandoned rodent or beetle burrows (Frankie 2009). These habitats are easy to provide in both urban and farmland environments, where not much space is needed to accommodate bees and their host flowers. Our goal is to see more urban gardens and natural landscaping throughout urban areas, but specifically on the peripheries of cities and in suburbs where bee habitats are less disturbed and can be more connected. Bees can also find habitat in riparian buffers, near forests, throughout parks, and in hedgerows and windbreaks on farms (USDA 2006). Since bee populations are mostly threatened by the conversion of wild habitat into areas of intensive agriculture or urban development, in this section I will focus mainly on the restoration of bee habitat in urban areas and farmland, although these techniques can be applied to any temperate ecosystem.

A variety of flowers are required to attract and maintain pollinators. They prefer flowers that are brightly colored, aromatic, open in daytime, and full of nectar (USDA 2004). A study performed by researchers at UC Berkeley found that the two most bee-attractive plant families were Asteraceae (such as sunflowers and daisies) and Lamiaceae (such as mint, sage and lavender), although each species displays slightly variable preferences, as indicated by Table 1 below (Frankie 2009). A statewide California survey indicated that predictable groups of native bee species visit certain expected ornamental plant species (Table 1), and this predictable relationship can be used to plan gardens to maximize bee visitations. Bees are active from mid-morning through the afternoon, though some species such as the squash bee are active in the early morning and the bumble bee is active late in the evening (Vaughn 2015). Table 2 shows the flowering times of various plant species and the bees that are attracted to those plants (Frankie 2009). Our goal with planting in any area is to maximize diversity of bees, which is attained by planting the widest variety of flowers and shrubs, which can bloom throughout the year in different periods and provide a variety of resources for bees throughout their active season.

Furthermore, these plants will attract other species of pollinators and flower visitors such as birds, butterflies, flies and wasps (Grissell 2001). Establishing these natural habitats can increase the abundance and variety of bee species permanently after only one year, and short-term maintenance is relatively simple, and in some cases long-term maintenance is not required (Vaughn et al 2015). However, since most bees are solitary, there is no minimum number of bees found in an area that would indicate a healthy bee population, unless there are colony bees present, in which case a colony of 75-150 bees is considered a healthy colony (Frankie 2009). Nevertheless, periodic bee surveys will provide valuable information on the success of the programs by showing the increase in abundance and variety of bee visitations.

Maximize ecological services provided by bees

Bees provide fundamental pollination services to farms, as well as pollinating a variety of flowering plants that provide aesthetic value to urban areas. As honey bee populations worldwide are declining dramatically, farmers are increasingly turning to the use of native bees to supplement the pollination services of honey bees, and even increase pollination rates, as native bees are much more effective pollinators than honey bees (Danforth et al, 2011). A study in California found that all pollination needs on a farm can be met if 30% of the surrounding landscape within half a mile is left as natural habitat (The Xerces Society). Creating natural habitat around farmland can be easy and effective without compromising farming space. Natural habitats can be established along the edges of roads, drainage ditches, unused land around fields or farm buildings, riparian corridors, or any other area left untilled. Planting bee habitat in 1,000 acres of farmland can fulfill all pollination requirements by the farm (Xerces). However, the habitat size does not have to encompass 1,000 acres to still be effective—even hedgerows of narrow width along a side of a field can provide sufficient habitat and pollination services for the farm. Soil that is unsuitable for crops, i.e. dry, poorly irrigated, inorganic land provides perfect habitat for ground- nesting bees (Vaughn 2015). Furthermore, planting along drainage ditches or field edges can reduce erosion of farm soil, reduce loss of irrigation water and leaching of pesticides and fertilizers. These native plant habitats can also replace weed species, and over time will reduce the time, resources, and herbicides used to maintain these areas (Vaughn 2015). Our goal is to modify farming techniques to reduce or eliminate the use of pesticides and herbicides, and reduce ground disturbances to provide stable habitat for bees. A California study found that farmers can expect a return on their investment from money required to establish native bee habitats in less than 10 years (Vaughn 2015), although the extent of the economic benefit provided by bees is still unclear.

B. Restoration Plan

Restore and improve habitat for native bees

- **Increase and improve habitats**

Providing bees with areas of bare soil with natural leaf litter, as well as areas of sand or heavy clay will be sufficient for ground-nesting bees. Habitat for cavity-nesting bees can be provided by drilling holes of different diameters (especially 3/16 to 5/16 inches wide) into wooden posts or other scrap lumber (Frankie 2009), or by maintaining existing rodent burrows.

Bees are actively foraging between early spring and late summer, so plants should be chosen that flower during that time period, and a variety of plants with varying flowering periods will sustain the bee population throughout the pollinating season. Table 1 and 2 below indicate the types of flowers that attract the various bee species, and a diverse array of flowers will attract the most number and variety of bee species (Frankie 2009).

40-60 wildflower seeds should be planted per square foot (Xerces).

Ornamental flowers should not be the only focus—native grasses and shrubs, although they don't provide nectar for bees, provide suitable habitat and increase ecosystem health (Xerces).

The two most common bee species found in California's Central Valley are the long-horned (*Melissodes robustior)* and leaf cutter bees (*Megachile perihirta)*. These bees also have a longer foraging season than other bees due to their ability to forage on a wide variety of flowers, such as the Mexican aster (*Cosmos bipinnatus)*, sunflower (*Helianthus annuus)*, and sea daisy (*Erigeron glaucus)* as well as many others (Frankie 2009). Seeds should be bought locally to ensure that they are adapted to local conditions, and planted in the fall for early blooming plants, and late January or early Feburary for late blooming plants. (Xerces).

- **Restore farmland, wildland habitats**

Bees travel between 50 feet to up to half a mile to forage, so areas of natural habitat should be within a half-mile of all insect-pollinated crops to maximize pollination services (The Xerces Society). Closer proximity to the farmland will increase the number of small bees that can reach the crops, but the natural habitat should still be beyond the range of pesticide drift, or outside the range of about 20 feet from the crop if pesticide use is unavoidable (Vaughn 2015). The size of natural habitat patches should be as large as feasibly possible, but minimum 6m diameter patch of flowering plants (Eviner, lecture). Many small patches connected through corridors can also provide sufficient habitat (Vaughn 2015).

Larger shrubs such as elderberry, Manzanita, deergrass, California lilac, showy milkweed, and many others, can be planted to stabilize soil and reduce erosion. These plants are drought resistant, and only need to be irrigated for the first two years. Supplementing these plants with smaller wildflowers such as the California poppy, Bolander's sunflower, and lacy phacelia further stabilize the soil and expand flower diversity (Vaughn 2015). Wildflowers planted in wildland habitats should be planted between October-January (Xerces 2013).

These seeds should be bought locally to ensure that the plants are already adapted to the conditions in the Central Valley, and planted in late fall or early winter. Farmers should also leave the areas of natural habitat as natural as possible—eliminating pesticides, leaving rodent burrows intact, and not weeding out certain types of weeds can all enhance the natural habitat (Vaughn 2015).

Maximize services provided by bees

- **Modify farming techniques**

Hedgerows between fields have proven to be extremely effective at promoting bee abundance and pollination. Scientists at UC Davis have found that after one year, nearly twice as many bees were found at hedgerows as were found on the edges of nearby farms, and that farmers can expect a return on their investment in the cost involved in planting a hedgerow in less than 10 years, due to enhanced crop pollination and reduced pest damage (Vaughn 2015). These hedgerows attract other beneficial insects that prey upon crop pests, further benefitting the farmer. Furthermore, planting bee plants in between rows of orchards provides greater penetration into the orchard without taking any land out of production (McGarry 2016), and plants such as sage are ideal as they are tough and drought-resistant.

Some ground-nesting bees, such as the squash bee, build nests in the ground adjacent to their host flowers. The egg-containing cells are concentrated between 6 and 12 inches below the surface of the ground, so farmers harvesting melon or squash should set their plows to a shallower depth, or use other techniques to harvest the fruit (Vaughn 2015).

Use a range of plants that bloom at different times of the year to lengthen the foraging season of the bees and maximize pollination services, which in turn increases their reproductive success. Farmers should allow their crops to flower, such as lettuce, arugula, radish, broccoli, potatoes, kale, basil, etc. before tilling to provide additional resources for bees (Vaughn 2015). Limit pesticide and insecticide use, choose less toxic pesticides, or use alternative techniques to manage pest species.

- **Promote urban gardens**

Establishing more urban and neighborhood gardens will increase the abundance and variety of native bee species. These gardens can also be used as a great educational tool for schoolchildren, or as a scientific research area to survey bee species, and can be established in any area of unused space. As noted above, plants that have diverse flowering periods will maximize the foraging season of bees and provide maximum aesthetic value to the gardens. Working with the local community, schools, and neighborhood gardens is the most direct and effective way to implement these natural bee habitats throughout urban areas.

- **Maintenance**

Bee habitat cavities in urban gardens (holes in wooden posts) need to be protected from sun and water exposure throughout the year (Frankie 2009). Established plants should be irrigated with a drip irrigation system, and some plants will not need that irrigation after a couple years.

Long term maintenance is relatively simple, as these bee populations and their host plants are a self-sustaining ecosystem within itself. A good habitat can support a diverse community of native bees, and if one bee species declines due to disease or other natural causes, other bee species can fill the void and continue pollination (Vaughn 2015).

Long-term monitoring has shown that even small urban areas can host a relatively high percentage of the bee species found in the surrounding area (Frankie 2009).

C. Monitoring Plan

Bee surveys should be conducted once a month between March and September for the first 3-4 years to ensure that a healthy bee population has been established and maintained. After the first 4 years, bee surveys should be conducted annually every May for the following 5 years to guarantee long-term establishment. Bee populations are fairly self-sustaining and should not need long-term maintenance after establishment. (Xerces 2013)

Perennial plants such as wildflowers and native grasses also do not need long-term monitoring unless there are fires or droughts that kill them off, but some of the other plants in urban gardens may need to be monitored annually to ensure regrowth. (Xerces 2013) (Frankie 2009)

- **Further research and improvement**

Research is currently being conducted at UC Berkeley to study the effects of modified farming techniques on the extent of pollination by native bees, the results of which will provide valuable information on the economic value of their ecological services. Furthermore, as organic farming techniques become more popular and affordable, creating a farm that integrates native bee habitat will become easier and more cost-effective.

Another issue is the disease and parasites that can potentially wipe out certain species of bees, and further research should be conducted to explore ways to protect bees from these diseases or mitigate their effects.

Reference Tables (Frankie 2009)

Table 1:

Ornamental plants and their origins, flowering season and their visitor bee groups in seven California cities, 2005–2007

A. Plants with restricted visitor bee groups	Family	Origin*	Flowering season	Restricted bee groups†
Yarrow (*Achillea millefolium*)	Aster.	CA	Summer	Halictidae
Mexican daisy (*Erigeron karvinskianus*)	Aster.	NN	Spring/summer	Halictidae, Hb, Megachilidae
Pumpkins, squash (Cucurbitaceae)	Cucurb.	NN	Summer	*Peponapis pruinosa*‡, Hb
Manzanita (*Arctostaphylos* spp.)	Eric.	CA	Spring	*Bombus*§, Hb
Palo verde (*Parkinsonia aculeata*)	Fabac.	NN	Summer	Hb, *Xylocopa*§
Wisteria (*Wisteria sinensis*)	Fabac.	NN	Spring	*Xylocopa*§, Hb
Autumn sage (*Salvia greggii* cvs¶/ 'Hot Lips' *S. microphylla*)#	Lamiac.	NN	Summer	*Xylocopa*§, Hb
California poppy (*Eschscholzia californica*)	Papav.	CA	Spring	*Bombus*§, Halictidae, Hb
Sky flower (*Duranta erecta*)	Verben.	NN	Summer	*Bombus*§, Hb, *Anthophora urbana*§
B. Plants with diverse native bees and two or three prominent bee groups	**Family**	**Origin***	**Flowering season**	**Prominent bee groups**
Blanket flower (*Gaillardia* x *grandiflora* cvs)§	Aster.	NN	Summer	*Melissodes*§, Halictidae, Hb
Sunflower (*Helianthus annuus*)	Aster.	CA	Summer	*Melissodes*§, Hb
Goldenrod (*Solidago californica*)	Aster.	CA	Summer	Halictidae, Megachilidae, Hb, *Bombus*§
Pride of Madeira (*Echium candicans*)	Borag.	NN	Spring	Hb, *Bombus*§
Lavender (*Lavandula* spp.)/cvs¶	Lamiac.	NN	Spring/summer	Hb, *Bombus*§
Russian sage (*Perovskia atriplicifolia*)	Lamiac.	NN	Summer	Hb, Megachilidae
Salvia 'Indigo Spires'	Lamiac.	NN	Summer	*Bombus*§, Hb, *Xylocopa*§
Bog sage (*Salvia uliginosa*)	Lamiac.	NN	Summer	Hb, *Xylocopa*§, *Bombus*§
Chaste tree (*Vitex agnus-castus*)	Lamiac.	NN	Summer	Hb, Megachilidae

* Origin: CA = native to California; NN = nonnative in California.
† Bee taxa listed from left to right, more frequent to less frequent; Hb = honey bee (*Apis mellifera*) (fam. Apidae).
‡ Squash bee of the family Apidae.
§ Family Apidae.
¶ cvs = cultivars. These and *S.* 'Hot Lips' were listed together because of their similar floral structure and reward (nectar), and because they attracted the same bee taxa.
# cv = cultivar 'Hot Lips'.

Table 2

. Selected plant types and periods of greatest daily bee attraction*

Plant type	Period of greatest attraction	Floral resource	Bee taxa
Goldenrod (*Solidago californica*)	11 a.m.–3 p.m.	Pollen/nectar	Halictidae, Megachilidae, Hb†, *Bombus*
Pumpkins, squash (Cucurbitaceae)	Before 9 a.m.	Pollen	*Peponapis pruinosa*, Hb
Palo verde (*Parkinsonia aculeata*)	Before 10 a.m.	Nectar	Hb, *Xylocopa*
California poppy (*Eschscholzia californica*)	Before 11 a.m.	Pollen	*Bombus*, Halictidae, Hb
Wild lilac (*Ceanothus* spp.)	Before noon	Pollen/nectar	Diverse native bees

* See also tables 1 and 2.
† Hb = honey bee (*Apis mellifera*) (fam. Apidae).

Common native bee species found in most (> 70%) California gardens surveyed

Common name	Scientific name
Andrenidae	
Mining bee	*Andrena angustitarsata*
Apidae (Including Anthophorinae)	
Small digger bee	*Anthophora curta*
Digger bee	*Anthophora urbana*
Honey bee*	*Apis mellifera**
California bumble bee	*Bombus californicus*
Black-tip bumble bee	*Bombus melanopygus*
Yellow-faced bumble bee	*Bombus vosnesenskii*
Small carpenter bee	*Ceratina acantha*
Small carpenter bee	*Ceratina nanula*
Gray digger bee	*Habropoda depressa*
Long-horn digger bee	*Melissodes lupina*
Long-horn digger bee	*Melissodes robustior*
Squash bee	*Peponapis pruinosa*
Cuckoo bee	*Xeromelecta californica*
Large carpenter bee	*Xylocopa tabaniformis orpifex*
Colletidae	
Masked bee	*Hylaeus polifolii*
Halictidae	
Ultra-green sweat bee	*Agapostemon texanus*
Large sweat bee	*Halictus farinosus*
Spined-cheek sweat bee	*Halictus ligatus*
Small sweat bee	*Halictus tripartitus*
Tiny sweat bee	*Lasioglossum incompletus*
Megachilidae	
Leafcutting bee	*Megachile angelarum*
Leafcutting bee	*Megachile fidelis*
Leafcutting bee	*Megachile montivaga*
Alfalfa leafcutting bee*	*Megachile rotundata**
Mason bee	*Osmia coloradensis*
Blue orchard bee (BOB)	*Osmia lignaria propinqua*

* Introduced.

Table 3

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North American Beaver (*Castor Canadensis*)

Background and Justification

North American Beavers (*Castor Canadensis*) are ecosystem engineers that can affect the spatiotemporal dynamics of the habitat they live in. Their ability to alter the geochemical and physical appearance of environments (mainly riparian areas) has caused people to label them as non-native pests (Hawkes, 2014). According to the California Department of Fish and Wildlife, beavers are only recognized as native species in a fraction of their real historic range including California's central valley, and bordering areas (Lanman et. al., 2013). Their coastal and mountainous ranges are ignored which allows them to legally be considered pest and removed. Also previous problems with over trapping and hunting have decimated beaver populations and almost drove them to be extirpated in parts of North America all together. However, society usually ignore the fact that beavers are important influences of carbon in water bodies, as well as many physical factors (Vehkoaja, 2015). These conditions can increase production in the area and provide a trophic cascade both upwards and downwards in terms of food (Collen and Gibson, 2001). By regarding all beavers as pests can cause many problems to many habitats. The most important step in managing both the destruction and benefits of beavers is by managing their population using the many studies on them.

Habitat Requirements:

- Beavers usually choose first and second order lakes (lakes with an average of 17.29 mg/L of dissolved organic carbon, 751.5 microgram/L of nitrogen, 39.65 micrograms/L of phosphorus, 3.52 mg/L of dissolved oxygen and 5.82 pH. (Vehkoaja, 2015)
- Some physical requirements for beavers to inhabit an area are stream gradient, stream depth, and stream width. Stream gradient (low stream gradient) seemed to be the most important because they increased the beavers ability to build dams. Less stream gradient causes less damages to the dams they build (Beier and Barrett, 1987).
- 80% of American beaver dams were built in depths less than 0.6m. Trees of 3-8cm in diameter were often used to build dams. Beavers require 22-23 oz of bark and sticks a day. Most of the time they feed within 100m of the water (Collen and Gibson, 2001).

Habitat Modifications:

- After three months at a lake, Beavers were shown to have increased the lakes dissolved organic carbon significantly. They did not create lakes but instead modified their geochemical and physical structure including depth and flow. These increased geochemical sites results in more chemical reactions that affected the production of the ecosystem. (Vehkoaja, 2015).

Threats:

- Often prey to many of the tertiary consumers of ecosystems including but not limited to wolves (*Canis Lupus),* coyote *(Canis latrans),* black bear (*Ursus americanus*), lynx *(Felix lynx)* wolverine *(Gulo luscus),* otter *(lutra Canadensis)*, red fox *(Vulpes vulpes),* mink *(Mustela vison),* alligator (*Alligator mississippiensis)*, puma *(Felis concolor),* and fisher *(Martes pennant)* (Collen and Gibson, 2001)

Threatening:

- After 40 years in an area, extirpation of woody vegetation such as aspen and cottonwood can be recognized and shows how beavers can have a negative impact on some plant species (Beier and Barrett, 1987).
- Beaver dams can cause serious problems to landscapes because when unregulated, the dams will cause extreme flooding to the banks. This can change the ecosystem to a totally different condition like expanding riparian habitat. They can also cause problems in the stream flow. (Collen and Gibson, 2001)

Benefits:

- Very beneficial to providing a habitat that is fish friendly by stabilizing the streams, temperature, food sources, and erosion in the stream beds (Collen and Gibson, 2001)
- Species are much more diverse in the riparian habitats that the beavers modify including the plants, and fish.

Life Cycle:

- Beavers usually live in a group of two parental adults, with their offsprings. The offsprings are born from May-June. Usually after 2 years, the offsprings will move out and colonize another area (Collen and Gibson, 2001).

Management Actions:

- Controlling beaver populations does not depend on dietary needs but more on the physical factors of the habitat (water level, soil, etc..) (Beier and Barrett, 1987)
- High population of humans with high density of beavers causes an increase of complainants who find beavers as pest. The attitudes of humans towards beavers ultimately determines the amount of management and regulation of local beavers. (Siemer et. al.
- Regulated trapping is considered the most efficient and effective for beaver population control by wildlife managers. (Siemer et. al.
- The effects of beavers however, can outlast their duration at the site because dams are much more lasting compared to other organisms. This alteration can alter the drainage and hydro network of the ecosystem greatly after they leave (Vehkoaja, 2015).

- Improved legislation, sound stewardship, and restoration efforts can help control the beaver population alongside proper education to the public about the effects of beavers and their significance. By fixing these, some states were like Arizona were able to prevent the extirpation of beavers. (Carrillo et. al. 2009)

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Beaver Management and Restoration Goals:

Because beavers have such a love/hate relationship with humans, they need to be managed but not restored. They usually inhabit lakes and streams with a certain amount of dissolve nutrients, pH, width and depth (Vehkoaja, 2015). Since the beavers are such an important environmental engineer, they can also alter the habitat to fit their needs. This is why the habitat also has to have plenty of vegetation that can be used for food and dam building

(Collen and Gibson, 2001). Beavers are regarded as pests and dangerous to many humans because of their role as environmental engineers/ keystone species. Beavers usually only regularly directly interact with vegetative species like aspen, cottonwood, grasses, aquatic plants etc. They indirectly affect fish, and their predators because of the dams they build. They can alter streams and cause fluctuations in the geochemistry of the water they inhabit (Washington department of wildlife). In California, the beavers can be found in many coastal areas as well as inland riparian, lake and river areas (Beier and Barrett, 1987).

Dispersal and Reproduction:

Beavers typically live in colonies of 2-12 that consist of the two parent partners and offspring. These offspring are born between May and June. They live with their parents until after 2 years, they will move out and colonize another area (Collen and Gibson, 2001). These colonies, under the best conditions will not exceed one per ½ miles in favorable conditions. (Washington Department of Wildlife). Beavers typically live about 10 years and will stay with one partner in the same place reproducing several times (Collen and Gibson, 2001). .

Goals for restoration:

The goal for this project is to create a new habitat in the central valley that will support and even control the beaver population. To do this, the habitat has to be isolated from streams that flow into human controlled areas. These can be creeks or rivers that lead into a lake. The lake has to have more than one water source flowing into it because the beavers might disrupt the water source they are inhabiting. The area will be biologically controlled by predators and recruiting trees. Overall, the habitat will mimic a mixed riparian forest similar to the lower Putah Creek (Putah Creek council, 2008).

Uncertainties:

This experimental procedure can be flawed because we are assuming that the beavers will like habitat even though, an individual beaver can decide that the habitat doesn't fit its needs. Also the biocontrol part of the project may be uncertain because we will be unsure of the behavior of the natural predators. They may not hunt the beavers but other small animals that are more readily available.

Restoration Plan:

Restoration Site: (Mixed Riparian Forest)

To prevent density-dependent limitations to the beaver colony, a certain site must have plenty of high recruiting native vegetation. This vegetation must be within 100m of the water because that is the furthest beavers will travel to gather food (Collen and Gibson, 2001). The site will be oriented in a fashion that involves many patches that are only connected by the stream. The patches will consist of about a 100m radius of fast recruiting vegetation that fit the beavers need. These site will initially be cleared of all invasive species to clear space for to transplant various riparian species from the central valley. These species can include cottonwood, oak, white alder, native sedges, grasses, willows taken from nearby riparian areas so that the plants can survive the slight change in conditions. The whole project will be a series of water connected patches that are spread at least ½ mile apart depending on the conditions of the water (Washington Department of Wildlife). The patches will have about a 100m radius so that the beavers will be able to forage and the trees will be able to recuperate before the beavers return to the site (Collen and Gibson, 2001).

Reintroduction:

First locate and monitor an existing Beaver colony from a central valley riparian area. To locate the beavers, go to different riparian areas that are similar to the restoration site and look for harvest sites, slides, channels and dams that prove the presence of beavers. To monitor beaver behavior, radio telemetry will be the easiest way. By using live traps with castor scent (a scent beavers use to mark territory) as bait, and collaring the trapped beaver with a gps collar, we can monitor the behavior of the beavers. Determine when and where the beaver will mate and raise young by tracking the beavers. When the young have been raised to a point where it will disperse and colonize (age 2) (Collen and Gibson, 2001). After, we will set another live trap and capture the new adults and reintroduce the young beaver into the newly restored site.

Control and Management:

Studies have shown that if a certain amount of stress from predation occurs in herbivores, their reproductive behavior can be decreased (Wingfield 2013). Using this theory, we can choose an area with a native predator that can specialize on predating on beavers. This way, if the food supply of the predator gets too high, the amount of beavers will decrease and vice versa. Also the vegetation must have a fast recruitment rate to support the beaver colonies and dams.

Monitoring Plan:

Before releasing the new beavers into their new habitat, a gps tracker will be collared onto them. We will then proceed to monitor their dispersal movements to collect more data on the conditions that beavers might prefer more. We can use this data to efficient create a better habitat for the next few generations. There can be a problem with uncertainties that may arise when assuming that the beavers will settle down at the created habitat. The gps tracking can help us relocate the beavers if they actually disperse to a totally different place. We also have to make regular trips to the new beaver dam to periodically check if they had mated and had offspring. After the first new generation of beavers is created, gps tracking will also be implanted onto them to check whether our predicted dispersal pattern is correct and whether we can continue to implement this same plan. After, the second generation has been established, we can continue creating new habitats until the stream or river runs out and from then on, we can just monitor the population of the beavers and the conditions of the water and forest. If the forest is unable to recruit because of the foraging pressures of the beavers, we can introduce more predators or let the population decline due to low food. However, this may risk in more dispersal of beavers which can have negative effect on the project's relation with humans. If they disperse without control, they can disturb other water bodies and forests.

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Coyote

Background and Justification:

The Coyote (Canis latrans) is a member of the canine family and is a common apex predator found all across North America. Coyotes belong to the same family (Canis) as foxes, wolves and domestic dogs. Because coyotes are so wide spread and are found in so many diverse ecosystems, they are a very common apex predator and help control and regulate the populations and movement of many other species across North America. Coyotes play an important role in the food web due to their diet of small rodents, birds, reptiles and deer, which helps keep these populations in check which in turn helps vegetation cover and seedling sprouting as well as other animals populations stay stable (Urban Coyote Research). Coyote populations and ranges have grown greatly in the past 200 years, expanding from the central US to all of North America (Urban Coyote Research). Such high population densities and range areas cause human development to directly impact coyotes because their habitat and range is adjacent to many cities and developments. Coyotes, like many apex predators, are vulnerable to habitat fragmentation and loss of habitat due to land conversion. In urban settings coyotes are often feared and blamed for pet death, so many negative incidents with coyotes are reported on the news and most people don't know how to act around them. In rural settings most states allow for open season on coyotes, which leads to many of them being killed or trapped (Urban Coyote Research).

Characteristics:

Description:

- Coyotes are medium sized canines, weighing around 25-35 pounds (Urban Coyote Research)
- Coyotes are grayish brown to red with white undersides, triangular ears and a slender muzzle and yellow eyes (Urban Coyote Research)
- Coyotes have a bushy tail which they keep down when they run, this is commonly used as an easy method of differentiating them from dogs or wolves.

Reproduction:

- Coyotes usually mate from January to March, usually in February (Coyote Fact Sheet).
- Mating pairs are usually monogamous and mate for life (Coyote Fact Sheet).
- The gestation period is about 65 days long at which the mother will look for or create a den for her pups (Urban Coyote Research).
- Fecundity of females as well as litter size and survival is dependent on nutrition levels, available prey, age, and size (Sacks 2005).
- The den is usually a crevice or outcropping with some cover, if none are to be found the mother will dig one for herself (Urban Coyote Research).
- The litter size is on average 6 but can be up to 19 (Coyote Fact Sheet).
- Pups are born blind and open their eyes at around 10 days old and leave the den at around 4 weeks old (Coyote Fact Sheet).
- Pups are usually weaned at around a month old and separate from their parents between 6

and 9 months (Coyote Fact Sheet).

Diet:

- Coyotes are primarily nocturnal solitary hunters but will hunt in packs for larger game such as deer, most often in winter (Coyote Fact Sheet).
- Coyotes are omnivores eating 90% mammals with a mix of birds, snakes, and berries and will sometimes eat carrion, all of which is highly dependent on what is in season and in the proximity (Coyote Fact Sheet).
- Coyotes are adaptive carnivores and will eat whatever is most convenient, when their habitat expanded over the years so did their diets. They now not only consume their original diet of small mammals and berries but now have expanded to deer, domesticated pets, livestock and sometimes garbage (Coyote Fact Sheet)
- Coyotes experience competition from various sources such as foxes, wild dogs, bobcats, mountain lions, wolves and other coyotes (Cypher 1998)

Territories, Packs and Social Behavior:

- A single pack is dominated by a single alpha breeding pair and others are accepted into the pack by that pair (Coyotes 101)
- Pack size depends on the environment and food availability, pack sizes tend to be larger with supplemented food from surrounding human settlements (Coyotes 101).
- Each pack has a territory and they defend it from other predators and coyotes (Coyotes 101).
- Coyotes use urine and scat to mark their territory that will range in size depending on food availability (Coyotes 101).
- Transient coyotes are individuals that don't belong to any specific pack but instead wonder around between packs by themselves but can be accepted into a pack by an alpha pair (Coyote 101).
- Transient coyotes don't have a traditional territory but instead cover vast areas that include many packs but tend to stay away from pack territory to avoid conflict (Coyotes 101).
- Coyotes are very social and use a series of yips, barks and howls to communicate with each other (Coyote- Canis latrans)

Habitat and Range:

- Coyotes are found all across North America, dramatically expanding their range from just a couple hundred years ago in the central US to all of North America (Tkaczyk).
- Because they are so adaptive their habitat can include: woodland, prairie, mountain steppe, savannahs, deserts, pine forests and temperate rain forests as well as urban neighborhoods (Tkaczyk).
- Habitats for coyotes must include dens to raise their young, ample habitat for their prey, and shelter from the environment (Tkaczyk).
- Coyote ranges and habitats often are near urban areas and so result in conflict with humans. Many coyotes end up crossing the road to hunt or forage or the road cuts into the

territory, causing many coyotes to be killed by cars (Tigas 2002).

- When coyotes are far from cities they will hunt during the day if prey is abundant. Scarce prey may force the coyotes to move toward human settlements and therefore hunt more nocturnally (Coyotes 101).

Threats:

- Because coyotes are so adaptable and live so close to humans they encounter many dangers especially from human traffic such as cars. Many coyotes are killed crossing the road at night although many use safe passages such as culverts or alleys (Tigas 2002).
- As apex predators with large territories coyotes are vulnerable to habitat fragmentation, human development and land conversion, all limiting their hunting and pup rearing area (Tigas 2002).
- Deaths from hunting, trapping and poison primarily in rural areas can cause death (Urban Coyote Research).
- Coyotes also face threats from Climate change, with differing prey rates and habitat changing.

Life Expectancy and Diseases:

- Coyotes can live up to 15 years but most die at around 6 in the wild (Urban Coyote Research)
- Major causes of death are mostly humans and disease. Most juveniles die in vehicle accidents but many coyotes suffer from diseases (Coyotes 101).
- Common diseases of coyotes include: ticks, fleas, worms and mange and very rarely rabies (Coyotes 101).

Management Actions:

- Restore natural habitat where possible for both the coyotes and their prey
- Provide a nature reserve with very limited human interference and natural boundaries such as shrubs, not adjacent to urban landscapes.
- Making sure that there is suitable habitat for dens and raising the young.
- Enhanced environmental cover to protect from storms
- More and better maintained fences along road ways to limit coyote death by vehicle.
- Management of livestock to prevent them from wondering into coyote territory or vice versa.
- Prevention of traps and poisons in rural areas
- Population and range monitoring throughout the state
- Education of the populous on how they should treat coyotes and their habitat.

Gaps in Knowledge:

- Coyote transient rates
- Coyote interaction with humans within a city
- Coyote vehicle deaths versus disease deaths

- Affect of retreat of wetlands on coyotes in California
- Interaction of packs within a city

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GOALS:

To restore natural habitat and prey to facilitate a stable coyote population:

The California Coyote (Canis latrans ochropus) is a very versatile species and has adapted to live in many diverse environments. Because of their adaptability, environmental suitability for the coyote really depends on prey abundance and shelter for their young. Therefore whatever habitat their prey thrives in and provides suitable dens for their young, is the preferred habitat to aim for in restoration. The coyote's prey, which can range from small mammals to birds and snakes and even to deer, often prefer a wide variety of habitats making it difficult to restore for all of them at the same time. Coyotes themselves prefer open areas, such as grasslands and chaparral, and forest edges as well as recently burned areas (Nature Mapping Program). Open areas allow for easy spotting of prey and maximum speed when pursuing an animal. Forest edges give the coyote a shelter and den sites while allowing them to live next to easy hunting grounds.

Restoration for this goal will focus primarily on forest habitat and more open chaparral grasslands, because these will provide the best habitat for the coyotes and prime hunting grounds to ensure a stable population. Ideal density for a stable population should be 1 coyote per Km^2. Controlled burning can be used to help reinitiate the natural disturbance regime in the coyotes' habitat. This can help bring back key plant and animal species that have been driven out by exotics or lack of natural fire and help diversify the available prey for the coyotes. This also creates more habitats for the coyote, as they favor burned areas. A 50% ground cover of native plants should be aimed for. Controlled burns should be executed on a rotating basis on different patches to allow multiple stages of regeneration of plants, which allows for a steadier repopulation of small mammals. Patches designated to be burned should not be critical habitat of other species. Forest thinning and cutting in areas throughout California can also be used to help restore habitat preferable to coyotes, by bringing back a more natural environment that the coyotes natural prey will prefer and one that the coyote is used to and leaving logs and holes for coyotes to nest in. Forests should be restored to their natural state that occurred with more frequent forest fires, such as less tree litter, more young trees and a higher small mammal forest population. This restoration goal is an ongoing process because the coyote's habitat spreads all across California, so areas will be restored over time. The restoration of the individual areas of forest zone will take about 5-10 years to restore and 10 more years of monitoring. The grasslands and chaparral will take 2-5 years of restoration and 10 years of monitoring.

Minimizing coyote fatalities in urban areas:

Because the coyote's range and habitat is so broad, they are bound to interact with humans. Although coyotes are nocturnal hunters and shy by nature, contact between them and humans is inevitable and many times these interactions lead to fatalities of coyotes. The most common cause of coyote death by far in urban areas is cars. Traffic fatalities of coyotes are responsible for up to 70% of urban coyote deaths (Kessler 2015). This happens so frequently because of two reasons. First, coyotes are nocturnal hunters and so they are very active at night which is when they are hardest see and it is harder for them to see cars. Secondly coyotes cover vast distances to find prey and travel and they often used established roadways, which they share with cars, to do this. Both of these coupled with poor driving causes thousands of coyote deaths a year. In rural areas, coyotes tend to be killed by ranchers through hunting or poison, because they prey on their livestock. Restoration and proper management can help reduce the number of coyote deaths. Connective pathways between wildlife areas that avoid roads can help coyotes move without crossing roads. Restoration for this can be in the form of planting vegetation and trees along roadways to limit contact with cars, as well as planting them in designated corridors to encourage coyotes to take those paths instead the roads. These corridors become especially important near major freeways. Freeway underpasses and tunnels under the freeways could also provide critical pathways fro the coyotes to use. Proper placement of these pathways requires detailed tracking of coyote movements and migration patterns, to determine where the highest coyote movement intersects with major roadways. Proper maintenance of fences along roadways will also help prevent deaths. To limit coyotes preying on livestock in rural areas, restoration of current wildlife areas and areas not occupied by livestock will help attract coyotes to those sites and away from livestock. The restoration and creation of wildlife corridors and improving wildlife areas is an expansive project that will take place all over the state with a timeline of about 5 years for each restoration and an additional 10 years of monitoring.

RESTORATION PLAN:

- *Restoring forest habitat*

As mentioned above in goal A, forested habitat is an ideal location for coyotes and one of their most preferred habitats because of its shelter and many locations for dens as well as prey that forage on the forest floor. Restoration of forests involves many complex factors and variables that must be taken into account in order to properly restore the area. These include: soil types, climate, topography, and competition. Depending on where in California the restoration site is located, the forest composition will change. Dense pine forests dominate in northern California and the Sierras while sparse oaks fill the central valley. Either way, making sure that the trees that are planning on being restored have adequate water and soil nutrients is key. Restoring forests often follows a severe forest fire or over harvesting of lumber. The remains of the old trees and nearby forests should give an idea of what species previously existed there and what to replant, but if no remains exist then the climate, soil type and topography must be used to determine what species of trees would thrive there. Pine trees need moist and well draining soils to survive as well as adequate rain fall and should only be planted when dormant if using bare root seedlings (Pierson). Oaks can go without rain for longer because of their deep tap roots, but still require well drained and slightly acidic soils. Oaks also are usually spread out farther than most pines but can be in clusters. After the correct trees for restoration have determined, next is the actual planting. When planting the tree seedlings give them proper space between each tree, about 30-40 feet between each cluster for oaks, and at least 8 hours of direct sunlight (McCreary). The area used for planting should be large enough to have a measurable affect on the coyotes and their prey, which could be up to 10 acres. The seedlings used for replanting should be of similar genetic make up of the neighboring forests to ensure the seedlings have any local adaptations needed. After the trees have been planted watering them weekly is important when they are young. Protection for the seedlings is highly important, especially if deer are present, and can take the form of fences or barriers around the seedlings. Fertilization is not needed but can be helpful to trees. Potential problems like the seedlings being eaten or out competed by other plants is possible but can be prevented through barriers, herbicides and proper management. Constant monitoring and management is required in the tree's early stages, about 4 years, but once they are several years old they only need minimal supervision. Management of the trees includes: pruning, watering, protecting and recording data for each tree. Tree thinning and clearing should be used once every 5 years to help maintain a healthy forest and habitat for the coyote's prey. All of these management practices are to restore a habitat that is ideal for the coyote itself and for its prey. Restoring the forests give the coyotes' their ideal habitat, with dens for their young and shelter from predators and the environment.

- *Restoring Chaparral and Grasslands*

While forest habitat provides shelter and dens for the coyotes, many of their prey live in open areas such as grasslands and chaparral. Grasslands and chaparral are home to many of the coyote's prey such as rabbits, birds, snakes and mice. These grasslands are ideal homes for these preys to nest, eat and reproduce. To restore a grassland or chaparral area, plant species that are native to the region should be planted to help facilitate the transition from disturbed land back to grassland or chaparral. These native species and their natural locations can be found in the California Native Plant Society website. Once the proper California native species have been chosen for the area, tilling and preparing the ground for planting is next. Spraying invasive weeds is an essential process if the seedling natives are to survive. Once the seeds have sprouted and are growing, water is a major concern especially if the species is highly water dependent. Irrigation for the first couple of years may be necessary depending on the species and climate. Pest, weed and herbivore management is critical in the first few years of growth of the seeds. Once the plants are established, a monitoring and data collection program should be in place for 5 years. A possible problem that can occur is the weed species and more competitive species can choke out the native sprouts. Invasive non native weeds are excellent at adapting and growing quickly and present the biggest threat to restoring wetlands (Young). Proper and thorough management and herbicides can help keep the weeds at bay until the native plants are competitive. Controlled burns can greatly help to restore grasslands and chaparral areas and are favored by coyotes. Fire can clear out invasive weeds, kill pests and diseases and cause seeds to germinate. Following a fire, vegetation grows quickly and in large quantities which provides an abundance for herbivores and therefore more prey for the coyotes. Controlled burns should be prescribed on a case by case basis, depending on climate, plant species and fire hazards. In general a burn every 2-5 years, which used to be done by the Native Americans, is recommended (Young). Burn times should be on days when it is safe to burn and not in the spring when the coyote babies are just being born. A burn in early fall is recommended.

- *Minimizing coyote fatalities in urban areas*

In order to provide safe and convenient travel corridors for the coyotes, to keep them off the roads, large coyote populations should be found and marked on a map and their travel and migration patterns and paths should be mapped out. Next is finding a way to connect these large populations through corridors. The coyotes should easily traverse the corridors and they shouldn’t intersect with any roads. The corridors can consist of plants or fences lining the edges to create a road or may use existing freeway underpasses and tunnels. These plants should be trees or shrubs that encourage the coyotes to stay in the corridor and not venture out onto the roads. Quick growing and self sustaining natural shrubs and trees should be used to allow for minimal management. These corridors should try and avoid urbanized areas and should not interfere with other species’ migrations. A 10 year implementation plan should be in place to get the corridors finished and then a 5 year monitoring plan should be established to make sure the coyotes are using the corridors and that the number of traffic fatalities is decreasing.

MONITORING PLAN:

Pre restoration monitoring of coyotes and their habitats should occur roughly every month for 2 years, to establish a baseline reproductive success, fitness and behavior as well as prey abundance. Post restoration monitoring should occur on a larger and longer time basis such as 2-3 times per year for 10 years. The monitoring and data collection times should be synced with major events in the coyotes life such as births in the spring, to measure reproductive success, summer hunting to measure the peak of prey and fitness, and then winter to measure the fitness of the coyotes at the lowest prey availability. Measuring at these times can also be used to compare original prey abundance to post restoration abundance. The coyotes can be monitored through radio tags put on through catch and release or by observation of fitness and evidence of births and deaths in a study area. If the data shows successful growth of coyote populations and fitness in restored areas then the restoration has done its work, however if the coyote populations decline then further investigation into the feedback and predator-prey dynamics of the systems needs to occur in order to fully asses and implement a new restoration plan. If the coyote population falls below an established threshold of .1 coyotes per Km^2 then immediate restoration action should be taken. This action should include reintroduction of coyote populations as well as reintroduction of any of the coyote prey that has also seen severe decline, as this may be the cause of the coyotes' decline. Further monitoring of the reintroduced species should continue on a once a month basis until the coyote reaches a stable population of .5 per Km^2. After this restoration goals should continue to get the coyote population to a thriving population of 1 coyote per Km^2. This restoration plan can answer research questions like: What is the affect of native grasslands compared to invasive grasslands on coyote prey?, How much do controlled burns increase coyote prey?, Do coyotes thrive more in pine or oak forests?, Do coyotes thrive more in forests or grasslands?.

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Racoon

Project Background and Justification

Procyon lotor, or commonly known as raccoon is one of the most versatile species in the world. They have a wide range stretching from Canada, throughout the United States all the way down to Central America (Erwin 2015). Unfortunately, because of climate change raccoons have been slowly migrating further north and becoming invasive. They are typically known as pest to many farmers as they raccoons love to go on night raids and forage for fruits and various crops (Fumito 2006). They are omnivorous and their diet highly diverse as they are known to consume anything from amphibians, smaller mammals, and crops. Throughout history invasive raccoons were known to decimate bird population as they are notorious for preying upon young birds and eggs (Zeveloff 2002). Having a low population of raccoons is also detrimental despite that they are considered pests. Predators higher up on the food chain rely upon them as a source of food. Too many raccoons in a habitat may decimate the bird population. For example, a case study has shown the detrimental effects on horticulture due to raccoons over foraging of Red Shoulder Hawk eggs. The decline of Red Shoulder Hawk has led to an increase in rodent population which ultimately led to low productivity in horticulture (Miller 2015). Thus it is important to come up with a management plan to keep a healthy raccoon population.

Literature Review

Characteristics of raccoon

Habitat and Characteristics

- P. lotor or the common raccoon can be found across Canada from Nova Scotia to British Columbia, throughout the United States (except for the Rocky Mountains and the Great Basin) and south through Mexico and Central America. (Erwin 1995)
- Raccoon are a highly versatile species capable of living almost wherever free-standing water occurs. (Erwin 1995). Since they are highly adaptable they are also found near city life (Glatston 1994). They have no aversion to living near humans and sometimes seek shelter in farm buildings and beneath dwelling houses. They are known to go on nocturnal raid on rubbish bins and are a source of annoyance to many people. (Markovchick 2008)
- General habitat is forested regions, usually near running water (Erwin 1995).
- P. lotor has spread as invasive species in Europe and Asia because they were used in fur farms for their pelage. Animals escaping from these farms have succeeded in establishing wild populations. (Erwin 1995).
- Raccoons generally live up to 2-3 years in the wild but it has been recorded that a domestic raccoon has lived up to 13 years (Link 2004).
- Males are considerably larger than females. The head and body length averages about 500mm, while the tail adds another 300mm. (Erwin 1995).

Space Use

- Home range may vary on food and water availability. Home ranges have been recorded up to 1 mile in diameter (Link 2004).

- Low raccoon density is typically 5 individuals or lower per sq kilometer. Raccoons can reach surprisingly high count as 68.7 per square kilometer. (Zeveloff 2002)
- Kits (adolescent raccoons) stay with their mother for the first winter and seek out own territories in the spring (Link 2004).

Food Habits

- They are omnivores that feed on frogs, crayfish, fish, birds and eggs. There are not restricted to wetland and they may also forage upland in upland areas for rodents, fruit, nuts and insects. They are known to raid on crops, particularly on fruits and corn, which has resulted in some persecution from farmers (Erwin 1995).
- They particularly are a threat to many bird species such as the Red Shoulder Hawk because they forage upon small hatchings and bird eggs. They like to predate upon the Western Pond Turtle. (Zeveloff 2002)
- They can forage in trees as well on the ground. It is a notorious pest of crops and well-known thief of eggs from bird nests and nest boxes erected to enhance waterfowl reproduction. (Zeveloff 2002).
- In captivity, raccoons are renowned for their fastidious behavior of washing their food before eating it. This has resulted in the species' scientific name *Procyon lotor* which means "he who washes his food" (Erwin 1995).

Reproduction

- Four seasons of a raccoon may be labeled: mating (6 weeks), gestation (9weeks), rearing (35weeks) and hiatus (2weeks) (Holmgren 1990).
- Pregnancies usually last 63-65 days with extremes of 54-70days (Zeveloff 2002)
- Raccoon typically have 2-6 kits with a mean at about 4 kits. (Holmgren 1990).
- Kits weight about 2-3 ounces at birth. Runts usually don't survive because they don't get enough nourishment but there are cases where runts do make it, rarely. (Holmgren 1990)

Environmental and Horticulture Concerns

- Their impact on bird populations can be devastating, especially when they are introduced where they or other predators do not occur. (Zeveloff 2002)
  - On the costal island of Massachusetts Raccoons and foxes almost entirely eliminated of young in herring gull colonies and the abandonment of some colony sites.
  - In the 1940s the fur industry incidentally introduced raccoons onto British Columbia's Queen Charlotte Islands that decimated burrow-nesting seabirds.
- Discusses the impact of Procyon lotor on Suburban Red-Shouldered Hawk nestling. The decline in Red-Shoulder Hawks have let to habitat change due lack of predation of certain rodent species (Miller 2015).
- Studies have shown that raccoons can be vectors of disease. Recently they have been carrying and spreading Salmonella in regions of California (Gorski 2016).

Threats

- Main causes of death of raccoons are encounters with vehicles, hunters, disease, starvation, and predation (Link 2004). Raccoon carcasses have known to attract certain species of scavengers along the freeway (Ng 2004).
- Some predators that prey on raccoon are bobcats, coyotes, cougars and domestic dogs. It is also known that large owls and eagles will prey on young raccoons (Link 2004).
- Young raccoons are victims of starvation during winter and early spring when food can be scarce (link 2004).

Management

- Knowing when raccoons are sexually mature is a key component to managing raccoons. Sub-adult males are not sexually active and considered adolescents. Sub-adult females are ready for sexual reproduction but do not contribute to the population as much as mature adult females (Zeveloff 2002)
- Several ways to keep track of populations as follows:
    - Scent Marking Indexes- Involves using scents to attract individuals.
    - Spotlight survey- driver and observer travel along routes in the evening using powerful spotlights to locate raccoons.
    - Fur Buyer's and Sealing Reports are used to keep track of numbers harvested.
    - Hunter success during field trials is also used as a method to estimate raccoon numbers.
    - Mark and Recapture
    - Direct Count
        - All of these techniques are used to create an index and fair estimation of population of the raccoons. These estimated numbers are largely imprecise and actually getting accurate numbers isn't quite feasible but it does still provide valuable information for managing raccoons. (Zeveloff 2002).

- It is important to maintain a healthy raccoon population. Not enough raccoons may also lead to decrease in predator population and too many raccoons may decimate the bird population in the area. Raccoons rely on sufficient amount of dens available. It is recommended that there should be one to two dens every 6 to 8 ha (15-20 acres) (Zeveloff 2002)

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A) Goals

Understanding Procyon lotor Habitat and Behavior

Procyon lotor, or commonly known as raccoon are one of the most versatile species in the world. They are highly adaptive and have a large range of food from insects, amphibians, birds and even small rodents. Having a wide range of food and having the capacity of being very adaptive allows raccoons to become very invasive. The riparian of California's Central Valley provides an excellent location for raccoons to thrive as "they are capable of living almost wherever free-standing water occurs" (Erwin 1995). Procyon lotor can be found all the way from Canada through Central America. They prefer moist woodland areas but they're also commonly found in farmlands, suburban, urban areas and typically considered as pest. It is unfathomable to get rid of all the invasive raccoons that are not native to the community but our goal is to understand raccoons and implement strategies to restore the habitats that they have been introduced to.

Knowing where their local habitat, breeding habit and what their diet consist would be very advantageous in developing a good plan manage raccoon population. Raccoons either build their home or find a suitable place to live, they prefer "dens in trees, but may also use woodchuck burrows, caves, mines, deserted buildings, barns, garages, rain sewers, or houses" (Noawk 1991, Wilson and Ruff, 1999). The typical home range of Procyon lotor is about one mile in diameter and can vary with the availability of water and food. Raccoons are mostly solitary but can be found in communal groups when it is beneficial, for example, they will go on "night raids into a farmer's storage foraging for fruits and various crops or they can be found sharing communal den during harsh winters" (Fumito 2006, Wilson and Ruff 1999).

Raccoon reproduction go through four phases, which Holmgren refers as, the "four seasons" and is comprised phases of mating (6weeks), gestation (9weeks), rearing (35weeks), and hiatus (2weeks) (Holmgren 1990). Females will rear about 2-6 kits at one time and will grow to adults that have a life span about 2-3 years in the wild. Raccoons propagate at an amazing rate as their "offspring's or kits only need to live through one winter before they can start looking for their own territories in the spring" (Link 2004). As good as they are propagating there are masterful foragers and their presence is known to impact the native community. Raccoons are notorious for foraging upon bird eggs and decimating bird population, "Their impact on bird populations can be devastating, especially when they are introduced where they or other predators do not occur" (Zeveloff 2002). Zeveloff mentions about two incidents where the introduction of raccoons nearly eradicated certain bird colonies from its natural habitat. In the 1940s the fur industry incidentally introduced raccoons onto British Columbia's Queen Charlotte Islands that decimated burrow-nesting seabirds. On the costal island of Massachusetts Raccoons and foxes almost entirely eliminated of young in herring gull colonies and the abandonment of some colony sites. This is important information in history that shows the potential threat and change that raccoons can bring when they are not manage properly.

B) Restoration Plan for Riparian Area

Reduce Exotic Species in Riparian Areas

Exotic or invasive species have the "ability to change topology of the riparian area by changing how sediments get trapped between vegetation" (Gregory et al. 1991). This can further promote more invasive species within the area which gets further aggregated because riparian provide excellent transportation of seeds via water. The goal is to reduce exotic species through herbicides and promote native species by either planting native seeds or plants. Note that appropriate amounts of herbicide should be used as excess amounts may contaminate the water and livestock around.

Population Management of Procyon lotor

- **Management Through Monitoring**

What is desired for this species is manage the population size of raccoons in riparian habitat in California's Central Valley. The first step to managing raccoons would to monitor changes in number through direct counts, mark recapture, field trail surveys, spotlight survey, scent marking indexes and even checking out fur buyers' and sealing reports (Zeveloff 2002). The goal isn't to eradicate all of the raccoons in the habitat but to maintain a healthy population where they don't cause a disturbance or imbalance in the ecology.

- **Reducing Population by Taking Away Dens**

One way to decrease raccoon population is to take away their access to dens that they may use, dens actually take many years to form, anywhere from 20 to 100 years in some cases. Zeveloff mentions that is estimated that there should be about 6-8 dens every 15-20 acres. Thus, a possible strategy to lower raccoon population would be to deny access to these dens. Information from monitoring could give a fair estimate of how much the raccoon population should be reduced. For instance if the population of raccoon have increased 12% over the last 10 years perhaps blocking access to about 12% of dens that year will bring it closer to desired raccoon population, especially right before a harsh winter.

- **Poison**

A controversial approach is to use "poisons such as strychnine and Fumarin, an anticoagulant, may be used to reduce especially high populations"(Fumito 2006). Poison is only used in extraordinary cases such as when raccoon may vector diseases. Efforts are made to avoid harming non-targeted species when using poison. Poison would not be good in a riparian setting as these harsh chemicals would leak into the local water and infect all the animals in that habitat. If poison must be used it should only be implemented in upland next to the riparian. Dosage amount wasn't provided but minimal poison should be used for the desired result.

Conservation of Native Species

To preserve some of the native bird species "erected nest boxes that are properly spaced out between them may minimize predation" (Zeveloff 2002). Though these erected boxes could potentially provide protection against terrestrial predators it may expose the eggs to aerial predators such as owls. However, if the tradeoff favors the waterfowls it may be worth keep but careful monitoring must be implemented to see if it is truly a success. There was no description of how high the nest should be erected or how far they should be spaced between. Miller et al explains the importance of maintaining species of birds that prey upon rodents, as an increase in rodent population often leads to low productively in certain plant species because the rodents devour many of the seeds.

C) Monitoring

Monitoring raccoons could be troublesome and techniques used to estimate numbers of raccoons and their populations are largely imprecise. However, they can generate valuable indexes that compare population sizes at different times and therefore help determine population trends (Zeveloff 2002). As mentioned above in Management Through Monitoring, here are a couple techniques that can be used in detail:

- Scent-Marking Indexes- technique involves using scents to attract individuals to a scent station. These stations are established at intervals, and the raccoon's seasonal use of different habitats is taken into account for their placement. Based on the number of visits to these, researchers can obtain a measure or an area's raccoon abundance (Zeveloff 2002).

- Mark and Recapture- It relies on capturing and marking the raccoon with tags that later will be recaptured and be identified. It is used to estimate population size, a formula is employed that considers the number recaptured relative to the number initially caught.

- Direct Count- is a technique that is seldomly used because it is highly improbable to count the raccoons accurately; it also cost a lot of time and money. As mentioned before an approximation is adequate for assessing numbers and trends for management (Zeveloff 2002).

Raccoons should be monitored at least once a month for at least 1 to 2 years and then once annually to keep track of population density and habitat use (Glaston 1994). Usually raccoon populations usually stay constant due their versatile nature and being able to adapt to most environment. Research has shown raccoon density varies depending on resource availability, "low raccoon density is typically 5 individuals or lower per sq kilometer. Raccoons can reach surprisingly high count as 68.7 per square kilometer" (Zeveloff 2002).

Research questions that need to be answered to improve plan

- What species of birds does raccoons prey upon the most? Are they predator birds that prey upon rodents?

- What kind of rodents live in the riparian area and what is their primary diet? Is it exotic or native species that they forage for?

- What is a healthy raccoon population in a given riparian area?

- How topography of the riparian area has changed since the introduction of invasive raccoons?

- Is it worth trying to reduce the raccoon population when they are so versatile? Cost effective?

Further research and improvement

Introduction of natural predators of raccoons could be used to control the population. Some predators that prey on raccoon are bobcats, coyotes, cougars and domestic dogs. It is also known that large owls and eagles will prey on young raccoons (Link 2004).

Main causes of death of raccoons are encounters with vehicles, hunters, disease, starvation, and predation (Link 2004). It is also known that they can be vectors of diseases such as rabies. Recent studies have shown that they were vectors of Salmonella.

Raccoon carcasses have known to attract certain species of scavengers along the freeway (Ng 2004). It is very plausible that raccoons may be a primary source of food and have possibly created a new niche.

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Zeveloff, Samuel 2002 Raccoon A Natural History. Smithsonian Institution Press Washington and London pg.121-145

Western pond turtle

1. Background and justification:

The western pond turtle is the last native freshwater turtle in California (Nyhof & Trulio, 2015). There was no discussion on direct involvement of the western pond turtle in key ecosystem functions. There is an empirical right for the western pond turtle to exist. Human interaction and manipulation of habitat has been the key point in reducing populations to the point of potential extinction in some areas. Exact numbers of the western pond turtle in central California are unavailable due to the lack and difficulty of efficiently conducting population and demographic studies (Germano & Bury, 2001). The western pond turtle is currently listed as a Species of Special Concern through California's Department of Fish and Wildlife (Spinks, Pauly, Crayon, & Shaffer, 2003). Historical populations estimated to be about 3 million in California (Belli, 2016). They are currently greatly reduced and fragmented from the historic state. The extent of this unknown due to lack of studies (Belli, 2016).

2. Literature review:
    a. Main factors affecting your topic?
        i. The main factor causing the declines of the western pond turtle in habitat destruction and modification for agriculture, flood control, water projects, and urbanization (Lovich, n.d., Spinks, Pauly, Crayon, & Shaffer, 2003).
        ii. Habitat can be degraded through complete removal (over 90% of wetlands in California have been lost), increased siltation, removal of vegetation, and increased channelization (Lovich, n.d., Spinks, Pauly, Crayon, & Shaffer, 2003).
        iii. Secondary factors that have added to the decline of western pond turtle are:
            1. Increased "take" by humans through pet trade, pets (such as dogs), contaminants entering water, and traffic/vehicles (Lovich, n.d.).
            2. Documented death of 42 turtles due to an upper respiratory disease (Lovich, n.d.).
            3. Introduced saltcedar altering channel morphology and hydrology (Lovich, n.d.).
            4. Grazing causing trampling (Lovich, n.d.).
    b. Characteristics/Needs?
        i. Life span of around 40 to 50 years but there have been some western pond turtles thought to be over 55 years old (Belli, 2016)
        ii. Geographic range from Washington to Baja California on the west side of the Sierra Nevada Mountain Range (Germano & Bury, 2001).
        iii. Demographics are very important to survival. There should ideally be more juveniles than adults (Spinks, Pauly, Crayon, & Shaffer, 2003).
        iv. Predators are raccoons, rats, skunks, otters, coyotes, bullfrogs and largemouth bass (Belli, 2016).
        v. Diet includes insects, algae, some plants including yellow pond lily, snails, crustaceans, isopods, midges, beetles, tule and cattail roots, catkins of alder and fish (Belli, 2016, Germano, 2010, Lovich, n.d.).

vi. Diet changes according to sex and age. Males eat more insects and larger items, females eat more algae, and juveniles eat a higher number of smaller items (Belli, 2016, Germano, 2010, Lovich, n.d.).

vii. Sex is determined by temperature. High temperatures above 86 degrees Fahrenheit yields females and below yields males (Lovich, n.d.).

viii. Habitat consists of:

1. The western pond turtle will live in a variety of habitats including lakes, ponds, streams, rivers, stock pond, sewage plants, canals, and reservoirs (Belli, 2016).
2. No preference toward perennial, temporary, or seasonal waterways (Belli, 2016).
3. Preference toward deep, complex ponds, complex runs, and backwaters (Belli, 2016).
4. Emergent vegetation is usually present (Lovich, n.d.).

ix. Migration/Overwintering

1. Depart aquatic home into upland area June to November depending on how dry the climate is. The drier it is, the earlier the departure (Belli, 2016, Pilliod, Welty, & Stafford, 2013).
2. Return to aquatic home from January to April (Belli, 2016, Pilliod, Welty, & Stafford, 2013).
3. Overwinters by burying underground or under grass, duff, litter, or low shrubs, leaving the top of the carapace exposed during overwintering (Pilliod, Welty, & Stafford, 2013).
4. Average distance travelled upland is 100 meters but up to 402 meters and as low as 1.3 meters have been observed (Belli, 2016).
5. Site will be flat to 40 degree slope (Belli, 2016).
6. Site of study in Carrizo Pain Ecological Reserve consisted of 40% cover of low vegetation within 1 meter of the ground and no more than 24% cover of vegetation more than 1 meter above the ground (Pilliod, Welty, & Stafford, 2013).

x. Reproductive biology

1. Poorly understood due to lack of studies (Belli, 2016).
2. Can begin to lay eggs at a size of 4.3 inches or about 6 to 7 years old (Lovich, n.d.).
3. Courting has been observed in all months besides January and December (Lovich, n.d.).
4. Nesting occurs April through August (Belli, 2016, Lovich, n.d.).
5. One to two clutches per year, usually not yearly, with one to thirteen eggs per clutch (Belli, 2016, Lovich, n.d.).

xi. Nesting and nest site

1. Well drained silt/clayey soils with less than 15 degree slope (Lovich, n.d.).
2. Usually selected on the south facing slope but not always (Geist & Gordon, 2015, Lovich, n.d.).
3. Nest site requires abundant light, dry soil, and sparse vegetation that usually includes herbaceous vegetation such as grass but no

trees or shrubs (Belli, 2016, Lovich, n.d.).

4. Nests are 2.6 to 3.1 inches deep, 2.6 to 2.8 inches wide, and has a 1.4 to 1.6 inch wide entry (Lovich, n.d.).
5. Site selection and use in April through August (Belli, 2016, Lovich, n.d.).
6. Nests are anywhere from near the edge of the water to 400 meters away from the water (Belli, 2016).
7. Incubation for 80 to 126 days at 77 to 91 degrees Fahrenheit with hatching occurring in late summer or fall (Belli, 2016, Lovich, n.d.).

xii. Basking

1. Important factors in digestions, temperature, metabolism, reproduction, feeding, predator avoidance, and growth (Nyhof & Trulio, 2015).
2. Preference towards logs, branches, or steep, concrete sites in water but will also bask on shore (Lambert, Nielsen, Wright, Thomson, & Bradley, 2013, Spinks, Pauly, Crayon, & Shaffer, 2003).

c. Climate tolerances?

i. Increased temperatures may induce faster growth rate and larger overall size (Germano & Bury, 2001).

ii. Increased moisture (through precipitation or irrigation) will cause eggs to crack or burst, killing the embryo (Spinks, Pauly, Crayon, & Shaffer, 2003).

iii. Increased temperature will cause more females to develop (Belli, 2016, Lovich, n.d.).

iv. Decreased precipitation may lower water levels to unsuitable levels (Belli, 2016).

d. Spatial scales?

i. Overwintering site up to 500 meters offshore and an average of 13 meters in elevation (Pilliod, Welty, & Stafford, 2013, Spinks, Pauly, Crayon, & Shaffer, 2003).

e. Temporal scales?

i. Overwinter begins around June to November and ends January to April (Belli, 2016, Pilliod, Welty, & Stafford, 2013).

ii. Nesting site selection and use during April through August (Belli, 2016, Lovich, n.d.).

iii. Incubation for 80 to 126 days at 77 to 91 degrees Fahrenheit with hatching occurring in late summer or fall (Belli, 2016, Lovich, n.d.).

f. Response to disturbances?

i. Size varies according to climate. Increased temperature will result in increased growth rate and size. (Spinks, Pauly, Crayon, & Shaffer, 2003).

ii. Departure and return dates for overwinter depend heavily on timing of decreased water levels. Drought conditions in which water levels drop earlier will cause earlier departure dates while conditions will delayed increases in water level will further extend the overwintering cycle. (Pilliod, Welty, & Stafford, 2013)

iii. Increased temperatures will cause more females produced due to the 86 degree cutoff temperature (Belli, 2016, Lovich, n.d.).
iv. Prescribed burning or wildfires during times of overwintering will result in death of turtles in the immediate area (Belli, 2016).
v. Human activity disrupts basking, especially vehicles (Nyhof & Trulio, 2015).

3. Factors that may increase/decrease topic:
   a. Spatial controls?
      i. It is suggested to have a buffer zone of 250 to 350 meters to protect migrating turtles (Pilliod, Welty, & Stafford, 2013).
      ii. Overwintering site up to 500 meters offshore and an average of 13 meters in elevation (Pilliod, Welty, & Stafford, 2013, Spinks, Pauly, Crayon, & Shaffer, 2003).
      iii. Nests are anywhere from near the edge of the water to 400 meters away from the water (Belli, 2016).
   b. Temporal controls?
      i. Overwintering occurring a majority of the year from June to April (Belli, 2016).
      ii. Nesting site selection and use from April to August (Belli, 2016).
   c. What has been effective? Does this change between sites?
      i. Suggested to provide vegetation cover to protect turtles basking (Nyhof & Trulio, 2015).
      ii. Suggested to provide a buffer zone of 250 to 350 meters surrounding the shore and restrict all human activity here, especially during migration (Pilliod, Welty, & Stafford, 2013).
      iii. Cover to keep basking turtles hidden from human activity will promote native turtles over non-native turtles who are more likely to use basking sites exposed to human activity (Lambert, Nielsen, Wright, Thomson, & Bradley, 2013).
      iv. Urban areas will have a high number of specific predators compared to non-urban areas. These include rats, raccoons, and wading birds. (Spinks, Pauly, Crayon, & Shaffer, 2003).
      v. Headstarting can be used to shift population demographics to favor long-term survival by introducing more juvenile individuals and increasing the ratio of juveniles to adults (Spinks, Pauly, Crayon, & Shaffer, 2003).
   d. Key gaps for restoration?
      i. It is not known if headstarting negatively affects western pond turtle behavior compared to non-headstarted individuals though research so far points to no negative effects (Spinks, Pauly, Crayon, & Shaffer, 2003).
      ii. The exact effects of non-native turtles on wester pond turtles is not known but it is seen as being negative (Spinks, Pauly, Crayon, & Shaffer, 2003).
      iii. It is not known why individuals select specific sites for overwintering (Pilliod, Welty, & Stafford, 2013).
      iv. The reproductive biology is not well known (Belli, 2016, Lovich, n.d.)

Part II – Goals, Management, and Monitoring Plan

GOALS

Restore terrestrial vegetation to provide nesting and overwintering habitat

Temporal scale	Use of upland vegetation will be during the overwintering and nesting period. Overwintering begins as turtles begin to leave the water from June to November and ends as they return in January to April (Belli, 2016, Pilliod, Welty & Stafford, 2013). Nesting is done April to August (Belli, 2016, Lovich, n.d.). Restoration of the upland vegetation can be completed during any time of the project or to coincide with the start of overwintering and nesting. Long term monitoring should be done to ensure ideal species composition. Any decisions on monitoring intervals and length will need to be decided based on other project criteria such as what plant species are going to be used.
Spatial scale	Turtles travel 1.3 to 402 meters from shores to overwinter and nest (Belli, 2016). Restoration of turtle habitat should span from the shore to 500 meters from shore (Belli, 2016). Nesting habitat should be focused on the south facing shore (Geist & Gordon, 2015, Lovich, n.d.). Nests are 2.6 to 3.1 inches deep, 2.6 to 2.8 inches wide, and 1.4 to 1.6 inch wide entry and should be kept in mind in order to set aside areas that meet nesting site requirements (Lovich, n.d.).
Vegetation specifics and gaps	Soils should be silty or clayey (Lovich, n.d.) Overwintering vegetation should consist of at least 40% low vegetation under 1 meter from the ground and less than 24% high vegetation over 1 meter from the ground (Pilliod, Welty & Stafford, 2013). Overwintering sites have slopes between 0 and 40 degrees (Belli, 2016). There are no known preferred plant species. Nesting sites consist of sparse vegetation with no trees or shrubs, abundant light, and dry soil (Belli, 2016, Lovich, n.d.). Nesting sites have a slope of 0 to 15 degrees (Lovich, n.d.). There are no known preferred plant species. There is no information on number of nesting sites within western pond turtle populations. It would be ideal to provide at least one nesting site per female at minimum since they will usually raise one clutch per year on an almost yearly basis (Belli, 2016, Lovich, n.d.).

Feasibility	With no specific species of vegetation required and a wide range of criteria, turtle habitat should easily be included in upland restoration. There should be a wide range of different plant species that meet the criteria and can be used in restoration. The limiting factor will be reducing human activity within the habitat range which is vital during times of use by turtles. This may be a challenge due to the limited control over human activity. Fences may be built and pathways to direct human traffic in order to increase chances of successful reductions of human caused disturbances in turtle habitat.
Interactions	The mixture of grasses, shrubs, and trees may interact in which the initial vegetation composition changes to no longer fit overwintering and nesting site requirements. Additional management would be needed to keep the habitat zone to favor western pond turtles. Grazing animals may trample turtles, eggs, overwintering sites, or nesting sites (Lovich, n.d.). Grazing should not be done within turtle habitat. Human activity increases the risk of capture for pet trade, pet interactions (such as dogs), water contamination, trampling turtles, eggs, or habitat, and predation (Belli, 2016, Lovich, n.d.). Human activity should be heavily restricted within turtle habitat.
Tradeoffs	Human activity will need to be restricted within terrestrial turtle habitat, especially during times of overwintering and nesting. This may be a challenge to do and creative solutions may be required. Limited human activity in the upland area may restrict access to waterways. This may limit potential recreational activities such as fishing and swimming. Paths may be needed to be installed to provide access to the waterways.

Restore aquatic habitat and provide basking sites within

Temporal scale	Western pond turtles are not known to have any preference for a specific type of waterway and have been found in perennial, temporary, and seasonal waterways (Belli, 2016). There is no specific restoration needed in timing or presence of seasonal drying.
Spatial scale	There is no information on exact depths or lengths of waterways in which turtles normally reside in. There is preference towards deeper ponds with complex runs and backwaters (Belli, 2016).

Specifics and gaps	There should also be emergent vegetation present in the preferred area (Lovich, n.d.). There is no preferences toward specific species of emergent vegetation or to what extent the vegetation should spread. Some vegetation that may be useful as part of the western pond turtle diet and used in restoration includes tule, cattail, and alder (Belli, 2016, Germano, 2010, Lovich, n.d.). Basking sites should be within the preferred areas. These can be logs, branches, or steep concrete sites in the water (Lambert, Nielsen, Wright, Thomson & Bradley, 2013, Spinks, Pauly, Crayon & Shaffer, 2003). The number of basking sites should support the turtle population. There is no specific ratio of basking site area to western pond turtle population. It would be ideal to provide a minimum amount of basking surface area that will support an approximate area that the entire population would cover if placed together. For example, if an adult turtle grows up to 7 inches long and 4 inches wide and the population consists of 6 juveniles and 3 adults, it would ideal to provide the area for 9 adults. A single turtle will cover an area of 28 square inches and 9 adults will cover 252 square inches. Therefore, a minimum basking surface area should be 252 square inches.
Feasibility	Providing adequate aquatic habitat and basking should be easily done once a preferred site is selected. There are many emergent plant species that may be chosen and multiple plant species that also can be used in the turtle diet. This will give many options for plant species to use in restoration and allow flexibility in selection. Once the site is selected, all that is required is ensuring basking sites. These should be cheap to make or find since basking sites are usually floating wood or rocks.
Interactions	Interactions between western pond turtles and non-native turtles are most noted on basking sites (Spink, Pauly, Crayon & Shaffer, 2003). This is mostly due to the response to human disturbance. Non-native turtles are more likely to remain on basking sites when disturbed while western pond turtles are more likely to leave the site and enter the water. This can have negative effects on digestion, temperature, metabolism, reproduction, feeding, predator avoidance, and growth (Nyhof & Trulio, 2015). More basking sites may be required if there is high competition between non-native and western pond turtles for basking sites.
Tradeoffs	Basking sites should be in areas with little human activity. Visitors may be tempted to search for basking turtles as well as other aquatic habitat. It may be beneficial to provide the majority of basking sites hidden from human activity and providing a small amount in a designated viewing area to deter disturbance from visitors searching for western pond turtles.

Introduce and maintain stable population demographics and numbers

Temporal scale	There is no information on the length of time it takes for western pond turtles to distribute between or to new habitats. The length of time to wait for turtles to distribute and establish to the restored site will have to be decided on a project by project basis. Since western pond turtles travel to and from overwintering sites between June and April, it may be appropriate to wait a full year after restoration is completed from June through the following June. If choosing to headstart western pond turtles, incubation occurs over the course of 80 to 126 days (Belli, 2016, Lovich, n.d.). The release of hatchling turtles should be planned to represent the time in which western pond turtles normally hatch which is during late summer or fall (Belli, 2016, Lovich, n.d.). If headstarting to the juvenile stage is done, the turtles should be released when overwintering usually ends during January through April (Belli, 2016). If any relocation of western pond turtle is done, it should not be done during overwintering or nesting use. Overwintering ends in April while nesting begins in April. April would be the most likely time to remove turtles during times in which they are not hibernating or actively nesting a clutch.
Spatial scale	Western pond turtles can travel up to 500 meters upland to overwinter (Belli, 2016). It would be plausible that they are able to travel up to 1000 meters in a season but dispersal distances may not be the same as overwintering distances. If there are no western pond turtle populations within 1000 meters of the restored site, it may be necessary to relocate or headstart the turtles to place at the restored site. There is no information on relocating or headstarting western pond turtles for restoration. Since most of the western pond turtle's diet is within water, it would be ideal to release these turtles close to the water's edge but on a very gradual slope to allow the turtle to ease into the water instead of drop in suddenly.

Specifics and gaps	If neighboring populations exist and sufficient connectivity between the two areas exists, it is feasible that members from the neighboring population will distribute to the restoration site. Western pond turtles travel to and live in habitats such as lakes, ponds, streams, rivers, stock ponds, sewage plants, canals, and reservoirs (Belli, 2016). There is little information on how turtles distribute between sites and may be further researched during restoration and monitoring. If no neighboring population exists or it is unknown, individuals may be captured from known populations in habitats similar to the restoration site and introduced. Eggs may also be taken from the populations and headstarted in order to introduce individuals. The appropriate permits will be needed if there is any handling of turtles or eggs. There is no information on exact demographics other than there should be more juveniles than adults present in the population (Spinks, Pauly, Crayon & Shaffer, 2003). Based on some known principles, it may be best to release juveniles if starting a population from scratch. If there is a neighboring population, adults, in addition to the headstarted juveniles, may be also moved into the restoration site's population in order to better represent healthy demographics. Both juveniles and adults may also be caught and released with no headstarting. If this is done, there will need to be more juveniles than adults. Any release should be done slowly at first and carefully monitored to ensure the conditions will sufficiently support western pond turtles. Once the turtles have successfully survived through an allotted time, full release can be done. The allotted time would ideally be at least a full year in order to include overwintering. There is no data on previous introductions of western pond turtle. There will need to further research done during restoration and monitoring to learn more about headstarting and introducing western pond turtles into new habitat.
Feasibility	This may be the most difficult goal to accomplish due to the limited information. More information gathered during restoration and monitoring may increase the likelihood of establishing a western pond turtle at the site. Until more information is gathered, educated guesses based on the known information will need to be done and mistakes may be made. This may result in turtle deaths and money used that does not result in successful introduction. Turtles are known to take advantage of many types of habitats and it is likely that if the restored habitat is suitable a wester pond turtle will be able to survive (Belli, 2016).
Interactions	There is also little information on the effects of headstarting on behavior and how these individuals interact with other western pond turtles, other species, and the environment (Spinks, Pauly, Crayon & Shaffer, 2003).
Tradeoffs	Ensuring introduction into the restored site may be complicated and require heavy monitoring. This may require additional staff or additional time to collect information and potentially headstart turtles.

PLAN

Restore terrestrial vegetation to provide adequate nesting and overwintering sites

Temporal scales	Western pond turtles spend a majority of the year roaming terrestrial habitat for overwintering and nesting. They can leave the aquatic habitat and travel upland for overwintering beginning anywhere from June to November and returning sometime between January and April or for nesting between April and August (Bell, 2016, Pilliod, Welty & Stafford, 2013). The nesting areas should be maintained April through August (Belli, 2016, Lovich, n.d.).
Spatial scales	Western pond turtles travel at a range of 1.3 to 402 meters upland with an average distance travelled upland of 100 meters (Belli, 2016). Terrestrial habitat restoration will remain within 500 meters of the water's shores. Nesting area should be focused on the southward facing slope up to 400 meters from the shore (Belli, 2016, Geist & Gordon, 2015, Lovich, n.d.). It is unknown how much area is required for nesting of western pond turtles. Most females will have one to two clutches in a year with 13 eggs in a clutch (Belli, 2016, Lovich, n.d.). In this case, it would be best to provide enough nesting sites to provide at least one clutch per year per females.
Specifics	The ideal soil is silty or clayey (Lovich, n.d.). The vegetation within the south facing slope must consist of at least 40% coverage of low vegetation under 1 meter off of the ground and less than 24% cover above 1 meter off the ground (Pilliod, Welty & Stafford, 2013). Restoration should include distribution of plants that meet this criteria within the designated area. What species of vegetation and exact extent should be decide based on the project site and other goals. Nest are 2.6 to 3.1 inches deep, 2.6 to 2.8 inches wide, and an entry of 1.4 to 1.6 inches wide and are located in areas with sparse vegetation, dry soil, high light, and herbaceous vegetation and without trees or shrubs. These are also to be under a slope of 15 degrees (Lovich, n.d.). The nests should be designed to be incorporated within the vegetation on the south facing slope.
Alternatives	There is no record of nesting areas being built for western pond turtle use. There is the option of building nesting sites and researching nest site preferences and use.

Risks and uncertainties	During times of nesting, there should not be irrigation in areas with clutches. Increased moisture may cause eggs to crack, killing the embryo (Spinks, Pauly, Crayon & Shaffer, 2003). It is unknown how much area is required for nesting and is crucial to ensure population growth and stability. Information should be gathered as monitoring is done and changes made according to nest use and population growth. Monitoring may be required to be done long-term to ensure adequate upland vegetation composition and nesting area. Preferences of plant species are unknown and may be found during monitoring. Further management may be advised or necessary to increase these species.

Restore aquatic habitat and provide basking sites within

Temporal scales	Basking sites can be used throughout the year.
Spatial scales	Aquatic habitat restoration should be focused in selected areas that include any deep, complex pools, runs, and backwaters (Belli, 2016). There is no data on preferences toward certain depths or sizes of aquatic habitat. The size and location of the aquatic habitat should be decided based on the project site and other goals.
Specifics	There should be emergent vegetation in the selected areas. The vegetation may include species such as tule, cattail, and alder (Bellli, 2016, Germano, 2010, Lovich, n.d.). There is no data showing the necessity of these specific species or the extent in which emergent vegetation should be present. The species planted should be decided based on the project site and other goals. In these selected areas, basking sites should be provided in the form of logs, branches, or steep, concrete sites (Lambert, Nielson, Wright, Thomson & Bradley, 2013, Spinks, Pauly, Crayon & Shaffer, 2003). The total area of basking should be based on ideal population projections.
Alternatives	In these selected areas, basking sites should be provided in the form of logs, branches, or steep, concrete sites (Lambert, Nielson, Wright, Thomson & Bradley, 2013, Spinks, Pauly, Crayon & Shaffer, 2003).
Risks and uncertainties	There is no data given on ratio of basking site area to population and may need to be further researched during monitoring. Research and monitoring may show the need to move or provide more basking and should be done if this is the case.

Introduce and maintain stable population demographics and numbers

Temporal scale	There is no data on the length of time it takes for turtles to populate new habitats. If no neighboring populations exist or do not disperse to the restored habitat, active introduction may be done. Incubation period lasts from 80 to 126 days (Belli, 2016). The time to wait before actively introducing turtles will have be decided on a project by project basis.
Spatial scale	Before restoration is done, research should be done to locate any neighboring western pond turtle populations and potential connectivity. There is little research on the movement of western pond turtle between habitats. The potential of a neighboring western pond turtle population dispersing to the restoration site will need to be based on factors such as a connecting tributary or corridor and distance. Since overwintering travel occurs up to 500 meters (Belli, 2016), it would be plausible for a turtle to travel up to 1000 meters within one season. There may be limited dispersal if the neighboring population is more than 1000 meters away.
Specifics	The western pond turtle is a Species of Special Concern under California's Department of Fish and Wildlife (Spinks, Pauly, Crayon & Shaffer, 2003). Special permits are required when handling the western pond turtle and must be approved prior to interaction. Individuals should be selected from areas with similar conditions to the restoration site. There is no ideal way to capture a turtle. Methods include cages, holes, and nets. Eggs may also be taken to be used for headstarting, if desired. If headstarting is done, temperature must be selected based on desired sex. Temperatures range from 77 to 91 degrees Fahrenheit. Temperatures above 86 degrees Fahrenheit yield females and temperatures below 86 degrees Fahrenheit yield males (Lovich, n.d.). Age of turtles released following headstarting should be decided on the current demographics, if any. There should be more juveniles than adults (Spinks, Pauly, Crayon & Shaffer, 2003). If no current population exists, juveniles should be released in order to provide fertile individuals to further increase the population. Release of these headstarted individuals should reflect when overwintering ends from January to April (Belli, 2016).
Alternatives	There are multiple options that may be chosen to ensure establishment of a western pond turtle population at the restoration site. The options are to allow natural dispersal from a neighboring population, active introduction through capture and release, active introduction through headstarting, or a combination of these.

Risks and uncertainties	There is no research on the effects of headstarting on western pond turtle behavior and should be researched during monitoring. There is also no data on the process of introducing western pond turtles to new habitat. Further research should be compiled during introduction and adjustments made according to information gained. With limited studies done on ideal population demographics, all that is known is there should be more juveniles that adults (Spinks, Pauly, Crayon & Shaffer, 2003). Further research should be done to compile more information on healthy population demographics such as sex ratio and age ratios. Headstarting may need to be done following introduction in order to maintain stable population demographics.

MONITORING

Pre-restoration	Research should be done in order to find any neighboring populations. If any are located, the population should be monitored to gain information on the number of individuals, sex ratios, and age ratios. Gathering this information can be very difficult. The usual way to compile this information is through observation and capture-release over the course of a non-overwintering season such as April to June. Monitoring would ideally be done over the course of multiple seasons but a minimum of one is required (Belli, 2016, Germano & Bury, 2001). Any movement that would indicate potential dispersal into the restoration site should be identified. If there is not any indication of movement between sites, active introduction should be further discussed as a possibility. It should be assessed whether the population is stable enough to spare individuals for introduction at the restoration site. There is no research on what constitutes healthy population levels or demographics other than there being more juvenile individuals that adults (Spinks, Pauly, Crayon & Shaffer, 2003). Monitoring any neighboring populations may provide more insight into stable population demographics. Monitoring of neighboring population should be done for 6 to 7 years since this is the time it takes for hatched individuals to reach sexual maturity. Hatched individuals should be monitored for the amount that reach sexual maturity and which do not. The death of these hatchlings should also be monitored in order to gain insight on what is causing deaths. If there are low levels of hatchlings reaching sexual maturity or deaths recently occurring due to disease, catch and release from this population should not be done.

Post-restoration	The terrestrial habitat should be monitored for any changes in species composition. While this is being monitored, selection of overwintering and nesting sites should also be monitored. If preferences are discovered and species composition does not reflect these observed preferences, changes may be needed to increase the preferred species and habitat. This may include planting additional plants, removing plants, or increasing density of vegetation. Overwintering site selection should be monitored from June to November and nesting site selection should be monitored from April to August. This should be done by observing turtles while they search for overwintering and nesting sites during the relevant months. This will give insight on what similar characteristics are seen between the selected sites and the methods that the turtle uses while selecting them such as digging. If any additional information is gained there may be changes needed to be made such as additional planting or removal of plants. There is no set length of time in which monitoring should be done in the long term and should be decided based on the resilience of the vegetation community, wester pond turtle population, and information collected on site selection. This could be decided ahead of time based on number of generations such as 5 or decided once a stable population is reached. The aquatic habitat should be monitored for basking site use. Basking sites should be assessed for any preference and adequate area to support the population. If any preferences are found, sites may be switched out for this type of basking site. If basking sites are too full, additional basking sites may be added. Monitoring should be done during times in which overwintering and nesting is not occurring from April to June. This is when use would be the highest (Belli, 2016, Lovich, n.d.). Long term monitoring should be decide based on population stability. If the population is still increasing, there should be continued monitoring to ensure adequate basking area and additional basking area may be needed. There is no data on how much basking area is required for western pond turtles and should be researched during monitoring. The population should be monitored for stable demographics to ensure long-term survival. Sex ratios, age ratios, and population numbers need to be measured. These would need to be done through catch-release in order to access exact age and sex of individuals. Little information is available on stable demographics. It is known that juveniles should outnumber adults but to what extent is not specified (Spinky, Pauly, Crayon & Shaffer, 2003). This should be further researched during monitoring and plans be based on information gained. These may need to be monitored indefinitely in order to ensure long-term survival. If unsafe demographics are found, there may be the need to headstart individuals into the population and underlying conditions of unstable demographics should be identified. This may mean that hydrology needs to be changed or additional vegetation is planted. If any changes are made, additional monitoring will be needed to ensure

	changes made result in positive outcomes in the population.

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Tiger Salamander

Ambystoma tigrinum

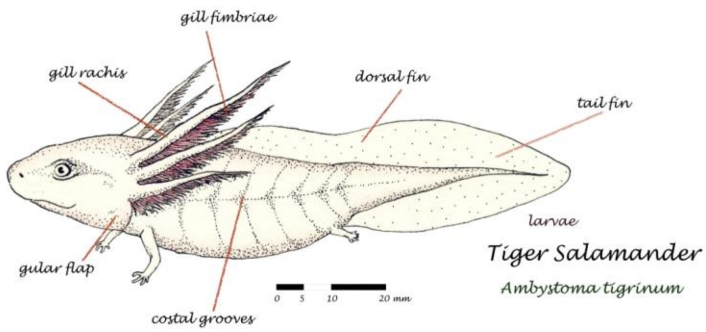

fig 1. Detailed Drawing of Larvae Tiger Salamander by Yangchuan Tian

Background and Justification

Salamanders (*Ambystoma tigrinum*), ancient vertebrates, are widely distributed in North, Central, and South America, Europe, and temperate eastern Asia (Davic, 2004). Especially, tiger salamander is a geographically widely-distributed and morphologically variable species in California's central valleys, adjacent foothills and coastal grasslands, which are characterized by a Mediterranean climate of hot and dry summer, cold and rainy winter (Loredo and Dirk, 1996). They are usually found terrestrial and aquatic habitats, for example, moist forest leaf litter, "underground retreats," tree canopies, "talus slopes," headwater streams, "riparian ecotones," ponds, swamps, caves, and "seasonally inundated pools" (Petranka, 1998). The tiger salamander has evolved "extensive ecological diversification" for 150 to 200 million years and plays an important role in ecology, helping to regulate food webs and ecosystem stability and integrity in many different ways. (Davic, 2004). Salamanders provide many important ecological functions in terrestrial and aquatic environments, which largely depend on their conservation (Davic, 2004). The tiger salamander population has reached a peak during the 1950s. However, factors including habitat loss caused by urbanization, pollution, infectious wildlife disease and warming climate have led this susceptible species to a dynamic decline and near extinction (Barry, et al., 1994). Research has shown that nearly three fourths of forest ecosystems in North America are considered endangered. Because of the huge threats to ecosystem integrity and health, the declining tiger salamander population needs more attention (Davic, 2004).

Literature Review- Part Ⅰ

<u>Basic Characteristics and Reproduction</u>

Tiger salamanders are "neotenic" species, which means the retention of some juvenile characteristic in salamander adults. They can grow to 6-8 inches (about 15-20 cm) and a maximum of 14 inches (about 36 cm) in length theoretically (Barry, et al., 1994).

Adult tiger salamanders usually have dark grey, dark green, or black body, blotchy dorsal and lateral with scattered white or yellow spots; larvae tiger salamanders are yellowish-grey long, feathery external gills and an elongated “dorsal-caudal” fin, which are very distinguishable (Barry, et al., 1994).

During the winter or early spring, tiger salamanders will come out of hibernation and start their breeding season. Female salamanders usually can laying up to 1,000 eggs, and those fertilized eggs would stick on the weed mass near water’s edge. The incubation of eggs usually takes from two to four weeks depend on water temperature. Warmer water could defiantly accelerate the development of incubation (Barry, et al., 1994).

Typically, tiger salamanders breed in “ephemeral ponds” that fill during winter and dry by summer. “Breeding migration are ‘nocturnal’ and begin with the onset of the rainy season, usually in November or December (Loredo and Dirk, 1996).”

The larvae tiger salamander is entirely aquatic and feed on algae and aquatic invertebrates. “They usually grow rapidly, and metamorphose as the pond water level recedes in late spring or summer (Barry, et al., 1994).”

Breeding population structure varies, potentially affecting “sexual selection,” “genetic drift” and “demographic traits.” Migration patterns of salamanders are largely influenced by environmental conditions such as rainfall and temperature. The migration of adult tiger salamanders from aquatic breeding habitat usually happens during he period from November to April. And rainfall would definitely affect the amount of available water in the wetland, that affects the breeding habitat suitability (Loredo and Dirk, 1996).

Sexual maturity of the tiger salamander is four to five years old, and individual longevity can exceed ten years (Trenham, et al., 2000).

Less than 50% of salamanders can breed more than once in their entire life due to the instability of climate. For example, when the weather condition is not suitable for them to reproduce (Trenham, et al., 2000).

Habitat Preferences and Environmental Tolerance

“Tiger salamanders is always found in the Central Valley and adjacent foothills and coastal grasslands (Loredo and Dirk, 1996).”

Tiger salamanders are almost entirely terrestrial, and only return to the water for breeding. They can partly live in both land and water, however, they are rarely in open space on the ground, usually live in burrows which are usually two feet from the surface (Trenham, et al., 2000).

Most adult tiger salamanders settled in mammal burrows and the distance between the pond and settlement sites ranged from 10 to 130 m (Trenham, 2001).

Tiger salamander can tolerate a wide range of temperature varying from less than 5°C at the beginning of the year up to 30°C during the hot summer (Semlitsch, 2002).

Mammal animals' burrows outside the wetland or ponds provide "refuge" for metamorphosed salamander in the terrestrial environment to avoid harsh environmental conditions (Semlitsch, 2002).

However the depth of those burrows reduces the distance over but also critical for salamander survival through the hot dry summer in central California, where daytime temperature commonly 37°C and monthly rainfall averages less than 1mm (Trenham, 2001).

They are extremely loyal to their birthplace, and will travel long distance to reach them (Trenham, et al., 2000).

Drought years may affect the breeding process of local tiger salamander, since "ephemeral rain pools" may dry up (Barry, et al., 1994).

Tiger salamanders are commonly associated with natural and artificial aquatic habitats in montane conifer forests, interior chaparral and subalpine grasslands at elections >1,500 m; (Collins, 1981).

Environmental and Ecological Threats

"The California tiger salamander is considered a species of special concern by the state of California, and recently the U.S. Fish and Wildlife Service listed the remaining populations in Santa Barbara County as endangered (Trenham, 2001)."

As a one of the wildlife disease, recurring "ranaviruses" infection cause severe morality of tiger salamander larvae (Daszak, 1999).

The population of California tiger salamander is susceptible to a unprecedented virus called "*Ambystoma tigrinum* virus" that may reduce survival and inhibit the larvae growth and development (Picco, 2007)

Invasive/alien hybrid tiger salamander are top predators in seasonal ponds which threatened native species (Ryan, 2009).

Global change including climate change and UV radiation penetration could cause the tiger salamander population decline by increasing the toxicity of the water and cause developmental abnormalities of salamanders' embryos (Collins, 2003).

Environmental contaminants, including DDT and DDE, have negative impact on amphibian's "gonaducts" which could disrupt salamanders and other amphibian's reproductive system (Clark, et al., 1998). The research studied the impact on immature gonads by immersing them in the solution of *p,p′*-DDE or technical-grade DDT (80% *p,p′*-DDT and 20% *o,p′*-DDT) and injecting DHT to the larvae (Clark, et al., 1998).

Urbanization and conversion of natural habitat to agricultural land use cause habitat loss and fragmentation which threat to this vulnerable species (Loredo and Dirk, 1996).

Conversion of grasslands to urban or agricultural uses in central California increase grazing, drought, pollution, harmful pathogens and human disruption that may harmful to tiger salamanders (Barry, et al., 1994).

Land development and grading operation disrupt tiger salamander's habitat, such as ephemeral pools and aestivation sites, which are probable reason of salamanders mortality (Barry, et al., 1994).

Human disruption kill large amount of salamander by using tiger salamander larvae as fishing bait, so called "water dogs" and translocating by anglers or for other pet trade (Barry, et al., 1994).

As a predator, the presence of tiger salamander in some "fishless" ponds could affect the population densities of zooplanketer, ostracods, macro invertebrates, odonate larvae negatively and correlated benthic chironomids positively (Holomuzki, et al., 1994).

Predation by non-native fish or bullfrogs decrease the population of salamander larvae (Maret, 2006).

Pathogens on diseased dead salamander could cause the massive death of salamanders through their cannibal behavior (Pfenning, et al., 1991).

Potential Management Actions

Overall, protecting wetlands, controlling habitat fragmentation and restricting movement of alien species all conserve native amphibians (Collins, 2003).

Conserving core terrestrial habitat (wetland) for maintaining the salamander population and diversity (Porej, et al., 2004).

Providing a "bidirectional" migration corridor between the lake and the hillside aestivation area to reduce the impact of automobile traffic on migrating salamanders and to minimize the loss of larvae during the lake drainage (Barry, et al., 1994).

Fencing the wetland pools help to divert post-spawning and post-metamorphosing salamanders to the same tunnels to reach their aestivation site (Barry, et al., 1994).

Slow drainage of the lake during late July which is the metamorphose time of salamanders could allow most or all of the larvae to metamorphose (Barry, et al., 1994).

A possible approach is excavating a long, shallow ditch in the lake bed would trap water and probably larvae as the lake is drained (Barry, et al., 1994).

Encouraging rodent populations, because rodent's burrows are salamanders' primary aestivation site (Barry, et al., 1994).

The small constructed and managed agricultural farm ponds could help sustain amphibian populations in landscapes where natural wetland is scarce (Knutson, et al., 2004).

Gaps in Knowledge

Tiger salamanders' terrestrial habitats, aquatic habitat, and buffer requirements are still relatively poorly understood.

The negative impacts or threats of the presence of tiger salamanders as predators on other species.

- California tiger salamanders microhabitat preferences within the total habitat area.

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A. Goal

The tiger salamander is federally listed as endangered. Specifically, California tiger salamanders will soon be in danger of extinction throughout its range and distribution (Barry, et al., 1994). Salamanders are very susceptible when they face fickle external conditions or events, such as drought, flooding and wildlife diseases. Urbanization and conversion of natural habitat to agricultural land use causes habitat loss and fragmentation which also threatens to this vulnerable species (Loredo and Dirk, 1996). Due to limited distribution and habitat, the tiger salamander is threatened in the Central Valley. From previous research on the tiger salamanders' life history, the threat and loss that led this species to be endangered includes warming climate, pollution, predation by introduced species, infectious wildlife disease, low genetic diversity, disappearance of natural standing water habitat, over-utilization by anglers and collection for bait (Barry, et al., 1994). Therefore, in order to achieve the success of restoring tiger salamanders, my main goals are listed as follows with the requirement each sub-goals:

Goal 1. Reducing habitat threats and maintain pools or waterways

- maintaining the water level through the breeding season
- preventing pollution
- stabilizing temperature and moisture
- preventing from drought and flooding

Goal 2. Reducing threats to tiger salamanders

- removing predators
- preventing infectious wildlife disease introduction
- preventing human 'take' consumption
- preventing traffic death

Goal 3. Restoring and introducing tiger salamander

- identify the current habitat
- ensure food resources
- release tiger salamander

B. Restoration Plan

Goal 1. Reducing habitat threats and maintain pools or waterways

- maintaining the water level through the breeding seasons from November to April (Loredo and Dirk, 1996)
- In order to prevent pollution, manager should regulate agricultural pollution to the waterways and pools. Eliminate any use of DDT & DDE near site pools, since DDT could disrupt reproductive system of tiger salamander (Clark, et al., 1998). Though there is no information found about specific distance should be aways from the restoration area, the selected site should be as far from potential DDT used area as possible.
- In order to maintain temperature and moisture, using adequate taller grass around the pools to keep cool and moist at the range from 20°C to 30°C (Semlitsch, 2002).
- To prevent restoration pools from drought, we can irrigate the pools as needed to maintain the water level during the breeding season.
- Try to avoid frequent-flooded area, even fast moving water is harm to juvenile tiger salamanders. If the site has fast moving water, it could definitely be a threat to tiger salamanders' eggs and larvae.

Goal 2. Reducing threats to tiger salamanders

- Removing and controlling introduced non-native predaceous animals, such as bullfrogs, fish, and cray fish. In the aquatic habitat, the presence of introduced non-native fish or bullfrogs will decrease the population of salamander larvae by preying on salamander larvae. "Several salamander population have been extirpated by fish introductions." The report shows that as early as the 1950's, various introduced fish species including "mosquito fish (*Gambusia affinis*), green sunfish (*lepomis cyanellus*), bluegill sunfish (*Lepomis macrochirus*), black bullheads (*Ameirus melas*) and largemouth bass (*Micropterus salmoides*)." Since at least the early 1970's, bullfrogs (*Rana catesbeiana*) have been introduced to the valley. From previous laboratory and field experiment, it demonstrated that all fish species listed above and metamorphosed bullfrogs can quickly eat salamander larvae (Maret, 2006). Non-native fish and bullfrogs should be considered a big threat to tiger salamanders, therefore, these non-native predator should be removed from the specific ponds that contain tiger salamanders.
- Preventing infectious wildlife disease by eradicating the diseased individuals and checking the disease potentials in other nearby areas. If possible choose the restoration site as far away from disease population if know as possible and continue monitoring the disease condition within the site.
- Preventing human 'take' consumption, such as over-utilization by anglers and collection for bait.
- Preventing and minimizing the mortality caused by traffic by providing a "bidirectional" migration corridor between the lake and the hillside aestivation area to reduce the impact of automobile traffic on migrating salamanders and to minimize the loss of larvae during the lake drainage (Barry, et al., 1994). Additionally, human transportation threaten the migration of tiger salamander and increase the morality rate to a large extent.

Goal 3. Restoring and introducing tiger salamander

- identify the current habitat before make a decision by testing the vegetation coverage, water temperature, heavy metals or environmental contaminant within the area and focus the effort on where has the best condition.

- Maintaining and enhancing the existing habitat where salamanders have been found in Central Valley; and designing ad creating them new habitat if deemed necessary. The most crucial habitat types for tiger salamanders in Central Valley, where is characterized by a Mediterranean climate of hot and dry summer, cold and rainy winter is the adjacent foothills and coastal grasslands (Loredo and Dirk, 1996). Most importantly, tiger salamanders begin their life in the water. They require the availability of aquatic habitats, like standing water, for breeding and larval growth from about December to June (Petranka, 1998). Because of the "restricted" distribution of tiger salamanders, they are very vulnerable to small-scale environmental disturbances and land-use changes (Collins, 1981). The proportion of larvae that metamorphose depends heavily on pond permanence. For example, In ponds that do not dry, approximately 17% of larvae that are large enough metamorphose; however, all larvae that are large enough metamorphose in ponds that are dry (Collins, 1981). In addition, tiger salamanders have prolonged time period of terrestrial activity throughout most of time in autumn till the winter for their following life stages, including juveniles and adults (Barry, et al., 1994). Since the natural standing water habitats continuously disappear, some remaining ponds from springs and "cienegas" and new built ponds become exclusive breeding habitat which means that nowadays tiger salamander are extremely dependent on human to maintain their habitat (Collins, 1981).
- Ensuring food resources, such as plankton, for introduced tiger salamander to live with.
- Release tiger salamander from nearby population in an adequate amount of population in multiple pools so that can increase the gene flow as well as genetic diversity.

<u>C. Monitoring Plan</u>

- In order to keep tiger salamanders away from DDT and DDE (Clark, et al., 1998), keeping track on those environmental contaminant within the site. If any pollutant is found, find the source and eliminant it.
- keep checking for the wildlife disease. Monitoring and making sure the infectious disease is not present anytime any place within the site. If any infectious disease or pathogen is found, find source, eradicate the disease and report it.
- keep checking food sources, such as plankton, to make sure tiger salamanders have enough resources in the site. If their food resource is not enough, reintroduce new resources as needed.
- Monitoring tiger salamanders' population and their habitat including age structure, female fertility and productivity, the number of breeding population, distribution, and type of available habitats by checking their egg mass or larvae mass (Gascon, 2007). Not only preparing monitoring schedule and protocol, monitoring should based on the idea of minimizing known threats by different factors listed before, such as non-native predator, fragmentation and extended habitat drying (Series, 2008).
- Controlling non-native predators inside and outside the aquatic area by doing survey, including dish, bullfrogs, and crayfish, by enforcing regulations prohibited the introduction of non-native predators to the designed aquatic ponds or watershed due to they threaten to eliminate the existing tiger salamanders (Series, 2008). If bullfrog can be founded, management group should search for those population and their access to the site.

- Conducting more specific field of research to acquire demographic and dispersal knowledge information and to develop a population viability analysis (Series, 2008), better understand salamander disease, like the control of “ranaviruses” infection, agricultural pollution such as DDT and DDE, lower pH and determine distribution of predaceous animals, etc. In order to improve the restoration plan, more supportive data are still needed to make final definitive statements about the long-term viability of tiger salamanders. Previous researches have very limited records to determine a larger scale trend of the salamanders’ population and make it more difficult to decide the suitability of previous recovery plan for salamander breeding habitat. Therefore, more useful data and knowledge on the ecology of tiger salamanders, such as life-span, life stages, frequency and distance of dispersal events are required to develop a suitable population viability analysis plan (Series, 2008).

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The Foothill Yellow-legged Frog (*Rana boylii*)

Background & Justification:

The foothill yellow-legged frog (*Rana boylii*) is a species of amphibian that once inhabited nearly every drainage in the western part of California from the Oregon border to Los Angeles County (Morey 2000). Currently, the population has become unevenly distributed and decreased in overall abundance (Morey 2000). The largest parts of the population inhabit the nearby north coast range (Lanoo 2005). However, this species is listed as near threatened as the population has dropped precipitously in some regions (Santos-Barrera 2004). The decline can be attributed to the introduction of aquatic species and the stabilization of historically changing water flows due to the construction of dams. (Santos-Barrera 2004). As *Rana boylii* was once one of the most abundant amphibians, its decline has consequences higher up in the food chain. A variety of animals prey upon these frogs – from herons to American Dippers, from raccoons to garter snakes (Ashton 1997). Additionally, native amphibians serve as a vital indicator of general environmental health. Since frogs have permeable skin, they are especially sensitive to water-borne contaminants. Thus when frog populations decline, they serves as a warning sign of potentially hazardous environmental conditions for other species, including humans (Chanson and Boucher 2004). Since their primary diet is insects and algae, they also may play an important role in keeping pest populations and algal blooms under control (Chanson and Boucher 2004). Therefore, it is essential to conserve the foothill yellow-legged frog.

Literature review:

Reproduction

- Breeding occurs only in low velocity pools along streams (Wheeler et al. 2008).
- The eggs are attached to underwater surfaces in slow moving parts of the stream (Wheeler et al. 2008).
- Masses typically contain around 900 eggs (Ashton 1997).
- The start of the breeding season is signaled by the rate of stream flow (Wheeler et al. 2008).
- The rate of stream flow on the first day of the start of the breeding season determines the length of the breeding season (Wheeler et al. 2008).
- They exhibit characteristics of either prolonged or explosive breeders, as their breeding season can last from less than three weeks to seven weeks (Wheeler et al. 2008).
- They display characteristics of lek mating system in which males display at one site and do not assist in providing resources for their offspring (Wheeler et al. 2008).
- Females assess males by their vocalizations (Wheeler et al. 2008).

Habitat preferences and requirements

- They require 20%-90% stream shading (Hayes and Jennings 1988).
- They are typically found in shallow streams (water depth of <.6m) with riffles and at least cobble-sized submerged substrates (Hayes and Jennings 1988)
- They require either intermittent streams with year-round pools of water or perennial

streams (Hayes and Jennings 1988).

- Tadpoles require water for a minimum of 3-4 months (Morey 2000).

Food sources

- Increasing the presence of algal diatoms is linked to increased tadpole survival to the juvenile life stage (Kupferberg 1997). Therefore land managers need to ensure the presence of some algal blooms in order to increase frog survivorship.
- The adult frog diet includes moths, ants, hornets, beetles, grasshoppers, water striders, flies, snails, and spiders (Ashton 1997).

Predators

- Garter snakes consume the tadpoles and juveniles (Lanoo 2005).
- Rough-skinned newts eat frog eggs (Lanoo 2005).
- Direct predation by bullfrogs, in addition to bullfrog larval competition for algal resources, reduces the foothill yellow-legged frog abundance by one order of magnitude (Kupferberg 1997).

Abiotic variables

- Frog developmental rates depend on the water temperature: slower development with lower temperatures (Ashton 1997).

Spatial scale needed

- Their average home range is no longer than 10m (Morey 2000).
- They are rarely found more than 50m from a water source (Morey 2000).

Temporal scale needed

- Their life span is not known (Lanoo 2005).
- They breed and lay eggs at the close of spring floods (March to May depending on the region) (Morey 2000).
- Tadpoles metamorphose in 3-4 months (Morey 2000).
- Most adults breed for the first time in the second year after metamorphosis (Ashton 1997).

Threats

- Aerial pesticide drift is a plausible cause of the observed California amphibian decline. This particularly impacts the Southern Sierra Nevada foothills because this region is downwind from the intensive agricultural region of the San Joaquin Valley (Davidson et al. 2002).
- Unnatural flow regimes because of dams can either desiccate or wash away egg sacs during times of low flow or high flow, respectively (Lind et al. 1996).
- The development of California's water infrastructure, specifically the construction of

dams in the last 40-50 years, has destroyed or fragmented this frog's habitat (Wheeler 2013).

Potential Management Actions

- Land managers should monitor stream flow to guarantee sufficient flow at critical times of the year.
- When replanting vegetation, land managers should plan for sufficient shade cover for suitable frog habitat.

Gaps in Knowledge

- Comprehensive surveys should be completed to determine the current population size and extent in Solano County.
- More research needs to be done on the feasibility of reestablishing a viable population in Centennial Park.
- More funding and research needs to be focused in better understanding the details of their life history, including such facts as the length of their life span.

I. Goals

A. Restore and Improve Physical Habitat

Setting clear restoration goals for *Rana boylii* is difficult as land managers need to know how many breeding females a population requires to survive a few consecutive years of low recruitment. Additionally, in order to set targets, scientists need to know how often the years of high recruitment must occur to keep up a viable population (Kupferberg 2009). As they are only a near threatened species, there is insufficient research focused on *Rana boylii* healthy population sizes, as funding and research tends to focus on more endangered species such as *Rana muscosa.*

However, in order to maintain a viable population (no matter the precise size), habitat is critical. The following bullet points outline the necessary habitat benchmarks:

- Unlike other ranids, this species has strict water requirements; it is rarely found far from water, as their home range is only 10m (Morey 2000).
- When replanting vegetation around restored stream sites, ensure that there is at least 20% cover over the water (Hayes and Jennings 1988).
- If the stream bed is manually reshaped, shallow riffle habitat of water depth of less than .6m comprising at least 40% of the total stream area is preferred by this species (Hayes and Jennings 1988) with slow moving regions for breeding and egg laying (Wheeler et al. 2008).
- Cobble stone sized substrates are required for egg mass attachment (Lind et al. 2015).
- The only temperature-related study was conducted on the dammed, snowmelt fed Trinity River in Northern California. For oviposition to occur, the water temperature warms to 12 degrees Celsius, the hydrograph is on the descending limb, and there are increased hours of daylight (Kupferberg 1996).

- A study conducted in the Coast Range rain-fed streams showed that water velocity needs to be 0.010–0.049 m/s in oviposition sites (Lind et al. 2015). As some of the streams feeding into the Central Valley are rain-fed, this knowledge is applicable.

Given adequate funding, physical site restoration is feasible. Revegetation and designing channels to include cobblestone substrates, slow moving pools, and riffles is possible. Restoration difficulties may arise in dammed systems as land managers may find it difficult to convince hydroelectric dam operators to release water according to natural regimes because this may decrease the efficiency of electricity generation.

B. Remove Invasive Species

Nonindigenous bullfrogs prey directly on foothill yellow-legged frogs, in addition to larval competition for algal resources. This reduces frog abundance (Kupferberg). Thus, bullfrog eradication would improve overall population viability. Depending on the site, this may not be feasible. Bullfrogs have a widespread distribution and thus recolonization following eradication is a serious possibility.

II. Restoration Plan

A. Providing vegetative cover

To ensure at least 20% shade cover over the stream, the restoration site needs to be carefully replanted. This may include such native plants as willows (*Salix)*, elderberries (*Sambucus*), and cottonwoods (*Populus*). However, land managers should be wary of planting areas of dense tree cover because the frogs are typically not found in sites with greater than 90% shade (Hayes and Jennings 1988). Thus, replanting streamside native grasses may be advantageous in conjunction with well-spaced tree plantings. Vegetative cover is not only important in regulating stream temperature, but it also provides places to hide from predators and other hazards.

B. Remove dams or mimic natural flow regimes

Since frog-breeding timing is dependent upon water flow, it is best if flows in dammed or controlled rivers mimic the natural flow regimes. This can be accomplished by removing dams or carefully releasing water in amounts proportional to precipitation and runoff (Lind et al. 1996). Food webs are more likely to be sustained when the dam operations are modeled after natural patterns of daily, seasonal, and annual variation in the flow of the river (Kupferberg et al. 2012). More specifically, suitable water velocity at oviposition sites was shown to be between .00-.15 m/s (Lind et al. 2015). If natural flow regimes are mimicked, food webs would remain intact and the risk of death by desiccation by dry spells or egg removal by floods would be greatly reduced. As a result, these frogs would have a better chance of survival. Dam removal would also prevent the release of cold water from the bottom of the dam, which in turn inhibits frog development. The breeding and egg-laying season occurs at the end of spring flooding, anytime from mid-March to May depending on the specific locality (Morey, 2000). Thus if dams are left in place, it is critical to simulate the natural spring flooding and then the typical lower flow regime from March to May, in order to maximize the chance of the frog's breeding success.

C. Eradicate bullfrogs

Bullfrog removal is time, labor, and cost intensive. Currently, the most cost-effective method is called electro-frogging. In this method, fisheries electro-shocker is modified to target frogs. These devices remove juveniles and adults and thus require successive sweeps each year to capture the next cohort (Orchard 2011). Removal efforts commence in spring (typically April) and can continue through the summer months (typically through October). One challenge following bullfrog eradication at the site is the potential for new sources of invaders through immigration or introduction. Therefore, restoration sites must be carefully selected to include somewhat isolated sites that do not allow for easy recolonization.

D. Reduce Risk of Predation

The formation of shallow water environments will reduce predation by such predators as Pacific giant salamanders and salmonid fish because they require deeper water. However, predation by garter snakes and wading birds will remain a concern (Lind et al. 2015). Furthermore, encouraging faster tadpole developmental rates by promoting optimal temperature conditions and forage availability would reduce individual risk of predation (Lind et al. 2015).

E. Estimation of Healthy Population Size

The largest intact healthy populations remain in the north coast range of California. At six separate sites, researchers estimated over 100 adult frogs while nine other sites had more than 50 adult frogs (Lanoo 2005). With this baseline estimate, we can use the range of 50-100 adult frogs in each population as a reasonable target population size restoration goal.

III. Monitoring Plan

Monitoring is crucial to determine the presence, relative abundance, distribution, and habitat use of the foothill yellow-legged frog. Monitoring should commence at least 1 or 2 years prior to the implementation of restoration efforts in the Central Valley because it is critical to have data to compare before and after restoration in order to analyze the success of the project. After project implementation, the frog monitoring should continue for 10 years as that adjustments could be made to future restoration efforts.

I recommend the following Visual Encounter Survey protocol in order to monitor the *Rana boylii* population in the Central Valley:
1) At least two surveyors walk upstream (so individuals are not counted twice) along the shoreline or in the shallows
2) Scan 10 meters at a time, looking for each life stage: eggs, larvae, juveniles, adults
3) Binoculars may be used to scan for basking adults as to not frighten them upon approach

4) Search meter-wide transects parallel to the stream along the shore
5) When searching water walk in zigzags so to only make one pass
6) Carefully record observations (refer to the following list)
(Yarnell et al. 2014)

Data Form for Records:
Date
River Name (River Mile)
Surveyor Names
Start/ End Time
Survey Time (Actively searching)
Start/ End GPS
Datum
Air/ Water Temp C
Weather
% Right/ Left Bank
Invasive species
Photos (Start and end locations, habitat)
Observations at a single location
Coordinates
Life stage/ Sex (Adult, Juvenile, Young of Year, Larvae, Egg Mass / Female, Male, Unknown)
Observed
Length (mm)
Total depth
Mid column velocity (m/s)
Egg or Perch Substrate Size: (Silt, Sand, Gravel, Cobble, Boulder, Bedrock, Woody, Vegetation)
Riparian type
Geomorphic Unit: (Riffle, Run, Pool, Step, Rapid, Bedrock)
Nearest Bank (Right, Left, Mid)

Surveys should be conducted at least twice a year at each site – once in the late spring to count tadpoles and another in late summer to count juveniles and adults. I recommend monitoring for a 10-year period following restoration actions. If after monitoring we find that there is a complete failure of reestablishment of the population, we will attempt the translocation of individuals from a different nearby source site and increase to daily monitoring to determine causes of failure. For instance, if reestablishment fails due to the bullfrog recolonization, we would need to halt other management actions in order to first completely eradicate the bullfrogs. Otherwise, further efforts would be a waste of both time and money.   We will then update and revise our restoration plan according to the updated information. If there is only partial, sporadic recovery, we will increase to weekly monitoring to pinpoint potential sources of failure. For example, if there is not sufficient shade cover over the stream bed or it lacks sufficient cobblestone-sized substrates for egg sac attachment, we must first address these issues in order for the population size to grow. Following these actions, we will update and revise our restoration plan accordingly until self-sustaining viable populations are established.

If this restoration plan is followed, unanswered research questions may potentially be answered. Once a healthy population is reestablished, we will know what population size is needed to be self-sustaining. Repeated biannual (or more frequent) surveys would accomplish this goal. The specifics of their life history may also be discovered. Filling out the detailed monitoring form and observing individuals over time will help illuminate such unknowns as their life span, activity during day and night, territoriality, and age of reproductive maturity. Thus, this restoration plan is not only useful on a local scale, but subsequent findings may benefit other greater restoration efforts and the scientific community in general.

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Exotic wildlife

Feral Cat

Background Information

Feral cats are essentially domestic cats that have been abandoned and left to roam free in the wild. Like most felines, feral cats are carnivorous and prey upon other small animals such as rodents, birds, and small reptiles. Feral cats are capable of eating quantities of food equal to their own bodyweight (Ogan and Jurek 1997). In the United States, feral cat predation is one of the leading causes of human-related deaths of birds and mammals. It is estimated that 1.3-4 billion birds and 6.3-22.3 billion mammals are killed by feral cats annually in the United States (Loss et al 2013). Studies have shown that the removal of feral cats improve the population dynamics of local bird species (Côté and Sutherland 1997). In addition, feral cats pose risks of rabies and parasite transmission to the public (Levy and Crawford 2004). It is likely that feral cats arrived in North America with the first European colonization a few hundred years ago, and they have spread ever since; feral cats are currently unprotected by any governmental agencies in California (Ogan and Jurek 1997). The true population size of feral cats is unknown, but it is estimated that there are 50 million feral cats in the United States, and the population is not in decline (Levy and Crawford 2004).

Literature Review

Life History

- Carnivorous. Generalist predator that feeds on other small animals such as birds, mammals, and reptiles (Ogan and Jurek 1997). When confined to a geographic location (i.e. an island), feral cat diets consist primarily of small rodents and birds, and are diversified with other animals during spring and early summer (Bonnaud et al 2007).
- Life span of feral cats estimated to be 4-5 years. Mating is polygynous. Female cats are capable of bearing 2 litters per year with an average of 4 kittens per litter. Kittens reach sexual maturity between 7 to 12 months (Ogan and Jurek 1997).
- Capable of living in a variety of environments. Distributed worldwide from tropical zones to sub-polar oceanic islands. Suitable habitats may include urban human settlements, abandoned buildings, places with trees and shrubs, or even culverts (Ogan and Jurek 1997).
- The present population of feral cats are dependent on nearby human settlements to some degree. Feeding of feral cats is a widespread activity in California, with an average of 0.5 cats supported by each household (Levy and Crawford 2004).
- Feral cats compete with native predators of the same area, as the cats consume rodents and other prey items that provide sustenance for predators such as red-tailed hawks (Ogan and Jurek 1997).
- Feral cats are common carriers of diseases such as rabies, feline immunodeficiency virus (FIV), and toxoplasma. High densities of feral cat populations increase the risk of such disease transmissions to local wildlife and human settlements (Levy and Crawford 2004).
- Male cats have a median home range size of 5.1 km^2, and female cats have a median

home range size of 2.46 km^2 (Bengsen et al 2015). Home rang sizes generally correlates negatively with local environment productivity and feral cat density (Bengsen et al 2015). GPS data also showed that feral cats avoided areas within 50 meters of roads and preferred areas with thick land cover (Bridges et al 2015).

Negative Impact on Local Wildlife

- Feral cats compete with local predators such as red-tailed hawks (Ogan and Jurek 1997).
- Feral cats kill 1.3-4 billion birds and 6.3-22.3 billion mammals annually in the United States (Loss et al 2013).
- Suspected substantial impact on local herpetofauna. Results are estimated due to lack of data in the United States (Loss et al 2013).
- In rural and suburban areas, the majority of mammals preyed upon by feral cats are native species. The majority of bird species preyed upon by cats are native (Loss et al 2013).
- Feral cats are carriers of many diseases that can be transmissible to local wildlife. 270 cases of rabid cats were reported in the United States in 2001. An estimated 4% of feral cats carry FIV and FeLV viruses. Feral cats may also carry tapeworm (26%), coccidian (13%), and toxoplasma (20%) (Loss et al 2013).
- Feral cats may also play a positive role in regulating local pest species such as invasive rats (Tennent et al 2009).

Potential Control Methods for Feral Cats

- Physical removal of cats using traps and other methods, and relocating the cats to animal shelters and sanctuaries. This may saturate local animal shelters that create additional problems (Levy and Crawford 2004).
- Trap-neuter-return method and trap-test-vaccinate-alter-release method. Sterilize the cats and return them to their original colonies. Vaccinate if necessary to reduce disease transmission. The ultimate goal is the large reduction/extinction of feral cat colonies due to the decreased reproduction rates. Highly successful, although there are cases of increases in local colonies from increased abandonment of domestic cats and increased migration from other colonies (Levy and Crawford 2004). Poses the least amount of stress on feral cats as the cats are exposed to a single handling session (Tennent et al 2009).
- Complete eradication of feral cat populations is usually unfeasible due to large numbers of domestic cat abandonment, feral cat reproduction, and feral cat migration (Tennent et al 2009).
- Chemical sterilization using oral pills are possible, but difficult to administer the correct dosage (Tennent et al 2009).
- Feeding stations may be established to control the migration of feral cats. Special care must be taken to prevent establishing feeding stations at places where local wildlife are vulnerable (Tennent et al 2009).
- Feral cats need to be managed at population levels that minimize the migration rates from outside colonies (Tennent et al 2009).
- Fences that are 1.8m high with a 600mm overhang may be used to protect areas of special concern from feral cats (Robley et al 2007).

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GOALS

- Maintain a local feral cat population at a year-round level that minimizes both the immigrations rate of nonresident cats and the predation rate of local wildlife in areas where feral cats are present.
    - Feral cat populations are difficult to eradicate due to ecological and ethical reasons (Tennent et al 2009). Likely requires long-term human intervention to maintain the desired population level. Requires regular monitoring of resident cats, nonresident cats, and predation rate of local wildlife to determine the population “sweet spot.” Requires regular feedback and adjustment to reflect the changes in population dynamics. Not completely eradicating the cats means that there will be constant predation pressure on local wildlife, which may be problematic for endangered species.
- Reduce year-round zoonotic disease transmission from feral cats to local wildlife and humans in areas where feral cats are present by as much as possible as allowed by available management resources.
    - Feral cats may carry rabies and other diseases that negatively affect local wildlife (Loss et al 2013). Likely requires long-term management due to new additions to local cat colonies such as outside immigration and abandoned cats from local residents. Likely requires long-term management of diseases in local wildlife.
- Maintain on-site feral cat populations in areas away from nesting sites of local wildlife during the spring/fall breeding season
    - Feral cats feed extensively on local birds and mammals, especially in the spring and fall (Bonnaud et al 2007). Removal of feral cats improves hatchling survival in bird species (Côté and Sutherland 1997). Requires seasonal/year-round intervention depending on management plan. May encourage new establishments of cat colonies in areas where the previous colony has been removed.

MANAGEMENT PLAN

- Operate one or several feral cat feeding stations to provide year-round food supply for resident cats
    - Studies show that feral cats establish their home ranges around food supplies (Bengsen et al 2015). Thus, feeding stations are a good way to encourage cats to settle in desired areas.
    - The amount of food supplied may vary, but should be able to support a regular population that neither decreases nor increases in size.
    - The locations of the stations may vary, but should generally be situated away from sensitive areas such as nesting sites. Male cats have an average home range of 5.1 km^2, so the stations should be far away enough to prevent the cats from extending their home ranges into the aforementioned habitats (Bengsen et al 2015).
    - Food should be supplied year-round to establish a regular population. Feral cats decrease their home range with an increase in local productivity (Bengsen et al 2015). Thus, food supply may be increased during the spring and fall breeding

seasons to further restrict the cats' active ranges.
    - Feeding stations may also attract other local wildlife such as raccoons and possums, and thus increase the risk of disease transmission between these critters and feral cats. Solutions may include supervised feeding sessions of the feral cats, as opposed to leaving the food out unsupervised.
    - It is observed that the prey drive of feral cats does not diminish even with feeding (Tennent et al 2009). Thus, protective fences may be used to further restrict the cats on preying on local wildlife.
- Trap-Test-Vaccinate-Alter-Release
    - Highly successful in controlling local feral cat reproduction rates (Tennent et al 2009).
    - Cats may be passively caught using baited Tomahawk traps.
    - The captive cats are then tested for diseases and neutered. If deleterious transmissible diseases, such as rabies, are present, the cats would be vaccinated before release. In the cases of parasitic diseases such as tapeworm, the cats may also be treated before release.
    - The treated cats are then released back to their local spots.
    - The location of operation may vary, but priority should be given to feral cats centered around feeding stations. The goal should be establishing a population of non-breeding cats with low disease risks around feeding stations that would prevent nonresident untreated cats from establishing in the area.
    - The timing of such operations may vary, but should ideally be carried out as new cats are spotted. The operations should be done as often as resources allow.
    - The treated cats carry a low risk of infection from the neutering operations, and thus may be monitored until the wounds heal in case infections do occur. The cat may then be taken in and treated accordingly.
    - It is possible that the treated cats may wander away from the desired locations. That is an unavoidable risk. Protective fencing may be set up to minimize this risk.
- Protective Fences to Restrict Feral Cat Activity
    - Fences that are 1.8m high with a 600mm overhang have been shown to be effective against feral cats (Robley et al 2007).
    - Fences may be utilized throughout the site to protect areas of special concern, such as spring nesting sites. Fences may also be used to restrict feral cats around the feeding stations until they are established in the area.
    - The fences should ideally be set up before spring/fall breeding seasons. Once set up, the fences may be left in place.
    - It is possible for occasional cats to breach the fence (Robley et al 2007). That is an unavoidable risk.
    - The fences may also restrict wildlife activities such as the activities of local small mammals. It is advisable to restrict the use of fences to the absolute minimum in order to protect local wildlife. On-going monitoring regimes of local wildlife may be implemented to discover this threshold. Small openings near the bottom of the fence may be excavated to provide access for small rodents and the like.

MONITORING PLAN

- Mark-Recapture
  - Suitable for both pre- and post- restoration with the above management options to assess the population size and density of feral cats in a given area.
  - Feral cats are captured using baited Tomahawk traps and are subsequently marked.
  - Seasonal timing is insignificant as feral cats are active throughout the year (Ogan and Jurek 1997).
  - Continuous monitoring. The optimum capture frequency is undetermined due to lack of information.
  - Ear tags, banding, collars, or chips may be chosen depending on the size of the cat.
  - May be integrated with TTVAR management.
    - It may be unnecessary to continue mark-recapture if all the feral cats are marked.
  - Mark-recapture monitoring is useful in determining the minimum stable population size of feral cats when subjected to management measures described above. Maintaining this population is the primary management goal. If the population increases consistently, it may be necessary to increase the intensity of the management measures described above.
- Radio Collar/ GPS Tracker
  - Suitable for both pre- and post-restoration with the above management options to assess the spatial movements of feral cats in a given area.
  - Cats are captured using baited Tomahawk traps, and are subsequently fitted with a radio collar/GPS tracker
  - May be integrated with mark-recapture monitoring and TTVAR treatments.
  - Seasonal timing is insignificant as feral cats are active throughout the year (Ogan and Jurek 1997).
  - Requires long-term continuous monitoring. The optimum frequency of tracking sessions is undetermined due to lack of information.
  - No threshold of action. Even if the entire population is fitted with trackers, the spatial information obtained from the trackers is still useful in advising management decisions.
  - Spatial monitoring is useful in determining home range sizes of individual feral cats. Although the average home range size for male feral cats is 5.1 km^2, it may vary significantly among individuals (Bengsen et al 2015). Thus, specific spatial information for individual cats may be needed determine the exact location where the feeding stations may be located.
  - Spatial monitoring is particularly important for gauging the success of the feeding stations. The goal of the feeding stations is to draw feral cats away from sensitive areas. Thus, spatial data is necessary to determine if the feral cats remained close to the feeding stations.
- Monitoring of Other Wildlife
  - Monitoring of other wildlife is likely required to help determine the optimum population size of on-site feral cats. For example, if the population of native birds decreases consistently, it may be necessary to consider reducing feral cat

populations further.

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Virginia Opossum (*Didelphis virginiana*)

The Virginia opossum (*Didelphis virginiana*) is a mesopredator (middle trophic level predator which both predates and is predated on) and scavenger that is increasing in population and often viewed as a pest (IUCN 2016). Despite this view, Virginia opossums can play a significant role in decreasing carrions that are left behind. By scavenging these carrions, there is less chance of rot and disease associated with organic decomposition. Additionally they are known to remove noxious species and are very good seed dispersers. While they remove carrions, they themselves can be transmitters of rabies and tuberculosis – this may be a threat to livestock and surrounding species in the area. However, rigorous studies have demonstrated that they are more likely to reduce disease (by removing carrions) than they are to increase disease (by direct transmission). The biggest concern for the area of focus, is the species' negative effect on struggling bird populations, particularly birds that nest on the ground. The services of opossums are similar to other mesopredators such as raccoons, and the two species have negative effects on each other, but Virginia opossums can co-exist by changing niches. Opossums are not currently endangered, and can tolerate a very wide range of environments, including living in fragmented, or urban areas (Conner et. al 2011). They have been introduced to San Jose, California in 1910 but have spread to the entire coast and interior west of the Sierra-Nevada axis and are thriving (Zeiner et. al 1988).

Characteristics

Reproduction

- Opossums mate twice a year, males directly compete for females. Males that are larger have more access to females, and all males increase their home range during oestrus which lasts 29.5 days (Ryser 1992).
- Males will mate with 0-3 females during mating season. The largest male will often win mates 20-23 times, as noted in this study conducted in Florida. Mate-searching activities are very costly, and males lose a lot of weight (Ryser 1992).
- There are two mating seasons each year, in Florida it was mid-January and late April. In colder climates they may only have 1 litter, but in warm climates like Florida it can increase to 3 but is mostly 2 (Ryser 1992).
- Virginia opossums are solitary, don't defend their home range, but are very aggressive (Ryser 1992).
- Females usually raise only one litter, whereas two smaller litters per year are common in southern latitudes (Hossler et. al 1994).
- Young remain in pouch for first 70 days of life, then left in the den while the mother forages. After weaning which is 93-103 days, young must forage outside the den, but most (60%) will die due to predation (Hossler et. al 1994).

Food Habits

- If patch sizes are small, raccoon and Virginia opossum predation on ground nesting birds increase (Disney et. al 2008).
- They can eat wide varieties of animal and vegetable foods. They eat carrion and insects –

including fruits, berries, and grains, green vegetation, earthworms, and fungi. Feeds on the ground in shrubs and tree, but winter is a limiting factor for food (Zeiner 1988).
- Ground nesting birds are at greatest risk to mesopredators such as Virginia opossums, as seen in a study done in North Carolina (Lumpkin et. al 2012).

Habitat Preference/Space Use

- Virginia opossums typically select forested habitats and woody cover in preference to other habitat types, and have a range of 12.5 to 38.8 (Gardner and Sunquist, 2003; Gehrt, 2003).
- This species lives in moist woodlands and brushy habitats at low elevations (Zeiner 1988).
- It can also live in riparian, wetlands, and agriculture/residential areas that provide abundant food and cover. Dense conifer forests and grasslands are less common, but they have been found (Zeiner 1988).
- Nests made of leaves and also human made structures as buildings culverts are also used. Den sites are used for mating, and can be a limiting factor as well. They live near moist sources as well. Ecotonal situations are preferred (Zeiner 1988).
- The opossums can live near urban proximity, but urban intensity can cause their decline. When given a choice, they will choose a natural environment where they can build their dens (Conner et. al 2011).
- Unlike the common opossum, the Virginia opossum has a much broader range of habitats it can live in, and a higher tolerance. After rough winters, they will often have missing ears and look sickly, but they are very tolerant and adaptive creatures. They respond well to habitat diversity an edge effect. They are solitary, and don't stay in one place for one time, that's why they don't defend, but they are very aggressive (Ryser 1992).
- It can share burrow systems with medium sized mammals. They are nocturnal and yearlong, activity is lower in winter but it's good at maintaining its body temperature in the winter (Ryser 1992).
- The opossums living in warmer climates will have smaller litters, but more than 1, and up to 3 rather than 1 larger litter (Rademaker and Cerqueira 2006).

Threats

- Predation is mostly felines, canids, and owls – the young are the most vulnerable, especially right after weaning in which they can only forage outside the den (Hossler et. al 1994).
- After weaning which is 93-103 days, young must forage outside the den, but most (60%) will die due to predation (Hossler et. al 1994).
- Current known predators (in New York) include raptors, domestic dogs (Canis familiaris), coyotes (Canis latrans), red foxes (Vulpes vulpes), raccoons (Procyon lotor), bob-cats (Lynx rufus) and large snakes (Ladine et. al 1994).
- Raccoons are especially dangerous to offspring, and young that are weaning (Ladine et. al 1994).

Provisions and Negative Effects

Ecosystem Services

- Serious studies done on Virginia opossums have shown that they actually don't have a serious effect on poultry and wildlife, and instead probably have a positive role by reducing noxious species, and suppressing diseases by removing dead animals. Most of the misconceptions arise from the reputation of common "opossums" (Gardner 1982).
- Virginia opossums are scavengers that remove carrions that often cause disease by organically rotting on their own (Gardner 1982).
- Removing scavengers will often have cascading effects on the ecosystem, but in many situations raccoons provide the same services to the ecosystem (Gardner 1982).

Negative Effects of the Species

- Ground nesting birds are at greatest risk to mesopredators such as opossums. If there are species of birds that we are attempting to conserve that nest on the ground, opossums may have a negative effect (Lumpkin et. al 2012).
- They compete with raccoons, so the removal of raccoons have a functional response on opossums – and they will actually thrive. It is important to note that an increase of raccoon population does not do the opposite, and the same proportion of carrions were split between species.
- Opossums can transmit rabies and tuberculosis to other species, including livestock (Hennessey et. al 2015).
- Raccoons and Virginia opossums have negative effects on each other, but Virginia opossums often change niches in the presence of these species. Also, when the raccoons are omitted, the Virginia opossums will consume more carrions but overall more carrions will be left in the ecosystem (Ginger et. al 2003).
- Virginia opossums that are isolated from their predators develop healthier traits (Austad 2003).

Gaps in Knowledge

- Information on the response of the Virginia opossum to fires and pesticides are not known. However, the above information suggests that they are very hardy creatures that can withstand urban conditions including agricultural areas (Zeiner 1988) (which may suggest pesticide tolerance).
- There are several studies on the species, but many are not in California. Some studies do mention how the species will act in warmer climates (such as more litter in warmer climates) (Kimble 1997).

Goals:

While the Virginia opossum serves many purposes such as eating carrions, controlling prey numbers, and seed dispersal – but the species is very detrimental to poultry, turtle eggs, and bird populations – especially ground nesting birds (Zeiner 1988). Secondly, the services of this species are not unique, for example the common raccoon can also eat carrions, and control populations (Gardner 1982). The current area has raccoons already, and certain species of bird and turtles are key species we are attempting to restore. Some species we are trying to conserve are **ground nesting birds** such as waterfowl. Lastly, the Virginia opossum has been introduced to this west coast (Zeiner et. al 1988) – so it is definitely not a native species

Elimination Plan	The goal is to eliminate the Virginia opossum from the site. Since they prefer riparian (Ryser 1992) habitats, the traps should be placed along the water where there is riparian habitat. They should be spaced at least 15 meters apart to cover the most distance without needing to buy too many traps (Tomahawk traps can be reused). We do not know how many opossums are at the site, this will need to be recorded as each individual is captured. We also need to know if opossums are living outside of the site such as in the urban development. A mark-recapture method will help provide data about the population, but since the species needs to be controlled, the rest must be euthanized (they are invasive to the West Coast, so there is nowhere ideal to release them that is feasible). The site provides the best habitat for the opossums so it's possible there are a significantly small number of individuals living in less habitable ranges of Centennial Park (or urban development) – however it's good to note these are very adaptable creatures (Ryer 1992) and they may be living there. We need to measure the population of opossums living within the site and if they are living in the nearby urban development. The process of trapping, recording, marking, releasing a few individuals, euthanizing the rest, and recapturing the marked individuals will take up to 6 years (Smith et. al 2013) (this is how long it took for one project).

Monitoring Plan	After the individuals have been euthanized, with a few individuals marked and re-released – the individuals can be recaptured to measure information about population size and how it is changing (this will also demonstrate if the plan is working, or if the euthanized individuals are being replaced by individuals from outside the site). If individuals from outside of the site are entering because euthanizing too many individuals is allowing for others to move in, it may be beneficial to leave a small population of opossums in the area and just continue to control the size (adapted from Smith et. al 2013). **If it is feasible, and necessary, newly marked individuals can have GPS trackers placed on them so traps can be relocated to adjust to their actual observed home ranges and roaming areas. The best time to capture these individuals is during their mating season, while they are not cryptic, they are most active during their mating seasons – males will increase their home ranges and home ranges may overlap (Ryser 1992).
Post Elimination Plan	The Virginia opossum is very adaptable, and has a large fluid home range (Ryser 1992). They are not territorial and often move from territory to territory. While the opossum is adaptable, they have preferred habitats such as moist environments, with old dens of other animals, and near a water source such as a wetland (this describes the site exactly) (Ryser 1992). This means that there is a possibility of the population returning, or a new population of opossums entering. The site will have to continually be monitored for several years to completely remove the opossums – OR monitored to keep a controlled small population. If the survival of the site is not contingent on interaction with the outside environments, then an enclosure/fence will help keep out new and returning mesopredators as a Plan B (see below).

Tradeoffs:

- In one study, eliminating one carrion-removing species (the raccoon) had a negative effect on the total number of carrions left at a site. Removing one species of mesopredators (raccoon) has a positive effect on the remaining mesopredators (Virginia opossum). Each of the remaining species will consume more carrions – but there is a chance that more carrions will be left out overall (Ginger et. al 2003). We know the effect of removing raccoons on the Virginia opossum, but we will find out the effect of removing the opossum on raccoons in this study.
- One thing to consider, is prey animals such as pond turtles and ground nesting birds are already struggling, so it's unlikely that the ecosystem has evolved and adapted to *requiring* the Virginia opossum (even if it can provide some services). Especially when there are other mesopredators such as the raccoon. It's more than likely that it is contributing to the problem and needs to be removed.
- Virginia opossums control prey populations, clean carrions, and can be somewhat good seed dispersers (Gardner 1982). However several species (raccoons and feral cats are present at the site) can also provide these species. There is an abundance of mesopredators.

Feedbacks:

- If eliminating all the opossums is achieved, and after eliminating the opossums, a new population of opossums have arrived to take the place of the old ones then it's better to control the species of opossums and keep them at a small number. This will depend on the way the site reacts. If a very small number of opossums can prevent more opossums from entering, this is ideal.
    - Adding raccoons will not work, because in the presence of raccoons, opossums will fill another niche and accommodate (Ginger et. al 2003).
- Since bird populations and ground nesting turtles are struggling, it's unlikely that this will happen BUT if for any reason suddenly there is an unsustainable number of prey populations:
    - Adding more opossums will not help. They are invasive, and it's unlikely that the ecosystem has adapted to require the opossums. Especially in the presence of other mesopredators.
        - Instead, look to options focusing on the prey populations.

Thresholds/Interaction:

- The Virginia opossum is not a native species. Controlling of this species is likely to result in an increased survivorship of birds, particularly ground nesting birds.
    - After removal of the species, achieving the original (desired) state will be possible. There will be less pressure on the key bird and turtle species we are trying to conserve.
- The best results will be achieved by completely removing the species.

Management/Restoration plan:

- To remove mammalian predators; Virginia opossums, use cage traps ((Tomahawk Live Trap Company, Tomahawk, WI) and soft-catch traps (Woodstream Corp., Lititz, PA). Snake trap arrays are also useful in catching these mesopredators (Burgdorf et al. 2005). This can take several years. In one study (Smith et. al 2003) it took 6 years to complete this process, including the time to mark the individuals and release them outside of the site (in our case euthanization may be the only option). The best time to capture the mesopredators is during the mating seasons – while mothers are with their babies it will be more difficult to capture them – but instead during mating seasons both males and females are more active (not before, not after, but during, which can span across a few months) (Ryser 1992).
    - While information is known about the mating seasons, there are not detailed studies on the Virginia opossum in California since it was only recently introduced to San Jose in 1910 (Zeiner 1988).
    - Close observation is needed to determine the mating seasons which can be 1, 2, or 3 times in warmer climates. In warmer climates, there 2 or 3 times during the year when the Virginia opossum goes into oestrus and males attempt to attract mates (Ryser 1992). However, it's best to adapt to information that is learned during the process of carrying out this plan. For example even though it's likely to mate 2/3 times in a warmer climate, for whatever reason it may be less in the Central Valley. It's a good use of time to change strategies when information like this is learned.
    - The opossum is solitary and not territorial. They change home ranges frequently (Ryser 1992).
    - They are also most active during the night time. During mating seasons, males will have larger home ranges, and both male and females will be more active. (Ryser 1992). This means that releasing them elsewhere may be ineffective, they could travel back over time.
- **Another KEY step is to inform nearby homes to seal up their homes and not leave out pet food or any garbage or food. This will prevent opossums from becoming a problem in the urban developments while working on this restoration plan.**
- **Depending on how many opossums there are, one option is to leave them at the Wildlife Care Association on McClellan Road.**
    - **This is a last resort**
    - **This can also be a first resort if there is only a small number of opossums or small number of recurring animals in the future, between 2-5 individuals**
- Cage traps and soft-catch traps are the best way to capture these mammalian predators (Smith et. al 2013). If an individual is recaptured within the site, it must be euthanized. It will take one year to remove all the mammals. During the two mating seasons in mid-January and late April the opossums will be more active, and easier to track. Opossums are solitary, but do meet to mate. Male opossums also have larger home ranges when females are in oestrus for 29 days (Ryser 1992). Catching the opossums before they have their litters will prevent the population from growing. Each mammal must be tattooed on the ear to know which opossums are being recaptured. The next few years, nocturnal thermal imaging, following tracks, and feces samples will help provide information about

whether the opossums are returning. In one study, making a fence enclosure kept out the opossum (Smith et. al 2013). However, the fate of this site involves interaction between wildlife within and outside the site. Instead, the captured individuals must be released several miles away, in an equally suitable habitat. The site meets all the preferred standards of habitats for the Virginia opossum, so it's necessary to make sure the opossums are being released in a habitat they will thrive in, and won't slowly make their way back. The best time of day to look for the opossums is at night as they are nocturnal. This is another time where a nocturnal thermal imaging camera may be of good use. The litter size in California is between 8-12 (Grinell et. al 1937), so capturing and releasing before the litters are independent from the mother is ideal otherwise the population would increase significantly.

Monitoring plan:

- Nocturnal thermal imaging cameras are up to $3000, but are the best way to keep track of activity at night (Optris Brand 2008), another option is trap cameras which will actually help note presence of all mammals in the site.
    - **In order to save cost of film, 3 times a year especially near the estimated mating seasons can be allotted to setting up the cameras and seeking out Virginia opossums**
- Other ways to observe recurrence of opossums is to look at tracks and feces near moist areas and old dens previously used by opossums or other animals (Based on Smith et. al 2013).
- Recaptured opossums must be euthanized, new animals can be marked to continue to monitor the site, and if new opossums continually reoccur then the opossums should be controlled, rather than eliminating all of them.
- If the the opossums keep reoccurring after several attempts, then a few other measures can be taken.
    - Another option is to set traps further outside of the site (particularly near the edges of homes and urban development) to eliminate nearby opossums from ***entering***.
- If the conditions permit (and this coincides with other restoration goals), making an enclosure around the riparian may help ward off new opossums (but this may not be possible for long-term use) (Smith et. al 2013 – used this technique for a research study)
    - Many other species and plants may depend on keep the site open for entry from outside the site
- If complete elimination is the best option, the species could take up to 3-6 years, post-monitoring could take 3 more years (Smith et. al 2013).
- In order to see if the population counting methods (thermal imaging, feces, track stations) are working, test the method outside of the site and comparing with expected values will determine the effectiveness of measuring the population with those methods.
- **Re-using and setting up traps will be expensive at first, but after the traps are bought the process will not cost extra money over the 3-6 years.**

If it fails/Plan B:

- If the **overall restoration plan permits**, an enclosure or fence around the site will prevent recurrence of removed animal species (Smith et. al 2016 - used this as an effective technique for a research experiment).
    - This may also help in eliminating other species as necessary
- Otherwise, the removed individuals will have to be euthanized until the threshold is met and Virginia opossums stop recurring.
- If this plan becomes too expensive, and is not responding well other options are:
    - Limiting the number of opossums via sterilization (tubal ligation of females)
    - If the overall restoration plan permits, (not very effective, very last resort) adding raccoons has a negative effect on opossums, but sometimes opossums will just find another niche – but it does have a small negative effect on population size (Gardner et. al 2016).
    - **Sterilization is another option, but it is very expensive and time consuming – this is also a very last resort.**

What will we learn:

- Finishing this project will teach us a lot about the species, as much research has not been done on the species living in California – things like time ranges for mating, and also the difficulty of eliminating them. The effect of removing the Virginia opossum on existing raccoons will also be new information.
    - Though they are adaptable, they have specific preferred habitats and the habitat we are preserving has all the features of their preferred habitats.
- The effectiveness of using a thermal imaging camera to count populations of mesopredators such as the opossum but even the raccoon

Gaps in knowledge/what we need to know:

- How many opossums are currently at the site
- How many opossums reside outside of the site
- Where to place the existing opossums after removal
- How raccoons respond to removal of a competitor
- Opossums mating time frame in California/Central Valley
- Specific home ranges in California/Central Valley
- **Will we be keeping raccoons or another mesopredator at the site**
    - **Will we be enhancing or lowering the number of that species**
- **How much money can we allocate to this**
- **Is there more wilderness area outside of the perimeter of Centennial Park outlined in the overall park project plan**
    - **Potential areas to release the opossums that are not near urban areas**
- **Will there be other uses for the expensive thermal imaging camera**

***This plan is based on examples from research in similar areas, however there can be significant differences due to several factors. Restoration is complicated, even using the same technique in the same site a couple years later could have vastly different results. Plan must continually be adapted as the years go by and new information is learned about the reaction of the ecosystem at the site.

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The Red Fox (*Vulpes fulva*)

Background and Justification

Historically, foxes were farmed and hunted for their fur. Factors that have caused the red fox to move westward are urbanization and expansion of the United States. According to earlier documentation, the subspecies found in the Central Valley were historically absent or extremely rare (Statham et. al 2012). It was originally thought that all red fox subspecies found in California were invasive, however, there are two native red foxes: the Sierra Nevada red fox, SNRF, (*Vulpes vulpes necator*) and the Sacramento Valley red fox, SVRF, (*Vulpes vulpes patwin*) (Sacks et. al 2010). Conservation efforts should be directed to the native subspecies and eradication efforts to the nonnative subspecies of the red fox. Nonnative red fox subspecies are affecting the native red foxes and decreasing the numbers of other endangered species (Massey and Fancher 1989).

The subspecies red fox (*Vulpes vulpes fulva*) is an omnivore that is native to the Eastern United States and may have been introduced in California through the European fur industry. *Vulpes vulpes fulva* was introduced into the San Joaquin Valley with minimal success but a few articles state that the subspecies has been spotted in the lowlands of the Sacramento Valley (Statham et al 2012). *Vulpes vulpes fulva* is currently found in the Sacramento Valley as an exotic species, but the SNRF population in Lassen Valley is native. Central Valley is nearby so it may contain a combination of both native and nonnative species. Although both species interact, currently there is a small narrow hybrid zone (Perrine 2005). The introduction of the European red fox (*Vulpes vulpes*) and other subspecies, including *Vulpes vulpes fulva*, has caused the classification and conservation of native red fox subspecies difficult.

California Fish and Wildlife has *SNRF* listed as threatened. (California Fish and Wildlife). The current range for the native SVRF can be found from Cottonwood to the Delta, the Central Valley (Sacks et. al. 2010). The SVRF and *SNRF* require protection; because they're low numbers make them vulnerable to extinction through environmental stochasticity. A possible reason for the population's inability to rebound from its low density is the lack of emigration of metapopulations caused by California's geography (Statham et. al 2012).

<u>Literature review of Red Foxes</u>

Note: The following information pertains to all subspecies of red foxes unless the location is specified. There is little known information on the California native red foxes at the moment.

<u>Characteristics of red fox</u>

- Typical characteristics of a red fox are their reddish fur, bushy tails, their dog size, large pointed ears, and pointy snout. SNRF can have a black fur coat (Casey 2005).
- A red fox body size can range between 56 to 63 inches in length and 35 to 41 centimeters tall. The average weight is three to seven kilograms (EPA 264).
- The SNRF can also have a " black cross marking formed by two black stripes on its back; one across the shoulders and the other down the back" (Casey 2005).
- Red foxes do not undergo hibernation and change their molt yearly. They begin molting

on April and finish by June. They regain their winter coat by October (EPA 264).

Reproduction

- Red foxes reproduce more offspring when the level of mortality is high or there is a low density (EPA 264). Little is known about the SNRF and SVRF, but the following provides information of red fox densities in various parts of the world:
  - "The UK, density varies between one fox per 40 km² in Scotland and 1.17/km² in Wales, but can be as high as 30 foxes per km² in some urban areas where food is superabundant (Harris 1977; Macdonald and Newdick 1982; Harris and Rayner 1986). Social group density is one family per km² in farmland, but may vary between 0.2-5 families per km² in the suburbs and as few as a single family per 10 km² in barren uplands (Macdonald 1981; Lindsay and Macdonald 1986). Fox density in mountainous rural areas of Switzerland is three foxes per km² (Meia 1994). In northern boreal forests and Arctic tundra, they occur at densities of 0.1/km², and in southern Ontario, Canada at 1/km² (Voigt 1987). The average social group density in the Swiss mountains is 0.37 family per km²" (Macdonald 2008).
- Gestation occurs in spring and early summer (EPA 264).
- Litter size ranged from four to six pups. Red foxes produce pups during their first year but they delay reproduction to a seasonal period when there is a high density (EPA 264).
- Pups are born and raised in the den. Pups exit the den when they reach their fourth or fifth week. Mothers wean their pups until they are 8-10 months (EPA 264).
- Males provide protection while the females provide food for the pups (EPA 264).
- After a year (during September to March), the juveniles disperse to find their own territory. Within their first year of reaching sexual maturity, they may produce their own offspring if food abundance is high (EPA 264).

Food habits

- As small omnivores, they feed on small mammals, birds, fruit, and insects (EPA 263).
- In some locations, the red fox seasonally depend on game birds and waterfowl (EPA 263).
- Red foxes are scavengers that store food in holes for later use (EPA 263).
- During the summer and fall, red foxes feed on fruits and nuts (EPA 263).
- In southern California, the daily food intake or requirement ranged from 0.27 to 0.32 kg per day. This depends on the sex of the fox, age and the reproductive status in female foxes (Golightly 1994).
- In a study in Alaska, red fox abundance was reduced by fluctuations in prey numbers. Environmental stochasticity indirectly affected red fox by reducing the prey density (Zabel and Spencer 1989).

Space use

- In general, red foxes are seasonally resident to areas. One possible reason for migrations is the availability of certain food resources. A rural fox disperses approximately 30 kilometers, but there has been an instance in which a fox has travelled 3000 kilometers (Perrine 2005).

- A single red fox can have many dens, but it has a main den used for rearing. A mating couple protects a territory for a year. After the year ends, the female abandons the territory while the male remains protecting the territory (EPA 264).
- Red foxes forage away from the den. Their forage site is within its home range. The exact distance is not known (EPA 264).
- In Illinois, Storm states red foxes are active two hours before night and stop four hours after dawn (Warner and Hendrix 1984).
- Coyotes (*Canis latrans*) prey and compete with red foxes (EPA 264).

Habitat preference and requirements

- Optimum habitat includes broken and diverse upland habitats and agricultural areas. Red foxes prefer grasslands and woody areas (EPA 263).
- The red fox species is globally found. Habitat ranges from the arctic to temperate deserts (EPA 263).
- *Vulpes vulpes fulva* is found on California's lowlands of the Sacramento Valley (Cleve 2005)
- Territories range from 50- 300 ha; the environment has an effect on the size. For instance, in rural environments the territories are greater than urban territory. Territories do not overlap and nearby ranges tend to be from relatives. Foxes visit their whole territory daily. The red fox marks its territory by using urine (EPA 264).
- Red foxes prefer natural fire regimes, because it increases rodent populations. Many small mammal populations increase after a fire, because vegetation becomes abundant (Tesky1995).

Threats

- The red fox is an amplifier for the zoonotic disease La Croxe. (Yuill and Amundson 1981).
- Hunting, trapping, disease, and road kills are causes of their high mortality rates (EPA 264).
- The main factors that affect red fox abundance is competition with other carnivores and the availability of food throughout the year (EPA 264).
- Hybridization between the native and nonnative species, competition, and transmission of pathogens is a problem for the Sacramento Valley red fox (Sacks et. al 2010).

Potential management actions

Improve habitat

- Interspecific interaction is one of the primary factors that shape the mesocarnivore structure (Perrine 2005).
- Red foxes in California depend on the environment's physical structure (Perrine 2005). Red foxes have a large tolerance for environmental conditions and habitats, but they tend to avoid swamps and dense forests. Favorable ecological structures include deep forest, woodlots, and croplands. The habitat must contain various plant communities (Casey 2005; Tesky 1995).
- In areas with high agriculture, disturbance should be minimized and certain areas should contain high diversity of food and plants. It is important to add travel corridors and

habitats should have an irregular shape (Tesky 2005)

Further Management of Native subspecies

- The spread of rabies should be controlled since it accounts for 60-80% of mortality when there is an outbreak. Dogs with canine distemper should not be allowed in the area (Tesky 2005).

Possible management for Non-Native Subspecies

- Flooding can deter the nonnative species to not settle in the Central Valley (Sacks et. al 2010).
- The California Fish and Wildlife Department recommends the following control methods of the nonnative population: encouraging a natural occurrence of the coyote, live trapping red foxes, and lethal injections. Relocation, sterilization, and adoption of red foxes as pets are not effective measures for controlling the population (CDFW).

Gaps in knowledge

- Distinguishing the SVRF from the non-native subspecies in the Central Valley. According to Roest's article, there is no accurate physical characteristic to distinguish the non-invasive species and *Vulpes vulpes necator* with red pelage. At the moment, hybrids are only found in certain locations, but can be a threat in the future (1977).

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Goals

A. We need to eradicate the invasive red fox through non-kill methods throughout Central Valley, CA during the restoration of the SVRF. This may be difficult to accomplish, since color pelage can be a deceptive way of distinguishing the native subspecies from the non-native. At the moment, there is no precise process for distinguishing SVRF from *Vulpes vulpes fulva* (Reese 8).

    a. Invasive red foxes complicate the protection of the SVRF. The invasive red fox can transmit diseases, lead to the loss of local genetic adaptation, or outcompete the SVRF from its native range. The red fox has a charismatic look which makes it difficult to eradicate since the public does not agree with the kill methods (California Department of Fish and Wildlife).

b. Completely eradicating the invasive red fox is not possible, because the identifiable characteristics are too similar to the SVRF.

B. Reintroduce the Sacramento Valley red fox (*V.V. ssp. patwin*), SVRF. Using mtDNA the SVRF constitutes as a new subspecies and it is closely related to SVRF (Sacks 2010). The identification is a recent discovery and research is currently being done on SVRF's ecology. Reintroductions are not possible until a species account of the SVRF with information that pertains to the Central Valley becomes available.

a. Information available on the SNRF is being used as a reference for our restoration plan and goals. According to Sack's presentation on the SNRF and SVRF, pelage may not be a reliable distinguishing characteristic. He recommends looking at the bottom of their paws- less hair seen on the Sacramento Valley red fox and hairier paws in the Sierra Nevada (Sacks 2014).

b. In order to secure a successful reintroduction of the red fox, we need to include the following habitat requirements:

i. Increase the amount of loose soils on well-drained areas (Tesky 1995).

ii. Red foxes require vegetative cover for hunting and predator avoidance. Grasses and mature native trees should be available during the summer. During winter months, we should protect and ensure native non-deciduous trees are available. The habitat must have patchy and open areas (Tesky 1995). Natural fire and flood regimes during early winter will allow small rodent populations to grow during spring and prevent deaths of SVRF pups. The sprouting plants will provide a food resource for both rodents and the SVRF (Tesky 1995).

i. In agricultural locations, foxes use agricultural area, shelterbelts and fencerows for hiding. Local farmers should be warned and fencerows should be placed in areas near livestock (Tesky 2005).

c. We need to protect at least 300 ha. for breeding habitat in urban areas during spring and early summer. In general red foxes have bigger home ranges in rural habitats, SVRF will need a bigger breeding habitat than urban areas. The area is dependent on the number of foxes and the food availability (EPA 264).

i. We need to include logs or rocks in areas where loose soils are not available. The SNRF use gaps between rock piles at base cliffs or slopes for denning sites. Research is required for the SVRF to determine whether their denning sites are similar (US Fish and Wildlife Service 2015; Grinnell et al. 1937, p. 394).

1. Red fox reproduce a litter of one to nine pups every spring to early summer. Juvenile red foxes can reproduce the following spring. In areas without rock piles, we should create rock piles or promote

"flat open areas, embankments, golf course sand traps, plantations, and rock or scrap metal piles" for dens (California Department of Fish and Wildlife; EPA 264).

ii. Lower the number of coyotes during spring and summer in order to reduce pup predation (EPA 264).

d. Ensure adequate food/ prey
   i. According to Tesky's species report, it is important to have controlled burns. Restoring natural fire regimes increases rodent populations, one of the prey species of red fox. Many small mammal populations increase after a fire, because vegetation becomes abundant (1995).
   ii. Provide native fruit trees during the winter, when food is scarce. Some food sources to consider for the SVRF, throughout the year, are small rodents, like voles, or black berry perennials (US Fish and Wildlife Service).
e. Maintaining a large population is important, so local genetic diversity is not lost with interbreeding of non-native species. Information of population size is currently not available.
   i. Improve road conditions to suit foxes' needs and avoid future losses through road kills (Reese 8). Road signs that warn drivers to yield for wildlife. There should also be different speed limits at night, because SVRF are nocturnal species. An alternative for public areas is to close the property after dusk (Tesky 1995).

Restoration Plan

A. Removing Non-Native Red Fox subspecies,
   a. In locations where non-native species are currently found, we should set fences where they have been spotted (CDFW). The following management plans are from the California red fox information website: we should encourage natural occurring coyote populations, invasive red fox subspecies should be captured alive using soft catch traps, and euthanasia. Relocation is not possible, because other states are not willing to take in the invasive species. California has attempted sterilization, but it has proven to be an ineffective method to decrease predation on endangered species and decrease competition with the native foxes.
B. Corridors:
   a. There is currently no information available on a specific width. Increasing connectivity between different habitats is favorable because it will promote large SVRF populations in the future and increase genetic diversity.
   b. Vegetation needs to be similar to its habitat and include areas that allow SVRF to hide from possible predators. The corridor cannot include habitat that it can use as a den, because the corridor should not be used as an extension of the habitat. The corridor should have grasslands and tall trees to provide the SVRF a place to hide from coyotes and other predators.
   c. In areas of high noise pollution, the older trees should be placed on the outer

section of the corridor to act as a noise barrier. Loud noises can deter SVRF from using the corridor. There is no available information of how noise pollution affects red foxes, but it should be considered during the corridor construction.

C. Maximize Genetic Diversity:
    a. Within a year, snares should be placed to capture fur and use fox scat for genetic analysis for diet information. This is a cheap, non-invasive method for collecting genetic information and determining the genetic status of SVRF. The genetic analysis can be used to distinguish whether SVRF, the non-native, or both are in the area. If the SVRF is experiencing an inbreeding depression, then SNRF should be introduced. Red fox subspecies from different areas may displace alleles that cause local adaptation. Snares should be checked frequently to ensure minimal habitat disturbance and SVRF injury, from snare rust or other factors.
D. Road kills
    a. Place signs that alert drivers that wildlife use this road to access other habitats and lower speeds during two hours before night and stop four hours after dawn (Warner and Hendrix 1984).
E. Habitat and Food Resources:
    a. Based on the best available science, logging and vegetation management do not impact SNRF. This may not apply to SVRF, because it is currently not spotted in protected national parks (U.S. Department of Fish and Wildlife). However, precautions should be taken. For instance, do not start logging during breeding season, because it minimizes cover for pups and female adult SVRF. The effects of logging and vegetation management needs to monitored. If SVRF's population is affected then it must be placed as a subgoal under habitat goal.
    b. Grazing should be minimal in order to support vegetation diversity. With excessive grazing, late successional species that depend on early successional conditions may not be able to grow. Once high plant diversity is restores, an increase of vertebrate diversity, including SVRF's prey, will follow (Tesky 1995).
    c. "Red foxes would probably benefit from prescribed fire that increases the proportion of edge and the complexity of the vegetation mosaic" (Tesky 1995).
    d. Set tracking devices to native species that have been captured and use the Kernel method to identify home ranges and preferred habitat.
    e. Fox scat can be used to determine fruit and animals being eaten. The information collected can be used to protect food resources. After two years of collecting scat, accounts for varying weather conditions, the restoration plan needs to include a section of how to increase the prey and flora used by SVRF.
    f. In places with minimal loose soils, gypsum or organic material should be used to loosen soils with high compaction.
F. Diseases
    a. Enforce pets to be vaccinated when visiting areas where the native red fox subspecies has been spotted. The spread of rabies should be controlled since it accounts for 60-80% of mortality when there is an outbreak. Dogs with canine distemper should not be allowed in the area (Tesky 2005).

Monitoring Plan

A. The current habitat the SVRF should be monitored to assess the preferred, available areas and examining scat should assess diet. This will require microscopes to identify vegetation eaten and the prey availability (red fox booklet).
    a. Motion sensor cameras should be used to assess whether the population are in areas that red foxes have been spotted. The cameras should be placed in the corridors to ensure SVRF is using corridors to cross roads. Scat analysis should be monthly to allow us to determine the diet variation of SVRF throughout the year. (red fox booklet). In order to increase the success of SVRF sightings, scent traps with bait has been proven to attract cryptic species (US Fish and Wildlife Service).
    b. If the SVRF is not using the habitat, then the area is not favorable to the red fox species. If they have been spotted in the area, then restoration of the flora and vegetation should be placed as a priority.
B. Monitoring should be performed in 10 years, because in this time frame we should have 5 generations. Five generations will allow us to determine if the population is self-sustaining or whether a new restoration plan is required. This allows us to determine whether food abundance is high to sustain a population. During times of high food abundance, juveniles produce offspring during their first year after reaching sexual maturity. If the population stops growing, then the population has reached its carrying capacity or our management plan is ineffective (EPA 264). To determine both the condition of the red fox, multiple mark and recapture methods and the Schnabel index will allow us to estimate the population abundance. This must be performed every year, so we can perform statistical evidence of the effectiveness of the management plan.
C. Look into historical data of red foxes with rabies and other transmittable canine diseases. Keep a record every year of foxes reported with rabies (Teskey 1995). If a SVRF population has some individuals with rabies or other canine diseases, we should euthanize those individuals and vaccinate the remaining individuals. This can be accomplished through a trap, vaccinate, and release method.

<u>Gaps in Knowledge</u>

A. There is limited information on the SVRF and management plans (Sacks 2010). At the moment we have to use information on SNRF or other native subspecies, because it is the closest native subspecies to SVRF.

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American Bullfrog (*Rana catesbeiana*)

A. Background

The American Bullfrog (Rana catesbeiana) has been ranked as one of the top 100 most invasive species throughout the world (Louette, 2012). Originally used as a food source and for pest control, the Bullfrog was brought to every human-inhabited country, and quickly its population inflated to uncontrollable numbers that began affecting other species as well as the environment (Witmer et al, 2015). Bullfrogs inhabit aquatic environments, and can prey on, outcompete, and push out native species because of their aggressive and territorial behaviors (California Herps). The bullfrog's relationship with other amphibians, especially frogs, is especially important because frogs are thought of as an indicator species of environmental conditions. Frogs have extreme responses to the stress of changing environmental conditions, and many species have already gone extinct (CDFW, 2014). The bullfrog is one such stressor. Any aquatic habitat with bullfrogs present should be considered for restoration purposes. Because of the detrimental effects this species is having, restoration of historical habitats is crucial to take away the American Bullfrog's ideal breeding habitat and allow for the return and proliferation of native species (Ficetola et al., 2010). However, limited funding in studying and eliminating the American Bullfrog contributes to the ongoing problem it is creating in ecosystems globally (Louette, 2012). Without a successful plan for elimination, the bullfrog will continue to deplete native species and degrade habitat crucial for these native species to thrive.

B. Literature Review
Family: Ranidae
Genus: Lithobates
Species: catesbeianus

<u>Species Identification</u>

- Wide heads, stout bodies, long hind legs and webbed feet (CDFW, 2016)
- Often characterized by a distinct fold from the posterior of the eye to the shoulder area (Washington, 2009)
- Skin color ranges from green to brown on their backs, and white to grey to yellow coloring on their underside (CDFW, 2016)
- Males have a smaller body size and yellow throat (CDFW, 2016)
- Adults can weight up to two pounds and eight inches in length (CDFW, 2016)
- Tadpoles are green to yellow in color with small, dark spots of their backs (CDFW, 2016)

<u>Species Characteristics</u>

- Highly mobile, and can hop long distances as well as being strong swimmers (California Herps)
- Commonly live between eight to ten years (California Herps)
- Active both day and night, but primarily at night (California Herps)
- Cannibalistic, and can often contribute to the maintenance of their own population

numbers by preying on tadpoles (Louette et al, 2013), and adults will eat anything they can fit in their mouths (CDFW, 2016)

Habitat Requirements

- Need an annual presence of water/permanent water is a requirement (Fuller et al, 2011)
- Found most often at sites of lower elevation (USFS, 2016)
- Can thrive in a variety of different habitats (lakes, ponds, swamps, marshes, brackish waters, streams, rivers, ditches, canals, mill ponds, cattle ponds, and reservoirs), and tend to do very well in human modified habitats (including influences from growing urban areas, cropland, and changing agricultural methods used to boost productivity) (CDFW, 2014)
- In a study on the bullfrog within central California, bullfrogs were found most often in habitat altered by human-related activities, more specifically banks trampled by cattle, areas with sediment from erosion from construction, and small impoundments (Moyle, 1973)
- Can live in small, shallow water bodies with fish (Louette, 2012)
- Good breeding habitat characterized by deep water body with rooted, floating vegetation (Fuller et al, 2011)
- The presence of fire has little to no effect of the success or failure of this species (USFS, 2016)
- Like many other amphibian species, the bullfrog is susceptible to the effects of pollution that can often lead to malformations in tadpole physiology as they mature (USFS, 2016)

Reproduction

- Males are aggressively territorial and compete for females (California Herps)
- Aquatic reproduction with external fertilization from May to August (phenology depends on climatic conditions) (California Herps)
- Females can lay up to 20,000 eggs in a sheet that can reach two feet in diameter (California Herps)
- Tadpoles grow large relatively quickly, but do not metamorphose for 1-2 years (California Herps)
- Tend to disperse locally (CDFW, 2014)

Rana catesbeiana as an Invader

- Native to the central and eastern United States, but are invasive to the western United States where they have been introduced (California Herps)
- First introduced to the western United States in the early 1900s (Witmer et al, 2015)
- A live amphibian trade continues to bring American Bullfrogs into unnatural areas, furthering the spread of this invasive species (CDFW, 2014)
- Overall, invasive species are considered the most important threat to biodiversity (Louette, 2012)
- The American Bullfrog shows several characteristics of a successful invader, including rapid recolonization of an area, high climatic tolerance, generalist feeding, and ability to

be prosperous in a variety of environments (Fuller et al, 2011)

- The presence of this species increases the possibility of changes in ecosystem function and abiotic features (Ficetola et al, 2010)
- Although not normally found in the same habitat, the bullfrog is leading to the decline of *Rana boylii* because of the bullfrog's increasing habitat range (especially human-altered environments) (Moyle, 1973)

Interspecies Interactions

- Decrease survival of cohabitating native species through competition, predation, and transmission of pathogens (Louette, 2012)
- The bullfrog competes with a variety of species apart from other amphibians, such as native birds, reptiles, and fishes often by reducing the available food to these native species or by pushing them out of an area with their aggressive behaviors (Witmer et al, 2015)
- Bullfrogs will eat anything almost anything, including birds, bats, rodents, frogs (particularly the California red-legged frog), newts, lizards, snakes, and turtles (CDFW, 2016)
- The majority of their prey is aquatic, including some aquatic vegetation (Hothem et al, 2009)
- Juvenile bullfrog diet can overlap as much as 80% with the diet of native frog species (Wu et al, 2005)
- The areas in which the frog is most successful do not have a natural predator (California Herps), such as snakes, turtles, fish, birds, and raccoons to control its numbers (fcps.edu)
- Bullfrogs are known to be carriers of the often fatal chytrid fungus, which leads to skin disease transmission to other amphibians (CDFW, 2016)
- Very few predators find the bullfrog palatable because of a mucus on their skin as adults, so any natural predators tend to feed on tadpoles exclusively (California Herps)
- The elimination of the bullfrog is an integral action in many existing plans to save threatened frog species (CDFW, 2014)

Efforts in Species Control

- Currently, there is a lack of a successful management plan to reduce numbers of the invasive species (Louette, 2012)
- Fyke nets may be a feasible methods to capture young tadpoles and keep them from reaching adulthood, which is overall a good conservation method in areas with bullfrogs inhabiting only a few water bodies of high concern (Louette et. al, 2013)
- In a study by Louette (2012), the author found that the presence of a large, piscivorous fish species (Pike) can reduce the number of bullfrog larvae/tadpoles through predation
- Decrease breeding habitat (Fuller et. al, 2011), possibly through the manipulation of water flows to mimic natural habitat condition, which will decrease the ability for bullfrogs to successfully colonize → increase the number of active side channels, shallow water, gravel substrate, and fast water moving through the area (Fuller et. al, 2011)
- A study in chemical control has found two chemicals proven success in controlling the

expansion of the American Bullfrog (Chloroxylenol and Rotenone), but this method is "only practical in an area where total rehabilitation of the water body is deemed necessary" (Witmer et al, 2015)

- Limited funding has provided a major obstacle in the history of controlling this species, and many authors note the monetary feasibility in their methods in hopes of showcasing the possibility that their method is a practical solution to this invasive species (Witmer et al, 2015)
- Changing of land use practices by humans make determining historical habitat conditions difficult, provided an obstacle for successful restoration of habitat that benefits native species (Ficetola et al, 2010)
- Restriction of take of the bullfrog (usually for purposes of consumption) allows for increasing population, but a reduction in these restrictions would reduce populations through hunting (Moyle, 1973)

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Goals and Processes for the Extermination of the American Bullfrog (*Rana catesbeiana*) in California's Central Valley

A. Goals

Because the American Bullfrog (*Rana catesbeiana*) is an invasive species plaguing the western United States, the species will need to be eliminated in the Central Valley to allow for native species recovery and restoration. Therefore, successful restoration of an area will only be possible with bullfrog elimination, or substantially bringing down the population in the area being restored. By evaluating this species' life history requirements and behaviors, a plan can be developed to reduce their population numbers. The following reflects aspects of meeting this goal.

Reduction of Metapopulation Connectivity

The American Bullfrog is a highly mobile species that has the ability to hop long distances and tends to be very strong swimmers. This characteristic allows for high dispersal and colonization of adjacent aquatic areas and can expedite further detrimental spread as an invasive species (Atobe et al, 2014). High aquatic habitat conductivity can decrease the rate of local extinction and can lead to increases in population numbers (Atobe et al, 2014). Although reduction in habitat connectivity is not ecologically sound because of the profound impacts it could have on the surrounding species and projects for native species restoration, evaluating microhabitats with an absence of bullfrogs and focusing on restoring these areas will prevent the spread of bullfrogs into these less habitable areas.

Reduction is Reproductive Capabilities/Opportunities

The American Bullfrog relies on an annual presence of water (Fuller et al, 2011) and can thrive in a variety of aquatic habitats (CDFW, 2014). Their ideal breeding habitat is characterized by deep water bodies with rooted, floating vegetation (Fuller et al, 2011). By making water bodies more shallow or eliminating certain areas of water, the bullfrogs will be unable to breed, which will lead to population reductions. Because of the bullfrog's highly competitive and territorial nature in regards to breeding – male bullfrogs have been know to fight off other male bullfrogs as well as individuals of other species when defending a breeding habitat – bullfrogs can often be the only species left in a small area (CDFW, 2014). This provides an excellent opportunity in species reduction (i.e. water drainage), as it could reduce the interference in restoration of another species in that the bullfrog has already eliminated other species from the area. Feasibility of this, however, depends on the connectivity and potential detrimental effects to other aquatic species in the area.

Focus on Reduction in Tadpole Populations

Previous efforts in the elimination of the American Bullfrog have ended up yielding backwards results; if adults are targeted for removal within an area, total population can actually increases due to the cannibalistic nature of the adult bullfrogs. Adults will prey on tadpole young, which decreases number of young metamorphosing into adults and can help reduce populations reaching adulthood (Louette et al, 2013). Therefore, the focus for elimination of this species must be on the reduction of tadpoles, which will then have trickle down effects on the gradual reduction of adult bullfrogs.

Collaboration

Many factors contributing to the increasing population of bullfrogs result from the continuous introduction from human sources. An illegal amphibian trade persists as tastes for frog legs as well as the demand for household pets increases (CDFW, 2014). The California Department of Fish and Wildlife works to monitor the influx of bullfrogs from this trade, and a collaborative effort with this department could yield a beneficial relationship with the goal of eliminating the bullfrog.

B. Eradication Plan

The elimination of the American Bullfrog will be a multistep process, involving the study of the habitat, study and trapping of the species, and followed by the monitoring of the species to ensure population numbers are not rebounding and cohabitating species are seeing an incline in species numbers. The following are steps in the restoration of native habitat, prior to the introduction of the highly invasive American Bullfrog by methods of eliminating the bullfrog. This is a comprehensive list of a variety of possible elimination methods, and one that best fits the needs of community restoration could be selected, based on the requirements and study of the region.

Assess Available Funding

There is a current lack of successful management plans globally to reduce the American Bullfrog (Louette, 2012) because of limited funding attributed to projects of this nature (Witmer et al, 2015). Therefore, a budget must first be established to determine the monetary confinements of this project. Many of the recommended methods below are drawn from studies that specify the reasonable budget of their plan being carried out. This is important because the scope of the project can be severely limited by available funding.

Site Mapping

As previously discussed, the success of the American Bullfrog is highly dependent on the connectivity of metapopulations utilizing microhabitats in California's Central Valley to persist (Atobe et al, 2014). By exploring the layout of the restoration site, the feasibility of reducing metapopulation connectivity can be evaluated. Proximity of neighboring aquatic habitats should be quantified (in meters), and evaluated for the presence or absence of the American Bullfrog. This will help in establishing a count of the bullfrog as well as determining the spread of the bullfrog throughout an area.

Manipulation of the Ecosystem

- **Manipulate Water Flows and Decrease of Breeding Habitat**

Although bullfrogs have been know to thrive in a variety of aquatic habitats, including habitats that have been heavily altered by human land use (CDFW, 2014), they prefer areas of slow moving, deep water to breed (Fuller et al, 2011). However, the natural conditions in many waterways are fast moving and shallow areas that cater to the needs of the native species within the region (Fuller et al, 2011). By manipulating water flows to create faster moving channels with turbulent water over gravel substrate, bullfrogs will hopefully have less successful breeding because of a decrease in their ideal breeding habitat conditions. The return of a habitat to its historical conditions can often decrease population of invasives and in turn increase the population of native species (USFS Invasive Species Program, 2014). The manipulation of the aquatic ecosystem to incorporate quicker water is important in decreasing bullfrog breeding, and in turn decreases the population of bullfrogs.

- **Introduce Piscivorous fish**

Part of the reason that bullfrogs remain such a huge threat to ecosystems is that many species that are potential predators find the larvae and adult bullfrogs unpalatable (Washington Department of Fish and Wildilife, 2016). However, a previous study on American Bullfrog elimination within an ecosystem found that the prevalence of a large piscivorous fish species in the community reduced the number of tadpoles within the habitat (Louette, 2012). This study used a native top predator fish species (the Pike) to assess the fish's success of reducing bullfrog larvae through predation. By introducing a fish species similar to the methods of this study, bullfrog tadpoles could be targeted in reducing population, which has been proven to be the best method of eliminating the American Bullfrog (Louette et al, 2013). However, the study does recommend that the large fish species is a native species that has previous been found in the area. This will prevent further problems with any introduced species within the ecosystem (Louette, 2012). Therefore, this method is best for aquatic habitats that used to house a native fish predator, but for one reason or another it no longer is present in the area.

Netting of Tadpoles

A more passive method of species control that has been studied in the elimination of the American Bullfrog is the use of fyke nets to capture tadpoles (Louette, 2012). Fyke nets are actually a form of trapping fish that consists of a few conical shaped net bags that end in a small hole large enough for tadpoles to enter through. However, the tadpole is then unable to exit the trap in the same manner that it entered (fao.org, 2016). A previous effort using fyke nets to capture and remove tadpoles from a water body in which the bullfrog was invasive lowered the population of tadpoles from 1,600 individuals to fewer than 200 three years later (Louette et al, 2014). This sets a precedent for an almost 90% reduction, a feasible goal if the time frame is feasible for the restoration project. The fyke net is able to catch and withhold tadpoles of length six centimeters or longer (Louette, 2012). Setting up a single fyke net within a body of water in which the bullfrogs are found that is checked daily to remove collected tadpoles has proven to be an extremely successful method that is not intrusive to other species in the area.

Each of these methods could be used individually or in conjunction to decrease American Bullfrog populations, and relieve native species of its detriments. It is also important to note that based on the requirements of other species in the community, some of these species elimination plans may not be viable. Once a plan is selected, monitoring not only the change in bullfrog population but also the effects of the plan on other species in the community should be evaluated. For example, using a monitoring plan specific to the other species in the area, is the population of the species increasing or decreasing? And if it's decreasing, could this be from an action being used to eradicate the bullfrog? Studying the effects of these potentially hazardous eradication plans to other native species will help in determining the best plan of action for ecosystem restoration.

C. Monitoring Plan

The monitoring of the American Bullfrog populations should continue for at least a three to four year period, and should continue longer if any of these methods are not proving successful. Young tadpoles require at least one full year to metamorphose, at which point they can begin to breed as adults (Washington State Fish and Wildlife Service, 2016). This length of monitoring can allow for a few years of reproduction and recruitment into the population, and the success of the restoration plan can be gauged to determine if the selected strategies are effective. Additionally, as shown in previous studies done with fyke nets, there is a clear and distinguishable difference in population size after the three-year implementation of the fyke nets. Monitoring over this period is crucial for the removal of the tadpoles and to determine the effect of the trapping on population reduction.

One of the best ways to quantify populations of bullfrogs in an area is by their loud and distinct call. Call surveys can be used during certain times of year, more specifically at the height of breeding season in July and August, to approximate a count of adult bullfrogs (Atobe et al, 2014). These surveys can be used to quantify the remaining population of adult frogs that are persisting, and can be used to determine if the population is decreasing. Because of the distinct call from the bullfrog, this is the best method in assess their population size.

Through the process of bullfrog elimination, a continued collaboration with the California

Department of Fish and Wildlife should be maintained to ensure that any introduction of the American Bullfrog to the area from illegal trading or importation is reported. Because the bullfrog is able to colonize a variety of habitats rapidly, these immigrations are important to note as they could again lead to the proliferation of the species.

Future research on how the elimination of the bullfrog is altering the success of native species should be conducted. Because the bullfrog affects other mostly native species through predation, competition, and habitat alterations, the American Bullfrog elimination will have profound effects on ecosystem and community functioning.

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Ring-necked pheasant

While the Ring-necked Pheasant is not a native member of the riparian and grassland communities of the Central Valley it holds interest for our restoration site because of its highly visible nature for the public. This bird also has potential value as an indicator of the health of grassland and riparian communities where the bird can be found in terms of available cover and food resources. Ring-necked Pheasants are a highly visible, popular game bird that has recently been experiencing population declines throughout North America, including in the Central Valley for more than two decades. While a great deal of the population decline of pheasants can be attributed to habitat fragmentation, the birds have also been negatively impacted by the lengthy drought California has been experiencing. The decline of this species, heralded by an increasingly fewer hunters, hunt days, and number of birds bagged according to the harvest data of the California Department of Fish and Game includes more than a twenty percent decline in harvest between 2007 and 2010, and even further decreased by 2015. This decline, dated back some twenty five years by multiple nonprofit groups (Ducks Unlimited, California Waterfowl Association), has been a concern for state and federal agencies as well due to not only the value of the pheasant as a game bird, but also the species value as an indicator of healthy grasslands and soil condition due to its diet and reproductive habits.

Species Characteristics:

- Polygynous breeders (Ahlborn 1988-1990)
- Clutch size of 10-12 eggs, precocial and nidifugous young, capable of leaving the nest and feeding themselves soon after hatch (Ahlborn 1988-1990)
- Major predators red foxes, as well as large raptors, which are a particular threat of mortality for chicks (Schmitz & Clark 1999, Riley & Shulz 2001)
- Shared niche with game birds of comparative size, prairie chickens, sage-grouse, neither present at site (Tesky 1995)
- Present in sagebrush, grasslands, prairie, wet grasslands, agricultural fields, with a preference for areas with available cover (Ahlborn 1988-1990, Tesky 1995)
- High mortality to chicks from predation and environmental exposure, with complete population turnover within five years on average (Tesky 1995)

Ecosystem requirements:

- Insects and invertebrates are an important part of the diet of adult birds in the spring and summer months, making up nearly the whole of the diet of chicks for the first five weeks post hatch. Includes crickets, potato beetles, gypsy moth caterpillars (Ahlborn 1988-1990, Natural Resources Conservation Service 1999)
- Ground foraging throughout the year, including waste grains from agricultural fields, native forbs, hard and soft mast from acorns and pine seeds, as well as wild growing berries as available (Ahlborn 1988-1990, Natural Resources Conservation Service 1999)
- Nesting cover must be dense enough to prevent detection from avian and mammalian predators, especially in early spring. Undisturbed residual cover from the previous year is preferred (Haensly et al. 1987, Tesky 1995)
- Brood rearing cover requires grass cover of variable thickness, between eight and twenty inches in height to provide protection from detection from aerial predators

(Haensly et al. 1987, Tesky 1995, Natural Resources Conservation Service 1999)

- Shade cover in summer months is provided by small trees and shrubs, which are also utilized for roosting and escape from predators (Tesky 1995)
- Winter habitat requires woody stands for wind and precipitation cover, located within less than a mile of food sources (Gatti et al. 1989, Tesky 1995)
- Cover in the form of reed stands and other wetland plants are used throughout the year as predator escape areas and sites of additional food sources (Tesky 1995, Natural Resources Conservation Service 1999)

Abiotic Tolerances:

- Most water needs met by diet, habitats with standing water are capable of supporting larger populations. Wetland plants provide cover and additional feeding opportunities. (Ahlborn 1988-1990)
- Capable of surviving in temperatures far lower than experienced at the site, given sufficient tree cover and roosting opportunities (past -8º C) (Perkins et al. 1997)

Spatial Scale:

- Daily activities of individuals typically occur within a square mile, though a smaller space can support more if the necessary habitat requirements are met. (Natural Resources Conservation Service 1999)
- Variable "crowing" area for territorial behavior in breeding season by males, 1 ha and up (Taber 1949, Ahlborn 1988-1990)
- Non-migratory (Natural Resources Conservation Service 1999)

Temporal Scale:

- Breeding season begins in March-April (Ahlborn 1988-1990)
- Incubation period of about 23 days (Ahlborn 1988-1990)
- Capable of breeding the spring following hatching (Tetsky 1995)

Management Response:

- Responds poorly to extensive use of pesticides and herbicides (Natural Resources Conservation Service 1999)
- Disking should be done in rotational sections, to allow sufficient amounts of cover and feeding habitat to remain, in January to February (Natural Resources Conservation Service 1999)
- Burning on a four to five year rotation in late winter to early spring (Natural Resources Conservation Service 1999), avoid burning in spring nesting season, always ensuring sufficient cover remains available (Tetsky 1995)
- Rotational mowing down to a height of 6-12 inches in the beginning of August retains sufficient cover and food sources (Natural Resources Conservation Service 1999)

Negative Impacts:

- Potential carrier of fowl cholera, of concern for waterfowl and gamebirds, not a significant threat to human health (Einum et al. 2003)
- Potential, but minor, vector for parasites such as *Heterakis gallinae* (a nematode) for other birds (Leigh 1940, Natural Resources Conservation Service 1999)
- Some detrimental effect on native lekking game birds (from physical presence on lekking grounds to the addition of pheasant crowing during displays), none of which are present at the site in question (Ahlborn 1988-1990)

- Potential carrier of *toxoplasmosis*, capable of transmitting to rodents (Hoare 1956)

Monitoring:

- Monitoring with call and brood counts are capable of supplementing population estimates in areas where harvest is not possible, though these methods indicate general population trends rather than providing more solid population estimates (Rice 2003)

Part II: Plan for the Central Valley

A. Goals:

Foster source populations of *Phasianus colchicus* on private lands.

- Work with private landowners and hunting clubs to create and maintain grasslands and wetlands suitable for pheasants
- Include private landowners (including agricultural landowners) in annual meetings on monitoring and conservation efforts
- Increase education about pheasant friendly management practices, including burning, mowing, and grazing schedules that do not disrupt pheasant populations
- Encourage the retention of brush and tree stands near agricultural and grassland areas
- Educate private landowners on pheasant ecology, as well as grassland and wetland easements

Maintain, restore, and manage pheasant habitat through adaptive management on both public and private lands, with the help of NGOs and government agencies.

- Utilize funds from the Pitman-Robertson Act, as well as funding partnerships with non-profit groups (California Waterfowl Association, Ducks Unlimited, Pheasants Forever) to acquire and maintain grassland and wetlands habitat
- Annually monitor breeding with brood and crowing counts, as well as annual hunter take statistics gathered by USFWS and CDFW
- Foster the use of native plants when possible to maintain habitat for pheasants and other wetland and grassland species of vertebrates
- Maintain sufficient wintering stands of trees and shrubs within 1 mile of feeding sites
- Continue and expand protection of grasslands and wetland habitats from exploitation and destructive land use

Increase pheasant numbers within the California Central Valley.

- Improve and protect current habitat through adaptive management
- Actively manage and monitor known populations to determine most effective management practices and timing of management
- Monitor populations for predation and disease mortality to determine influence on population numbers

Increase public awareness and support of pheasants within the California Central Valley, as well as support for grassland and wetland habitats.

- Involve private landowners in monitoring and management decision making

- Increase educational opportunities concerning pheasants and their habitats for public consumption
- Collaborate with non-profit groups to increase public awareness of pheasants and conservation concerns

B. Restoration Plan:
Increase and improve pheasant habitat:

- Provide sufficient seasonal cover within areas for pheasant conservation

Spring	Grasses (preferably native) between eight and twenty inches tall, of variable thickness (Haensly et al. 1987, Tesky 1995, Natural Resources Conservation Service 1999) Undisturbed residual cover near and within woody and shrub stands (Haensly et al. 1987, Tetsky 1995). This may interfere with efforts to reduce fire risk in dry areas
Summer	Small stands of trees and shrubs, preferably separated into complexes by grasses (Tesky 1995)
Fall	Maintain sufficient woody, shrub, and grass cover throughout typical dry season
Winter	Woody stands, within less than 1 mile from food sources (Gatti et al. 1989, Tesky 1995)
Year-round	Stands of reeds and wetland foliage, may require irrigation in dry years (Tesky 1995, Natural Resources Conservation Service 1999). Reed stands may be unsupportable in highly managed wetlands, where early successional stages are preferred. Stands of cover, shrubs, tree stands, thorny bushes, should be within less than 1 mile from food resources (Gatti et al. 1989, Tesky 1995). These may be unsupportable by "clean farming" practices and agricultural interests.

- Ensure sufficient food availability throughout changing seasonal demands of the pheasant life cycle.
  - Pheasants ground forage throughout the year, drawing resources from agricultural waste grain, native forbs, wild growing berries, and hard and soft mast from acorns and pine seeds (Ahlborn 1988-1990, Natural Resources Conservation Service 1999). Cover stands should include oak and pine trees, and stands of berry producing bushes such as black berry

and elderberry plants to augment cover and feeding resources while adding to riparian habitat, though adding these plants to existing stands would take multiple years if not decades to establish.

  - Wetland areas provide sources of invertebrates for calcium and invertebrate needs of pheasants in the spring and summer months, as well as providing additional sources of cover and water (Ahlborn 1988-1990, Tesky 1995, Natural Resources Conservation Service 1999). This may require irrigation and ensuring water flow to wetland sites during dry years, in opposition to agricultural interests.
  - Provide areas of cover within less than 1 mile of agricultural areas, to allow access for foraging on waste grains without undue risk of predation (Ahlborn 1988-1990, Gatti et al. 1989, Tesky 1995).

Reduce pheasant mortality from indirect human behavior:

- Limit the use of pesticides and herbicides on public lands, particularly during brooding season, as chicks are more vulnerable to toxins than adults, and pheasant diet is heavily reliant on insects and invertebrates during the spring and summer months (Ahlborn 1988-1990, Natural Resources Conservation Service 1999). Efforts to encourage this on private lands may be impeded by agricultural interests. This may be further impeded by mosquito control efforts in wetlands and riparian areas, as well as herbicide use on lands to control invasive non-native plant species in both grasslands and wetlands, though delaying the application of such chemicals until June-July allows the bypassing of the wholly insectivorous stage of the pheasant chicks life, minimizing secondary poisoning from insecticide. (Ahlborn 1988-1990).
- Rotational mowing down to a height of 6-12 inches in beginning of August allows sufficient cover and food resources to be retained, while controlling grass growth (Natural Resources Conservation Service 1999). This timing also avoids additional mowing and predation related mortality amongst chicks, as earlier mowing might add to the already high chick mortality.
- Burning should be carried out on a four to five year rotation in late winter to early spring (Natural Resources Conservation Service 1999), avoiding burning in spring, and allowing sufficient cover to remain to avoid undue loss of cover for predation escape and increased chick mortality from the fires themselves (Tetsky 1995).
- Disking, if carried out, should be done in rotational sections, rather than an entire area in a single instance, in order to allow sufficient amounts of cover and feeding habitat to remain, in the months of January and February (Natural Resources Conservation Service 1999). This prevents undue loss of population from predation and loss of food resources, as well as avoiding direct chick mortality from disking itself by timing the management before brooding season, as well as avoiding interfering with breeding season territorial behavior.
- As needed, in sites with high levels of predation mortality of nesting females, particularly by invasive species such as feral cats, humane trapping and relocation of predators may be necessary, and kill traps are increasingly difficult to support

to public opinion, though may be an option with red foxes on private lands.

Risks:

- Habitat loss may not be the primary reason behind the declining population of pheasants. If this is the case, then efforts to maintain and restore pheasant habitat will not bolster populations. If so, a ban on pheasant hunting will eventually be enacted in the state, until population levels recover. It is worth noting that despite recent declines, a hunting ban has not yet been called for (California Department of Fish and Game 2011, California Department of Fish and Wildlife 2015).
- There is potential for certain proposed management actions, specifically wetland irrigation, pesticide and mowing limitations, and retaining residual cover to increase the risk of danger to humans in terms of fire and mosquito exposure. In these cases, the interests of human safety supersede the interests of pheasant conservation.

C. Monitoring Plan:

Brood counts and call counts during breeding season along set transects through pheasant habitat will be undertaken on an annual basis. Both count systems have been found to be capable of indicating low, medium, and high harvests over state-wide areas (Rice 2003). While these methods are not as accurate in estimating population as take statistics, the non-invasive monitoring will allow greater flexibility on the short term management of pheasant conservation, as it does not rely on data gathered from previous years, as well as offering an opportunity to observe pheasants interacting with their environment, which will help determine habitat use.

Hunter take statistics (California Department of Fish and Game 2011, California Department of Fish and Wildlife 2015) will be compiled on an annual basis and assesses for major losses based on a statistically significant difference in take rates between a five year period based on a p-value of 0.05. This 5 percent error in addition to the five year span of evaluation accounts for yearly environmental and population stochasticity, while still remaining focused enough to allow for habitat alteration before dramatic damage to the population of pheasants occur. Hunter take counts have been the traditional method for monitoring game birds, and provide a year to year estimation of population values, without creating significant additional efforts of monitoring by government agencies.

Monitoring will also be undertaken on private and public lands that have not been under this restoration plan, with the permission of landowners as available, for comparative purposes. Brood and call counts are the most applicable for these sites, as areas with hunter take counts available are under management.

This monitoring will be focused on the impact of habitat on pheasant populations, concerned with the notion that habitat loss and degradation are the primary drivers of the decreasing numbers of pheasants within the state of California. The majority of monitoring and restoration works on the assumption that brood and chick mortality are responsible for the largest proportion of pheasant mortality on a whole, though the influences of predation on adults, the impact of drought on pheasant populations and habitat, and the scope of influence the use of pesticides and herbicides has on direct and secondary mortality should be explored to improve the plan. Monitoring pheasant populations in unrestored and unmanaged pheasant habitat as well as the populations of restored and managed habitat will help determine the impact of restoration work on pheasant numbers.

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Ecosystem services

Minimizing wildfires

Background:

In California's Central Valley there are a few plant communities that have interesting relationships with fire. Those two are the valley grassland and riparian woodlands. Valley grasslands usually have high intensity fires and exhibit a short fire return interval. In contrast, riparian woodlands vary greatly in severity from low to high and have a long fire return interval (Sugihara 2006). However, some of the Central Valley is also dominated by urban environment, in these areas minimizing fire is the desired goal. Currently the valley grasslands are characterized by having annual grasses as the dominant plant species. The high turnover of this type of vegetation allows for frequent fires when ignition sources are high (Sugihara 2006).

Riparian woodlands are characterized by the presence of water, the creeks and rivers that run through these areas creates an ecosystem that is highly diverse and productive (Pettit 2007). The way the water interacts with the vegetation, either by flooding, varying flow, or changing water levels creates a heterogeneous mix of vegetation (Pettit 2007). As a result of its moisture regime and vegetation variation this system is innately resistant to fire, however it is not free of fire (Pettit 2007). Managing has always been a difficult task, each system has a specific fire regime and eventually human interaction will fail and wildfires will start (Sugihara 2006). Although, it is possible to manage risk to some areas with different management strategies.

Literature Review:

I. Natural Fire Management

   Riparian

   - Riparian woodlands have a higher resistance to fires and can act as a natural fire break (Pettit 2007)
     - The moisture level of the waterway reduced the ability of fire to spread through these areas (Pettit 2007)
     - "fire frequency and severity in the riparian zone usually decrease as channel size increases" (Pettit 2007)
   - Promoting beaver populations not only benefits a riparian ecosystem but it can also reduce the risk of fire in these areas, including the upland. (Baldwin 2015)
     - Beaver dams can collect sediment and create wet meadows
       - These can moderate floods, maintain stream flow levels longer into the dry season, and cool stream temperatures all of which are effective at reducing wildfires. (Baldwin 2015)

   Grassland

   - Native grassland vegetation, which is possibly perennial bunch grasses, are resistant to fire and do not produce as much fuel loads per year as annual grasses (Sugihara 2006)
     - In the absence of nonnative annuals, the native grasses can reduce the occurrences of fires (Sugihara 2006)

- The ideal goal is to get the cover of nonnative invasive plants down to 20% in grassland communities (Tjarks 20012)

II. Management strategies
   - Human made fire breaks create barriers to the spread of fire and provide access for emergency firefighting services (Keeley 2006)
   - If possible to use fire, targeting the invasive nonnative is the most effective use of the tool (Sugihara 2006)
   - Fuel reduction practices can decrease fire risk (Sugihara 2006): fuel reduction is defined as "altering the volume, size-class distribution, arrangement, moisture, or chemical content of these fuels (Choosing Fuel Treatment Methods).
     - This is done by removing dead material, reducing fuel loads by cutting the grasses to approximately 6 inches or less. When these height limitations are set in narrow areas, such as 30 feet to 100 feet wide, can dampen the fire and make it easier to put out (HEF Management Recommendations)
     - In grassland communities, one should focus on the reduction of surface fuels (Choosing Fuel Treatment Methods)
     - For riparian habitats, it is important to remove surface fuels, as well as ladder fuels to prevent the occurrence of destructive crown fires (Choosing Fuel Treatment Methods)
     - Target fuel treatments to defensible spaces
   - Defining high risk areas in the Wildland Urban Interface and focusing fire minimizing efforts in these locations to reduce risk to property (Tolhurst 2013)
   - Grazing is an effective method to reduce fuel loads in grassland communities (Using Livestock Grazing…)
     - Using sheep, goats, and cattle to grasses short, reduce buildup of thatch, and increase nutrient cycling (Choosing Fuel Treatment Methods)

III. Challenges in management strategies
   - Fire is largely uncontrollable and while the patterns of fire can be predictable, the exact occurrence and the result of a fire in an ecosystem is highly uncertain (Sugihara 2006) – Assumption made based on site data presented in *Fire in California Ecosystems*
   - Prescribed burns are a common method to reduce fuel loads and reduce wildfire risk (Sugihara 2006) however the close proximity to a wildland urban interface makes using fire as a management strategy a high risk situation (Haight 2004)
   - Sugihara, through his research, found that despite the large changes to the "historical" fire regime of grasslands, these changes are less important for management strategies than in other plant communities. As a result of the changes to species composition and structure, burning alone has been found ineffective for managing wildfires (Sugihara 2006).
   - Fire breaks create areas of high disturbance where annual nonnatives are more likely to colonize uninhibited, this produces a problem site in an area that was developed to mitigate fire. (Keeley 2006)
     - Effective fire breaks could require maintenance depending on invasive species composition (Keeley 2006)
   - Social implications of fire management
     - People want to protect the aesthetic beauty of the ecosystem, but also want

to minimized their risk of loss due to fire damages (Dickinson 2015)

- Humans increases the possible ignition sources, and consequently increasing fire frequency (Sugihara 2006).
- Under drought conditions even riparian systems are vulnerable to fire (Pettit 2007)

IV. Implications of nonnative species

- Using fire has provided mixed results across California's ecosystems. In some areas using fire has promoted the growth of nonnative invasive annuals creating more fire prone systems (Keeley 2006)
- Many nonnative species are well adapted to fire prone environments, are annual species which respond well to disturbances, and in most systems are the dominant species and likely also dominate the seed bank. (Sugihara 2006)
- These nonnative species are highly resilient to disturbances and often repopulate within "two to three years" post fire (Sugihara 2006)

V. Climate change effects

- Global warming will continue to increase global temperatures (Baldwin 2015) and areas have greater fire risk in warmer temperatures because fuels are drier (Sugihara 2006)
- Precipitation is likely to be more variable, and could result in long periods of drought (Baldwin 2015)
  - "project[ed] that snowpack and summer flows will continue to decline, winter and spring flood magnitudes will increase, spring stream recession will likely continue to occur earlier and more quickly…highland fires will be more extensive" (Baldwin 2015)

Goals:

The goal of this project is to attempt to minimize wildfires in the grasslands, riparian habitat, and the adjacent residential communities. The management will want to make use of the natural fire resistance of riparian habitats and native perennial grasses (Pettit 2007). The areas dominated by annual grasses will incorporate more involved management practices to counter act the high fire risk of this vegetation type (Keeley 2006). Finally, intense focus to minimize risk to residential communities by similar management practices to the grassland communities. Fire is a variable ecosystem function and as such complete reduction of fires is not possible for this landscape, therefore success is measured by the reduction in severity. How well is the landscape able to recover and was economic damage minimized? The science of fire behavior is based on patterns and assumptions therefore there will always be an inherent uncertainty and risk in fire management (Sugihara 2006).

- Reduce occurrence of wildfires from the historical average for the site.
- Reduce risk of high intensity fires, such as crown fires (Katelman)
- Reduce risk to residential communities
- Use reduced fuel loads targeted at roads, homes, and other critical areas to minimize risk during fire suppression efforts (Katelman)

Management plan:

Riparian

- Fire risk is greatly reduced when there is water present in the channel (Pettit 2007)
    - The works because moisture regime prevents the vegetation from drying out and being fire prone
    - Maintaining a water level at a height that all the vegetation can access it will make this possible.
        - Having this water year round keeps vegetation alive and moisture levels high reducing fire risk around the channel (Sugihara 2006)
    - Beaver populations can be a natural strategy to increase fire resistance in riparian systems (Baldwin 2015)
        - Beavers inhabit an area of 30-50 meters surrounding their dam, therefore there should be no more than one of the beaver dams with in that habitat range to preserve the positive benefits without risking over population (Baldwin 2015)
        - The beaver dams with maintain water levels in the channel even during the drier periods of the year because the ponds that form behind the dam (Baldwin 2015)
        - The risks with this management practice is that beavers are a destructive species, if numbers become too high then the riparian vegetation suffers (Baldwin 2015)
        - Finally, the ponds allow for flooding, which may not be desirable (Baldwin 2015)

Grassland

- Native grasses such as some perennial bunch grasses are resistant to fire and produce less biomass per year compared to annual grasses (Sugihara 2006)
    - Transitioning some of the annual grasses, such as the nonnative invasive species to a perennial grassland with minimize the effects of fire and can potentially increase the fire return interval (Sugihara 2006)
        - The ideal goal is to get the cover of nonnative invasive plants down to 20% in grassland communities (Tjarks 20012) while increasing native plant concentrations.
- Fuel reductions are also an important task in reducing fire risk (Sugihara 2006)
    - This is done by removing dead material, reducing fuel loads by cutting the grasses to approximately 6 inches or less. When these height limitations are set in narrow areas, such as 30 feet to 100 feet wide, can dampen the fire and make it easier to put out (HEF Management Recommendations)
    - Fuel reductions will be most effective when implemented shortly after the growing season and before the start of the fire season, which for California grasslands is late July through October
- Grazing is an effective method to reduce fuel loads in grassland communities (Using Livestock Grazing…)

  - Grazing treatments should seek to reduce fuel loads to approximately 300 pounds per acre or less (Using Livestock Grazing…)
  - Grazing can include sheep, goats, and cattle; the species used is dependent upon the vegetation that will be eaten because the animals find different vegetation palatable (Choosing Fuel Treatment Methods)
  - Grazing is most effective when the treatment is placed before the vegetation becomes undesirable for the animals to eat (Choosing Fuel Treatment Methods)
  - This method will help keep grasses short, reduce buildup of thatch, and increase nutrient cycling (Choosing Fuel Treatment Methods)
- When permitted, prescribed burns can have some success at reducing fuel loads and reduce the presence of nonnative invasive annual species
  - Targeted small burn in areas that have high fuel loads
  - Targeted areas of invasive species to reduce their presence (Sugihara 2006)
  - However, there are mixed results on the effectiveness prescribed burns have on invasive species and altering the fire regime of grassland communities (Sugihara 2006)
  - The fuels that are of greatest risk are large accumulations of ladder fuels that create high continuity of fuels, this level of fuel loads increase risk of crown fires. These fuels will need to be manually removed before prescribed burns can take place (Katelman)

Wildland Urban Interface

- Human made fire breaks will be most effective in these areas, but can also be implemented within the grassland areas (Keeley 2006).
  - These areas will be cleared of all vegetation to disrupt the spread of fire
    - Compacting soil can help decrease the spread of plants into the fire breaks
  - Provides access for emergency firefighting services (Keeley 2006)
  - Grassland fires can have flames that reach 12 to 38 feet, depending on the intensity of the fire in that area, the fire breaks will need to be sufficiently large to prevent the spread of these fires (HEF Management Recommendations)
  - The drawback of this method is that species that are highly adapted to high disturbance can quickly recolonize these cleared land, therefore the fire breaks will need continuing maintenance (Keeley 2006)
    - Dependent on the life cycle of vegetation in the area, which is usually annually for grassland communities (Sugihara 2006)
- Many of the same fuel reduction strategies favored for the grasslands with also provided benefits to the wildland urban interface.
- When housing communities are developed adjacent to a wildland, the homes should be built with fire resistant materials to limit the economic damages of fires.
  - Homes can replace their roofing material with a Class A rated roof material
  - Use fire resistant siding materials (HEF Management Recommendations)

Monitoring plan:

Fire management strategies often are destructive to the ecosystem, as seen in the method to create fire breaks (Keeley 2006). As such the best plan is to identify areas of high fire risk or areas that contain the highest risk to life or property (Tolhurst 2013). By focusing the management strategies in these areas it can reduce cost financially and ecologically while maximizing fire reduction. A question that will want to be answered through this risk assessment is: Where are high risk areas, where preforming fuel treatments will have the most effect on the overall reduction of wildfires?

For this management plan it will require constant maintenance to maintain the benefits. Fire functions on a cycle, and the ecosystem is always trending in the direction of promoting wildfires.

- The beaver populations will need to be maintained to prevent overpopulation.
- The grassland being dominated by annual grasses will need to have fuel treatments done every year to prevent to accumulation of fuels (Sugihara 2006).
- Finally, the same fuel treatments will need to be done in the wildland urban interface on the same scale as the grasslands to prevent fire risk there.

When it comes to fuel treatments and the frequency of application, they are very dependent upon the vegetation in the area (Choosing Fuel Treatment Methods), therefore part of the monitoring plan will be to create a complete mapping of the species present at the site. The question that will be answer through this monitoring is: Where are different types of vegetation located on the site, and how will that influence the treatment practices implemented?

As mentioned in the plans goals fire is generally an uncontrollable event in ecosystems, although with monitoring the pattern or trends of the fire can be observed over the years. Once a general pattern is determined the focusing of fire prevention treatments can become more effective.

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Maximizing Carbon Storage on Restoration Sites

Increasing amount of Carbon dioxide in the Atmosphere is the most important problem we have faced in modern times. There are currently many ways to address reducing the amount of CO2 released into the Atmosphere, and it is an area that can continue to innovate. Innovation and reduction may not be enough, we will need to focus capturing CO2 and holding it in the soil or in the vegetation. We know soil is capable of storing vast amounts of carbon in organic matter for long periods of time. Permafrost and peat bogs are great examples of this. Restoration sites will undoubtedly hold capture more carbon post restoration compared to pre restoration even if that is not a goal of the project. But what if It is possible with just a few simple adjustments to capture significantly more carbon than compared to business as usual restoration projects? That is the question I will attempt to out answer for you.

A Baseline

- Restoring disused agricultural land, revegetating barren soils, planting grasses and stabilizing soils are all actions that can increase carbon sequestration and storage (Booker et al. 2013)
- "Among the most important factors for increasing soil organic carbon storage are increasing the input rates of organic matter, changing the decomposability of organic matter, placing organic matter deeper in the soil and enhancing the physical protection of the soil fractions." (FAO 2009)

Wetlands and Riparian forests

- As riparian forest age they store more and more carbon. The location of the carbon and bio mass changes with the age of the forest. Young Riparian forests have high net primary productivity. Older forests have a larger root carbon pool. (Giese, et al. 2002)
- Wetlands can store twice as much carbon in their soils as no till croplands (McCarty, et al. 2002)
- A 1 Km long 45-year-old riparian restoration project can contain 4,419 tons of Carbon with an equivalent of 16,217 tons of Carbon dioxide. (Lewis et al, 2015)

Grasslands

- Establishing and maintaining soil organic matter is key to restoring grasslands. Many tradition management techniques may increase soil organic matter. Grazing, Fire, Fertilizer, mulch, compost, earth worm introduction are all traditional rangeland management techniques that may increase soil organic matter. (Conant, et al. 2001)
- Grassland soils accumulate organic matter with slow carbon turnover. Because of this grassland accumulate large amounts of carbon in the form of soil organic matter (FAO, 2009)
- In Grasslands carbon is stabilized by chemical, biochemical, and physical processes. This blinded carbon is in the form of soil organic matter. (FAO 2009)
- "California's native grasses, maintain an unbroken interaction with the soil and atmosphere on a year round l basis. Deep roots to exploit the full soil volume for water, a

dense aboveground structure inhibits soil evaporation, and high root production to store water. Soil carbon accumulation also fits into a strategy of water conservation, as soil organic matter is highly charged and bonds with polar water molecules." (Koteen, et al. 2011)

Composting

- AB 34 sets a goal for California to divert 75% of state wide waste to be recycled by 2020. CalRecycle's number one priority to achieve that goal is to move organics out of Landfills. (CalRecycle, 2006.)
- Diverting organic wastes to composting systems can offset greenhouse gasses. The composting process can be specifically managed to be aerobic and maintain high C: N ratios. Composting is generally thought to produces emissions than would be found in landfills (Delonge 2013)

Compost use on grasslands

- Compost in grasslands can serve many purpose. It's addition not only immediately increases soil carbon also a recent study in Californian Grasslands found a measurable increase in soil carbon years after a single compost addition. Two grassland sites in California were measured for below ground Carbon storage before and years after a single compost addition. The Compost amendment resulted in a significant increase in soil organic C carbon content. (Ryals et al. 2014)
- Compost is added to home gardens across the country to increase yield it has been proved to provide the same benefit in native grasslands (Ryals et al. 2013)
- In a 4 year study a onetime addition of compost increased above ground biomass by 71% without affecting diversity (Ryals et al. 2016)

Extra carbon may benefit native Grasses

The findings of the following studies suggest that C addition in grassland restoration is a useful management method to reduce N availability.

- "Microbial activity is high under moist conditions in grassland soils, and during the growing season, microbes have access to a lot of available C in the form of shoot and root litter produced the previous growing season as well as exudates from freshly growing roots. These conditions allow for high rates of microbial growth, leading to net N immobilization." (Parker et al. 2011)
- "If soil N availability is high through the fall–winter–spring growing season, fast-growing annuals could be favored over slower-growing perennials. Restoration efforts to reestablish native perennial grass species are more likely to be successful under conditions where perennial growth is favored over annual growth. This might include high N availability and soil moisture during the late spring and summer months." (Parker et al 2011)
- "Adding carbon to moist soil should decrease N availability in soils at the time it is

needed most by annual plants, but increase it in late spring and summer when it can be used by perennial grasses" (Koten 2011)

- "Soil nitrate concentrations were reduced at all sites within weeks of the first C addition, and remained low until cessation of the C additions. The soil N availability, composition of soil micro-organisms and vegetation characteristics continued to be affected after cessation of C additions." (Eschen et al. 2007)

A. Goals for maximizing carbon storage on restored central valley landscapes

1. Each restoration site is dramatically different but every restoration plan should consider how it can maximize its contribution to offsetting carbon emissions.

The EPA calls for a 21.3% reduction in California Greenhouse gas emissions by 2020. Restoration projects all over the state can help achieve that goal by offsetting carbon emissions.

2. Increase productivity of native grasses and forbs by improving soil.

Degraded soil can be immediately improved by utilizing large scale county composting programs. There are multiple large scale composting programs across the state. California has called for a 75% diversion of waste from landfills by 2020. Each restoration project should focus on using mulch and compost in order to help the state achieve that goal. However, the project must keep in mind the carbon cost for transportation.

3. Establish conditions where perennial growth is favored over annual growth.

Restoration sites should have a realistic goal of 75-90% perennial native grass, perennial forb, and woody plant Coverage of upland areas though 100% coverage would be ideal for carbon storage, it is not realistic due to water conditions and other goals. Perennial grasses and forbs do a much better job at sequestering and storing carbon in the soil compared to nonnative grasses. (Koteen, et al. 2011)

4. Increase tree and woody shrub coverage in riparian areas as much as other goals will allow.

Riparian areas can store tremendous amounts of carbon. When restoring riparian areas emphasis should be placed on the carbon storage potential of these areas. A reasonable goal for these areas is 4,000 lbs of stored carbon in a 1 Km section of water way. (Lewis et al, 2015) Though it may take 40 years to achieve, stable long term carbon storage is the goal.

5. Slow stream water flow to increase infiltration.

Where possible streams and creeks should be slowed to their historic flows. Creation of wetlands and widening of water ways will increase infiltration. An increase in ground water will have a positive effect on all other goals.

B. Guide lines for Increasing Carbon

The Ecosystem service of carbon storage is by its very nature inclusive of all other aspects of a restoration project. The guidelines below focus on maximizing carbon storage and ignores, or potentially at the expense of other restoration goals.

Restoring native grasses forbs and trees while keeping nonnative annuals out of the restoration site will be critical to the success of increasing carbon storage. Sequestering and storing Carbon is an extremely complex and difficult to understand process. Our knowledge of the processes that go on beneath our feet has only recently been expanding. However, the planet has been storing carbon very well on its own long before we got here and made alteration so the most basic approach to ensuring we sequester and store carbon is to simply plant native vegetation and ensure that it thrives. Moving beyond that there are individual steps we can take to increase sequestration and storage. Any of the steps below can work independently of each other but each will work better in addition to another.

The keys to increasing carbon storage will be increasing soil organic matter and net primary productivity. For this plan mulch and compost are interchangeable terminology either way it should be fine processed organic material high in Carbon Nitrogen and Phosphorous. It can be sourced cheaply from composting facilities. The N and P content in the compost will increase plant production so it should be turned into the soil deeply to keep it out of reach of nonnative germinating seeds. The nonnative seed bank will be suppressed by a layer of wood chips to be applied 3 inches thick around every plug planting covering as much area as possible. Wood chips should be course, the size a standard tree chipper produces, and can produced on site from downed logs or imported. The wood chips are high in Carbon and low in nitrogen. The microbial life that breaks down organic carbon captures and holds Nitrogen will thrive in this layer. This dip in available nitrogen is an important window for native vegetation to gain an upper hand on non-native species. The larger sized particles can take many years to fully break down whereas small particles can break down in a season. Native plugs should thrive below the 3inch thick woodchip layer but very few plants native or nonnative will germinate until after the wood chips have broken down. A wood chip layer of about three inches will also be most effective at retaining moisture from evaporation, and blocking the light which any nonnative seed below the wood chip layer needs to grow. Soil amended with wood chips and compost has larger pore spaces which will hold more water compared to compacted coils which again will increase plant production. Some of the added carbon will break down and be lost via natural processes but some will be stored in stable carbon pools for many years to come.

Adding carbon above and beyond that of what would normally be added in a restoration project will have significant costs involved. However, if the plan calls for more carbon being stored than would be stored under standard conditions it may qualify for carbon offset credits which can significantly increase funding. Cal Fire is administering grants to qualifying projects. The details for qualifying projects are out of the scope of this document however more information can be found at www.AmericanCarbonregistry.org the Registry has detailed specific guidelines for qualifying carbon offset projects in Grasslands. The document can be found in the resources section of this paper.

Long lived woody shrubs and trees will build and maintain carbon pools. Tree selection should be a mixture of fast growing species near the water's edge and slow growing deeper rooted, longer lived further out. Selection of longer lived trees is preferred provided the project does not need immediate results. Again a 3inch thick Layer of wood chips should be laid down in shrub planting areas and at the base of trees. This layer should not touch the trunks of the trees or shrubs as that will cause rot but instead should be laid down in a large doughnut around the tree or shrub. If nonnative woody vegetation is to be removed prior to restoration it can been chipped on site, vs being hauled away. Care would need to be taken to not incorporate seeds.

For Tree species selection the USDA has produced a powerful suite of tools collective called i-Tree to aid in the decision process. i-Tree Species is a utility found at www.itreetools.org that can help planners choose trees species based on specific environmental services and geographic regions. Another suite of tools for focused on carbon and energy impacts of trees can be found at www.ecosmartlandscapes.org As a general rule: in most woody species, carbon makes up around 50% of above ground weight. (Lewis et al. 2015) In general selection can consist of fast growing Alnus spp. Salix spp. and Populus spp. Adoxaceae spp. Cornus spp. Many members of the Ericaceae, Fagaceae, Grossulariaceae familes should be considered for areas just upland of stream banks.

On sites with historic beaver activity an option of carefully designed flood plains and weirs to promote seasonal flooding should be considered. The yolo bypass is an example of successfully designed flood plains that have been beneficial to aquatic, terrestrial, and wetland plant and animal species. (Sommer et al 2001)

Grasslands

Upland grasslands provide a great opportunity to increase below ground bio mass. Perennial grasses and forbs hold on to their carbon year round whereas Annual grasses release their carbon yearly. Perennial grasses have more below ground bio mass than annual grasses. The bio mass translates to higher amounts of carbon storage. Studies have found consistently higher amounts of below ground carbon in California native perennial grasslands compared to nonnative annual grasslands. (Koteen et al. 2011)

As many native species as possible should be selected but the project can be started with as few as 5 grasses. The 5 cores species will be Nassella pulchra (Purple Needle Grass), Leymus triticoides(Creeping Wild Rye) Elymus glaucus (Blue Wild Rye), Muhlenbergia rigens(deergrass), Melica californica (Melica). These 5 grasses are native to the central California and can be sourced reliably from Hedgerow Farms in either seed or plug form. Other grasses may be used as well, they just maybe not be as easily sourced and these selected grasses are thought to be dominate in native grasslands. The success of these grasses in out competing nonnative exotics is dependent on many factors that may or may not be in our control. Even if we can control the factors they are often prohibitively expensive and or labor intensive. Which is why grassland restoration in California is an uphill battle and often not overly successful. While seed spreading is a cheaper option up front, plug planting gives the grasses and forbs a jump start as well as the added benefit of being able to reach a size that can start to suppress seed germination of nonnatives more quickly than seeds can. Which by its self will not control nonnatives but in conjunction with other control methods such as grazing fire, herbicide, and mowing can provide an advantage. The plugs have a better chance of survival under these control methods compared to seeds, because they have established root systems.

There is no simple easy method for grassland restoration in California, rather many methods must be used in combination. Which tools are used is dependent on site specific variables. Timed Grazing can be a great tool. Fire Is one of the best tool available to a restoration team. A properly timed fire or two can drastically deplete a nonnative seed bed. If grazing and prescribed fire are not realistic management strategies broad leaf herbicide application and timed Mowing with selective string trimming is critical to establishing perennials grasses in seeded areas. The goal of the trimming will be to increase native grass coverage by removing nonnative seed heads before they have a chance to develop. As many as 8 mowing's may be required yearly in the first 3-4 years. Any material that blocks the light will prevent or suppress the growth of weeds. If that material is organic, it can be broken down and stored in plants and the soil. Organic material is preferred the thicker the layer the better It will be at both providing carbon to soil microbes and blocking the light to suppress weed seeds. Compost and wood chips across and entire large restoration site may be cost prohibitive. It takes 200 cubic yards of compost to cover 1 Acre 1.5 inches deep in compost. Strategic strips of planting plugs and mulch can be utilized to save costs. Seeds can be spread in between strips.

Monitoring

Carbon sequestration should be monitored over the course of a 40-year period. A successful project will continue to accumulate increasing amounts of carbon over this period. "At the moment, no standardized guidelines for C monitoring or reporting exist for restoration projects within most funding bodies, let alone between them". (FAO, 2009) In general, once restored healthy landscapes will continually accumulate carbon. Some carbon is likely to only be released in events of plant death however carbon storage in the soil is likely to remain stable. If the Project was funded by carbon capture grants or offset programs, the funding organization will likely require periodic verification by a third party certifier, which includes several site visits for measurement. Following each successful verification, carbon credits are issued to the project and can be sold in the marketplace. If the project just has a general interest in increasing carbon storage on a site, then measurements or below ground carbon and biomass as well as above ground biomass should be take prior to restoration efforts. Increases in these measurements should be evident each year after restoration. If carbon monitoring finds less carbon on site, then actions can be taken such as additional plug planting more wood chips or further water way modifications. Further research need to be performed on unifying standard for carbon storage monitoring.

Resources for Carbon Calculations, Grants, and offset programs

http://www.fire.ca.gov/grants/grants

www.ecosmartlandscapes.org

www.itreetools.org

www.americancarbonregistry.org

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Flood Mitigation and Water Retention

Background & Justification:

Water storage/supply and flood control is significant because it impacts most, if not all, nearby life, including the people living in the adjacent neighborhoods. With a system of pipes and drains that delocalizes water, an area usually experiences periods of drought or flooding. This is caused mainly by the presence of impervious surfaces, such as concrete or asphalt, which brings about the need for drains and pipes. Water is unable to infiltrate and be filtered naturally by the ground, and is instead, drained into a body of water, bringing along with it all the chemicals the runoff has picked up from the impervious surfaces. Without being able to infiltrate into the ground, rainwater begins to flood impervious areas when the volume of rain falling exceeds the volume of water the drains can handle. And because the rainwater is drained away, these areas do not have much groundwater stored.

Localizing water and decreasing runoff is beneficial to all affected environments. By locally storing water, groundwater is recharged and water is more evenly distributed in an area instead of drained away and concentrated in one large body of water. Water that infiltrates into the ground is also filtered by the ground, leading to fewer pollutants in the water, and lowering the need for the intensive filtering of water. The presence of water also keeps the temperature in its immediate area moderate, effectively mitigating the urban heat island effect caused by paved surfaces. Runoff also contains many types of chemicals that have a huge impact on the body of water that the runoff is usually drained into, oftentimes completely changing the ecosystem.

The quicker water leaves a site, the less time it has to infiltrate into the ground. With paved surfaces, water leaves the site very quickly, and so, with more paved surfaces there are, the amount of water stored locally decreases. Obstacles that slow down the flow of water, such as vegetation or beaver dams, allow more water to percolate into the soil, and be stored for later use (Grecco). Beaver dams are also a method of flood control, to decrease the harmful effects of flooding. Erosion caused by flooding can be mitigated through the presence of vegetative roots, which hold onto the soil (Dunne, Zhang, Aubry).

Literature Review:

- A lack of water storage is most likely caused by inhibiting water from percolating into the soil and a lack of vegetation
    - Vegetation also decreases the available water supply by taking it up themselves, and releasing it into the atmosphere in the form of water vapor (Shafroth, Patrick B., et al., 2005), (DeBano, Leonard F., and Larry J. Schmidt, 1989)
        - Using plants that have a lower water requirement can increase the amount of water readily available during the dry seasons
        - Roots loosen soil and allow for better water penetration (Dunne, Zhang, Aubry)
        - Habitat created encourages presence of microbes and other organisms (Dunne, Zhang, Aubry)
            - Increased porosity

        - More porous soils can absorb more water (Dunne, Zhang, Aubry)
      - Increased organic matter
        - Organic matter is crucial for water absorption (Saxton, Rawls)
- Wetlands have a huge impact on the hydrology of an area
  - They can reduce floods, and recharge/discharge groundwater (Bullock, A. & Acreman, M., 2003), (Martinez, E.M., Nejadhashemi, A.P., Woznicki, S.A., & Love, B.J., 2014)
- Increased water absorption leaves less water for flooding events and becomes water stored on-site
- Slow the flow rate of the water / increase time for percolation on site
  - Addition of obstacles in channel for greater channel roughness
    - Rougher channel beds decrease the volumetric flow rate (Grecco)
      - Based on velocity of flow equation
      - Vegetation can act as an obstacle, increasing the channel roughness
        - Stones, boulders, and debris from dead plant material work as well
  - Widen the channel
    - More of the flow is exposed to the channel bed, which slows flow rate
      - Based on velocity of flow equation (Grecco)
  - Change to a meandering channel
    - A meandering waterway from one point to another will have water travel a longer distance than a waterway that is straight between the two same points (Grecco)
      - Bends cause a change in direction, and a mass that changes direction loses its speed, kinetic energy, and momentum
        - Leads to an overall slower flow rate
        - Based on acceleration and speed-velocity equations
  - Addition of waterways
    - A division of the waterway into multiple waterways
      - More flow is exposed to channel bed and rate of flow is decreased
      - More surface area for water to percolate
- Increase water retention / installation of retention & detention basins or wetlands
  - Wetlands are hydrologic buffers
    - Hold water well, and will slowly release it back to the environment (Eviner)
- Reduce water absorption times
  - Different soils have different runoff / infiltration rates based on particle size
    - Sand – low runoff, quick infiltration
    - Loam – medium (in between sand and clay)
    - Clay – high runoff, slow infiltration
    - (Rawls, Brakensiek, Saxtonn)

Goals:

The strategies used to increase water retention and improve flood mitigation are not limited to specific conditions or locations.

WATER RETENTION: to increase the amount of water readily available during dry seasons

Native and planned vegetation / wildlife should be able to survive without human intervention for water needs.

- Improve surface permeability
  - Increasing vegetation density throughout the site to 90% - 100% in open areas
- Slow the flow rate of the water / increase time for percolation on site
  - Addition of obstacles in channel for greater channel roughness
    - Bring vegetative cover or aggregate cover of channel bed to 10% - 25%
  - Widen the channel to 1m - 1.5m
  - Change to a meandering channel
  - Addition of a waterway
- Increase water retention / installation of retention & detention basins or wetlands
  - Install 1-3 constructed wetland(s) or retention/detention basin

FLOOD MITIGATION: to decrease the frequency and intensity of flood events during wet seasons

Flooding and backflow should not occur in adjacent neighborhoods.

Damage caused by flooding should not occur in adjacent neighborhoods, and damage on site should be minimal; ecosystems are disturbed and will recover.

Many of the strategies for mitigation of flooding are also strategies for water retention.

- Increase water absorption
  - Improve surface permeability
  - Slow the flow rate of the water / increase time for percolation on site
- Reduce water absorption times
- Reduce volume of flowing water / runoff
  - Division of water flows – multiple waterways
  - Install 1-3 retention / detention basin / constructed wetland

UNKNOWNS: What is the volume of water expected to flow through the site? The size/number of wetland areas, size/number/shape of channels (potential presence of riprap), and species composition/density of vegetation is dependent on this answer.

FEASIBILITY: Feasibility will be based on what volume of water is expected to flow through the site, but they will probably have an inverse relationship. If a larger volume of water is expected to flow through the site, the site may need a more dramatic change and so, the feasibility drops. If the volume of expected water is low, the site will need less dramatic changes and there is a higher feasibility of these plans getting implemented. Depending which goals are chosen, the cost of implementing some strategies will be relatively cheap (increasing vegetative cover), while other strategies will be very expensive (make waterway more meandering, addition of waterway, construction of wetland, etc.).

TRADEOFFS: Also dependent on the unknowns, the tradeoffs increase as the volume of expected flows increases. The greater the expected flow, the greater the changes in the site, such as an increase in meandering water ways, which will decrease the habitable area for some species, or a reduction in other resources such as food. If water is not readily available, and action is taken to increase water availability during the dry seasons, these actions may increase the chances of flooding (ex: replacing plants with high water needs with other plants that have a lower water requirement to increase the amount of water readily available). If cost is a huge limiting factor, some strategies or goals will have to be prioritized over others to achieve as many goals as possible, while staying within the spending limits.

INTERACTIONS: The strategies for water retention are the same as those for flood mitigation, so the interactions between these two goals are complements of each other.

Restoration Plan:

CHANNEL ALTERATIONS:

- Change to a meandering channel
    - A meandering waterway from one point to another will have water travel a longer distance than a waterway that is straight between the two same points (Grecco)
        - Bends cause a change in direction, and a mass that changes direction loses its speed, kinetic energy, and momentum
            - Leads to an overall slower flow rate
            - Based on acceleration and speed-velocity equations
    - Map out the general shape and direction of the current waterway
        - While following the flow of the waterway, draw in curves that bend and cross over the current waterway
            - The expected volume of water for flood events is also unknown.

            - Greater flows will require bigger bends and will take up more of the site
        - Curves elongate the water’s path and slows down the flow, increasing time and surface area for greater infiltration (Grecco)
    - To reduce future, natural alterations and migrations of the channels, ripraps (stone or boulders used to prevent erosion of a bank) may be implemented (Grecco)
    - For use if flooding is very destructive and major
        - This is a very dramatic strategy
    - Should be done in spring, after the chances of flooding has decreased
- Widen channel
    - More of the flow is exposed to the channel bed, which slows flow rate
        - Based on velocity of flow equation (Grecco)
    - During alterations, be sure to widen the channel as well, bring the water way to 1m wide along the entire channel
        - At this width, there will be space to plant vegetation, and the channel will be able to accommodate for greater flows
            - I am in the lab, and much of the channel is 1ft. wide, or less, and based on what I’ve seen of the neighborhood, flooding is likely based on how large of an area the neighborhood is
                - This is just an estimation, but the channel is very thin and the adjacent neighborhood is relatively large, so the channel must be able to handle the runoff
            - Given this wider channel, as well as the additional ones to be constructed, the chances of flooding should be greatly reduced since the channels will not be filled as quickly
    - For use if flooding is only a slight issue
- Increase channel roughness
    - Slow the flow rate of the water / increase time for percolation on site
        - Addition of obstacles in channel for greater channel roughness
            - Rougher channel beds decrease the volumetric flow rate (Grecco)
                - Based on velocity of flow equation
                - Vegetation can act as an obstacle, increasing the channel roughness
                    - Stones, boulders, and debris from dead plant material work as well
    - Add rocks and pebbles along the entire channel bed
        - A single layer will suffice, it is the surface area of the rocks and pebbles that will reduce the flow rate
        - At the site, the water level is very low, sometimes 1-2cm and these flows do not require large boulders to slow their flow
        - With a greater number of channels and wider channels, the water level should not be very deep, so rocks and pebbles should suffice in slowing the flow rate
            - Vegetation will also be planted in the channel, which adds an additional slowing factor
    - For use if flooding is very minor, to be used with another strategy

        - Can be implemented anytime

CHANNEL CONSTRUCTION:

- A division of the waterway into multiple waterways
    - More flow is exposed to channel bed and rate of flow is decreased
    - More surface area for water to percolate
- Plan for an additional waterway to distribute the runoff during wetter seasons
    - One additional waterway can will stem from the original, near the beginning to better distribute the waters
        - Water availability on site is already very low, more than one additional waterway will decrease the flowing water by too much
    - Smaller offshoots that reconnect to the original waterway are a less expensive and less drastic option
        - Less change to the existing site
        - Will not decrease the amount of flowing water too dramatically
        - Areas between offshoots and main waterway can be a constructed wetland or detention/retention basin
- Additional waterway(s) will be dug out
    - Waiting for naturally forming waterways will take too many years
    - Will require the use of heavy machinery
        - If not, it will require a huge amount of manual labor to dig out each additional waterway
    - Must be graded to have a downhill slope for water flow
- The number of waterways/offshoots will also depend on the expected volume of runoff
    - The greater the volume, the more additional waterways
- Another option if flooding is very major and intense
    - Very dramatic strategy
- Should be done in spring, after the chances of flooding has decreased
    - Reduce disturbances for vegetation to establish, which will decrease erosion and keep the grading and waterways more intact (Dunne, Zhang, Aubry)

VEGETATION:

- Improve surface permeability
    - Increasing vegetation density throughout the site
        - Roots loosen soil and allow for better water penetration (Dunne, Zhang, Aubry)
        - Habitat created encourages presence of microbes and other organisms (Dunne, Zhang, Aubry)
            - Increased porosity
                - More porous soils can absorb more water (Dunne, Zhang, Aubry)
            - Increased organic matter

        - Organic matter is crucial for water absorption (Saxton, Rawls)
- Types of vegetation will depend on proximity to the water, some will grow in water, some along the banks, and others in the upper lands
- Plant cattails in and along the edges of the channel
    - Plants that are already existing on site in that position, they will be able to grow and fit into the landscape well
    - Having vegetation in the water will increase water uptake (Dunne, Zhang, Aubry) and decrease the chances of flooding, if there is less water in the channel
    - Vegetation will slow down flow rate and increase time for percolation and uptake (Dunne, Zhang, Aubry)
- Plant other herbaceous plants, shrubs, and trees
    - Proximity to water will depend on plant selection
        - No woody species in channel or waterway (RCD's instructions)
    - Vegetation should cover at 90%-100% in open spaces
        - Reduction of erosion
- Planting within the channel will be done in spring
    - Majority of the rain will have passed, chances of flooding will be decreased
        - New plantings will have a higher survival rate with fewer disturbances

Monitoring Plan:

PRE-RESTORATION:

- Monitoring duration – 10 years
    - Many flood plain maps include information for 10-year recurrence interval floods, which can be used to track success/failure of flood mitigation strategies
    - 10 years is also long enough for planned vegetation to mature and increase in density, allowing time for the effects of vegetation to be observed
    - Focus mostly on dry and wet seasons (summer and winter)
        - Monitor for the presence of available water during summer
            - Summer is the driest and hottest season, so water should be scarcest then
            - Record water levels
                - One of the goals is to retain water at the site
            - Study what vegetation / wildlife survives if any, and record species distribution and density
                - Good to know what types of vegetation / wildlife can survive during one of the most stressful times of the year and how many survive
                    - Useful information for species selection in the restoration plan
        - Monitor for flooding during winter / heavy rainfall
            - Winter is the wettest season, so chances of flooding are greatest

during winter

- Record water levels and look for flooding events
  - One of the goals is to prevent flooding at the site
  - Check for backflow and flooding in the adjacent neighborhood
- Study what disturbances occur due to flooding (if any)
  - Good to know what disturbances occur, and how the ecosystem is affected by these disturbances
    - This information can be use in the future, for any other plans that need to be made

POST-RESTORATION:

- Monitoring duration – 10 years (same as above)
  - Focus mostly on dry (summer) and wet (winter) seasons
    - Monitor for the presence of available water during summer
      - Record any local droughts and the species and density that survives
    - Monitor for flooding during winter / heavy rainfall
      - Record any flooding events and the disturbances
        - Effects of disturbances too

THRESHOLDS FOR ACTION:

- Flooding
  - Implement more of the channel alterations or additional channel construction strategies to reduce flow rate
    - If dramatic changes have not been made, now may be the time to do so since the other strategies may not be functioning as well as expected
- Lack of water
  - Begin partial replacement of vegetation with high water requirements with species with low water needs
    - This will increase the amount of water readily available
    - Water uptake will be decreased, but increased percolation due to root growth should suffice for water retention & flood mitigation
    - (Shafroth)
  - Observe after replacement during summer for any more ready-available water
    - If not, continue replacement and observe again; repeat until water is readily available for most species to survive during summer
- Channel avulsion (Grecco)
  - Reconstruct the channel
    - Implement more strategies to reduce flow speed (other than creating more bends in the waterway)

        - Observe after implementing additional strategies, continue implementing until avulsion no longer occurs
            - Will usually occur with a major flooding event to have enough water at a fast enough pace to cause channel avulsion
- Major erosive events where channel walls have caved in and impede or stop water flow
    - Repair any damage, if necessary
        - Additional vegetative plantings will prevent further erosion (Dunne, Zhang, Aubry)
        - Ripraps can also function as a protective layer against erosion (Grecco)
- Major death event (loss of 40%) of channel vegetation
    - Observe and find the cause of the major death
    - If the cause is preventable, revegetate the area and implement strategies to prevent further death
        - If death due to grazing:
            - Eradicate invasive / non-native species
            - Install mesh to prevent beneficial / native species from targeting population
                - Allow for population to become established and large enough to survive grazing
        - If death due to disease:
            - Implement strategies to prevent further spread of disease
            - Consider using different types of vegetation that are immune to disease
        - If death due to random event:
            - Revegetate if random event is rare
            - Wait and observe if random event may become regular
                - Ex: irregular weather patterns due to climate change

UNKNOWNS:

- Severity and recurrence intervals of floods
- Species composition and density of vegetation
    - Current state and the end goal

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Reducing air pollution

BACKGROUND & JUSTIFICATION:

We care about this topic because it is a way to reduce the pollutants we have emitted to the atmosphere through use of transportation and other things creating exhaust, while also providing other benefits to other aspects such as soil and temperature. The annual pollution removal is estimated about 80 pounds per acre of tree cover while annual carbon removal by trees is 2.4 million tons in the United States (on an acre basis= 1.2tons per acre of tree cover). Trees vary across the nation but tree canopies on average, when viewed from above cover about 27% of urban areas in the United States. The influence of trees caries by geography, with cities developed in forested areas averaging about 34% tree cover, trees in grassland areas averaging about 18% and trees in desert regions averaging about 9%. Trees have been seen to remove pollutants for a long time where in the1800s the Royal Parks of London were referred to as the "Lungs of London" and later Central Park in New York city were referred to the "lungs of the city". (Nowak and Heisler, 2010) Increasing trees in urban areas also reduces air temperature by transpiration and shading urban buildings. (McPherson et. al, 1994) Cooling also reduces the speed of chemical reactions that form ozone and particulate matter. (Lashgari, 2012). Urban trees also provide air quality benefits by absorbing pollutants such as ozone and nitrogen oxides through leaf surfaces, intercepting particulate matter (e.g., dust, ash, pollen, smoke), releasing oxygen through photosynthesis, and transpiring water and shading surfaces, which reduces ozone levels by lowering local air temperatures. (McPherson et. al, 1999).

LITERATURE REVIEW:

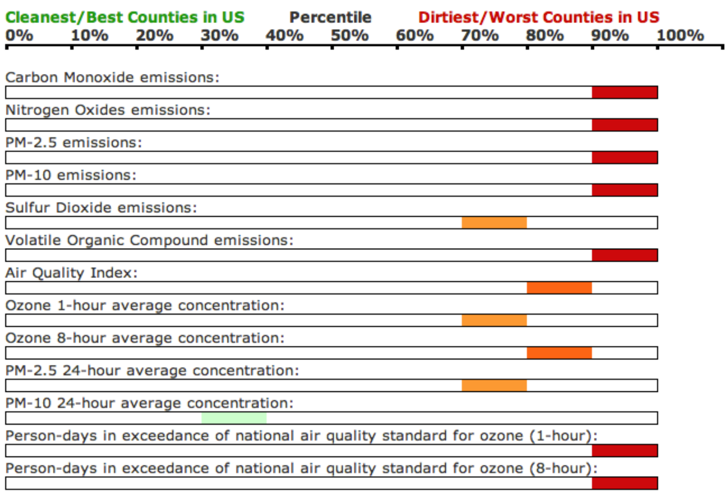
◦ **Microclimate:** Trees evaporate significant amounts of water through their leaves (transpiration), which reduce local air temperatures. Lower temperatures lead to lower emissions of pollutants by cooling homes and offices, trees reduce power generation emissions and also reduces speed of chemical reactions that lead to the formation of ozone and particulate matter. (Lashgari, 2012, Nowak and Heisler 2010)

◦ **Removal of Air Pollutants:** Removal through uptake in leaves and intercepting airborne particles but intercepted particles usually are washed off by rain. One acre of tree cover in a park will likely have pollution removal totals around 80 pounds per year but the total could exceed 200 pounds per year in more polluted areas with long growing seasons. It depends on the surface area of the leaves that allow for a certain amount of pollution. (Lashgari, 2012)

-Trees remove carbon and store it in their tissue. Reduce air temperatures and associated carbon emissions for building energy use. Trees can remove carbon, emit carbon from the vegetation or vegetation management practices and alter urban microclimates. Trees can sequester carbon as well as emit it so it can add to climate change as well as help reduce the effects depending on how many trees are present. (Nowak and Heisler, 2010).

○ **Tradeoffs:** Trees can also add to the pollution. They release volatile organic compounds which when oxidized it becomes CO2 so increasing the amount of trees may increase the amount of volatile organic compounds being emitted. Volatile organic compounds also contribute to O3 ozone being formed but since this is mostly temperature related and trees reduce temperature that means that increased tree cover reduces the overall emission of O3 and VOCs. (McPherson et. al, 1994)

- **Sacramento County Pollution Data**: The Sacramento area has some of the highest pollution in the state making it hard to have safe breathing air especially in the hot summer months as shown below. (Bill, 2011).



This table is from the country report of the Sacramento County showing the percentage of the particulates in the county. They are all in the critical range besides the particulate matter 10. Planting the trees in the heavy pollution areas will allow for the most uptake of pollution. (Bill, 2011)

2003 Summary of Pollutant Concentrations:

Pollutant	NAAQS Standard	Highest Recorded Concentration	Second Highest Recorded Concentration	Number of NAAQS Exceedances
Carbon monoxide				
1-hour average	35 ppm	8.5 ppm	6.7 ppm	0
8-hour average	9 ppm	4.5 ppm	4.3 ppm	0
Nitrogen dioxide				
Annual arithmetic mean	0.053 ppm	.01 ppm	.01 ppm	0
Ozone				
1-hour average	0.12 ppm	.14 ppm	.13 ppm	7
8-hour average	0.08 ppm	.11 ppm	.11 ppm	69
PM-25				
24-hour average	65 ug/m3	65 ug/m3	58 ug/m3	0
Annual arithmetic mean	15 ug/m3	12.2 ug/m3	11.6 ug/m3	0
PM-10				
24-hour average	150 ug/m3	75 ug/m3	73 ug/m3	0
Annual arithmetic mean	50 ug/m3	28 ug/m3	23 ug/m3	0
Sulfur dioxide				
3-hour average	0.50 ppm	.009 ppm	.008 ppm	0
24-hour average	0.14 ppm	.004 ppm	.004 ppm	0
Annual arithmetic mean	0.03 ppm	.001 ppm	.001 ppm	0

The table above shows the pollutants emitted in the Sacramento County area compared to the standards of the allowable pollutants. (Bill, 2011).

- **Tree Species:** Table 5. General recommendation of best tree species for reduction of various pollutants (not a comprehensive list, see i-Tree Species program (www.itreetools.org) for specific local recommendations) (Nowak and Heisler, 2010)

Species Latin Name	**Common Name**
Carbon Monoxide	
Aesculus hippocastanum	horse chestnut
Betula alleghaniensis	yellow birch
Carpinus betulus	European hornbeam
Carya glabra	pignut hickory
Catalpa speciosa	northern catalpa
Celtis occidentalis	northern hackberry
Chamaecyparis thyoides	Atlantic white cedar
Fagus grandifolia	American beech
Fraxinus americana	white ash
Ligustrum sinense	Chinese privet
Liriodendron tulipifera	tulip tree
Paulownia tomentosa	royal paulownia
Picea rubens	red spruce
Prunus serotina	black cherry
Sassafras albidum	sassafras
Thuja plicata	western red cedar
Tilia americana	American basswood
Tsuga canadensis	eastern hemlock
Ulmus americana	American elm

Ozone	
Acer rubrum	red maple
Aesculus hippocastanum	horse chestnut
Betula alleghaniensis	yellow birch
Carpinus betulus	European hornbeam
Carya carolinae–septentrionalis	southern shagbark hickory
Celtis occidentalis	northern hackberry
Corylus colurna	Turkish hazelnut
Fagus grandifolia	American beech
Fraxinus americana	white ash
Juglans nigra	black walnut
Liriodendron tulipifera	tulip tree
Magnolia acuminata	cucumber tree
Metasequoia glyptostroboides	dawn redwood
Sassafras albidum	sassafras
Sequoia sempervirens	coast redwood
Prunus serotina	black cherry
Tilia americana	American basswood
Tsuga canadensis	eastern hemlock
Ulmus americana	American elm
Zelkova serrata	Japanese zelkova

Sulfur and Nitrogen Oxides	
Acer rubrum	red maple
Aesculus hippocastanum	horse chestnut
Betula alleghaniensis	yellow birch
Cedrus deodara	deodar cedar
Celtis occidentalis	northern hackberry
Fagus grandifolia	American beech
Fraxinus americana	white ash
Ginkgo biloba	ginkgo
Gymnocladus dioicus	Kentucky coffeetree
Juglans nigra	black walnut
Liriodendron tulipifera	tulip tree
Magnolia acuminata	cucumber tree
Picea abies	Norway spruce
Pinus strobus	eastern white pine
Platanus hybrida	London planetree
Populus deltoides	eastern cottonwood
Tilia americana	American basswood
Tsuga canadensis	eastern hemlock
Ulmus americana	American elm
Zelkova serrata	Japanese zelkova

Particulate Matter, PM10	
Abies concolor	white fir
Calocedrus decurrens	incense cedar
Cedrus deodara	deodar cedar
Chamaecyparis thyoides	Atlantic white cedar
Cryptomeria japonica	Japanese red cedar
Cuppressus macrocarpa	Monterey cypress
Magnolia grandiflora	Southern magnolia
Picea abies	Norway spruce
Picea pungens	blue spruce
Picea rubens	red spruce
Pinus ponderosa	ponderosa pine
Pinus strobus	eastern white pine
Pinus taeda	loblolly pine
Sequoia sempervirens	coast redwood
Taxus cuspidata	Japanese yew
Thuja plicata	western red cedar
Tilia americana	American basswood
Tsuga canadensis	eastern hemlock
Ulmus americana	American elm
Zelkova serrata	Japanese zelkova

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A. Goals and Restoration

- Short Term:
    - Improve the air pollutant uptake by local urban trees by making sure the trees have optimal living conditions; for example, no water or nutrient stress that would limit their ability to take in pollutants
    - This would be focused small scale in the busiest, most polluted places of the city before expanding outwards to a more large scale
- Long Term:
    - Decrease the amount of biogenic volatile organic compounds, nitrogen oxides, particulate matter and ozone
        - The Clean Air Act of California requires that the Sacramento Metropolitan area reduces its VOC emissions by 12 tons per day and NOx emissions by 21 tons per day by 2018 (USDA Forest Service 2014)
    - Increase planting of street trees in urban areas and housing areas, plan to make more urban forests (Figure 1)

Table 1. Numbers of street trees, vacant sites, tree density and trees per capita in each climate zone and statewide.

Zone	Total Street Trees	Vacant Sites	Density (trees/ mi.)	Trees/ capita
IE	1,671,362	2,651,488	81.7	0.29
IV	2,042,700	4,895,861	62.2	0.28
NC	1,994,793	2,618,074	91.3	0.30
SC	2,763,290	4,334,530	82.2	0.21
SW	631,146	1,569,132	60.6	0.50
IW	26,516	502,568	10.6	0.13
Total	9,129,806	16,042,568	75.0	0.26

Note: IE=Inland Empire; IV = Inland Valleys; NC = Northern California Coast; SC = Southern California Coast; SW = Southwest Desert; IW = Interior West.

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    -
        - The number of street trees in California has increased from 5.9 million to 9.1 million since 1988 but tree density has declined from 105.5 trees per mile to 75.0 trees per mile. (McPherson et. al 2015)
    - Replace less productive trees that don't remove as much pollution or that aren't as efficient for those environments
        - Introduce non-native drought tolerant species such as Colorado mesquite, Texas red oak, Chinquapin oak. A study done in Davis to see how these species could survive 14 years and these species

had a 0-25% mortality rate. This would increase the diversity of tree species helping the uptake of urban air pollutants. (McPherson and Albers, 2014)

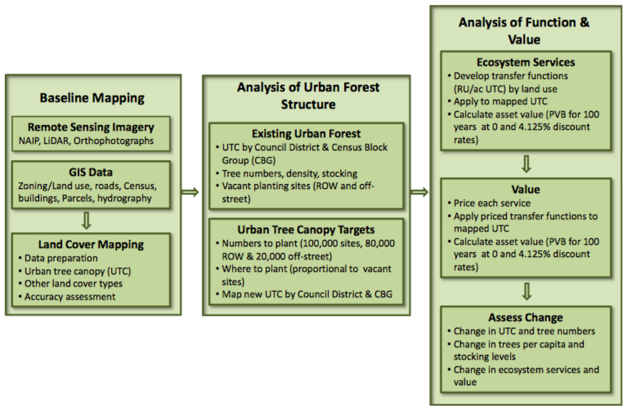

Figure 1. Project process overview.

- Figure 2: This map above would allow for analysis of the current urban tree cover to understand the state and what changes should be made in restoring trees in the urban landscape. This type of mapping also allows for the appearance to show bare soil to see where new trees may be placed. (Xiao et. al, 2013)
    - Increase small trees in densely populated areas that don't have any tree vegetation and larger trees that can be supported in that area
- Complications:
    - It depends on the amount of space present in the urban center available to plant more trees (McPherson and Albers, 2014)
    - The cost that is associated with removing dying large trees to replace them and plant the new ones
    - Need more drought tolerated species to live in the Central Valley to handle the increase in climate temperature and lack of water seasonally
    - Measuring is going to be difficult on a short term scale since you need initial data and it would need to be checked on a longer term basis
        - The Clean Air Act is the main controller of measuring and making sure that the cities are following this Federal act in California (USDA Forest Service 2015)
        - The Clean Air Act monitors and measures the amount of produced pollutants and uptake of pollutants that is given to Congress every five years to asses the effectiveness (USDA Forest Service 2015)

B. Monitoring Plan

- The map used in Figure 2 also shows how to monitor the goals for restoring trees to remove air pollutants. Looking at the canopy cover to see where there is room for change to replace or add more trees based on the cover and efficiency. (Xiao et. al 2013)
- Will need to measure the area initially before planting the trees. Once trees are planted re-measure every year up to five years and compare to area close with the same amount of initial pollution. Measure during high pollution times of the day usually the hottest.
- When monitoring it needs to be monitored initially when new trees are planted to make sure they are established enough to live without extra help or watering. Though monitoring will never stop because of the changing life stages of the trees so it will need to be monitored but not as frequently once established.
- Measuring the urban tree canopy can allow for check ins to see how the tree grow is going along with the pollutants that are being taken up such as the volatile organic compound, nitrous oxide and ozone
- Depending on what stage the trees were planted, either yearlings or more mature, checking yearly on the newly planted trees to make sure they are efficient in pollutant uptake and then on a five year monitor plan to check for any trees that are declining that would need to be replaced.
- Questions:
    - Further research questions that needed to be asked before planting are: Where is it socially desirable to plant trees? Or what is the Preferable Tree Canopy? Where is it financially efficient to plant trees? Or what is the Potential Tree Canopy? (Forest Service 2014)

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Pollination

Pollination is the act of transferring pollen grains to the female stigma from the male anther, which produces plant offspring and increases the rate of genetic spread throughout a given landscape (USDA.gov, 2008). To the agricultural industry, the ecosystem service of pollination has the economic value worth $3.07 billion per year (Vaughan, 2006). Although some species of plants rely on either wind or water to help transfer pollen, almost 90% of all plant species rely on animal pollinators to accomplish this task (Marks, 2005). Therefore, native pollinators are immensely valuable to the environment, the economy, and to humans (Marks, 2005). However, due to factors such as land use change, climate change, pesticides, herbicides, and habitat degradation, floral biodiversity in California is declining at a rapid rate (Marks, 2005). This, in turn, also means that pollinator populations and the rate of pollination is declining as well (Marks, 2005). The US Fish and Wildlife Service has listed over 50 pollinator species as endangered that are native to California, such as the *Xylocopa brasilianorum* (the carpenter bee) and the *Danaus plexippus* (the Monarch Butterfly) (fws.gov, 2009). Pollination restoration in California is important to both the survival of humans and to ecosystems alike.

<u>Fact Sheet:</u>

Project Goals:

- Restore habitat to attract native pollinator populations.
- Choose native wildflower species that are different shapes, colors, sizes, and have different overlapping blooming periods to provide the pollinators with food throughout the year.
- Increase overall pollination services.

Key Disruption by Humans:

- **Pesticide/Insecticide/Herbicide use:** Pesticides and insecticides are deadly to insect pollinators (plants.usda.gov, 2006). They either kill the insect directly, or the insect (such as a bee) comes in contact with the insecticide and transports it back to the colony, either as a contaminated pollen or nectar on its body (ent.uga.edu, 2015). The latter is more dangerous for insect populations, because rather than one insect dying, the entire colony has a high probability of dying from pesticide toxicity. Herbicide use is just as dangerous as pesticide use for pollinators, as herbicides are toxic to their food source, such as wildflowers and flowering shrubs.
- **Climate change:** Due to California suffering from drought, vegetation and flowers in the Central Valley have dried up, which results in a loss of pollinator species as well (xerces.org, 2015). There is a projected general decline of pollinator populations due to impacts from climate change (Potts, 2010). Such impacts of climate change occur at all organismal levels, such as the individual level (such as changing the temporal activity for pollinators (Stone, 1989)), to population levels (such as evolutionary changes in pollinator species overtime, (Hegland et al., 2009)).

- **Habitat degradation:** Habitat degradation affect pollinators primarily by the loss of flowering species and nesting resources (Potts, 2010). Pesticides used on plants are directly lethal to the pollinators, while herbicides and fertilizers indirectly harm pollinators by reducing the amount of flower resources that are available (Brittain et al., 2010). Plant biodiversity has also declined due to climate change, which in turn corresponds to pollinator population decline (Potts, 2010).

Key Enhancements by Humans:

- Establishing wildflower habitat so the pollinators can have access to food (whitehouse.gov, 2015).
- Removing harmful invasive species of plants, so that they don't outcompete the wildflower species (USDA, 2006).

Pollinator Food Requirements:

- Pollinators generally eat nectar and pollen from flowers (fcps.edu, 2014). Nectar is the liquid in the flower, and pollen is the powdery substance that must be transferred from flower to flower in order for the flower to have sex and reproduce (fcps.edu, 2014).
- In order to support pollination and the native California pollinator community, a wide and biodiverse flower selection is necessary (USDA, 2006).
- Locally native species of plants, which can thrive well with minimum management and low water requirements, are good sources of pollen and nectar for native pollinators (USDA, 2006).
- Flowers with a large diversity of shapes, sizes and colors will attract a wide variety of crop pollinators (USDA, 2006).
- Crops that benefit both humans and bees, such as almond trees, cherry trees, or berry producing shrubs can also be used to attract pollinators (USDA, 2006).
- Consistent and adequate floral resources with overlapping blooming periods must be available for pollinators to provide food throughout the year (xerces.org, 2015).

Pollinator and Wildflower Habitat Needs:

In general, choosing a potential habitat in California to host a wide variety of floral biodiversity should take the following characteristics into consideration (Vaughan, et al. 2013):

- **Decreased Pesticide Use:** Habitats should be protected from the use of pesticides, herbicides and fungicides (Vaughan, et al. 2013). The uses of these chemicals can also alter soil and water chemistry, and are deadly to bees (Pettis, 2012).
- **Exposure to sunlight:** Most flora grow best in full sunlight (Vaughan et al. 2013).
- **Site history:** Factors such as past plant cover (such as weeds, native species, crops, or herbaceous plants), past use of chemicals on the land, and soil and habitat history (such as areas that are vulnerable to floods, poor drainage, or experience long periods of drought) can make establishing wildflower diversity more difficult (Vaughan et al. 2013).

- **Identifying and understanding invasive species:** Understanding invasive species composition (such as percent ground cover, their reproductive cycles, whether they are grass or broadleaf, or woody or herbaceous) will aid in planning the site preparation (Vaughan et al. 2013). Identifying invasive species are helpful for their removal.

Wildflower space requirements:

- Habitats that are bigger (one acre or more in size) and much closer to other patches are generally better off because they attract more pollinators than smaller, isolated patches (Xerces.org, 2015).
- Flowers that are grown together into clumps of one species do a better job at attracting pollinators than individual plants scattered through a habitat patch (Xerces.org, 2015).
- At least half an acre in size is recommended to restore the ecosystem service of pollination (Xerces.org, 2015).

Restorations that have been effective:

- Restoration of the Manassas National Battlefield Park. Ecologists identified 18 acres of upland meadow habitat that was inhabited by exotic plant infestations. A species survey of birds, plants and pollinators took place for monitoring populations and trends. Site preparation began, which involved vegetation surveys, and studying exotic plant life cycles. The park obtained 122 pounds of seed mix obtained by the Xerces Society, which included 17 different species of native annuals and perennials which would keep the pollinators supplied with food all year long. In the end, the project was deemed successful when wildflower biodiversity increased, exotic plant species decreased and there was a noticeable increased amount of pollinators in the habitat (nps.gov, 2008).

Restorations that have been ineffective (still needs to be revised):

- Experimenting with habitat fragmentation (whitehouse.gov, 2015). Since small pollinators can only travel approximately 50 feet from their nesting area, habitat fragmentation with isolated patches of floral resources have proven stressful (whitehouse.gov, 2015).

Gaps in our Knowledge:

- To obtain a better understanding of the spatial and temporal relationships between native plants and their pollinators (whitehouse.gov, 2015). This will help determine where specific plant species should be located, and what plant species are “specialized” (in the sense they support only one or a few pollinators) (whitehouse.gov, 2015). A better understanding of plant-pollinator interactions is important for aiding future pollination restoration plans.
- To fully comprehend the nutritional needs of pollinator populations (whitehouse.gov, 2015). This would require a greater understanding of pollinator food storage (temporally and spatially) throughout the seasons, and understanding blooming periods and lifecycles of different species of wildflowers (whitehouse.gov, 2015).

- To learn to identify malnutrition in pollinator populations (whitehouse.gov, 2015). Such identification, including knowing how and why malnutrition is occurring, is essential to prevent population loss (whitehouse.gov, 2015).

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Goals:

Pollination restoration in California's Central Valley is important to both the survival of humans and ecosystems alike. Establishing wildflower habitat for pollinators is one of the most effective course of action to conserve the ecosystem service of pollination. Therefore, the main goal of pollination restoration is to renew habitat and establish floral biodiversity to attract native pollinators that thrive in California's Central Valley, such as the *Xylocopa brasilianorum* (the carpenter bee) and the *Bombus crotchii* (the bumblebee) to increase pollination services.

In order to reach the main goal, four crucial steps must be executed. First, a survey must be conducted to gain knowledge of already existing areas of high levels of floral biodiversity and healthy pollinator populations, which would suggest high rates of pollination. The second step should be to determine areas that are likely to support high levels of biodiverse flora (based on hydrological, geological, and microclimate aspects) and thus attracting pollinators to increase pollination levels. The third step should be to modify areas that have potential to support a range of flora biodiversity, but would require habitat alterations like removing invasive plant species, such as *Elymus caput-meduae* (Medusahead) or *Lolium multiflorum* (Italian ryegrass). Steps 1-3 should be conducted during the four major seasons of the year in the Central Valley (fall, winter, spring, and summer) for a period of one year, to analyze fluctuations of pollinator-plant interactions with the habitat, microclimate, water and soil quality, species distributions, population patterns and overall habitat use throughout the year (whitehouse.gov, 2015).

Lastly, the fourth step is choosing appropriate native California wildflowers species that are different shapes, colors and sizes, have overlapping blooming periods that would provide the pollinators with food throughout the seasons, can tolerate a wide variety of soils, and require a minimal amount of management and water to survive. Examples of such flowers include the *Eschscholzia californica* (the California Poppy) and the *Epilobium canum* (California fuchsia) (whitehouse.gov, 2015). Established floral biodiversity in these sites should also be protected from herbicide and pesticide use (whitehouse.gov, 2015).

These goals will be accomplished through seeding a wide diversity of flora to applicable or restored habitat by the use of a lawn-fertilizer spreader, which is a low-cost method of seed dispersal, and more efficient than hand scattering seeds (Vaughan, et al. 2013). Success will be measured by the establishment, resilience, persistence and genetic diversity of wildflower in restored habitats, which is a direct indication of increased levels of pollination (Whitehouse.gov, 2015). The overall timeframe to execute this plan should be at least two years (whitehouse.gov, 2015).

On both large (more than one acre in size) and small areas of land (half an acre in size or less), short term goals include managing herbivores as needed, protecting the habitat from the use of pesticides and herbicides, and hand weeding the area to control harmful weed species (Xerces.org, 2013). Long term goals include re-seeding when necessary to maintain floral biodiversity and pollinator habitat (Xerces.org, 2013).

In due time, these goals are feasible. However, the tradeoff of conducting a year-long survey of various habitats throughout the four main seasons is the use of time; the rate of pollination will only continue to decline (Brown, 2009) while surveys are being conducted, and action is not being executed. It's a risk that must be taken in order to fully understand the physical and chemical components of the Central Valley for potential habitats suitable for pollination restoration at different times of the year (whitehouse.gov, 2015).

Restoration:

Selecting and conserving a site:

By conducting surveys about where floral biodiversity is currently thriving, where it has the potential to thrive, and areas that would need to be modified in order to support floral life, we are able to analyze the of conditions of where flora can grow and where flora growth is stunted. Comparing and contrasting the hydrology, geology, microclimate, species interactions, and soil and water chemistry of various areas will assist in establishing a plan to increase floral biodiversity across California's Central Valley (Vaughan, et al. 2013).

In general, choosing a potential habitat in California's Central Valley to host a wide variety of floral biodiversity should take the following characteristics into consideration (Vaughan, et al. 2013):

- **Decreased Pesticide Use:** Habitats should be protected from the use of pesticides, herbicides and fungicides (Vaughan, et al. 2013). The use of pesticides, herbicides and fungicides has the potential of killing flora, which is what we're trying to conserve. The uses of these chemicals can also alter soil and water chemistry, and are deadly to bees (Pettis, 2012).
- **Exposure to sunlight:** Most flora grow best in full sunlight (Vaughan et al. 2013).
- **Site history:** Factors such as past plant cover (such as weeds, native species, crops, or

herbaceous plants), past use of chemicals on the land, and soil and habitat history (such as areas that are vulnerable to floods, poor drainage, or experience long periods of drought) can make establishing wildflower diversity more difficult (Vaughan et al. 2013).

- **Identifying and understanding invasive species:** Understanding invasive species composition (such as percent ground cover, their reproductive cycles, whether they are grass or broadleaf, or woody or herbaceous) will aid in planning the site preparation (Vaughan et al. 2013). Identifying invasive species are helpful for their removal.

Habitats that are bigger (one acre or more in size) and much closer to other patches are generally better off because they attract more pollinators than smaller, isolated patches (Xerces.org, 2015). Flowers that are grown together into clumps of one species do a better job at attracting pollinators than individual plants scattered through a habitat patch (Xerces.org, 2015). Conservation of such areas with a high density of wildflowers within half an acre ought to take place, as they will require less active management and restoration (whitehouse.gov, 2015).

Restoring a site:

If an area of land in California's Central Valley does not meet the above criteria for supporting floral diversity and pollination services, then modifications must be made. One of the most important habitat modifications is removing an invasive species (Brown, 2009).

Invasive plants in California's Central Valley take the form of woody species such as *Ficus carica*, and herbaceous species, such as grasses (*Phragmites australis*) and forbs (*Silybum marianum*) (Lebuhn et al. 2013). Since herbicide and pesticide use is not recommended when restoring the ecosystem service of pollination, the best way to rid of invasive species is either by hand, mowing, or trimming (Lebuhn et al. 2013). Invasive species removal should take place within the first year of planting wildflower seeds, to prevent weeds from growing and producing seeds (Xerces.org, 2013).

Selecting Wildflower Species:

For California's Central Valley, wildflower selection should be limited to species that have different blooming times throughout the year, as to provide pollen and nectar rich resources for pollinators throughout all the seasons, need little water and management to survive, and can tolerate a wide variety of soils (Vaughan et al. 2013). In order to provide continuous and suitable floral resources throughout the year, and to provide flowers of different shapes, sizes and colors, a minimum of seven different flower species is recommended for restoring the ecosystem service of pollination (Vaughan et al. 2013).

An example chart is shown of seven different plant species that are native to California and fit all the above criteria, and are optimum for attracting pollinators and increasing levels of pollination.

Common name:	Scientific name:	Bloom time:	Water needs:	Life Cycle:
Baby Blue Eyes	*Nemophila menziesii*	Early in the year	low	Annual
Golden Lupine	*Lupinus densiflorus*	Early in the year	low	Annual
California Poppy	*Eschscholzia californica*	Early in the year	low	Both Annual and Perennial
California Fuchsia	*Epilobium canum*	Middle of the year	low	Perennial
California Phacelia	*Phacelia californica*	Middle of the year	low	Perennial
California Aster	*Symphyotrichum chilense*	Late in the year	low	Perennial
Vinegarweed	*Trichostema lanceolatum*	Late in the year	low	Annual

Citation: (Xerces.org, 2013)

Native seed mixes that support pollinator conservation can be purchased through local and independent farmers, such as Hedgerow Farms in the Central Valley (Xerces.org, 2015). Seeds purchased from local sources will generally establish and grow better because they are already adapted to the climatic conditions (nrcs.usda.gov, 2013). These seed mixes have been scientifically formulated to provide high quality foraging resources for pollinators, and is appropriate for habitat restoration in California's Central Valley (Xerces.org, 2015). In order to compensate for half an acre of land, about 3-5 pounds of seed mix is required (Xerces.org, 2015). In the Central Valley, wildflower seeds are planted into the ground once during the fall, before the winter rains start, and germinate during the spring (nrcs.usda.gov, 2013).

While research for using native plant species mixtures shows their effectiveness on small scales (such as areas at least half an acre in size), uncertainties lie within their effectiveness on larger scales (Mader et al. 2011). Since soil type, elevation, and degradation vary on larger scales, different mixtures may be needed to ensure success in agricultural, urban or wildlife landscapes (whitehouse.gov, 2015).

Monitoring:

Pre-restoration monitoring techniques include weeding out the invasive species in preparation for planting wildflower species, and managing herbivores as needed (Xerces.org, 2013). Post-restoration monitoring technique both large and small areas of habitat include keeping irrigation at a minimum when growing the wildflowers from seeds (Xerces.org, 2015). By doing so, the native plants are at an advantage of out-competing non-native weeds, that have higher moisture requirements to grow (Xerces.org, 2015). Another short term monitoring goal is to include mowing and trimming to control harmful weed species within the first year of the wildflower seeds being planted, before the weeds flower and produce seeds (Xerces.org, 2013).

If total failure of the reestablishment of wildflower population occurs, the next step would be to take another year for more careful surveying of the habitat in question (whitehouse.gov, 2015). More variables should also be considered, such as projected future climate conditions, proximity to urbanized or agricultural areas, and analyzing plant-species competition (whitehouse.gov, 2015).

Scientific gaps in our knowledge that can be addressed through monitoring would be to obtain a better understanding of the spatial and temporal relationships between native plants and their pollinators (whitehouse.gov, 2015). This will help determine where specific plant species should be located, and what plant species are "specialized" (in the sense they support only one or a few pollinators) (whitehouse.gov, 2015). A better understanding of plant-pollinator interactions is important for aiding future pollination restoration plans.

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Weed control

Background and Justification

Weedy species, by definition, are plants that become dominant in a given region over time (Baker, 1991). They can be native or exotic by nature (Baker, 1991). Weeds can typically outcompete native plant communities with their large seedbanks, high dispersal rates, and fast growth rates (Groves, 1992). Many of the weeds currently active in the Central Valley – such as yellow starthistle (*Centaurea solstitialis*), medusahead (*Taeniatherum caput-medusae*), and Italian ryegrass (*Lolium multiflorum*) – were initially introduced from Europe and Asia a couple of centuries ago (DiTomaso et al., 2007). Today, these weedy species have done so well that they now completely dominate much of the landscape (DiTomaso et al., 2007). In fact, yellow starthistle is estimated to cover as much as 15 million acres of land around the West Coast, while medusahead has invaded approximately 2.4 million acres (DiTomaso et al., 2007).

By being so widespread, invasive weedy plants species introduce a host of problems for many humans. For instance, many ranchers rely on California rangelands to feed and support their cattle. However, many of the weedy species that now dominate most of these lands tend to have natural defense mechanisms against herbivores (such as thorns) or be much less palatable than non-weedy species (Popay and Field, 1996; DiTomaso, 2000; DiTomaso et al., 2007). Because of this, ranchers have less land available for grazing, causing $2 to $13 billion in economic losses every year (DiTomaso, 2000; Sheley et al., 2011).

Weedy species are not only problematic for humans but they also fundamentally alter the ecosystem as a whole. Some weedy species, for example, are more fire prone than native species (DiTomaso, 2000). This may cause fires to become increasingly frequent in a given area and thus lower overall diversity by preventing fire-intolerant species from recolonizing (DiTomaso, 2000; DiTomaso and Johnson, 2006; DiTomaso et al., 2007). Other weeds have pervasive taproot systems that prohibit water from percolating through the soil and cause widespread runoff issues (Groves, 1992; DiTomaso, 2000).

Considering the tremendous impact of weedy species on both human industries and the natural environment, it is imperative that noxious weed control is taken into account when restoring a site. To help plan for this, the remainder of this literature review will provide important information on weedy species, their ecology, methods of dispersal, and available management tools.

Literature Review

I. Key Species

The following plant species have been identified by the scientific community as weeds found throughout the western United States. It is expected that many of these species should be found in the Central Valley; however, it should be noted that an extensive survey will need to be conducted in order to confirm their presence (DiTomaso et al., 2007). Furthermore, it is possible that an extensive survey will reveal other invasive species that are not listed below.

- **Chinese tallow tree** (information provided by Rogers and Siemann, 2004)
  - ***Scientific Name:*** *Sapium sebiferum*
  - ***Growth (i.e. how it grows and when it grows):*** Perennial
  - ***Invasibility (as defined by the California Invasive Plant Inventory or by other validated research):*** High

Figure 18: Chinese tallow tree. Photo Credit: Geosystems Research Institute at Mississippi State University

- **Fennel** (information provided by DiTomaso et al., 2007)
  - ***Scientific Name:*** *Foeniculum vulgare*
  - ***Growth:*** Perennial
  - ***Invasibility:*** High

Figure 19: Fennel. Photo Credit: Carnegie Mellon University

- **Italian ryegrass** (information provided by DiTomaso et al., 2007)
  - ***Scientific Name:*** *Lolium multiflorum*
  - ***Growth:*** Winter annual
  - ***Invasibility:*** Medium

Figure 20: Italian ryegrass. Photo Credit: Penn State University

- **Mediterranean barley** (information provided by DiTomaso et al., 2007)
    - ***Scientific Name:*** *Hordeum marinum*
    - ***Growth:*** Winter annual
    - ***Invasibility:*** Medium

Figure 21: Mediterranean barley. Photo Credit: California State University, Chico

- **Medusahead** (information provided by DiTomaso, 2000 & DiTomaso et al., 2007)
    - ***Scientific Name:*** *Taeniatherum caput-medusae*
    - ***Growth:*** Winter annual

- *Invasibility:* High

Figure 22: Medusahead. Photo Credit: Wisconsin Department of Natural Resources

- **Ripgut brome** (information provided by DiTomaso et al., 2007)
    - ***Scientific Name:*** *Bromus diandrus*
    - ***Growth:*** Winter annual
    - ***Invasibility:*** Medium

Figure 23: Ripgut brome. Photo Credit: University of California, Berkeley

- **Yellow starthistle** (information provided by DiTomaso et al., 2007)

- *Scientific Name:* *Centaurea solstitialis*
- ***Growth:*** Winter annual
- ***Invasibility:*** High

Figure 24: Yellow starthistle. Photo Credit: East Multnomah Soil & Water Conservation District

- **Wild oats** (information provided by DiTomaso et al., 2007)
  - ***Scientific Name:*** *Avena fatua*
  - ***Growth:*** Winter annual
  - ***Invasibility:*** Medium

Figure 25: Wild oats. Photo Credit: Utah State University

II. Basic Weed Ecology

Many weedy plant species are able to adapt to new environments that they are placed in (Turner et al., 2014). While weeds may differ slightly in the specific traits they possess, they all tend to share similar physical, genetic, and other biological characteristics that allow them to outcompete other species for resources (Groves, 1992; Popay and Field, 1996; Turner et al., 2014). These include the following:

- **Fast growth rate**
  - Weedy species share a rapid growth rate, whether initially or throughout their lifetime (Groves, 1992).
  - As a result, some weedy species are able to obtain a large leaf area index and thus shade out other species (Sutherland, 2004). This process initiates a positive feedback loop that may eventually lead to a weed-dominated system (Buhler et al., 1997; Sutherland, 2004).
- **Seed dormancy**
  - Weedy species have seeds that do not sprout immediately after being released (Groves, 1992).
  - These seeds usually burrow themselves in the first few inches of topsoil and will only sprout after certain environmental cues are met (Groves, 1992; Buhler et al., 1997).
    - For example, for some weedy plants, if their seeds are buried under plant debris, they will not sprout (Groves, 1992). This is likely because these seeds cannot access sunlight and therefore cannot conduct photosynthesis under the given environmental circumstances (Groves, 1992; Buhler et al., 1997).
  - By having dormant seeds, weedy plants can wait for the most opportune environmental conditions before sprouting (such as ensuring high nutrient and water availability) (Groves, 1992; Buhler et al., 1997).
- **High reproductive output & large seedbank**
  - Weedy species generally have a high reproductive output, which results in a high production of seeds (Groves, 1992; Turner et al., 2014).
  - Studies have shown that weedy species can deposit as many as a million seeds in a square meter of land (Buhler et al., 1997).
    - Up to 90% of these seeds belong to just a handful of weedy species (Buhler et al., 1997).
  - When these seeds sprout under the right environmental conditions, they can grow rapidly and quickly dominate the landscape (Groves, 1992; Buhler et al., 1997; Sutherland, 2004).
- **Defense against herbivores**
  - Herbivores have long been known to keep plant cover under check (Popay and Field, 1996).
  - Over time, weedy species have evolved to develop traits that deter herbivores from consuming them, such as thorns and trichomes (Willis et al., 1999; Turner et al., 2014).
  - As a result, herbivores avoid weedy species and are no longer able to control plant

growth; thus, weedy species proliferate rapidly (Willis et al., 1999).

- **Tolerance to adverse environmental conditions**
    - Weedy species can adapt to many of the stresses that they experience, such as:
        - An arid or dry climate, such as that in the Central Valley (Turner et al., 2014);
        - Toxic soils (Turner et al., 2014); and
        - Soils with low nutrient availability (Turner et al., 2014).
    - They are usually able to do this via trade-offs (Turner et al., 2014). In other words, weeds may choose to sacrifice certain functions (such as reproductive output) in order to survive in an unfavorable environment (Turner et al., 2014).

III. Spread of weedy species

Many of the weedy species present in the Western United States were introduced from Asia and Europe long ago (DiTomaso et al., 2007). Their prevalence throughout the years up to today can be attributed to the following reasons:

- **Natural dispersal**
    - Weeds, like many other native and non-weedy species, are deposited into new areas by using elements of the natural environment, including:
        - Wind (DiTomaso, 2000);
        - Rivers, creeks, tributaries, runoff, and other waterways (DiTomaso, 2000); and
        - By animals through direct consumption or attaching onto the animal itself (DiTomaso, 2000).
- **Human-assisted dispersal**
    - Other times weeds can enter a new habitat due to human activity (DiTomaso, 2000; Smith et al., 2012).
    - This is likely how weedy species were introduced into the United States in the first place (DiTomaso et al., 2007).
    - Today, railroads, canals, roads, and other transportation hubs may cross weedy-dominated fields (DiTomaso, 2000). A gust from a nearby railcar or an open cargo bed may provide an opportunity for seeds of a particular weedy species to access a new area (DiTomaso, 2000; Smith et al., 2012).
- **New ecological niches**
    - Studies have indicated that weeds will capitalize on environments that meet three general requirements:
        - There are resources available to be extracted (Shea and Chesson, 2002);
        - There are few natural enemies present (Shea and Chesson, 2002); and
        - The abiotic environment will support the growth of the species (Shea and Chesson, 2002).
    - Examples of habitats that fit these requirements include:
        - Highly perturbed environments (DiTomaso, 2000)
            - This includes sites that have exposed soils or have been converted

for human use (Colorado State Parks, 2000).

- Although these sites may appear to offer few resources for plants, some weeds have taproots that extend far into the soil (DiTomaso, 2000). This allows them to extract water and nutrients that other non-weedy species may not be able to access (DiTomaso, 2000).

▪ Highly deteriorated environments (Colorado State Parks, 2000)
  - This primarily includes places where a healthy, native plant community is no longer able to establish and flourish (Colorado State Parks, 2000).
  - Typically, healthy, native plant communities are functionally diverse and would otherwise inhibit invasive species from accessing open niches (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011).

IV. Future impacts on the spread of weedy species: Climate change

Although climate change will undoubtedly affect countless ecosystem processes, its impacts will be especially profound on the reproductive capabilities of weedy species (Dukes and Ziska, 2014; Makra et al., 2014). As a result, it is essential that the long-term management plans consider how to block potential weedy species from expanding their range. Research has shown that climate change will cause the following:

- **Weedy species will expand their home range.**
  - Some weedy species such as Japanese knotweed (*Polygonum cuspidatum*) and hawkweeds (*Hieracium* spp.) are restricted in location due to low temperatures (Clements and Ditommaso, 2011; Blumenthal and Kray, 2014).
  - Since temperatures are likely to increase due to climate change, these weedy species will no longer be limited by temperature and will be able to colonize new habitat as they open up (Sorte, 2014).
  - This means that weedy species may colonize new habitat towards the poles or up mountain slopes (Clements and Ditommaso, 2011; Blumenthal and Kray, 2014).
- **Weedy species will alter parts of their life cycle.**
  - Some species, such as ragweed (*Ambrosia artemisiifolia*), have increased the total amount of pollen that they produce under warm climates (Makra et al., 2014).
  - More airborne pollen gives ragweed more opportunities to colonize new habitat (Makra et al., 2014).
- **Weedy species will mature faster.**
  - Other species, such as barnyardgrass (*Echinochloa crus-galli*) and jimsonweed (*Datura stramonium*), grow quickly under warmer conditions (Clements and Ditommaso, 2011).
  - Thus, with climate change imminent, it is likely that these weeds will mature earlier, set seed faster, and produce offspring that could potentially shade out non-weedy species (Sutherland, 2004; Clements and Ditommaso, 2011; Dukes and Ziska, 2014).

V. Management tools that influence ecosystem processes and provide weed control

Since weedy populations are associated with numerous problems, restoration managers will need to examine methods to control their population. Fortunately, managers have a range of tools to select from, many of which have already been thoroughly analyzed and widely applied to past restoration projects.

- **Implementing native plant communities**
    - As indicated earlier, a native plant community is functionally diverse and does not allow noxious weeds to colonize a site (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011).
        - It is important to note that a functionally diverse native plant community does not necessarily mean a higher number of native species overall (i.e. species richness) (Dukes, 2002). Often this is the case, but the plant species that are selected need to be able to partition resources amongst themselves and leave no niche space for potential invasive species (Shea and Chesson, 2002; Dukes, 2002).
            - A study by Selmants et al. (2012) support this idea. When native species integral to ecosystem function were removed from their study plots, there would be significantly more invaders present (Selmants et al., 2012).
        - Furthermore, despite being in low numbers, rare plant species often serve in important functional groups within native ecosystems and significantly impact ecosystem processes (Lyons and Schwartz, 2001). Consequently, the absence of a rare plant species will leave open important ecological niches that invasive species may seize (Lyons and Schwartz, 2001; Shea and Chesson, 2002). Therefore, when restoration managers are trying to implement a native plant community that is weed resistant, it is absolutely essential that they do not overlook the seeds of rare native plant species (Lyons and Schwartz, 2001).
    - In California's Central Valley, rangelands that used to be dominated by native perennial grasses are now full of invasive annuals (Dukes, 2002; D'Antonio et al., 2007). With this major ecosystem shift, resources that used to be readily available for perennials are now being locked up for use by competitive annual species (Dukes, 2002).
        - Thus, when trying to build a native plant community that is resistant to weed invasion, it is important that managers select native plants that are strong competitors and prevent any invaders from growing on a given site (D'Antonio et al., 2007). To be strong competitors, native plants must possess physical, biological, or physiological characteristics that give them an advantage within a Central Valley setting (D'Antonio et al., 2007).
        - For example, the invasive species *Centaurea* grows relatively late in the growing season and requires a sufficient level of soil moisture to complete its life cycle (Dukes, 2002). If managers select native plants that lower the soil moisture before *Centaurea* can sprout and reproduce, they will be able to outcompete *Centaurea* for nutrients and other resources (Dukes, 2002).

- Additionally, native plants need to be carefully selected depending on the local geographic context (Whisenant, 1999). Failure to do this will result in the death of native plants and consequently open up new niches for invasive species (Shea and Chesson, 2002). Some factors that should be considered include:
    - *High productivity vs. low productivity*. Highly productive native plant species are severely limited in dry climates such as that of the Central Valley (Whisenant, 1999).
    - *Nutrients*. Native species that produce a sizable amount of biomass also require a large quantity of nutrients from the surrounding environment (Whisenant, 1999).
- Finally, native plants need to reflect the genetic makeup of other nearby plant communities.
    - Seeds that are selected from faraway native plant communities may not be able to withstand local conditions (Whisenant, 1999).
    - Seeds selected from faraway native plant communities that can withstand local conditions may contaminate the local gene pool (Whisenant, 1999).
        - For example, hybridization may occur after multiple breeding seasons and result in undesirable phenotypes (Whisenant, 1999).

- **Fires**
    - Historically, fires have always been an essential component of Central Valley rangelands (D'Antonio et al., 2007). Over time, the intensity, frequency, and patchy distribution of fires have caused native plant species that are increasingly fire tolerant to be selected (D'Antonio et al., 2007). Today, however, the invasion of noxious annual species can cause fires to occur much more frequently – perhaps even at a rate that native plants cannot withstand (Brooks et al., 2004; DiTomaso and Johnson, 2006; D'Antonio et al., 2007).
    - Despite this, research has shown that fires that are used and monitored regularly are effective in limiting noxious weed growth because they can manipulate the following ecosystem processes (D'Antonio et al., 2007):
        - *Enhance short-term nitrogen (N) and phosphorus (P) pools*: After a major fire passes through an area, nitrogen and phosphorus levels are elevated due to an increase in ash and microbial activity (D'Antonio et al., 2007). These nutrients may have been previously taken up by exotic annuals for use but were released back into the soil after being burned (Dukes, 2002; D'Antonio et al., 2007). Native plants can now use these nutrients for their own use.
        - *Increase in long-term N volatilization*: If an area is exposed to numerous fires, more N will be volatilized and lost to the atmosphere (D'Antonio et al., 2007; Perry et al., 2010). With less N in the soil, exotic annuals – especially those that require large quantities of N for rapid growth – will have difficulty trying to reestablish on site (D'Antonio et al., 2007; Perry et al., 2010; Blumenthal et al., 2003).
        - *Increased access to sunlight*: Some invasive species can shade out native plants and thus limit their growth (Sutherland, 2004; D'Antonio et al., 2007). After a large fire event, these invasive plants are removed. As a result, sunlight is no longer a limiting factor – the remaining native plants

(or their seeds) now have ample sunlight to photosynthesize and grow (Groves, 1992; D'Antonio et al., 2007).

- Furthermore, it should be noted that fires are just one of a few management tools that can kill off the seedbanks of weedy species (DiTomaso and Johnson, 2006).
- Most importantly, it should be duly noted that fires *do not always have a perfect success rate* (DiTomaso and Johnson, 2006). Depending on how a fire is implemented or managed, it can increase or decrease the total number of invasive plant species at a given site (DiTomaso and Johnson, 2006; D'Antonio et al., 2007). Thorough testing and long-term monitoring will be required to determine whether fires serve as an effective management tool (D'Antonio et al., 2007).
    - *Situations that can increase invasive plant cover:*
        - A threshold temperature was not met (usually 400°C) (DiTomaso and Johnson, 2006).
        - Seeds were already mature during the time of the burn (DiTomaso and Johnson, 2006).
        - Uncontrollable weather conditions (e.g. precipitation) (D'Antonio et al., 2007).
    - *Situations that can lower invasive plant cover:*
        - Multiple fires are implemented on a yearly basis (DiTomaso and Johnson, 2006; D'Antonio et al., 2007).
        - Burns are conducted before annuals are able to set seed. For sites in the Central Valley, this is usually during the spring or summer (DiTomaso and Johnson, 2006; D'Antonio et al., 2007).

- **Grazing**
    - Grazing is an important management tool. By allowing animals to access a site, they have the ability to selectively choose which plants to eat (D'Antonio et al., 2007). As a result, grazing can alter the plant community as a whole. By eating some plants and leaving behind others, the plants that are left alone can increase rapidly in numbers and exclude the plants (or the seeds left behind) that were eaten by grazers (D'Antonio et al., 2007). This ecosystem process is known as "competitive displacement" (D'Antonio et al., 2007).
        - Along with this term is the fact that grazers are often used to target certain invasive species (Sheley et al., 2011). Goats, for example, can be used to target barbed weed species (such as blackberry, i.e. *Rubus fruticosus*) and other weeds that are considered to be unpalatable by other species (such as galvanized burr, i.e. *Sclerolaena birchii*) (Popay and Field, 1996).
    - Grazers can also alter the characteristics of a site and make it more favorable for native species to thrive (D'Antonio et al., 2007).
        - *Trampling:* By trampling on weedy vegetation, grazers can increase the total amount of sunlight penetration into the soil where seeds of native plants are stored (Groves, 1992; D'Antonio et al., 2007). Consequently, with sunlight no longer being a limiting factor, these seeds can begin to sprout, establish on site, and compete against the weedy species that are already there (Groves, 1992; D'Antonio et al., 2007).
        - *Nutrient inputs:* Some native plants are limited in productivity due to the presence of low nutrients (Whisenant, 1999). The manure from grazers

        can resolve this issue since it is essentially works as a fertilizer (Atiyeh et al., 2001). As a result, it is possible that manure can increase the growth of native plant species and allow them to compete against weedy species for resources, but restoration managers will need to confirm this using test plots (Atiyeh et al., 2001; D'Antonio et al., 2007).

    - To become a successful management tool, grazers must be strategically placed on a site (Henneman et al., 2014).
        - It is strongly recommended that grazers are allowed to cycle around a given site (Henneman et al., 2014). After an area is grazed, native plants need to be given an opportunity to take up the resources that were left behind by weedy species (Henneman et al., 2014). This will allow the native plant community to grow and take over any other open functional niches, thereby preventing weedy species from reestablishing on site (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011).
    - It should also be noted that grazers will *not* eat weedy species if their physical or chemical defenses are active (thistles, trichomes, thorns, etc.) (Willis et al., 1999; DiTomaso et al., 2007; Turner et al., 2014).
        - As a result, timing of grazing is critical (Henneman et al., 2014). Some studies recommend grazing to occur during the first few months of spring, yet others suggest that grazing during the summer is more successful (D'Antonio et al., 2007; Henneman et al., 2014). Since there is no general consensus as to when grazing is most optimal, restoration managers should test out this strategy multiple times by starting over many different months.
    - Finally, grazers' consumption rates need to be monitored.
        - If the stocking rate is too high at a site, grazers will remove an excessive amount of plant cover (DiTomaso, 2000).
        - Without the presence of any plants, noxious weeds will be able to take advantage of the available resources at the site and thus dominate the ecosystem (Colorado State Parks, 2000; Shea and Chesson, 2002).
- **Immobilizing nutrients on site**
    - In order to grow quickly, invasive plants need to capitalize on nutrients that are present within the soil (Groves, 1992; Perry et al., 2010).
        - For example, invasive dandelions (*Taraxacum officinale*) are typically unable to grow in a native plant community due to a lack of open niche space (Tilman et al., 1999).
        - However, by manipulating nutrients on site (e.g. potassium), dandelions can become highly competitive against native plant communities (Tilman et al., 1999).
        - This intense level of interspecific competition can permanently alter the plant community and make it difficult for native plants to recolonize the site (Tilman et al., 1999).
    - Thus, another way to deal with invasive weeds is to make the nutrients that they need – primarily nitrogen (N) – inaccessible for uptake. There are many ways to approach this:

- *Prescribed or natural burns*: Fires can volatilize a percentage of the N located in plant leaves and thus make it unavailable for use (Perry et al., 2010). Additionally, fires can change plant communities by removing plant debris and thus opening up new habitat for native species (DiTomaso and Johnson, 2006; Perry et al., 2010).
- *Adding soil carbon (C)*: Adding C to the soil often serves as a signal for microbial communities to rapidly increase in population size (Perry et al., 2010). As microbes multiply in numbers, they begin to remove and utilize the N from the soil (Perry et al., 2010). As a result, little N is left over for weedy species to use.
- *Removing topsoil*: N is typically stored in the upper horizons of the soil profile (Perry et al., 2010). By removing these upper soil layers, the soil becomes N-poor and thus the site is no longer a desirable habitat for most weeds (Blumenthal et al., 2003; Perry et al., 2010).

- However, it should be noted that this management strategy may not be perfect and could result in other undesirable species. Each of the previously mentioned tools – prescribed burns, adding soil carbon, and removing topsoil – result in the removal of weedy species and thus new niche space becomes available (Shea and Chesson, 2002). This niche space might be utilized by weeds that do not need high nutrient (such as N) levels (Perry et al., 2010). Therefore, for this management strategy to be effective, a thorough plant survey and monitoring plan must be implemented. If weeds with low nutrient levels are found on site, managers may also want to consider combining this management strategy with another one.

VI. Additional management tools

Unlike the previous management tools, the techniques that are described below are not provided by the ecosystem on its own. To be successful, they require some form of human input and management. Moreover, as a side note, this section is mainly for informational purposes.

- **Herbicide use**
  - Many land managers use herbicide for weed control (DiTomaso, 2000).
    - In 1997 alone, herbicides were used on about 100 million hectares of rangeland (DiTomaso, 2000).
    - Herbicides can be applied specifically to a plant of interest and kill it off by manipulating one of three functional processes (DiTomaso, 2000):
      - *Block amino acid synthesis*. These herbicides include Roundup®, Arsenal®, and Escort® (DiTomaso, 2000).
      - *Block photosynthesis*. This includes Spike® (DiTomaso, 2000).
      - *Control and manipulate growth rate*. Herbicides that accomplish this include Vanguish® and Remedy® (DiTomaso, 2000).
  - Research has repeatedly shown that herbicides are best used in conjunction with other management tools such as mowing or tilling (House et al., 1967; Colorado State Parks, 2000; Dorner, 2002; DiTomaso et al., 2013). This is because when herbicides are applied, they usually leave behind open space (House et al., 1967). These spaces are essentially open niches that are often full of resources, resulting in the colonization of new weeds from surrounding patches (Shea and Chesson,

2002). Other times, weedy seeds that lay dormant within the soil can now sprout as they are no longer shaded out by other plants (House et al., 1967; Sutherland, 2004). Thus, by using additional management tools, restoration managers will be able to keep weedy plant cover low once it is removed by herbicides (House et al., 1967; Colorado State Parks, 2000; Dorner, 2002; DiTomaso et al., 2013).

- It should be noted that extensive or inappropriate use of herbicides can alter the ecosystem through the following processes:
    - *Death of non-weedy species*: During one study, herbicide removed all of the native plant cover at a study site and consequently allowed invasive leafy spurge to spread (Sheley et al., 2011). Once this occurred, native plants were never able to fully recover (Sheley et al., 2011).
    - *Alter wildlife dependency*: Wildlife sometimes rely on weedy species to nest or hide from predators (House et al., 1967). If herbicides remove too much of a site's plant cover, wildlife may have to move to new habitat to satisfy their needs.
- Finally, restoration managers should be aware of growing evidence suggesting that extensive herbicide application is causing certain weedy species to become increasingly resistant (Yu and Powles, 2014).
    - Yu and Powles (2014) showed that some weedy species such as *Lolium rigidum* can neutralize harmful herbicidal compounds. These plants are increasing in prevalence (Yu and Powles, 2014).

- **Prescribed burns (logistics)**
    - As indicated earlier, fires are beneficial for ecosystems. They can discourage weed growth and encourage native plants to grow by building up the short-term storage of nitrogen and phosphorus, volatizing more nitrogen into the atmosphere over time, and increasing sunlight penetration into the soil (see the subsection labeled **Fires** for more details) (Groves, 1992; D'Antonio et al., 2007; Perry et al., 2010).
    - Unlike a natural burn, prescribed burns require long-term planning. If a manager wants to conduct a prescribed burn on a site, he will need to contact stakeholders that are involved, such as:
        - A lead agency is needed to direct the fire (DiTomaso and Johnson, 2006);
        - A responsible party is needed to assume liability (DiTomaso and Johnson, 2006);
        - A fire manager is needed to help plan the logistics behind the prescribed burn (DiTomaso and Johnson, 2006);
        - A sufficient budget is required to obtain necessary equipment and personnel (DiTomaso and Johnson, 2006);
        - Personnel need to be trained on handling equipment and have basic knowledge of fire ecology (DiTomaso and Johnson, 2006);
        - Land owners, other participatory agencies, and members of the public need to be notified (DiTomaso and Johnson, 2006); and
        - Local, state, and federal permits need to be obtained as necessary (DiTomaso and Johnson, 2006).

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Goals

The ultimate purpose of this management plan is to control the presence of weedy species at a site located in the Central Valley. To accomplish this, managers will need to develop a set of attainable goals and objectives; a restoration plan that would denote the methods and strategies to achieve these objectives; and a monitoring plan that would determine the success of the project as a whole. Each of these three parts will require extensive knowledge of the project site and the plant community located there.

It should be noted that the following goals are by no means complete; the methodology and potential concerns of the goals will be further discussed in the restoration and monitoring plans.

- ***Primary Goal*: Eradicate weedy species to 20% cover and prevent them from recolonizing the site.**
  - *Scale:* Large scale
  - *What would we measure:* Weedy species cover
  - *How long will it take to implement:* Months, although monitoring may prolong this into years.
  - *Sample tools:* Mowing, herbicides, and prescribed fires
  - *Explanation:*
    - Weedy species are usually problematic and they need to be reduced because:
      - They outcompete other species for resources (Groves, 1992; Popay and Field, 1996; Turner et al., 2014).
      - They alter the environment and make it unfavorable for other species (Groves, 1992; DiTomaso, 2000).
      - They perform well in terms of survival and reproductive output in a variety of stressful environments (Turner et al., 2014).
    - Thus, managers must substantially reduce weedy cover at a site in order for other non-weedy plants to establish (Sheley et al., 2011).
    - After managers lower the weedy cover, managers will need to introduce intense ecological pressure on weedy species (Shea and Chesson, 2002; D'Antonio et al., 2007). This will limit their growth and allow native species to flourish (Shea and Chesson, 2002). For instance (this will be further covered in the restoration plan):
      - A native plant community could compete with weedy species for

resources (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011)

            - Grazers can act as a natural enemy by consuming weedy biomass (D'Antonio et al., 2007).
            - Preventing land conversion (e.g. maintaining grassland that was originally planned to be converted into roadways) keeps the abiotic environment (e.g. soil) intact (Colorado State Parks, 2000; DiTomaso, 2000).
        - Finally, restoration managers need to prevent the seeds of weedy species from entering the site from outside sources (DiTomaso, 2000; Smith et al., 2012).
            - Human-assisted and animal-assisted dispersal are two ways that allow weedy species to access a new site (DiTomaso, 2000; Smith et al., 2012).
            - By blocking human access (including roads, canals, etc.), seeds of weedy species can no longer be deposited onto a site by cars, boats, trains, or any other similar method of transportation (DiTomaso, 2000; Smith et al., 2012).
            - By limiting animal access, animals can no longer carry the seeds of weedy species onto the site (DiTomaso, 2000).
                - However, this will be extremely difficult to achieve. Many animals play an integral role in the ecosystem structure at a given site (e.g. food web).
                - Thus, we will need to work with other managers who are focusing on Central Valley wildlife. We must understand their *behavior* and change their behavior by manipulating elements of the landscape (e.g. providing clusters of perch sites).
    - *Tradeoffs, feedbacks, interactions, and thresholds that should be considered:*
        - *Arbitrary threshold*
            - It should be noted that the 20% threshold is an arbitrary value but reflects the fact that weedy species in large numbers can change the ecosystem at a site (Groves, 1992; Popay and Field, 1996; DiTomaso, 2000; Turner et al., 2014).
            - This value was generated based off successful restoration projects in the Central Valley that were able to reduce weed cover to as low as 4% (Tjarks, 2012).
            - The reason why we would like to have a threshold of 20% weed cover instead of a value less than 5% is because some wildlife species might rely on weedy species for nesting habitat or hiding from overhead predators (House et al., 1967). However, to confirm this, we will need to talk with other wildlife restoration managers to fully understand their species' habitat needs and collaborate on a plan that will determine whether the 20% threshold is sufficient or if it needs to be further adjusted.

- To see whether our goals and restoration plan are effective will require extensive monitoring.
- Based on the data we collect, we will need to adjust the 20% threshold accordingly.
  - If weeds continue to exclude native plant communities and impact resource availability even at 20% cover, we will need to lower the threshold.
  - If weeds consistently occupy less than 20% cover and native plants are able to colonize the site, we may leave the threshold as is.

▪ *Which weedy species are present*
- An extensive survey must be conducted in order to see which weedy species are present at a given site.
- Weedy species likely respond differently to various management tools, but we will need to confirm this with additional research and test plots.

▪ *Potential for weedy species to recolonize a site or resurge in dominance*
- To prevent a weedy species from recolonizing a site, we may choose to implement management tools such as herbicides, prescribed fires, and grazing.
- However, many of these tools do not have a perfect success rate (DiTomaso and Johnson, 2006; Sheley et al., 2011).
- For example, in one study, barb goatgrass covered ten times more area than before a series of prescribed fires (DiTomaso and Johnson, 2006).
- Secondary invasion might also occur. A site with a dominant weed may inhibit other weeds; however, when this dominant weed is removed using a management tool, the previously inhibited weeds can colonize new niche habitat (see ***Potential Issue #3*** for more details) (Groves, 1992; Popay and Field, 1996; Shea and Chesson, 2002; Turner et al., 2014).
- Thus, weedy species will require extensive monitoring and long-term implementation of management tools.

- ***Goal 1:*** **Provide 80% cover for a healthy native plant community.**
  - *Scale:* Large scale
  - *What would we measure (note: this will be further discussed in the restoration plan):* Native species cover
  - *How long will it take to implement:* Years. Although planting seeds may take less than a week, we will need to extensively monitor native plant growth over the long term as a way to measure their performance. The tools that are used in the management plan suggest surveying native plant cover for three years (D'Antonio et al., 2007; Tjarks, 2012).
  - *Sample tools:* Seeding, mowing, and herbicides
  - *Explanation:*
    - ▪ Native plant communities are functionally diverse (Colorado State Parks,

2000; Shea and Chesson, 2002; Sheley et al., 2011).
        - In other words, well-functioning native plant communities do not have any open ecological niches for weeds to exploit (Shea and Chesson, 2002; Dukes, 2002). As a result, weeds are prevented from re-establishing on-site.
        - Native plant communities tend to provide a more desirable suite of ecosystem services that is not provided by noxious weeds (e.g. water infiltration into the soil) (Groves, 1992; DiTomaso, 2000).
    - *Tradeoffs, feedbacks, interactions, and thresholds that should be considered:*
        - *Arbitrary threshold*
            - If 20% of plant cover is for weed species, the remaining 80% should be dedicated to native plant cover.
            - As with threshold present in the ***Primary Goal***, this 80% value is arbitrary. We will need to have an extensive monitoring plan to determine whether 80% native plant cover is enough for the site or needs to be further adjusted.
            - Since native plant cover fluctuates due to external factors such as rainfall, it may be difficult to determine if a restoration project is on a successful trajectory (D'Antonio et al., 2007; Jackson et al., 2012). Therefore, based on data from previously completed Central Valley restoration projects, the following goals should be met:
                - Generally, 70-90% of all plants that are sowed need to survive after two years (Jackson et al., 2012).
                - After three years, total native plant cover should grow and reproduce enough to reach 70% cover (Tjarks, 2012).
                    - As a side note, the 80% native plant cover goal was generated from this value.
        - *Genetics* (more details in the Methodology section)
            - When we select native seeds to use for our site, we must be mindful of where these seeds came from.
            - For example, seeds that are picked from sites located in wetter climates may not survive in dry Central Valley conditions (Whisenant, 1999).

Restoration Plan: Methodology

This section of the management plan will discuss the specific methodology that should be implemented during the restoration process. The specific timeline (i.e. the temporal aspects) of this restoration plan will be further discussed in the monitoring plan. Finally, it should be noted that this restoration plan is primarily designed for sites within the Central Valley.

- ***Step 1: Preliminary survey***
    - Weedy species share many characteristics (fast growth rate, large seedbank, etc.) (Groves, 1992; Buhler et al., 1997).
    - However, weedy species respond differently depending on resource availability and other environmental cues (Groves, 1992; Buhler et al., 1997; DiTomaso and

Johnson, 2006; Turner et al., 2014).
- Thus, we will need to curtail our management plan to whichever noxious weeds are on site.
- *Methodology:*
  - We will recruit 20 scientists who have background experience on weeds and can identify weedy species.
  - We will divide the site into a grid system by overlaying latitude and longitude lines.
  - The location where latitude and longitude lines intersect will be the sites that will be surveyed for plant cover.
  - We will randomly select at least 80% of these sites for surveys (to ensure a representative sample).
  - At each site, we will lay out a 5 meter by 5 meter quadrat and survey the plant composition.
  - Finally, we will estimate the percent cover of weedy species (to be used for later steps).

- ***Step 2: Soil evaluation***
  - The next step is to see which native plants will be suitable for growth at the site.
  - We will need to look at soil texture, pH, and the amount of organic matter (OM).
    - Soil texture, pH, and OM affect nutrient retention and soil moisture, which consequently influence plant function (Dorner, 2002).
  - *Methodology:*
    - We will use the same sampling method that we used in ***Step 1***.
    - For soil texture, the Natural Resources Conservation Service or the county's Conservation District will usually have conducted a soil survey beforehand (Dorner, 2002).
    - For pH, please use the following steps (quoted directly from Dorner, 2002):
      - "Use a 2 mm sieve to remove particles >2 mm.
      - Mix 20 to 25 grams of the sieved soil with a 1:1 or 2:1 ratio of water to soil. Add just enough water to saturate the soil (when forming a depression in the sample, water just begins to move into the hole and puddle).
      - Let the mixture sit for half an hour to equilibrate.
      - Stir it again.
      - Measure the pH of the mixture with a pH meter."
    - For OM, please use the following steps (quoted directly from Dorner, 2002):
      - "Use a 2 mm sieve to remove particles >2 mm.
      - Dry the soil sample at 105°C overnight.
      - Weigh the sample and record the value (this is the initial dry weight).
      - Burn the sample in the muffle furnace at 450°C for four and a half hours.
      - Weigh the sample and record its weight again. This is its final

weight.
- Calculate the percentage of organic matter in the soil using the following equation: (Initial dry weight - Final weight) / Initial dry weight x 100 = % organic matter"

- ***Step 3: Research***
  - Managers will need to research each plant's life cycle and physical characteristics.
    - Some management tools such as grazing and prescribed fires are most effective if they are timed properly around the growing season (Willis et al., 1999; DiTomaso and Johnson, 2006; DiTomaso et al., 2007; Turner et al., 2014).
  - *Methodology:*
    - There are other restoration managers who are focusing on individual weedy species. Many of them have already gathered information on life cycle, phenology, and growth rate.
    - There are many research publications and handbooks available that have collected information from other studies on individual weedy species. One such example is the book *Weed Control in Natural Areas in the Western United States* by DiTomaso et al. (2013). It covers 340 weedy species and details which management tools are effective for each species. A lot of the methodology behind each of the management tools are also region-specific (e.g. Central Valley).
    - However, it is important to remember that weedy species will behave differently depending on the resources and other environmental factors present (Groves, 1992; Buhler et al., 1997; DiTomaso and Johnson, 2006; Turner et al., 2014). Thus, test plots will be necessary (see ***Step 5***).
- ***Step 4: Native plant selection***
  - Native plant communities that are functionally diverse prevent noxious weeds from returning to a site (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011).
    - Studies by Selmants et al. (2012) show that plots with 16 native species reduced the presence of invasive weeds by approximately 75% compared to plots with just 2 native species present.
  - By being "functionally diverse", native plant communities need to utilize or store various resources (sunlight, nutrients, etc.) at a given site before weedy species are able to exploit them (Selmants et al., 2012).
  - In summary, we will use a management tool to initially remove the weeds, and then seed native plants to stop the weeds from reestablishing.
  - *Methodology:*
    - We will need to consult local seed experts on which seeds to use. Given this, there are some factors to keep in mind.
    - First, the plants will need to be able to grow in the soil at the site (i.e. soil texture) and withstand the site's pH and OM levels.
    - Additionally, we must consider the geographic context of the Central Valley. The Central Valley has a uniquely dry climate that not every plant can survive in. Therefore:
      - We should try to select seeds that were collected from the Central

Valley.

    - If seeds were selected from a wet climate, for example, they would not be able to survive in the dry Central Valley (Whisenant, 1999).
    - Native plants should reflect genetic makeup of nearby native plant communities to prevent hybridization and thus unwanted phenotypes (Whisenant, 1999).
    - Finally, a variety of native seeds need to be selected such that they are able to divide available resources amongst themselves and leave few resources for weedy plants (Shea and Chesson, 2002; Dukes, 2002).
  - In their adult form, the native plants need to have low productivity. Overly productive plants require a large amount of nutrients, which is something that the Central Valley is typically unable to offer (Whisenant, 1999).
  - We should try to incorporate any rare native plants that are well-adapted to the Central Valley, if possible. Many rare plants provide many desirable ecosystem services, including enhancing soil fertility and increasing carbon sequestration (Lyons et al., 2005).
- Generally, we will need to have enough seeds to have a seeding rate of 30 seeds per square foot (Amme, 2003). However, this value may vary depending on which species we use, so we will also need to discuss with local seed experts for a more accurate estimate (Amme, 2003). By using a proper seeding rate, we will ensure that native plants will have sufficient access to resources and enough room to grow (Amme, 2003).
- Ideally, native plants need to be able to establish and develop quickly before weedy species are able to take root.

- ***Step 5: Test plots for native plants***
  - Once the seedbank has been selected, it needs to be tested to see if it can exclude weedy species from the site.
  - *Methodology:*
    - In ***Step 3***, we should have been able to determine which management tools are best to remove weedy plant species at the site.
    - Usually a combination of herbicide use and mowing is extremely effective (Colorado State Parks, 2000; Dorner, 2002; DiTomaso et al., 2013).
    - To test this, we will use the same sampling method in ***Step 1***.
    - We may want to set aside 3 or 4 plots as controls (i.e. no preparation and no treatment).
    - We will also need to properly prepare the entire site.
      - Many weedy species have large seedbanks that are scattered throughout the 10 centimeters of topsoil layer (Buhler et al., 1997; de Silva, 2011). Therefore, the first 10 centimeters of topsoil should be removed and replaced (Dorner, 2002; de Silva, 2011).
      - The plots need to be plowed such that they follow the site’s natural topography (Dorner, 2002). This lowers the chance for the site to be eroded and thus prevents new ecological niches around eroded

habitat from opening up (Dorner, 2002; Shea and Chesson, 2002).

- We should use a seeding rate of 30 seeds per square feet (Amme, 2003). However, as mentioned in ***Step 4***, this value may change based on which native plants we select (Amme, 2003).
- Despite this, it should be noted that most herbaceous species need 3 – 5 inches of space to grow (The Xerces Society, 2002).
- Seeds need to have ample access to sunlight (Dorner, 2002). Most seeds should not be planted further than 0.75 inches into the soil (Dorner, 2002).
- The seeds should also be planted during the fall (before the rainy season) (Dorner 2002; The Xerces Society, 2002).
- Although not necessary, some native perennials such as purple needlegrass (*Nassella pulchra*) can grow faster if they are irrigated with 1" of water per week during the dry season (The Xerces Society, 2002; Amme, 2003; Miller et al., 2013). Other native perennials such as California oatgrass (*Danthonia californica*) do not need to be irrigated (Amme, 2003).
- Any remaining open spaces should be filled with mulch or wood chips (de Silva, 2011). This will prevent the seeds of weedy plants from accessing any leftover niche space (Shea and Chesson, 2002).

▪ Then, we will need to begin applying herbicides.

- Herbicides should be used first because they can be used to target weedy species without harming native species if used appropriately (House et al., 1967; DiTomaso, 2000; de Silva, 2011; Sheley et al., 2011).
- We should already have been able to determine which herbicides should be used based on research from ***Step 3***.
- Herbicides usually need to be applied every six months after the winter season (The Xerces Society, 2002).
- Once native plant cover approaches our goal of 80%, herbicides can be more effective if they are combined with other management tools such as mowing (House et al., 1967; Colorado State Parks, 2000; Dorner, 2002; DiTomaso et al., 2013).
- When native plants grow, they remove nutrients from the soil (Whisenant, 1999; Dukes, 2002). Therefore, mowing regularly will force native plants to regrow numerous times, resulting in even lower levels of nutrients within the soil structure. This will discourage weed establishment since weeds need many nutrients to survive (Groves, 1992; Buhler et al., 1997; Perry et al., 2010).
- If mowing is pursued, it needs to be conducted on a monthly basis (The Xerces Society, 2002).

▪ From these test plots, we will need to conclude whether we were able to achieve 80% native plant cover and reduce weedy plant cover to 20%.

o *If 80% native plant cover was not met, please check the following factors:*

▪ Were the native plants selected from a local population (i.e. Central

Valley)? Seeds that are not from a local population may not be adapted to the Central Valley's dry climate (Whisenant, 1999).

        - *Threshold for action*: If the seeds are not from the Central Valley, consult local seed experts who know where they collected their seeds. Obtain a new seedbank. Till the soil and remove the old seedbank if it was already planted. Plant the new seedbank using the methodology from that was described above.
    - Were the seeds given enough water? Plants during the dry season will need at least 1" of water per week (The Xerces Society, 2002).
        - *Threshold for action*: If <1" of water is present during the dry season, make sure to install irrigation system if it is not present. If the irrigation system has been already installed, restructure the irrigation system such that each plant gets 1" of water every week. Keep in mind that plants do not need as much water during the wet season (The Xerces Society, 2002).
    - Were mowing and herbicides implemented on a regular basis? If treatments were halted for a significant time, weedy species can outcompete the native species (Groves, 1992; Sutherland, 2004; Sheley et al., 2011).
        - *Threshold for action*: Mowing needs to be done monthly; herbicide application must be done every 6 months (The Xerces Society, 2002). If these time frames are not met, work out a sign-up schedule with managers and employees such that one person is at the site to do treatment when appropriate. Make sure this individual is well-informed of the restoration plan, management tools, and the noxious weeds on the site.
- *If 20% weed cover was not met, please check the following factors*:
    - Was mowing undertaken every month and done correctly? Were herbicides applied every half-year and correctly? Treatments that were used inappropriately may result in the proliferation of weedy species (Groves, 1992; Sutherland, 2004; Sheley et al., 2011).
        - *Threshold for action*: If mowing and herbicides were not done regularly (i.e. >1 month and >6 months respectively), it is essential to communicate with other managers and employees. Ensure that someone will be available to apply treatment. This person needs to be well-versed on the restoration plan, management tools, and the noxious weeds on-site.
    - Are there other sources of dispersal (e.g. humans, wind, and animals)? Humans, other animals (such as birds), and natural elements can bring to a site the seeds of weedy species from faraway sources (DiTomaso, 2000; Smith et al., 2012). A head count, animal surveys, site surveys, and weather data can help confirm this.
        - *Threshold for action*: If humans are seen accessing the site, make sure that fencing is properly installed around the site. "NO TRESPASSING" signs should be placed visibly in front of access points to the site. Additionally, make sure that bare soil is planted

with native plants so that weedy plants cannot proliferate even if their seeds are brought in via wind or water (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011). If animals are seen on-site, work with other managers and try to have resources (e.g. perching sites) clustered together. Make sure that these areas are also covered during the treatment process.

- ***Step 6: Large-scale implementation***
    - Assuming that ***Step 5*** was successful, we can now sow the seeds across the entire site.
    - *Methodology:*
        - We will use the same seeding rate, management tools, timing, and spacing requirements that were indicated in ***Step 5***.
        - Furthermore, the management tools will be implemented at the same frequency as in ***Step 5.***
        - Depending on the size of the site, it may be wise to split the site up into numerous phases. This will also make monitoring more manageable.
- ***Step 7: Prevent dispersal from external sources***
    - Humans and animals – particularly birds – may introduce seeds of weedy species from faraway sites (DiTomaso, 2000).
    - *Methodology*:
        - For humans:
            - Fence off the site.
            - Deter human access by posting "NO TRESPASSING" signs.
        - For birds:
            - We will need to work with other managers who are focusing on wildlife.
            - We can change their behavior by manipulating elements of the landscape (e.g. providing clusters of perch sites).
            - By following the methodology listed in ***Steps 5*** and ***6***, management tools for weed control will also cover areas where birds spend the most time. Thus, if a bird accidentally carries a seed of a weedy species from another site and deposits it near a perch site, mowing and herbicides will prevent it from proliferating.

Restoration Plan: Alternative Strategies

This section of the restoration plan will discuss other alternative strategies that should be used if mowing and herbicides in ***Steps 5*** and ***6*** are unsuccessful.

- ***Alternative Strategy #1: Grazing***
    - Grazing can be extremely useful because they can selectively choose which species to eat (D'Antonio et al., 2007).
    - Grazers also help maintain many abiotic processes, such as nutrient cycling (D'Antonio et al., 2007).
    - However, herbivores may prefer another species instead of the targeted weed (D'Antonio et al., 2007).

- Additionally, grazing may be more time-consuming than other management tools because they require precise timing and constant monitoring (Willis et al., 1999; DiTomaso and Johnson, 2006; DiTomaso et al., 2007; Turner et al., 2014).
    - Grazers will avoid a weed if it has defensive capabilities (Willis et al., 1999; DiTomaso et al., 2007; Turner et al., 2014).
    - If a pasture is not given enough time to recover, grazers will remove all plant cover – both native and weedy (DiTomaso, 2000; D'Antonio et al., 2007; Henneman et al., 2014). This then opens up new niches for other weedy species (Shea and Chesson, 2002).
- *Methodology:*
    - First, divide the site into many subunits such that there is a high stocking rate (e.g. 100,000-150,000 pounds of cattle per acre) (Henneman et al., 2014).
    - Leave three subunits as control plots (i.e. no grazing) (Gillespie, 2006). If we are not able to achieve our goals, we can later use these control plots to determine if we need to adjust our thresholds (Gillespie, 2006).
    - Then, rotate grazers through each subunit (Henneman et al., 2014).
        - If this were not to occur during the growing season, grazers can be rotated on a weekly basis (Henneman et al., 2014).
        - If this were to occur during the growing season, grazers should be rotated on a daily basis (Henneman et al., 2014). This provides less time for weeds to recover if they are present (Henneman et al., 2014).
    - Finally, we will have to conduct vegetation surveys using a sampling method similar to that in ***Step 1***.
    - Were we able to achieve our goals?
    - Although grazing may seem like a cumbersome task, one study that used this type of grazing rotation managed to increase native plant cover from 8% to 80% within a two-year period (Henneman et al., 2014).

- ***Alternative Strategy #2: Prescribed fire***
    - Fires are especially useful for killing the large seedbanks of weedy species (DiTomaso and Johnson, 2006).
    - They also increase the amount of nitrogen and phosphorus in the soil, both of which are necessary for plants (D'Antonio et al., 2007).
    - However, prescribed fires are not always a successful long-term solution. Some studies have shown barb goatgrass covering ten times more area than they did before a series of prescribed burns (DiTomaso and Johnson, 2006). To avoid this, managers should use the research from ***Step 3*** to determine whether a prescribed burn is useful in controlling the proliferation of a specific weed.
    - *Methodology:*
        - First, a plan should be made. Managers should consider that:
            - Burns need to be conducted before seed dispersal (D'Antonio et al., 2007). For the exotic annuals that dominate California grasslands, this usually means spring or summer (DiTomaso and Johnson, 2006; D'Antonio et al., 2007).
            - Since most weeds in the Central Valley are annuals, burns should

be done on a yearly basis for successful control (DiTomaso and Johnson, 2006; D'Antonio et al., 2007). However, this depends on the plant composition at a given site, which was already evaluated in ***Steps 1*** and ***3***.
            - It may be necessary to set aside control plots (i.e. no burning) for comparison purposes.
        - Secondly, managers need to obtain any permits, consult with other stakeholders, designate parties, assume liability, and train personnel (DiTomaso and Johnson, 2006).
            - A full list can be found in the **Prescribed fires** subsection under Section VI.
        - Then, conduct the prescribed burns and survey plant cover across the entire site (D'Antonio et al., 2007). Use the sampling method similar to that from ***Step 1***.
        - Were we able to achieve our goals?

Restoration Plan: Potential Issues

This portion of the restoration plan will address any potential issues and their respective solutions regarding the use of the aforementioned management tools.

- ***Potential Issue #1: Overuse of herbicide***
    - Excessive use of herbicide may cause weedy species to select for resistance (Yu and Powles, 2014).
    - Thus, managers should follow recommendations that are listed on the label.
    - Generally, for the best use, herbicides should not be applied more than every half-year (The Xerces Society, 2002).
    - If herbicide resistance becomes increasingly prevalent on a site, we may have to stop using herbicides and implement other management measures (see ***Alternative Strategies***).
- ***Potential Issue #2: Liability issues***
    - Many of these management tools come with serious liability issues.
        - For example, a prescribed fire that burns out of control may damage neighboring properties.
    - Consequently, these management tools need to be handled and implemented carefully.
    - If liability issues are too great of a concern, <u>do not</u> implement that management tool and use an alternative option.
- ***Potential Issue #3: Secondary invasion***
    - The presence of a particular weed may naturally inhibit the growth of another weed by competition (Groves, 1992; Popay and Field, 1996; Turner et al., 2014).
    - By removing this dominant weed, weeds that were previously inhibited can now capitalize upon the open niche and extract resources that were left behind (i.e. secondary invasion) (Shea and Chesson, 2002; Pearson and Ortega, 2009).
    - As a result, the inhibited weed now begins to proliferate.
    - To prevent secondary invasion from occurring, native plant communities should

be planted when a weed is removed (Dorner 2002; Selmants et al., 2012). Robust native plant communities prevent weeds from sprouting and colonizing a site (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011).
    - If secondary invasion has already occurred, another management tool needs to be added to the treatment process.
        - ***Step 3*** should have already revealed which management tool is effective for each invasive weed at the site.
        - Apply the treatment using the methodology listed above.
    - Long-term monitoring will be needed.
- ***Potential Issue #4: Spatial issues***
    - Depending on the budget, manpower, and size of the site, it may be necessary to apply treatment across multiple phases.
        - A good example of this is the spatial division for grazing, in which a large cattle herd was rotated over many subunits of land (see ***Alternative Strategy #1***).
    - For herbicide, mowing, and prescribed fires, managers could target patches with weeds that are deemed highly invasive by the California Invasive Plant Inventory or other scientific research (e.g. medusahead and ripgut brome) (DiTomaso, 2000; DiTomaso et al., 2007).
    - Another option would be to divide the site into rectangular plots and target each plot individually.
    - In either scenario, long-term monitoring will be required.

Restoration Plan: Other Risks and Uncertainties

Ecosystems are extremely complex and consist of many integrated biotic and abiotic processes. With so many working parts interacting with each other, it should be no shock that the listed treatment strategies are *not* guaranteed to work – despite the fact that many of them have been validated across many research studies. As a result, we must include adaptive management principles into our restoration plan at all times. When an issue that was previously unaccounted for arises, the restoration plan needs to be revised and appropriate solutions must be integrated accordingly.

The key to determining whether a restoration plan is working is a long-term monitoring plan. Monitoring plans are the equivalent of a fail-safe: using the data from a site, monitoring plans lay out backup options in case a restoration goal is not met. The monitoring plan that is associated with weed control is described in the following section.

Monitoring Plan

- ***Pre-Restoration Monitoring***
    - The preliminary survey (***Step 1***) must be done before the treatments are applied and should be conducted as soon as the project location is known. If possible, the preliminary survey should be conducted multiple times since species composition naturally fluctuates over time (D'Antonio et al., 2007). The weeds that are most ubiquitous over multiple surveys may pose an ecological risk and thus may have to be dealt with using the aforementioned treatment strategies (Groves, 1992).

- ***Restoration Monitoring***
  - ***Steps 1, 2, 3,*** and ***4*** primarily consist of site evaluation, research, and obtaining materials; therefore, long-term monitoring is not necessary.
  - ***Native plants did not increase to 80% cover (Steps 5 and 6)***
    - *Initial monitoring:* Most invasive weeds in the Central Valley are annuals and may outcompete native species during their quick life cycles (Groves, 1992; Dorner, 2002; D'Antonio et al., 2007). Therefore, once native plants are sowed, they should be monitored during the peak of their growing season. Native plants should be monitored for at least three years since weedy and native species composition can fluctuate over time (Dorner, 2002; D'Antonio et al., 2007). Generally, monitoring plots must cover at least 5% of the site for a representative sample (Dorner, 2002). It is recommended to monitor the test plots from ***Step 5***.
    - Please make sure that the restoration plan is followed according to the guidelines listed above. If 80% cover was not reached, it is possible that some guidelines were overlooked. Please see the subsection labeled *If 80% native plant cover was not met, please check the following factors* under ***Step 5***.
    - If these guidelines were followed, managers should consider using the following contingency plans:
      - *Native plants are dying, unable to increase in cover, or reproduce despite being given enough water.*
        - If native plants are unable to establish 80% cover despite being given 1" of water, it is likely that the seedbank that was selected was either unaccustomed to Central Valley conditions or could not tolerate soil conditions (Whisenant, 1999).
        - *Threshold for action*: If native plant cover is below 80% over three years of monitoring, managers should remove native plants from areas with low establishment (i.e. <80% native plant cover) and plant a new mixture of seeds possessing characteristics that resolve the issue (e.g. if the seeds were unable to adapt to Central Valley conditions, select a new seedbank that is drought resistant).
      - *The 80% threshold was not realistic.*
        - As indicated earlier, the 80% threshold was an arbitrary value that was based off other successful restoration projects (Tjarks, 2012).
        - *Threshold for action*: After three years of monitoring, managers should have collected enough data to see whether native species composition built up over time. If the vast majority of plots leveled off and remain steadily under the 80% threshold (e.g. 65%) over three years, managers should adjust the threshold to that level. It should be noted that this should be considered as a last resort and only with sufficient data; there are plenty of other reasons that were

listed in this monitoring plan on why the 80% threshold was not met.

- *There are other management tools available*.
    - It could be, just by chance, that mowing and herbicide application are ineffective at this particular site.
    - *Threshold for action*: There are two other management tools available, grazing (see ***Alternative Strategy #1***) and prescribed burns (see ***Alternative Strategy #2***). These tools might be end up being more effective if combined with other management tools than if each tool was used by itself (Colorado State Parks, 2000).

- ***Weedy plants did not reduce to 20% cover (Steps 5 and 6)***
    - *Initial monitoring*: Most Central Valley weeds live an annual life cycle (Groves, 1992; Dorner, 2002; D'Antonio et al., 2007). Since they grow and reproduce in such a short amount of time, they should be monitored for their cover at the peak of the growing season beginning with the pre-monitoring plant surveys (see ***Pre-Restoration Monitoring***) (D'Antonio et al, 2007; Henneman et al., 2014). This should be done over a course of a minimum of three years (D'Antonio et al., 2007). Furthermore, having the weedy plant surveys use the same temporal scale as the native plant cover surveys will reduce the total amount of work that needs to be done. After being reduced to 20% cover, weedy species should still be monitored every month for the length of the project since species composition change over time (Dorner, 2002; D'Antonio et al., 2007). Managers should use the test plots from ***Step 5*** for monitoring since they have already been set up.
    - Please make sure that the restoration plan is followed based on the steps that were described above. If 20% weed cover was not reached, it is likely that some steps were implemented improperly. Please see the subsection labeled *If 20% weedy cover was not met, please check the following factors* under ***Step 5*** for more details.
    - If weed cover was properly managed, restoration managers must consider the following contingency plans:
        - *After native plants are sowed, weed cover is still greater than 20% due to the presence of open niches.*
            - After native plants are sowed into the ground, it is possible that weedy species continue to establish in areas with open niches (e.g. bare dirt or in between hedgerows of native plants). This is because these areas have resources that can be extracted (Shea and Chesson, 2002).
            - *Threshold for action:* If weedy species are taking over sites with open niches and maintaining a cover level greater than 20%, they should be removed using one of the management tools (i.e. grazing, herbicides, etc.). Then, these treated areas should be planted with native species using the methodology described in ***Step 5***. A plant community with

many native species is functionally diverse and can keep weedy species out (Colorado State Parks, 2000; Shea and Chesson, 2002; Sheley et al., 2011). Furthermore, managers should use mulch or wood chips to prevent seeds from invasive plants from settling into the soil (de Silva, 2011).

- *Secondary invasion.*
    - After the application of a particular treatment, did another weedy species suddenly proliferate (>20% cover)? This ecological phenomenon is called secondary invasion (see ***Potential Issue #3*** for full details).
    - *Threshold for action:* If a weed was able to produce more than 20% cover, the research from ***Step 3*** should indicate which management tool is best for that weedy species. Use the best management tool for this proliferating weedy species more heavily (or begin to incorporate it into the treatment process).

▪ Finally, if these issues are addressed and weedy cover is not reduced to under 20%, the following should be considered:

- *The 20% threshold was not realistic.*
    - This value was based off other restoration projects (Tjarks, 2012).
    - *Threshold for action*: After a year of monitoring, managers should have sufficient data to analyze how weedy species fluctuate over time. If the majority of plots leveled off and remained steadily above 20% (e.g. 35%), managers should consider moving the threshold to that level. However, managers should try to avoid this option; there are many possibilities denoted in this monitoring plan on why the 20% cover threshold was not met.
- *There are other management tools available*.
    - It could be, just by chance, that mowing and herbicides are ineffective at this particular site.
    - *Threshold for action*: Grazing (see ***Alternative Strategy #1***) and prescribed burns (see ***Alternative Strategy #2***) are other treatments that may work.

o ***Monitoring: Grazing (if Alternative Strategy #1 is used)***

▪ *Initial monitoring:* Based on the successful rotational grazing experiment laid out by Henneman et al. (2014) (see ***Alternative Strategy #1*** for more details), each subunit will need to have its plant cover surveyed yearly (for a total of three years). These surveys should be conducted when plant cover is at its maximum, which is usually when the growing season ends (approximately July) (Henneman et al., 2014). Although Henneman et al. (2014) suggests to survey the subunit using a “zigzag pattern”, the test plots from ***Step 5*** should still be set up and can be used for monitoring instead.

▪ If native plant cover were not able to reach 80% cover, see the subsection

titled ***Native plants did not increase to 80% cover (Steps 5 and 6)***.
        - If weedy plant cover were not able to be reduced to 20% cover, see the subsection titled ***Weedy plants did not reduce to 20% cover (Steps 5 and 6)***.
    - ***Monitoring: Prescribed fires (if Alternative Strategy #2 is used)***
        - *Initial monitoring*: Most studies on prescribed fires that are published in scientific literature have conducted vegetation cover surveys on a yearly basis (D'Antonio et al., 2007). Some studies only conduct one total survey; other studies conduct three (D'Antonio et al., 2007). In order to have sufficient data to validate prescribed fire as a successful management tool, it is strongly recommended that managers conduct at least three years' worth of surveys. Test plots from ***Step 5*** should still be set up when the treatment process starts, so it is highly suggested that managers use these test plots for monitoring purposes.
        - If native plant cover were not able to increase to 80% cover, there may be a number of explanations responsible. See the subsection titled ***Native plants did not increase to 80% cover (Steps 5 and 6)***.
        - If weedy plant cover were not lowered to 20% cover, see the subsection titled ***Weedy plants did not reduce to 20% cover (Steps 5 and 6)*** for possible reasons.
- ***Post-Restoration Monitoring***
    - Once the restoration project is completed, the owner of the site should continue to implement treatment and monitor the cover of the native and weedy species. Any monitoring that was originally done on a monthly basis should continue as such if possible; those that were conducted yearly should also be continued. If a noxious weed begins to be problematic during the post-restoration monitoring process, research such as the information found in ***Step 3*** should tell land owners which treatments to use. Land owners should also be given contact information for the county's Conservation District in case they have any other questions that arise during the post-restoration process.

Unanswered Research Questions

The following questions were not found in the scientific literature that was used for this restoration plan. Answering these questions would significantly bolster the methodology and the long-term success of this management plan.

- What underlying ecological processes are responsible for the success of a particular treatment at one site but not another site?
- Is it possible for a native plant to become "weedy" during the restoration process and, if so, what would we do? For example, if a native plant was selected for fast reproduction and ends up dominating the entire landscape, should we allow the native plant to exist as is?
- How likely will secondary invasion occur on a given site?
- With climate change in the near future, which invasive weeds are most likely to move northwards and invade California grasslands? Will our current management plan be

sufficient to deal with these new weeds?

Answered Research Questions

The following research questions were thoroughly explored in this restoration plan.

- How does a site's plant composition change over time?
  - Pre-monitoring plant surveys are conducted.
  - Each management technique spaces out replicate plots throughout the site.
  - These plots are constantly monitored for plant composition (monthly, yearly, etc.).
  - Post-monitoring plant surveys will also be conducted.
- Is herbicide use and mowing an effective management technique for sites within the Central Valley?
  - We set aside 3 or 4 plots as controls.
  - Replicate test plots were then mowed and applied with herbicide.
  - We can determine the success rate by:
    - Comparing the replicates to the controls
    - Monitoring whether weedy cover reaches 20% by conducting monthly plant cover surveys
    - Monitoring whether native plant cover surpasses 80% by surveying the plant cover monthly

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