2014 ENH 160 Project: Solano County RCD: Urban Greening Project
Bike path/Riparian site (Tulare Dr)
And Flood Detention Basin Site

Report by students of UCD's Restoration Ecology Class (ENH 160 & 160L)
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Notes
This document is a product from UC Davis' Restoration Ecology class (ENH 160 & 160L) in the spring of 2014, and is a result of the hard work of the students. Each topic was written by an individual student, as noted at the start of each report. Some of these reports have been modified in an effort to synthesize and streamline this report. Due to logistical issues (inability to import parts) some figures are missing. Synthesis sections derive from class discussion and lab data collected.

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

Contents:

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

<u>RCD URBAN GREENING PROJECT- TULARE DR SITE</u>

Introduction

This is a stretch of riparian and upland habitat on the bike path.

Site goals include:

- Enhance native vegetation for aesthetics, habitat and shade to the bike path
- Expand the riparian corridor in available open fields
- Remove Arundo and decrase other invasive species
- Stabilize creek bank with herbaceous species (e.g. native sedges and grasses, the need for maximum creek volume during flood precludes the use of woody vegetation)

Site restrictions include:

- Limits to woody vegetation within the creek channel to enhance flood water volume of the channel
- Fire prevention
- Safety (decrease potential hiding places for criminals- this limits the height and density of tall/woody vegetation near the bike path)

Site challenges:

- Highly incised and eroded creek channel (uplands very separated from the water)
- Proximity to houses, high human activity
- Prevalence of invaders- Arundo in the creek channels, upland grasslands are almost entirely non-native species

Site benefits:

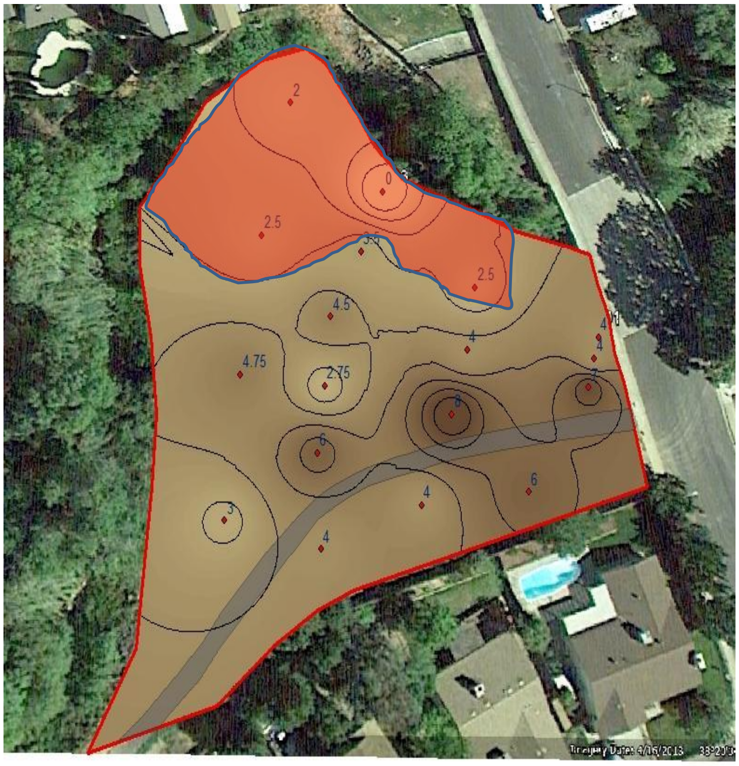
- High riparian tree establishment- dense tree cover, mix of old and young trees
- High native cover of riparian trees
- High use by turtles

Site survey summary:
One focal area along the bike bath is an extended area between the bike path and the creek, of varying elevations from the creek. This currently has a mix of herbaceous and riparian tree cover, but it's likely the creek is incised enough, that many riparian trees would have a hard time establishing now (difficult to get their roots deep enough). To assess the conditions at this site for plant restoration, we determined:

1. Elevation from the Creek

Meters from creek level of "bench" (above steep slope to creek) (used as index of which species have deep enough roots to grow)

2. Erosion potential

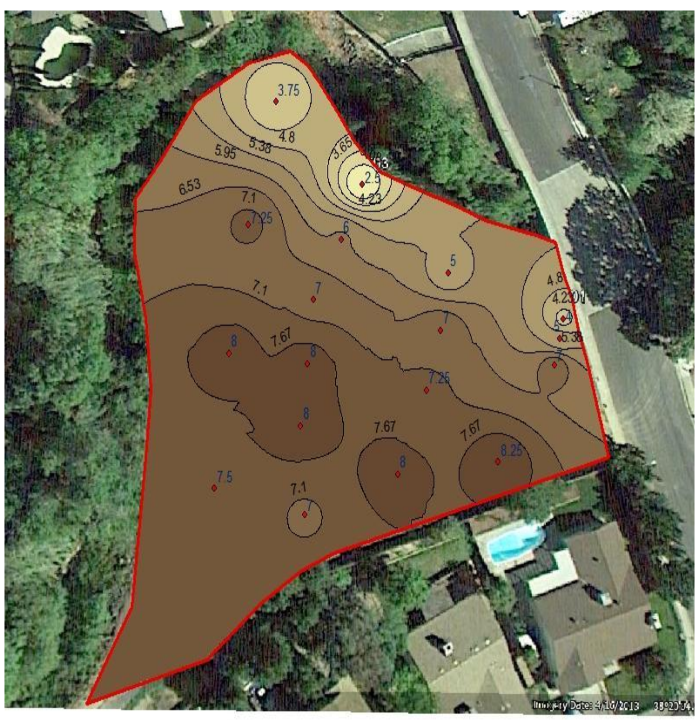


Red= high erosion concern into creek

Erosion resistance- units are kg/cm2 (so that low numbers are more susceptible to erosion)

Site has ample N, K, low to ample P- no spatial trend

3. Soil texture



Texture – relative scale 0= pure sand 10-pure clay

4. Current vegetation

Species lists- bike path

- Animals
  - Snakes
  - Songbirds
  - Turtles
  - Fish
  - Frogs
  - Mice
  - Squirrels
  - Hawks/raptors
  - Insects
  - Lizards

Red= dominants on site

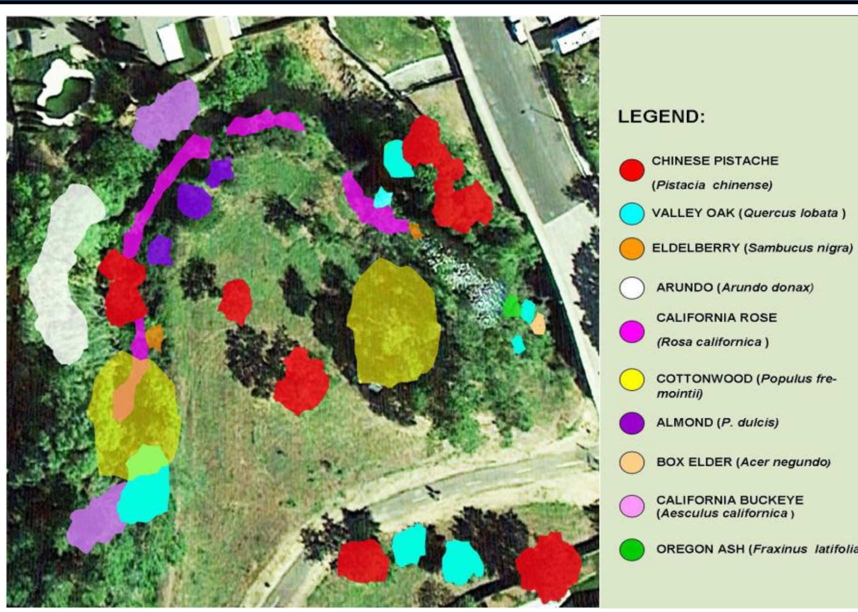
RIPARIAN

- Native plants
  - Oregon Ash
  - Wild Alder
  - Box Elder
  - **Valley Oak**
  - CA buckeye
  - Willows
  - Cottonwood
  - Elderberry
  - Coyotebush
  - **California wild rose**
  - Mugwort
  - Poison Oak
- Exotic plants
  - Walnut (likely non-native)
  - Fig
  - **Chinese pistache**
  - Arundo
  - **Ripgut brome**
  - **Soft chess brome**
  - **bedstraw**
  - Plantain
  - **Virginia creeper**
  - Radish
  - Wild lettuce
  - Bindweed
  - Mustards
  - Dandelion
  - Periwinkle
  - Italian thistle
  - **Fennel**

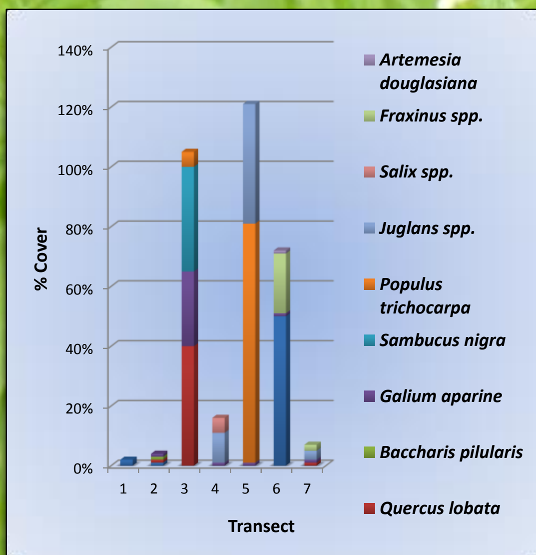
UPLAND

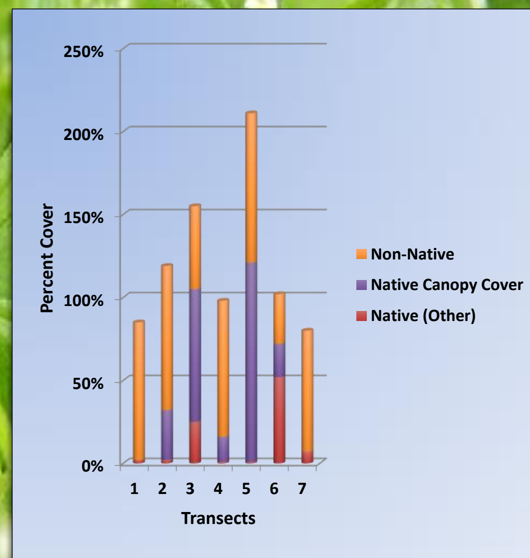
- Native plants
  - Cottonwood
  - Valley Oak
  - Elderberry
  - Coyotebush
  - CA buckeye
  - Bedstraw (Galium)
  - Poison Oak
- Exotic plants
  - Walnut (likely non-native)
  - Fig
  - Almond
  - Chinese pistache
  - Arundo
  - **Ripgut brome**
  - **Soft chess brome**
  - Wild oats
  - **Barley**
  - **Filaree**
  - **Geranium**
  - Plantain
  - Radish
  - Wild lettuce
  - Bindweed
  - Mustards
  - Dandelion
  - Periwinkle
  - Italian thistle

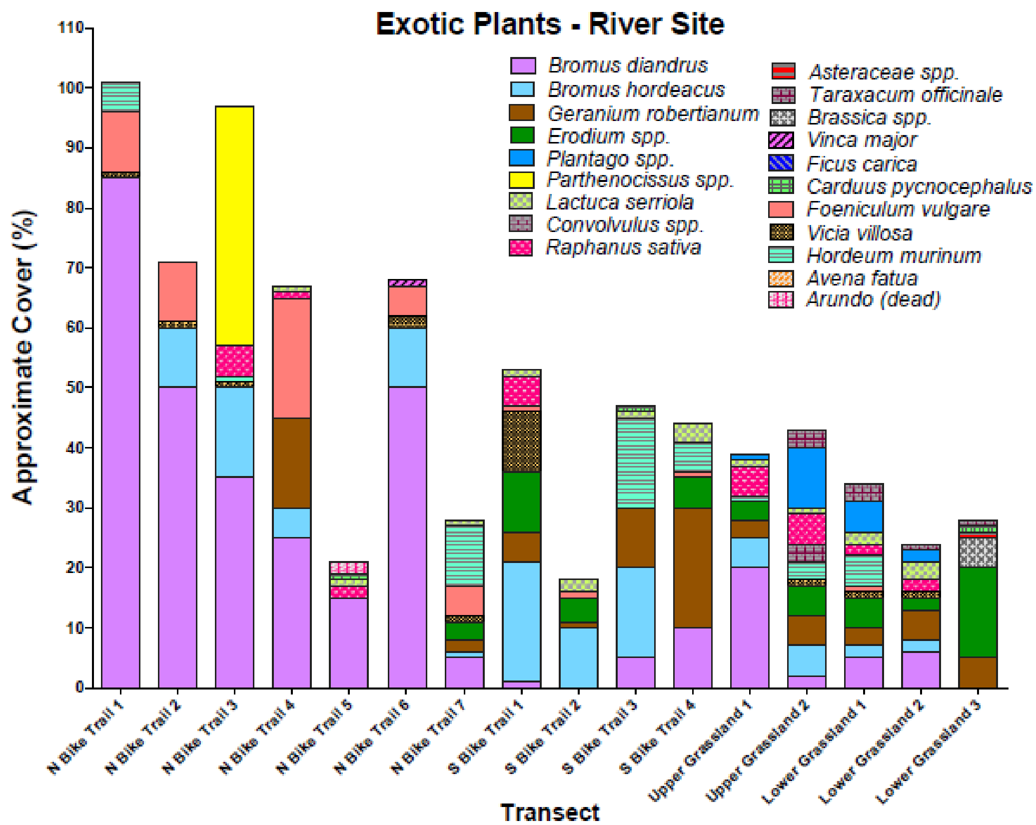
Existing Vegetation at River site



Alamo Creek Riparian Site – Vegetation Profile







Management recommendations based on lab data:

- Key goals to focus on
  - Red shoulder hawk
  - Increase voles
  - Decrease Bromus diandrus, Bermuda grass, Arundo
  - Decrease erosion
  - Increase water quality
  - Increase shade along bike path
  - Control fire
  - Safety
  - C storage
- Constraints
  - Limited habitat for wildlife
  - Limited new woody plants on banks
  - High human activity
  - Feral cats
- Opportunities
  - Good establishment of trees, shrubs, herbaceous, good native representation

Restoration Map

Legend:
- Blue: Sedges and rushes
  - Santa Barbara sedge
  - Slender sedge
  - Baltic rush
  - Mugwort
  - Grindelia
  - California Rose
- Orange: shrubs and trees
- Green: Upland bunchgrasses
  - Purple needlegrass
  - Foothill needlegrass
- Pink: Forb/grass mix
  - Poppies
  - Showy milkweed
  - Lupine
  - Mule's ear
  - Purple needlegrass
  - Yarrow

General mgt plan

- In creek
  – Promote basking sites for turtles
- Creek banks- erosion key
  – Control invaders - Chinese pistache, Arundo, Ripgut brome, Soft chess brome, bedstraw, fennel
  – Enhance native herbaceous/ small woody (see next slide for specifics on zones)
    - Mugwort, leymus, sedges
  – Zonation is key- with height from water, and shade vs. sun
- Upland- shading key
  – Replace older riparian trees (concern that some are nearing the end of their lifespan)
  – Control invaders- Ripgut brome, Soft chess brome, Barley, Filaree, Geranium
  – Enhance shrubby species, trees, herbaceous diversity
  – Spatial considerations
    - Benches- distance from water determines who can grow at site (see next slide)
  – Control feral cats, red eared sliders
  – Maintain/enhance large trees for hawks
  – Key zones
    - For 6 feet from bike path- keep vegetation under 3ft tall for safety concerns(so plant herbaceous species here)
    - 6 ft from bike path and more- maximize woody species, with shade-tolerant herbaceous (see next slide)

Zones

- **Slopes- lower (near water)**
  - Sun-sedges, rushes, meadow barley, Grindelia (gum pl) Milkweed
  - Shade- sedges,
  - Either- mugwort, bentgrass , Creeping wild rye- rhizomatous, CA fuschia
  - try to get woody species- CA rose, blackberry, snowberry, monkey flower, buttonbush, dogwood, blackberry (these can handle shade and flooding)
- **Slopes- mid (occassionally flood)**

  same as lower, but
  - not sedges,rushes
  - add fescue and junegrass (any light for both) and
  - if can do woody add spicebush, redbud, mulefat, small willows
- **Slopes- higher**
  - Same, add:
  - Sun- bluewildrye, meadow barley (sun), slender wheatgrass
  - Shade
  - Either purple needle grass , fescue
- **Upper benches**
  - For all- herbaceous:
    - Sun- milkweed, aster, poppy, lupines, phacelia, fescue CA brome, poa secunda, milkweed, lupine,
    - Shade – yarrow, blueeyed grass, fescue mule's ear
  - Approx 3 m Slump area 2.9-3.1 m- on edge of mixed riparian zone (2-3 m)
    - Mulefat, buttonbush, CA rose, blackberry, eldeberry, ash, alder, sycamore, walnut, cottonwood, gooding's willow, valley oak
    - Mugwart
    - ? Dogwood, fuschia?
    - Invasion- grasses, Himalayan blackberry, Ficus
  - Zones of 3.4 m from creek
    - Valley oak, goodings willow, buttonbush, eldeberry, mugwort
  - Others- 4.4-4.8 m from creek
    - Boxelder, CA 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
- Upland- back from path- more woody?
- Upland- near path- more low-growing shrubs and herbaceous

plants- 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

3-4 m

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

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

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?
-

<1 m

- **Goodings willow**
- **Narrowleaf willow**
- Red willow
- Aroyo willow
- White alder
- Ash
- Cottonwood
- Valley oak
- Interior oak
- Buttonbush
- CA rose
- Blackberry
- Mugwort
- dogwood

Slopes

- sedges, rushes
- Mugwort
  Grindelia (gum plant)
- Creeping wild rye- rhizomatous
- CA fuschia

try to get woody species- CA rose, blackberry snowberry, monkey flower, buttonbush, dogwood, spicebush

(these can handle shade and flooding)

- Shade tolerant
  - Blackberry
  - Snowberry
  - Toyon
  - Poison oak
  - Coyotebush
  - Purple needlegrass
  - Leymus triticoides
  - Monkey flower
- Full sun
  - Snowberry
  - Milkweed
  - Goldenrod

BASIN SITE

Site introduction: This is a detention pond that handles overflow during flooding.

<u>Basin site goals:</u>
1. Enhancing storm water infiltration and retention in the basin through planting native herbaceous vegetation.
2. Which natives are most appropriate for the site?
3. In areas within the basin dominated by natives, how should these be managed?
4. In areas dominated by invasives, who are the invaders and how can they be minimized?

<u>Site restrictions:</u>

- No woody vegetation in the basin

<u>Site benefits:</u>

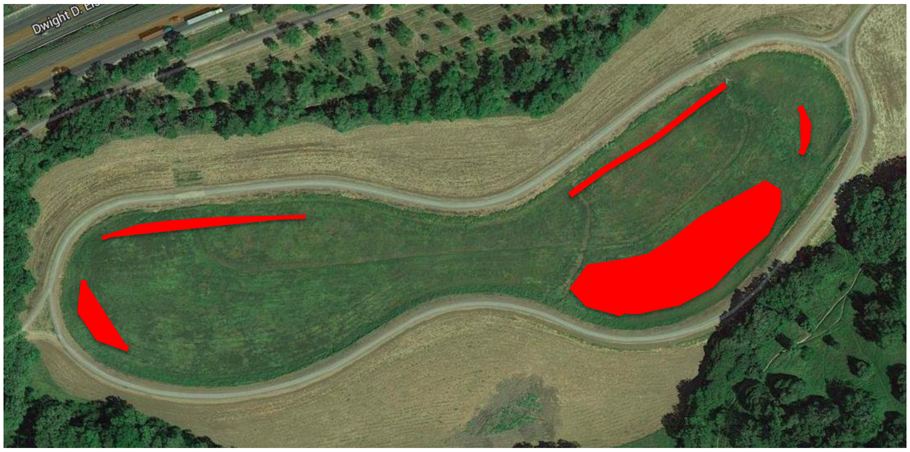
- Connected to braoder landscape of natural vegetation
- Good reference native communities in uplands/riparian areas
- Diverse habitat types (basin, grasslands, oak woodland, riparian, wetland-ish site)

<u>Site challenges:</u>

- Varied conditions- dry vs. flooded
- Proximity to freeway
- Proximity to houses
- High human activity
- Invasion

Site survey summary
1. Map of natives (dominated by *Stipa pulchra*)

Basin Site- maximum depth = 9m
Depth from top edge to nearest basin floor = 4.8-6.4 m
(spillway is 2m)



Red designates native remnant patches- tend to be in areas with slightly less compaction and more moisture than exotic dominated areas in basin- Purple needlegrass, California Poppy

Low erosion concern, low N but ample P, K

2. Vegetation list

Species lists- basin

In basin

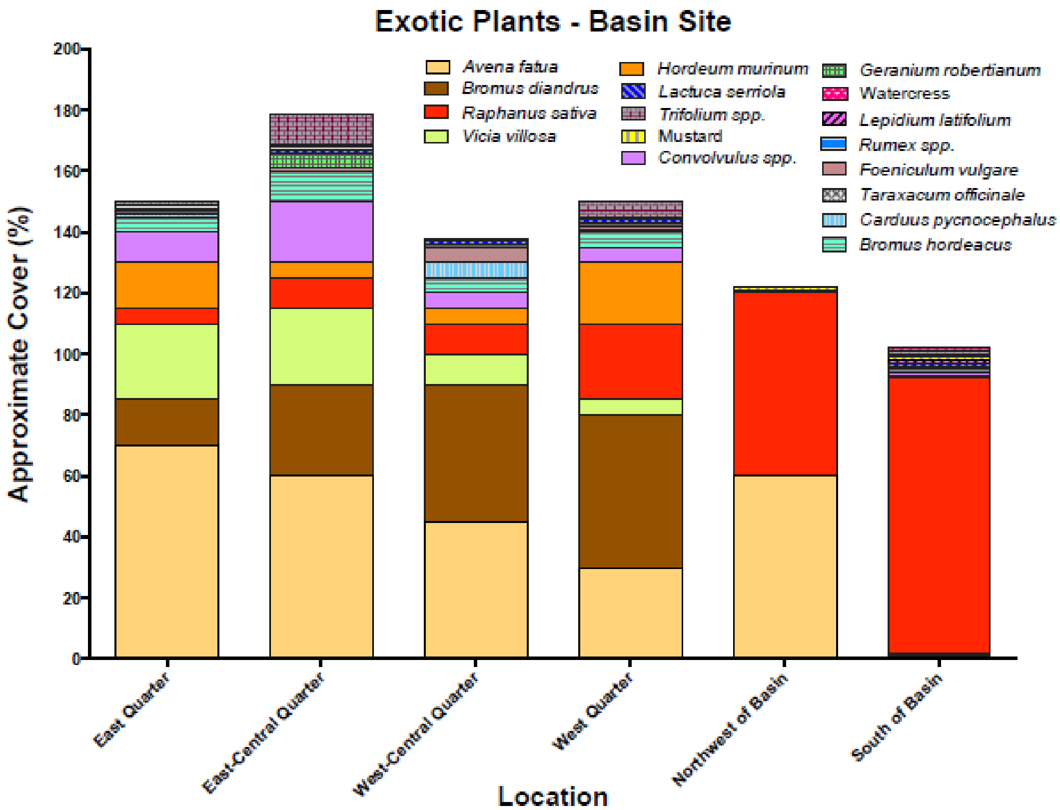
- Natives
    - Purple needlegrass
    - CA poppy
  - Exotics
    - Fennel
    - Yellow starthistle
    - **Wild oats**
    - **Ripgut brome**
    - Softchess brome
    - **Barley**
    - Radish
    - **Periwinkle**
    - Wild lettuce
    - Clovers
    - Mustard
    - Bindweed
    - Geranium
    - Watercress
    - Pepperweed
    - Dock
    - Italian thistle

Red= dominants on site

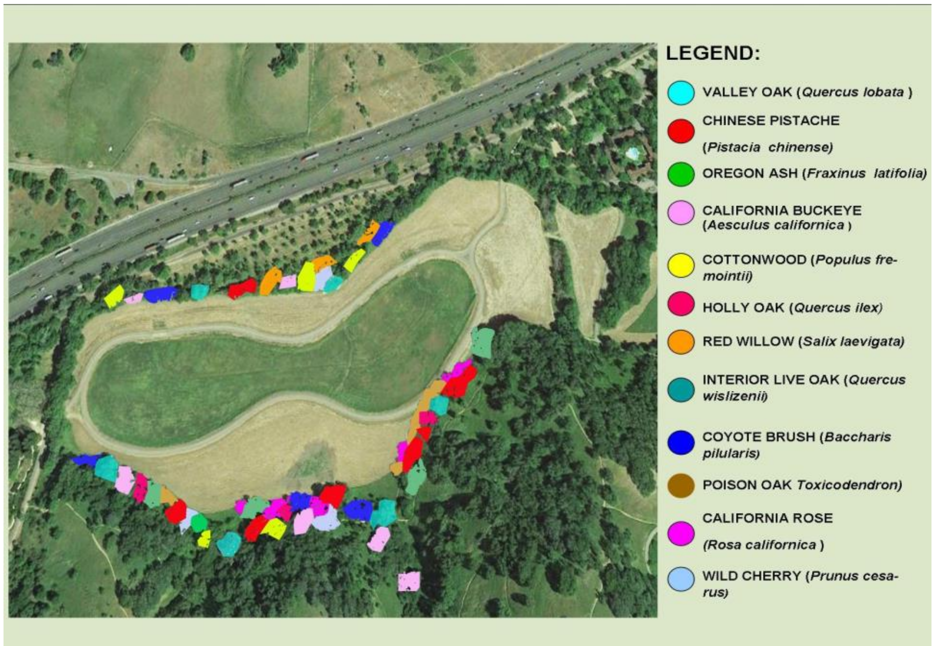
Surrounding basin

- Natives
    - Valley Oak
    - Holly Oak
    - Oregon Ash
    - Cottonwood
    - CA buckeye
    - Elderberry
    - Interior live oak
    - Red willow
    - Wild cherry
    - Toyon
    - Coyote bush
    - CA rose
    - Wedgeleaf Ceanothus
    - Poison Oak
    - Purple needlegrass
    - CA poppy
    - Cattail
    - Rushes
    - Soap plant
    - Yarrow
    - Lupine
    - Bulbs (e.g. Triteleia, Brodeiaea)
- Exotics
    - **Chinese pistache**
    - **Wild oats**
    - **Radish**
    - Wild lettuce
    - Mustard
    - Pepperweed
    - Fennel

- Animals
  - Burrowing rodents
  - Snakes
  - Songbirds
  - Hawks/raptors
  - Insects
    - Bees
    - Crickets
    - Flies
    - Butterflies
  - Frogs/ tadpoles
  - Lizards
  - Mountain lion
  - Coyotes


Exotic Plants - Basin Site
Approximate Cover (%)
0
20
40
60
80
100
120
140
160
180
200
Avena fatua
Bromus diandrus
Raphanus sativa
Vicia villosa
Hordeum murinum
Lactuca serriola
Trifolium spp.
Mustard
Convolvulus spp.
Geranium robertianum
Watercress
Lepidium latifolium
Rumex spp.
Foeniculum vulgare
Taraxacum officinale
Carduus pycnocephalus
Bromus hordeacus
East Quarter
East-Central Quarter
West-Central Quarter
West Quarter
Northwest of Basin
South of Basin
Location

Woody vegetation surrounding basin



3. Soils
Potassium: High Levels
Phosphorus: Medium-High Levels
Nitrogen: Low
- Due to leaching?
Cohesion/erosion control is ample throughout basin
Water infiltration is high throughout basin (no significant compaction)

Management recommendations

Restoration Map

- Lower elevation zones (blue) to be planted with hydrophilic sedge/grass mixture
  - Mugwort, grindelia, bulbs, Santa Barbara sedge, slender sedge
- Higher elevation zones (purple) to be planted with upland bunchgrass/forb mixture
  - Purple needlegrass, creeping wildrye, foothill needlegrass, California poppies, soap plant, phacelia

Management plan

- Within basin- exotic dominated areas
  - Decrease invaders- avoiding native patches
    - Herbicides for grasses (possibly with tilling)
    - Manual removal for forbs (e.g. fennel)
    - Need buffer zones around native areas
    - During this process, need to consider disruptions to habitat of small mammals, ground nesting birds, pollinators→ either do a portion of the basin, or be sure to coordinate with municipality to keep upland herbaceous area around basin intact
  - Plant natives according to zones of inundation (see next slide)
  - Maintenance
    - Minimize soil disturbance (to minimize invasion)
    - For invasive species control, and particularly to maintain forbs and legumes, will need to occassionally use grazing, fire or mowing (e.g. every 3-5 years).
      - Tradeoffs-
        - » timing for invasive control at key time for ground nesting birds
        - » Erosion
        - » Pollinator habitat
        - » Voles
    - Maintain voles- need mix of low (1-3”) herbaceous vegetation and high vegetation cover (so have protection and can maintain populations, but also provides access for predators)

- Within basin- native dominated areas
  - Maintain/protect these- no disruptive management (e.g. herbicides for invasives)
  - Regular monitoring to determine if invasion control is needed
  - Management for invasives- hand pulling, timed grazing/burning/mowing (perennials can handle losing a year’s seed crop)

Management plan

- Outside basin
  - Under/overpass for wildlife crossing freeway safely (but could be "trap" for prey species)
  - Connection with upland herbaceous areas for escape routes for animals during flooding, mowing, fire, grazing. Also for pollinators
  - Maintain and enhance tall trees for perching and nesting of hawks (red-tailed, Swainson's)
  - Upland herbaceous areas important for: voles, ground nesting birds
    - Need to balance protected cover (no mowing/grazing/burning) with occasional management (to allow invsaion control and forbs), and spatial management to decrease cover (to allow predators access to voles)

Vegetation zonation

- Basin- frequency and duration of flooding biggest factor for all zones (few days during long storms, and then once creek levels drop, drains within 24 hours)
- Basin upper edge- species typical of uplands (can handle drier conditions)- also appropriate for surrounding grassland
  - Lupine, muledeer, milkweed, poppies, brodeia, soap plant, purple needle grass, wildrye, CA brome
- Basin bottom- longest, most frequent wetups (but also long dry conditions)- e.g. no floods last 4 years, tolerance to: flooding, alluvium deposition, abrasion, low light (submersion), saturated soils, hypoxia, anoxia- dense roots to minimize erosion, dense ag to slow flood water and increase pollutant filtration (ruderals
  - Current "upland" conditions vegetation in basin
    - Native hotspots
    - Invasive dominated areas (annual grasses, fennel, radish)
  - Species that can handle variable moisture conditions (general plantings for basins)
    - Yarrow, brodiaea, tritelia, Lillies, poppy, phacelia, lotus purshianus, lupinus succulentus, lupinus densiflorus, milkweed, blueyed grass, aster chilensis, solidago californica (goldenrod) , stachys ajugoides (hedge nettle), lathrus vestitus (wild pea), licorice, sedges, rushes, grindelia, mugwort, elymus triticoides (creeping wild rye), sednges, rushes, annual native forbs (may die during flooding, but extensive seed bank which can recover)
- Basin rings- intermediate depths- physical force of flow, short periods of inundation, longer preriods without water- erosion prevention, tolerate anoxia– depends on how expect flooding to occur, similar to bottom?
  - Lower- similar to bottom site, milkweed, centromadia sp, (tarweed), lupinus sp, trifoium wormskioldii, licorice,
  - Upper basin (also ok lower?)- soap plant, poppy, brodeia, milkweed, , centromadia sp, (tarweed) licorice, lupinus sp, trifoium wormskioldii,,purple needlegrass, elymus, leymus
- Species that can handle both flood and drought- can plant throughout
  - Asclepias fascicularis, (narrow leaf milkweed)
  - Tarweeds (Centromadia)

Goals Around Basin

- Vegetation
  - Surrounding dense woody vegetation (habitat for mountain lions)
  - Enhance native grasses
  - Wetland
  - Enhance native forbs
    - Will require repeated disturbances to control grasses (e.g. grazing, burning, mowing)
      - Milkweed and lupine bad for grazers
        - » Wet-season grazing can compact soils and decrease ground nesting bees
      - Burning- issue with ground nesting birds
      - Mowing- issue with ground nesting birds- especially April-August
      - All disturbances can be disruptive to ground nesting bees
    - For pollinators- have diverse forb species that flower throughout the year, 6 ft diameter clumps scattered through
  - Remove invasives
    - Avena, fennel, yst,

- Wildlife
  - Focus on larger open grassland
  - Red- tailed and Swainson's hawks (but not enough habitat for both?)- add trees for perching/nesting
  - Grasshopper sparrow
  - (burrowing owl, but likely can't do with others)
  - Voles- already there, so maintain (and try to keep populations high, even during low population swings)
  - Grass height with enhancing voles (3" or higher veg) and giving access to predators (2-3")
  - Higher trophic levels- bobcat, mountain lion, coyotes (conflicts within these?)
    - Provide corridors (e.g. especially over/under I-80)
  - Corridors/alternative habitat for all species during flooding
  - Enhance pollinators
  - Keep out feral pigs, cats
    - Issues with dogs?

Tradeoffs- Basin

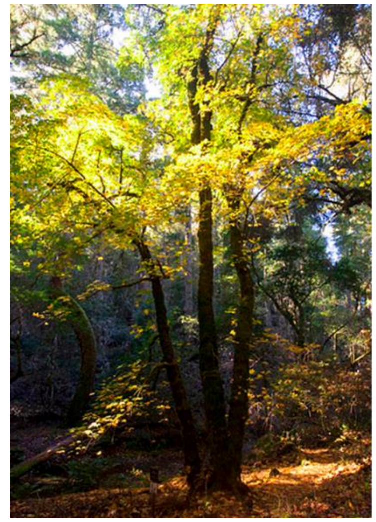
- Mowing
  - height- voles vs. predators
  - Spring mowing
    - Pros
      - To manage weed populations, often need to mow April/May
    - Cons
      - To protect ground nesting birds, no mowing April-August
      - To protect pollinators, no mowing during flower blooms (March-June/July, possibly later), need to maintain 6 ft diameter areas
      - Can enhance erosion
  - Fall/winter mowing- good to enhance forbs, good for wildlife?
- Tilling
  - Pro: Good way to begin restoration, to decrease invasives
  - Con: disruptive to: AM, ground nesting bees, voles
  - Timing effects
- Removal of invasive forbs (radish, fennel, thistle?)- can be important for pollinators (also herbicides, etc. can be detrimental)
- Voles
  - Critical for wildlife
  - Can decimate restoration plantings

Other basin considerations

- If el nino next year
  - Best to plant plugs later in the year (when soil is really moist, but flooding likely minimal)

INDIVIDUAL STUDENT REPORTS

Native plant species
Moist trees
Big leaf maple (*Acer macrophyllum*) Jerome Peters



Bigleaf Maple (*Acer Macrophyllum*) Management Strategies for Riparian Zones

Group: **Dicot**

Family: **Aceraceae**

Duration: **Perennial**

Growth Habit: **Tree**

(PLANTS, 2014)

<u>BACKGROUND AND JUSTIFICATION</u>

The Bigleaf maple *(Acer macrophyllum)* is one of the few commercial hardwood trees native to the West Coast, found throughout California, Oregon, and Southern British Columbia(Burns, 1990). It has a diverse range, however it is mostly found in Riparian zones, with well drained alluvial and colluvial soils (Burns, 1990). Bigleaf maple would be useful for riparian restoration, as this tree has many soil enhancing properties. It produces a great deal of leaf litter that contains high levels of calcium, potassium, and other nutrients (Fryer, 2011). Both the bark and leaf litter of the Bigleaf Maple contain high Nitrogen and Calcium content, which can support large epiphyte populations, like mosses, liverworts, and ferns (Fryer, 2011), on its bark. (Turk et al, 2007). This is also an important species in many ecosystems, because it provides many animals with habitat. Deer, beavers, and other rodents feed on the tree's foliage. Any woody debris that falls into a river channel will slow water flow, enhancing habitat for a variety of fish, like the steelhead. Bird species use the tree as habitat, including harlequin ducks and a variety of woodpeckers. Honey bees and other insects are drawn to areas with Bigleaf maple to feed on its nectar. (Fryer, 2011).

<u>FACT SHEET</u>

Specific characteristics of Bigleaf Maple

LIFE CYCLE

<u>Growth Characteristics</u>

a) Native deciduous tree that grows to about 80 feet in height (USDA, 2006)

- 12 to 36 inches Diameter at Breast Height (OSU)
- It has leaves about 15-30 centimeters wide and long (USDA, 2006)

- Taproots must reach moist soil before the dry season for the plant to survive (Fryer, 2011)
- If grown in the open, they will have rounded crown. They will also have “short, branching boles,” which are the part of the trunk above the roots and below the first branch (Burns, 1990).
- If grown in dense area, they will be structurally sound and will usually have no branches for the first half to two-thirds of their height (Burns, 1990).

- Bigleaf maple litterfall was found have higher concentrations of Nitrogen, Calcium and Potassium than other trees in western North America (Turk et al, 2007).

Reproduction

- It has both hermaphrodite and unisex flowers at the same time. Has both the staminate and perfect flowers in the same cylindrical raceme (Burns, 1990).

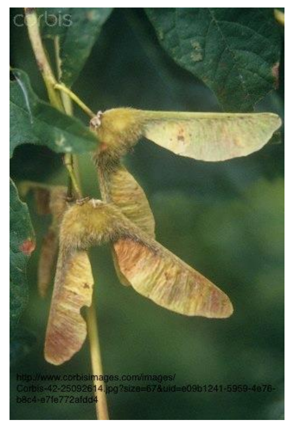
- Produce yellow-green in color, scented flowers. These are produced in March in in the southern part of the distribution and at low elevations. While at higher elevations and in the North, they are produced in June. (Burns, 1990).

- Seeds are pollinated by bees, flies, and beetles (Fryer, 2011).

- Bigleaf Maple seeds (Samaras)are often triangular with two lobes and are 4-12 mm long and 4-9 mm wide. The seeds are wind dispersed. (Burns, 1990).

- Begin producing seeds at age 10, and continues this prolifically every year after (Burns, 1990)

- Trees grown in the open usually have good seed production, however trees grown in the shade have more irregular seed production (Fryer, 2011)



http://www.corbisimages.com/images/Corbis-42-25092614.jpg?size=67&uid=e09b1241-5959-4e76-b8c4-e7fe772afdd4

- Seed banking for the bigleaf maple cannot exceed one winter. (Fryer, 2011).

RANGE AND DISTRIBUTION

- Found widespread throughout Western North America. The native range is from Southern British Columbia to Northern California, latitudes 33° to 51° N (Burns, 1990). It also always stays within 300 miles of the Pacific Ocean (Turk et al, 2007)

- Bigleaf maple trees are found in moist mountainous zones, in Southern California they are found at a range from 915 m (3,000 ft) to 2135 m (7,000 ft) (Minore).

- Liberal moisture and well drained alluvial and colluvial soils, produce the best growth. This can be found in flood plains, river terraces, and seepage locations. The tree is found in a wide variety of soils, such as "Inceptisols, Ultisols, Spodosols, Mollisols, Entisols, and Alfisols" (Burns, 1990).
- The bigleaf maple does not require a large nutrient load, however best growth does occur in rich lowland soil (Fryer, 2011).

Habitat and Ecosystem Associations

<u>Habitat</u>

- Bigleaf maple is commonly found in mixed conifer, evergreen, and hardwood communities and in several brush-fields. Of several plant communities that bigleaf Maple is important in, it has its greatest frequency in mixed-evergreen forests in Northern California and Oregon. (Fryer, 2011)
- They are also found in conifer dominant communities. Often they will be along riparian borders of dominant conifer communities, or scattered within the conifer forest (Fryer, 2011).
- Bigleaf maple is a fast growing species, with disturbance tolerance to fire and flood. These characteristics allow it to grow in a variety of areas whenever there is an opening in the forest canopy (Minore).
- Laboratory findings reveal that bigleaf maple seedlings had the greatest photosynthetic yield in sites resembling forest edges or gaps, which show a preference for open conditions (Fryer, 2011).

<u>SUCCESSIONAL STATUS</u>

- The Bigleaf maple is not a rapid invader of a disturbed site. However it is present in undisturbed areas and will have intense sprout growth after disturbance (Burns, 1990).
- Bigleaf maple can respond to disturbance by sprouting from the root crown or stump after top-kill by fire, cutting, or herbicide use (Fryer, 2011).
- Bigleaf maple have shallow root systems that are better suited than deep rooted plants for saturated and shallow soils (Burns, 1990)

<u>TOLERANCES</u>

- Frost tolerance low. Soil cannot freeze before first snowfall (Fryer, 2011).
- Somewhat shade tolerant. Seedlings can form under sparse conifer colonies, however the tolerance decreases with age (Fryer, 2011).
- Fire tolerance, due to its sprouting after damage (Minore).
- Bigleaf maple tolerates short-term flooding. It does not tolerate sustained flooding, as all age classes die after 2 month inundation (Fryer, 2011).

INTERACTIONS

Wildlife

- The Bigleaf Maple's seeds provide food for a variety of animals, like squirrels, mice, chipmunks, and many birds. Elk and deer also forage on the young saplings and branches. (USDA, 2006)
- The carpenter worm *(Prionoxystus robiniae)* burrows inside the tree and creates larval tunnels that degrade the wood. These worms usually attack trees that are open-grown (Burns, 1990).

Plants

- The high Nitrogen and Calcium content support large epiphyte populations on its bark. Epiphytes on the bark were shown to add four times the foliar biomass to the host tree. These add critical nutrient cycling to ecosystems (Turk et al, 2007).
- The epiphytes include Mosses, liverworts, and ferns. Bigleaf maple's have the most moss growth than all other tree species in the Pacific Northwest. (Fryer, 2011)
- The bigleaf maple is more at risk to wind damage than species that are not covered with as large epiphyte communities. (Fryer, 2011)

- Bigleaf maple is competitive and limits conifer survival, as bigleaf maple sprouts usually grow faster than conifer seedlings (Turk et al, 2007)

Pathogens and Fungus:

- The Bigleaf maple is one of many native non-oak hosts of the pathogen, Phytophthora ramorum, that causes sudden oak death (Fryer, 2011).
- Wood Rotting Fungi are a big problem for Bigleaf Maple. Fungi, like *Heterobasidion annosum, Fomitopsis pinicola,* enter the tree through damaged stems and branches.
- Overmature Bigleaf maple are also at risk of root rot by *Armillaria* spp. and two butt rots *Ganoderma applanatum* and *Oxyporus populinus. (Burns, 1990).*

Benefit to Humans

- Infused bark was used in the past to treat tuberculosis (USDA, 2006)
- A fiber found in the inner bark of the tree was historically used to make ropes, baskets, and clothing. (USDA, 2006)
- Economically, the tree wood is used to make furniture and musical instruments (USDA, 2006)

MANAGEMENT OPTIONS

Establishment:

Propagation by seed:

- In a cold frame, soak the seeds for 24 hours, and then gradually increase the temperature from 1 to 8 degrees Celcius over a two to four month period. Then harvest the seeds after they have become fully developed, without allowing them to dry too much. This will ensure that no germination inhibitors are produced. (USDA, 2006)
- seeds should be sown immediately after they ripen, in early September and October (OSU).

Planting:

- Wait until seedlings are large enough to move without damage. Move them to individual pots until they are 20 centimeters or larger. Then plant into permanent positions. (USDA, 2006)
- Dig the planting hole as deep as the maple's root ball and three times as wide (Teo).
- Juvenile height growth of over three feet per year should be expected (OSU).

KEY KNOWLEDGE GAPS

- I would like more information for the planting of the tree and how to actively integrate it in a restoration project. I was able to find the expected growth rate of the tree once it has been planted, however I was unable to find an exact method for use of this in a restoration site. I have looked through many websites that offer information on how to perform the cuttings and get the seedlings to start growing, however I cannot get concrete information on how large to let it go before transplanting it and how to do it effectively. These websites offered the information on the techniques (http://plants.usda.gov/plantguide/pdf/pg_acma3.pdf) and (OSU) even said "there are no specific studies of site preparation and vegetation management practices for bigleaf maple" (OSU).
- Necessity for restoration. I was able to go back and understand its role in a riparian restoration on this revision. The tree is fast growing, with shallow root structures that allow it to adapt to various soil conditions and increase erosion control. The tree also increases habitat for wildlife by altering water flow, providing physical space for birds and other animals, and by distributing leaf litter to the floor which bugs can use for habitat and will also increase the fertility of the soil for other plants to grow. This tree is a medium succession plant which is great for restoration projects in riparian areas that

need to add soil retention and diversity of shade and canopy space. These things have been added throughout this document above on this revision.

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Part II. Management of *Acer Macrophyllum* in Central Valley riparian zones

II. Goal:

Restoring and maintaining populations of Big Leaf Maple (*Acer Macrophyllum*) Tree in the Central Valley:

Assessing whether Big Leaf Maple is a viable species at the site:

Big Leaf Maple trees are native to riparian zones throughout California, and therefore rely on a permanent water source (USFS). They commonly occur in moist forests, canyons, and floodplain habitats. The tree thrives under well drained alluvial or colluvial soils (Burns et. al, 1990). However, the tree is well adapted to many conditions and is found on a variety of soils and topographical gradients like these soil orders: Inceptisols, Ultisols, Spodosols, Mollisols, Entisols, and Alfisols (Burns et. al, 1990). The tree is evolved to handle varying nutrient levels, but it does not have a salt tolerance and cannot grow in an area with a high concentration (Costello et. al, 2003). The Big Leaf Maple is found at a pH range of 4.8-7.2. This shows that the tree prefers slightly more acidic soils than basic, which is why it is often seen in Douglas fir stands and other conifer tree communities that have acidic needles (USDA, 2006).

I. Establishing Big Leaf Maple population at the site:

Big Leaf Maple establishment methods will depend on the size and characteristics of the restoration site.

Sowing seed: Sowing and seed germination methods will be used when it is a large area and there is open space without an established tree stand.

Transplant: Transplants will occur where there already are trees present or spatial distribution needs to be precise.

II. Maintaining populations of Big Leaf Maple

Management of the site should be done to limit destruction of the plant by foraging animals. Managerial use of fire, herbicide, and cutting can be used to promote Big Leaf

Maple dominance in a system, due to it's sprouting and fast growth rate.

<u>III. Monitoring</u>

Monitoring should take place short term to see whether the plants have established in the year they were sown or planted. If not, the processes must be repeated due to the short seed bank and lack of seed bearing capacity of the transplanted plants until they are ten years old (USFS).

Potential of the goals: interactions and trade-offs

interactions:

These goals should be feasible given that the Big Leaf Maple is quite resilient and open to many different habitats, given that it has ample water. In riparian zones, this tree would do very well for restoration as it does not require as much water as the apex, very large pines while still performing necessary soil building and retention functions (Fried et. al, 1990).

The Bigleaf maple provides great ecosystem services by increasing native biodiversity, providing biomass to the soil through tree litter, strengthening the soil structure with strong root systems, and providing habitat and feeding niches for a variety of species. The Bigleaf maple's shallow root system can also outcompete many deeper-rooted conifer species due to the shallow, saturated soils in the Riparian zones.(Burns et. al, 1990)

trade-offs: Big Leaf Maple are not as flood tolerant as red alder, black cottonwood, Sitka spruce, and western red-cedar, as flood inundation for 2 months during the growing season kills both mature plants and seedlings (Burns et. al, 1990).

B. Restoration Plan

- <u>Establishment</u>

The establishment of the Big Leaf Maple will depend on the spatial distribution of plants and space at the site. If there is a moist open area available for the Big Leaf Maple, then I believe seeding will be the best strategy. However, if there are already tree stands or large bush populations on the site where the Big Leaf Maple would be best situated then a transplant is most applicable. A transplant is more applicable because it will be important to place an individual or cluster of individuals in a particular place that gets the most sunlight through the canopy of the surrounding tree stand. Transplanting the plant will give a higher likelihood of survival for that location than seed scattering. Due to the Big Leaf Maple's high production, there is little needed for site preparation for seedlings. Basic methods of limiting fast growth weed species can be applied, so this slower growing tree species can have an advantage over invasive weeds. Regeneration from sprouting requires no site preparation (OSU).

<u>Seed Dispersal</u>— If seed dispersal is chosen for the site, one should collect seeds from a nearby Big Leaf Maple population. This way, the seeds will likely have a genetic disposition that will fit the sample site characteristics. This is not a steadfast rule, however, as the closest population could be located at a different altitude range or other unrelated conditions to the restoration site. In this case, it may be beneficial to find a population that is in a habitat mimicking the restoration site, with an emphasis on soil dynamics, moisture availability, and altitude. When a population has been chosen, the seeds should be collected and stored for preparation before they are sown. Bigleaf maple seeds are enclosed in double samaras, with wings about 1.4 to 2 inches long. The actual

seeds are oval in shape and range from about 0.2 - 0.45 inches in length. Seeds typically ripen from early September through October, and are dispersed by wind from October to January (OSU). The seeds should be collected when the minimum moisture content, 10-20% dry weight, is reached. These seeds can be stored in this condition for one year only, as the viability of the seeds is drastically reduced past then (Burns et. al, 1990).

These seeds should be developed for about four months in a cold-frame before planned sowing. First, presoak the seeds for twenty-four hours. Then gradually progress from 1-8ºC during a two to four months interval in the cold-frame. The seeds can be harvested when they are fully developed, but before they have dried. The seeds should then be sown immediately (Mcmillan 1985). The sowing should not exceed a density of 30 seedlings/m², to not overcrowd the plot and have intraspecies competition. This is based off of the North American Silvics manual that states an increase from 1 to 60 seedlings/m² could cause a 50% decrease in seedling mass (Burns et. al, 1990).

Transplant:

As with the seed dispersal, Big Leaf Maple population should be chosen based on similar characteristics of that area and the restoration site.Young shoots should be cut in June or July. A cutting should have three pairs of leaves and one pair of buds on the base. Place each cutting into a sealed container to manage moisture loss. Trim the cuttings below the lowest node to Take off the lower leaves and only leave three or four at the tip. Place the cutting half way into a rooting material that will resemble soil at the sample site (Heuser 1997). After three weeks, they should have rooted and will now be potted. Place each into a separate pot with soil from the intended restoration site, and grow until they are greater than twenty centimeters in height before planting them permanently in the restoration site (http://plants.usda.gov/plantguide/pdf/pg_acma3.pdf). When planting, the minimum density is 300 individuals/ acre and the maximum is 700 individuals/ acre (USDA, 2006).

II. Management of Big Leaf Maple Populations

Wildlife can damage Big Leaf Maple seedlings and sprouts. Deer feed on young plants while birds and rodents eat the seeds. Deer also use saplings for rubbing their antlers, which may also harm the plant. If it is a large area, it will be easiest to focus on keeping deer out of the site by erecting a fence. Other animals can be kept away by placing nets around the young trees until they are resilient enough to deal with foraging animals.

Bigleaf maple respond well to disturbances like fire, cutting, or herbicide usage by sprouting from its stump or root crown, the part of the the stem where the root arises (http://www.fs.fed.us/database/feis/plants/tree/acemac/all.html#205). Big Leaf Maple are also very reactive to changes in canopy space. Controlled fires allow the Big Leaf Maple to sprout and outcompete other tree species, while destroying understory conifer and ladder fuels and slowing succession to late-seral species such as western hemlock.

III. Monitoring:

All bigleaf maple seeds germinate during late winter and spring after seed dispersal.The seeds will not live more than one winter. This is important for monitoring the population, especially in the first establishment period. A minimum number of successful establishments should be created for your site, and if this is not reached, more seed dispersal must be completed the following year, as the seed bank would be destroyed by the winter and there is no possibility of reaching your target (USFS).

Seedlings grown in open conditions can grow about 1-2 meters in one growing season. This rate can be reduced by half on sites with dense vegetation. Monitoring should take place every year of a representative sample of the trees to get an idea of whether there is too much vegetation around the trees, and whether any competition needs to be destroyed or limited. (USFS).

Risks:

Risks are inherent in some of the management techniques, like fire, herbicide, and cutting. These can all damage the surrounding areas by contaminating air and water quality, and by damaging other animals habitats in the cutting.

Research questions that need answered:

1. It would be nice to have a field study at several locations directly comparing sewing methods to transplanting potted plants. This would be influential in the restoration of this species, as it would guide future sites management choices. This could be started in our restoration project by making a small portion of our site have seeding and transplant neighboring each other.

2. The relative effectiveness of the different management techniques of fire, herbicide, and cutting and which has the greatest influence on Big Leaf Maple. We could try to answer this by performing different methods on separate portions of the population, if the restoration site was large enough.

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Dry trees

Valley oak (*Quercus lobata*)- Sylvia Delfino

Background and Justification

Valley Oak (*Quercus lobata)* is a California endemic species that once populated the valley and foothills of California with "2.2 to 48.9 trees/ha" (Whipple). *Q*. lobata is challenged with declining recruitment due to habitat alteration, fragmentation, change in the hydrological cycle (soil moisture and ground water) and climate change " and most remaining stands are degraded due to persistently low oak recruitment, disease, invasive exotic species, and altered fire regimes." (Whipple). Riparian sites of *Q. lobata* have almost completely disappearead due to conversion to crop and agricultural land. There is an estimated that 21,449 hectares of mature riparian forest is left in the Great Valley, most of which has been disturbed (Meyer). *Quercus lobata* has many cultural as well as ecological uses. It creates a diverse habitat for many different species whether it is in an oak woodland (similar to a savanna) or riparian setting (Meyer, Whipple). Conservation and restoration efforts using Valley Oak have been very successful due to the nature of the species (discussed below).

Specific Characteristics

Valley Oak (*Quercus lobata)* is found in the valleys and foothills of CA and is provides a diverse habitat for many species (Whipple) including woodpeckers, predatory birds, burrowing mammals, and reptiles. It is a quick growing species that effects soil and land formation in the areas it populates, creating islands of fertility in the savanna setting (Hayes). *Q. lobata* is both flood tolerant and is dominant in both oak woodland and riparian areas. In woodland the distribution is savanna-like with individual to small clumps of trees in an annual grassland (Hayes). Valley Oak is usually found in valley bottoms and floodplains with deep fertile soils. This particular species of white oak is very long lived; heart rot makes hard to date but some have been dated at 200 years and others estimated at 400-500 years. Adults have been found to grow within 200m of a stream bed that fills either annually or perennially, while seedlings and saplings have been observed to grow within 100m. Studies by Meyers, Hayes, and Danielsen have found that growth and recruitment of *Q. lobata* depend on the hydro cycle and soil moisture. Valley Oak is widespread due to they many bird species that harvest their acorns and fly several kilometers away (Sork).

Ecosystem Needs

When using Valley Oak in restoration it is best planted at higher elevations in the floodplain so as to avoid prolonged inundation during flooding. While *Q. lobata* is flood resistant it does best when soil moisture is high, but does poorly when the roots are held under water for prolonged periods of time (Trowbridge). *Q. lobata* is drought resistant, but not as much as other deciduous oak species (Meyer). Its use in restoration can extend to areas affected by drought as long as it has time to establish and there is enough soil moisture present in its early years. It has been found that Seedling and saplings survive more in mesic habitats but it is noted that other obligate phreatophytes were present like cottonwood (Meyer). It is suspected that the other species present were facilitators, but the mechanism of the facilitation is not known. When using *Q. lobata* in restoration it is worth keeping in mind that establishment near riparian areas may be increased with natural flooding events. This could be due to increased soil moisture and decreased predation by burrowing mammals (Trowbridge). Valley Oak also does better when not too surrounded by vegetation; this keeps down herbivory on the seedlings and saplings.

Responses to Management/Ecosystem Changes

It has been observed that Valley Oak recruitment and establishment has changed with climate change, doing better in cooler, wetter settings (McLaughlin), and poorer in the savanna setting. It has also been observed that restriction of habitat due to climate change has little effect on populations growing in riparian areas due to the fact that seedlings and saplings have a narrower range of micro-climate they can establish in (McLaughlin). This is not to say that the species as a whole is not effected by climate change, just the opposite. Climate change is a restricting factor for *Q. lobata* regeneration, especially in savanna habitats. Climate change will effect *Q. lobata* on the local scale; southern areas will have the most impact because the temperatures tend to increase more there (Sork).

If used in a savanna site for restoration fire can be used to control invasive species. This species has adapted to fire, so use of fire to prevent regeneration of annual invasive grasses (which inhibit Valley Oak establishment due to decreased soil moisture) does not harm the oak saplings (Danielsen, Holmes). It was observed that after a burn, there was a sharp increase in growth for the following two years (Danielsen).

- Goals
    - Long Term Goals
        - Increase recruitment of seedlings and saplings- long term
            - This will be easiest to accomplish near riparian habitats where soil moisture is high enough, and competition is low from invasive species of grasses. In addition, facilitating species such as cottonwood are present in these ecosystems. Restoring riparian areas could lead to overall restoration of *lobata* due to the moderating effects of water on temperature, lessening the effects of climate change (Whipple).
        - Restore riparian habitats of Valley Oak
            - Valley Oak is a dominant species in riparian ecosystems. The presence of *Q. lobata* in riparian ecosystems has decreased due to the

conversion of riparian areas of the Central Valley to agricultural uses. This conversion has led to the overall decrease of Valley Oak densities due to habitat destruction and fragmentation (Whipple).

- Decrease invasive grasses in both types of habitat (savannah and riparian)
    - Invasive grasses are detrimental to the establishment of *Q. lobata* seedlings and saplings by decreasing soil moisture. Decreasing the invasive grasses increases soil moisture, which leads to an increase of *lobata* establishment (Meyer). Valley Oak is fire adapted due to indigenous uses of fire in the California landscape (Holmes), therefore fire can be used in invasive grass management in Valley Oak ecosystems.

- Increase native grasses in both types of habitat (savannah and riparian)
    - Valley Oaks grow in conjunction with grass species, especially in the savannah setting. As mentioned above, invasive grasses are detrimental to *lobata* establishment, but native grasses do not decrease soil moisture enough to effect *lobata* establishment (Meyer).

- Short Term Goals
    - Reconnect rivers with their floodplains
        - Evidence suggests that recruitment of Valley Oak saw increases when

the connection between rivers of riparian areas and their floodplains were reconnected. Though Valley Oak cannot withstand their roots being inundated for extended periods of time, a properly draining floodplain (or upland riparian ecosystem) with loamy soils provides the best conditions for not only recruitment but establishment of Valley Oak (Trowbridge). It is also suggested that there is a high probability that these conditions could lead to the establishment of a dense mature forest.

- Increase recruitment of seedlings and saplings- short term
  - By planting saplings as well as acorns to promote seedling recruitment and establishment in the immediate time period. Protection from herbivory will have to be taken into consideration, especially in riparian areas with existing woodlands in surrounding areas.
- Restore connectivity of habitat systems between Valley Oak and related species
  - Valley Oak woodlands in both savannah and riparian habitats provide a habitat for many organisms: predatory birds, woodpeckers, reptiles, biota, and other plant life (Whipple). Many birds (like the woodpecker) and squirrels act as facilitators for the spread of Valley Oak acorns. They do this by sequestering the acorns and burying them for later retrieval. These animals like to bury the acorns in sandy loam soils, which are the preferred soils for these trees.

- Restoration Plans

For the restoration of *Q. lobata*, transplants from container stock would see the best results in both riparian and savannah settings. While the use of acorns would increase genetic diversity and should be considered, the chances of survival for consecutive years is greatly increased if a root system is already established. The transport of invasive pests, such as Argentine ants, is something to take into consideration and take precautions against (Young). The cost of container stock (which increases with the size of the plant) is also something to be taken into consideration. If seed stock is the method chosen, successful establishment of *lobata* would increase substantially if the seeds come from the surrounding area. Local adaptations and resistance to pathogens increases survival. Planting at the beginning of the growing season, in conjunction with natural flood and fire regimes, help promote grow and establishment in both riparian and savannah settings due to increased soil moisture from flooding, and nutrient inputs from the immediate after effects of a low-severity fire (Young, Holmes).

Drip irrigation and hoods to protect from herbivory (especially in wooded areas like riparian systems) are needed to promote the establishment of *Q. lobata*. Irrigation can be lessened in areas that flood regularly. Seasonal monitoring of *lobata* is recommended, especially in areas with high populations of invasive grasses. In areas where there is complete failure to establish I would first determine the reason for the failure, then take measures to eliminate that factor for as much as is feasible before reattempting restoration. For example, if the failure is due to decreased soil moisture as a result of invasive grasses I would do prescribed burns before the flowering of the grasses to manage and eliminate the grasses during the growing season before replanting *lobata*. In that situation I would use almost exclusively transplanted container stock from the local area if possible. If recruitment was poor I would take similar measures and replant more individuals. Monitoring can taper off after the first two or three years, and establishment has been confirmed. Irrigation can stop after establishment is confirmed.

Climate change poses a problem with long-term recruitment of *lobata*, especially in savannah ecosystems. The increased temperature and decreased relative humidity and soil moisture lead to decreased establishment of seedlings by natural seeding (McLaughlin). Despite precautions taken in order to promote establishment, the change in micro-climates within *Q. lobata* habitat over long periods of time may render our precautions useless. When using *lobata* in restoration of systems with hot, dry climates irrigation is crucial to the successful establishment of *lobata* in these areas. Another challenge can come from herbivory in riparian areas where there is already and established woodland. In savannah settings herbivory is an issue in “oak woodland” groupings more than the small clusters that also occur. High grasses around seedlings and saplings can also lead to increased herbivory as well as decreased soil moisture. All of those factors lead to decreased establishment of *Q. lobata* (Meyer, Trowbridge).

The largest uncertainty when using *Q. lobata* in restoration is the response of pollination, recruitment, and establishment to climate change over the long term. By using *Q. lobata* in both a savannah and riparian setting we can compare the specie's long term response to the shift in the world climate as well as the shifts in micro-climate in local areas. By using a mixture of seed stock and transplant stock in both systems we can compare the rates of recruitment as well as establishment separately.

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Moist or shady small trees/shrubs

Dogwood (*Cornus sericea*)- Heidi Jansen

REDOSIER DOGWOOD

Cornus sericea

A. Background and Justification

Cornus sericea is a California native, deciduous species, part of the dogwood, or Cornaceae family; common name Redosier dogwood. It is commonly found in wetlands and riparian areas but is not obligated to only this kind of habitat. It prefers wet, high nutrient conditions, and can be a very strong competitor in newly developing communities because of its high rate of establishment. The Redosier dogwood is not only beautiful and vibrant with its red coloring, but it is also is very useful for stabilizing eroded stream banks and riparian areas. It has a good root system for soil stability and can live in moist and even inundated conditions. It has high rates of survival even with disturbance and has the ability to bounce back after fire or partial damage to its branches. Because of all of these characteristics, the Redosier dogwood is an important species to establish near eroded riparian areas in order to help them recover and maintain the desirable riparian habitat.

OUR GOAL: Restoration of stream banks by using the native Redosier Dogwood

B. Literature Review

Species Characteristics:

CLIMATE:

Redosier dogwood is abundant in boreal, temperate and cool mesothermal climates, (Klinka 1989) usually growing in areas that get 20 inches of rain or more per year. Sometimes rain can be very limiting for the establishment of dogwoods but once established, studies have proven that redosier dogwoods can show "extreme" drought tolerance (Barry 1988) but this is not always the case so it is unknown why it can sometimes tolerate it.

Redosier dogwood can also endure very cold temperatures (USDA hardy zones 2 to 7) (Gucker 2012). Once acclimated, they can survive very severe winter temperatures just fine. Dogwood trees acclimated to different temperatures show different growth rates when all transferred to the same site, but each clone was able to acclimate and survive regardless (Smithberg 1968).

HABITAT:

Redosier dogwood trees found in California typically grow up to around 9200 feet elevation and grow best in rich, moist, poorly drained soils, with high levels of nutrients. Although it is most abundant where conditions are as listed above, the redosider dogwood has the ability to grow on a wide range of soil types (Pijut 2004). Surveys have shown that farmers using dogwood as windbreaks for their crops ranked their endurance much higher if they gave the dogwood irrigation, as opposed farmers who didn't, showing that the dogwoods prefer wetter conditions (Tuskan 1991). Redosier dogwood has been found in northeastern Illinois in very wet marshes with little to no drainage and where the water table is very shallow in the soil showing that similar conditions in our site can also be tolerated. Because they like wet soils, dogwoods can tolerate very long periods of inundation, up to 7 years in some studies (Green 1947). Although they can tolerate inundation and flooding, they do prefer soils that can drain standing water but still provide lots of moisture.

Redosier dogwood can live in many different types of plant communities, ranging from forest with high canopy cover, woodland with high ground cover but more sun exposure, shrubland with lots of vegetation similar to dogwood, and grasslands They can also live in a variety of geologic conditions as well, such as near streams or in canyons.

PLANT AND FLOWER MORPHOLOGY:

Redosier dogwood is most often found as a multistemmed, deciduous shrub, but can sometimes grow as a one-stemmed tree in some locations. Shrubs growing with more light availability tend to be denser and more compact than those growing in shady areas, which tend to be taller and thinner (Monsen 2004).

The Redosier dogwood flowers in spring, and sometimes will flower more than once in a growing season (Chapman 1990). They have flowers with both male and female parts, but require cross pollination to produce fruits. Flowers are small and arranged in dense cymes creating showy inflorescences. Each inflorescence can produce 10-30 small fruits. Time of flowering largely depends on temperature so it will sometimes flower slightly earlier in the southern part of its range where temperatures tend to be slightly warmer. The most common pollinator is the bumblebee, but bee, fly and butterfly pollinators have also been seen pollinating the dogwood trees (Gucker 2012).

REPRODUCTION:

How many seeds a dogwood produces can be related to how old the plant is, time since last large seed crop (Haeussler 1990, Hardy 1989), and the age of the forest habitat (Noyce 1990). They typically start making seeds when they are 3 or 4 years old and produce them in small amounts which increase in the following years (Haeussler 1990, Hardy 1989). The seeds of the dogwood fruit are dispersed mainly by animals that eat the fruit that grows in the form of drupe. Many different birds and mammals like bears and squirrels eat the fruit. Studies have shown that seeds that were found in animal feces had much higher germination rates than seeds that were not consumed and digested. Rodents also play a role in the secondary dispersal of the seeds from animal feces by burial (Gucker 2012).

Cold stratification can also help improve germination rates.

IMPORTANCE TO WILDLIFE:

Many wildlife species depend on Redosier dogwood for the resources it provides. Many species like moose, deer, elk, mountain goats, beavers, bighorn sheep and rabbits browse the stems, while others like bears and other small mammals eat the fruit. Some amphibian species also use the surrounding habitat as an egg deposition site. It has been reported to have high palateablity or being an "ice cream" plant to animal species. This is why so many species feed on it. It also provides a good nesting habitat for birds and gives summer cover.

DISTURBANCE AND HERBIVORY:

Dogwood in general is very resitant to disturbance and herbivory. I can withstand losing high percentages of its stems due to browsing and can regrow quickly after disturbance that can destroy above ground vegetation like fire.

An experiment in northeastern Alberta showed that dogwoods are highly resistant to damage by rodents. They were tested with 0%, 25%, 50% and 75% of the stem circumference removed. Up to 50% the dogwoods had 100% survival and still 93% survival when 75% of the stem was removed. Even with these high rates of survival, seedlings' growth was still largely effected. Seedlings that were eaten had much slower growth rates even after survival. In most cases, the seedling died-back to the point of injury and began new growth from there. (Pauls 1986)

Redosier dogwoods have the ability to have vegetative regeneration by stolons, layering and root crown sprouts (Pijut 2004), it's previous classification was because of the first feature: *stolonifera.* Stolons can be up to 10 feet from the original base, resembling many coastal dune vegetative species (Haeussler 1986). Regeneration from root crowns is also possible for the redosier dogwood after the plant suffers damage to its top.

SUCCESSION:

Redosier dogwood has been observed in all stages of succession but is more typical in earlier stages with more light availability, but can still survive in conditions with high canopy cover and highly shaded areas. Establishment of redosier seedlings is common in floodplains with newly deposited sediments, and can become a dominant species in many riparian environments in the Western United States. Because of the Redosier Dogwood's ability to regenerate and establish after disturbance, it can become a tough competitor with conifers when they are growing in conifer forests (Haeussler 1990).

With heavy browsing, Redosier Dogwood has not proven to be quite as strong of a competitor. With even moderate cattle grazing, abundance of the dogwood was reduced. With heavy browsing, dogwoods can be eliminated and taken over by invasive grasses.

FIRE:

Adaptations include growth from stolons, and occasionally establishment from seeds that are heat activated and stored in the soil.

Responses include sprouting from stolons or other root and stem material in the soil.

Redosier dogwood cover has been reported to restrict fire spread in wet areas (Smith 1978).

Fire intervals have ranged from 10 to 70 years but is likely to be a greater range because of the dogwoods varied distribution and habitat that it can live in (Arkle 2010, Larsen 1998).

WHY GROW DOGWOOD?

Because of the Dogwood's many favorable characteristics, it is often a good species for revegetation and erosion control in riparian habitats. It does well on wet soils and has fast establishment and growth, providing rapid stability and cover for wildlife.

Not only does dogwood provide structural benefits for a plant community as a whole but it can also be a good species to grow where there is disturbance and herbivory because it is highly resistant and can eve benefit from these aspects.Studies in Montana showed that seed planted on burned plots had better seedling establishment than plots that were not burned. And they had even worse establishment where the plots had been logged with slash scattered (Schmautz 1950).

Dogwood also helps the entire ecosystem by providing the favorable characteristics that wildlife need in order to nest, feed and live. It is overall, a very useful plant to use in restoration projects

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REDOSIER DOGWOOD

Cornus Sericea

Dogwood is a very important player in promoting the restoration of Californian riparian zones. They are accustomed to moist conditions and can stand the long periods of inundation the sometimes occur with occasional cyclical flooding of these areas. They not only grow readily in these conditions but are major help in giving bank soil the stability it needs in order to support other forms of plant growth and wildlife habitat. Without having appropriate native vegetation along the banks of riparian areas, they are prone to non-native weed invasion because of the favorable conditions; however, these weeds can easily be outcompeted by native species that are more meant to withstand the cyclical flooding of riparian areas.

OUR GOALS:

We want to control invasive weeds and restore native species *Cornus sericea* in order to help restore riparian areas as a whole. By focusing on the restoration of this species along with a mix of other helpful vegetation we can get many positive results for the entire area. The spatial scale of the restoration will depend on the specific site and how much of it needs to be restored. The area will need to be assessed for invasive species that could be competitors for newly established Dogwoods, and then assessed for the level of degradation of the banks of the riparian area. If grazers are an issue in the area, control for this factor will need to also be put in place during the growth of the Dogwood.

1. Remove invasives

The first step would be removing invasives to the fullest extent that we can. This would most likely include manual removal of the invasives and light use of herbicides. Because herbicides could cause damage in runoff in an area so close to the water, we need to be very careful about what herbicides we use; we would need herbicides that are especially labeled for riparian areas (Sheley 1995). Even if we are not able to fully remove them, they will not be a strong enough competitor to re-grow with natural ecological conditions put back in place. Native species in general are much stronger competitors and will be able to outcompete any native species in natural riparian conditions once established. This goal would be more short-term because in the long run invasives will naturally be outcompeted with the restoration efforts and won't be a concern.

2. Establish early successional native species, including dogwood

Ideally, we would use cuttings of dogwoods because they have a higher rate of establishment. However, when creating a revegetation with many types of plants, this may not be practical; we might rather use a seed mix that includes all species of vegetation that we are trying to establish. We would need to put irrigation in place for at least three years, making sure that the plants are receiving adequate moisture during their development

In our efforts to restore the areas to their natural, more native conditions and structure, they will better serve as a favorable habitat to many native riparian species, both aquatic and terrestrial. Wildlife will benefit from the stability of the banks because stability will help prevent erosion and sediment pollution in the water, which can make it shallow and murky for aquatic species. The water temperature can also be changed with more cover and shade, which many fish species require. Also some species, especially amphibians, depend on the damp soil and shady conditions in order to reproduce.

3. Monitoring the success rate

With all of these efforts to establish Dogwoods, we will need to monitor the site to ensure that the Dogwoods are surviving. It is our concern that conditions are kept favorable for the growing shrubs during their time of growth. We will need to take samples of the surviving plants approximately every two weeks during the first few months following restoration. Any plant that is still alive can be considered surviving.

MANAGEMENT PLAN: RESTORATION

Before beginning the restoration project, it will be necessary to evaluate the specific site through surveying. We will need to collect data on factors like climate, and flooding regimes in the current conditions of the site in order to know if our vegetation will be able to survive these conditions until the natural conditions are restored. We should monitor the growth of invasive species and what kinds of invasives we would be dealing with. The best removal method will need to be chosen based on the types (e.g. full root removal vs. removal of just above ground growth vs. use of herbicides). We should also survey soil conditions including factors like salinity, pH, and moisture as well as the soil structure if it has been altered at all by growth of invasives. In order to gather information on longer term cycles, like flooding regime, we could consult historical records that would give us this information. If there is any visible destruction of the site (bank erosion, stream widening and shallowing, non-native invasion, etc.) we will need to take action. Once the process of riparian degradation has started, it is likely to spiral into a positive feedback in which it further diminishes.

After surveying we can go about removing invasives that could be considered competitors during the young growth stages of the Dogwood. Like stated above, the necessary method for their removing should be determined based on the specific type of plant. If we are removing invasives with herbicides we should do so when there will be little runoff, so during the dry season. Since removal of these invasives could in itself allow for changes in soil, we should take new measurements of soil conditions before making any necessary changes or before establishing Dogwoods.

In order to establish Dogwoods the best method is to do so by using hardwood cuttings. These cuttings should be taken in the spring from a part of the plant that has wood around 1 year old, or has potential growth from axillary buds at the base of the branch being cut; these axillary buds are where the roots potentially grow from so it is important to get them in the cutting. These cuttings can be replanted and will root readily given that conditions are moist enough (Cooksey 2003). These cuttings need to be at least 18 inches long and 3/8 inches across. If conditions are unusually dry during the time of restoration, basal leaves can be removed to prevent water loss through evapotranspiration. (Cooksey 2003). In order to make sure we plant the Dogwood at an appropriate distance from the water, we should observe it in its naturally growing habitat first and find the average distance from the water that it is most abundant. We will also need to provide irrigation for the mix of vegetation that is being planted for at least 3 years.

To make sure that the young cuttings are able to root, we need to continue to monitor them and the habitat to make sure it stays suitable for the Dogwood to grow there. We will need to continue to monitor climate to make sure that the Dogwoods are not losing too much water. We should be taking measurements for soil quality periodically during their growth. We should also be aware that grazers might be an issue. Small mammals like rabbits can browse on the wood of the dogwood and cause harm. During the young development of the cuttings, it might be necessary to fence off the areas where they are planted in order to keep wildlife from grazing on them. We will need to take samples of the dogwoods to calculate their success rate often during the first few months after planting.

If for some reason the cuttings are not able to survive, or if it is easier to plant by seed, would use seed instead. When collecting seeds we should collect them from plants living in similar climate and conditions. Dogwood is highly able to acclimate in gradually changing conditions but when conditions change too quickly, they will likely die, this is why we try to collect the most similar ecotype to avoid abrupt changes. Since cold stratification is a big help in the germination of Dogwood seeds, we will need to place collected seeds in a moist peat, and store it in a refrigerator for up to two weeks to help trigger germination in the seeds. Once the seeds have been in the refrigerator for two weeks, we can plant them at the site, and again continue monitoring success rate about every 2 weeks to make sure they can establish (Roof 2008).

This plan requires that we monitor the plants very carefully through their development, and it is very possible that the plants might not be able to root or grow if the conditions are not moist enough or there is too much or not enough shade. Also, by planting these dogwoods, we may see effects on the ecosystem that we were not expecting; these could be positive or negative effects. This kind of project can be risky, especially because of the focus on the species level, but it can provide a lot of insight to the ecology of the species and its effects on the ecosystem and community as a whole. There are not many current studies that focus just on this one species, rather they are focused on the restoration of multiple riparian species which is why we should try and create a good mix of riparian species to plant. This will help them feed off each other and create the balance that they would in a naturally occurring riparian system.

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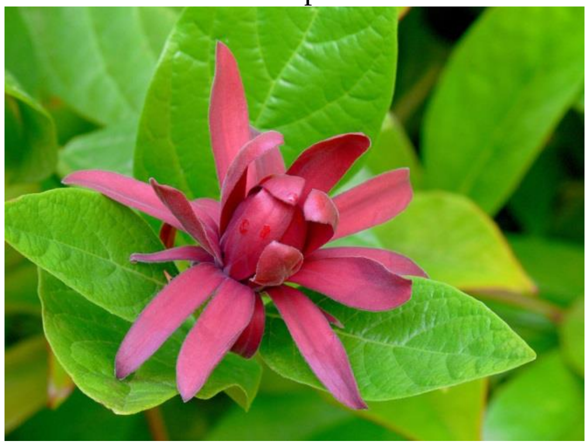
Spice bush (*Calycanthus occidentalis*) Steven Vitales

Calycanthus occidentalis

Western Spicebush



Background:

Agricultural runoff of fertilizers into riparian ecosystems has been a major concern in California due to farmers not having a mandate for any maximum cap on fertilizer use (Eviner 2014). In addition, *Arundo doniax* has also greatly spread throughout California's riparian areas, displacing many natives in the process (Cushman 2010). As restoration ecologists focus their attention repairing these ecosystems, it is important to choose plants that will be successful in current environmental conditions, as well as making note of anticipated changes in climate over the next one hundred years. Calycanthus fits this roll as it develops roots under wet soil conditions, which makes it a great plant to use after clearing out some Arundo off a riparian slope, or as an addition to a riparian forest meant to slowly purify its river/stream of nutrient and pesticide runoff.

Why *Calycanthus occidentalis*?

When selecting a reference site for restoring ecosystems, it is important to devise a reference site using both a historic reference, and observing similar sites and observing its success there. *Calycanthus* has traditionally been a California native to the riparian environment (Ferris 1968), and a common plant found along streams and river ways in today's riparian ecosystems (Brenzel 2012).

"Native along streams and moist slopes in California's Coast Ranges and Sierra Nevada foot-hills. To 4-12 ft. high and wide. Bright green leaves turn yellow in fall. Brownish red flowers to 2 inch across, resembling small water lilies, appear in mid-spring to summer, depending on climate. Both flowers and bruised leaves have the gragrance of an old wine barrel. Can be trained into a multistemmed small tree, but is most useful as a background shrub." (Brenzel 2012)

Main Targets for Riparian Restoration:

"…results indicate that *Arundo* invasion was associated with significantly lower richness of native perennial plant species on stream banks and floodplains, whereas there was no relationship on gravel bars. Additional research showed that plots invaded by *Arundo* and *Vinca*, both individually and collectively, exhibited significantly lower native and exotic species richness and abundance of both established plants and seedlings than uninvaded plots. Finally, after 2 years, experimental reductions of *Arundo* biomass via cutting and herbicide resulted in significantly increased native plant species richness and abundances of both established plants and seedlings, while having no effects on other exotics. In summary, our results indicate that *Arundo* and *Vinca* have strongly negative effects on diverse components of a riparian plant community, which must be addressed via effective control and restoration efforts." (Cushman 2010)

Pesticides and fungicides (Wauchope 1978) and nutrients, mainly Nitrogen, Phosphorous, and Selenium are running off the surface of agricultural fields and into riparian ecosystems. This surface water also increases surface erosivity of streams (Rice 2014). Restoration ecologists are going in and removing invasive species that are flourishing under the nutrient load and restoring classic riparian forest plants that will remove the nutrients from the water, and develop root matrices that will help stabilize riparian banks.

Literature Review:

Native Range:

- Native Distribution: CA Coast Ranges & w. Sierra Nevadas from Tulare Co. to Shasta Co. (Wildflower)
- Native Habitat: Moist stream banks below 4000 ft. (Wildflower)

Species Characteristics:

- Can develop roots in wet soils (Brenzel 2010)
- 3x3 meters mature size (Practical Plants)
- Perennial
- Hermaphroditic flower (Practical Plants)
- Even heavy levels of inundation does not greatly affect net photosynthetic rate (Stewart 2007)

Ecologic Requirements:

- 6.1-7.5 pH Soil Tolerance (Kubitzki 1990)
- Sandy / Loamy Soil (Practical Plants)
- Up to -15C temperature tolerance (Kubitzki 1990)
- Moist, well-drained soil (Practical Plants)
- Any shading or open sun (Watershed)

Pollinators/Herbivores/Diseases

- Beetle Pollinated (Kubitzki 1990) Which the California Poppy can also be pollinated by Endeodes insularis, a beetle (Garvey 2010)
- Resistant to Oak Root Fungus (Yerba Buena Nursery 2014)
- Deer resistant (Brenzel 2012)
- No known insect or disease problems (Brenzel 2012)

Propagation:

- Removing suckers from parents is an easy way to propagate this species. (Brenzel 2012)
- Cold stratification required to overcome dormancy of seeds. Stratification involves placing seeds in a moist 70% peat moss and 30% vermiculite

environment from one-to-five degrees Celsius for one-to-two months prior to spring planting, and is required to deactivate dormancy in this species (Practicalplants).

Calycanthus is a fairly tolerant and hardy plant that naturally fits into California's riparian ecosystem, being a native, that shouldn't be disturbed by the main forages of small shrubs in that ecosystem, deer. Being that it develops roots under wet soil conditions, it makes a great plant to use after clearing out some Arundo, or as an addition to a riparian forest meant to slowly purify its river/stream of nutrient and pesticide runoff.

My main concern with this plant is that under drought conditions *Calycanthus* did not perform so well. While there was no correlation between control and flood conditions on photosynthesis rate, under drought conditions an estimated 30-35% drop in net photosynthetic rate occurs (Stewart 2010). As climate change progresses and California's current drought problems become exacerbated, use of Calycanthus in drying up riparian ecosystems might no longer be favorable depending on the cost and availability of water. If affordable, irrigation could be set up for five years to get newly started *Calycanthus* established long enough to develop enough roots to support itself.

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<u>Part II</u>

A. Goal:

<u>Establishing and maintaining populations of *Calycanthus occidentalis* in the target site:</u>

1. <u>Providing sufficient genetic diversity, and hopefully some acclimation, in collected *Calycanthus* seed from reference sites.</u>

First thing to establish is the reference site where we will collect our seed. Being a plant with a wide native and current range in California, we have a large amount of ecosystems we can visit for our reference site. Collection would be from reference sites similar to our target site so that our plants might have some passed-on genetic acclimation from parents living in similar conditions. From each site, ten seeds from ten plants will be collected until enough seed is collected for the size of our target site. If the target site is so large that five-thousand or more seeds need to be collected, fifty seeds from fifty plants will be collected.

2. <u>Ensuring high recruitment percentage from planted seeds, and ensuring juvenile plant health</u>

High recruitment percentage will be considered forty to fifty-five percent of sprouted plants of seeds planted. Anything above fifty-five percent would be considered a great success. This will be accomplished through proper storage of collected seed, stratification of seed before planting, ensuring soil conditions are ideal, ensuring shading aspects are ideal and restricting access to the area with plastic fencing to exclude herbivores from eating juvenile plants.

3. Ensuring safe juvenile to adult transition and long term survival of the population.

At the end of the first year if twenty-five to forty percent of initial planted seeds reach the adult stage, this goal will be considered a success. Anything above would be considered a great success. After juvenile plants have grown to three feet tall, fencing can be removed. The adult plants are rarely eaten by deer, one of the major herbivores of California (Brenzel 2012). To attract more beetle pollinators, which the *Calycanthus* is pollinated by (Kubitzki 1990), native forbs which are also beetle pollinated will be planted in the first step of the restoration plan. Planted populations will be monitored monthly for the first five years, and every six months for the following fifteen years to ensure population health. Suckers can be cut from mother plants and transplanted in areas that there is die-off, or seed from the original planting can always be sown any spring using stratification, or during fall using dry seed.

B. Restoration Plan

I. Introduction

II. Seed collection and storage

III. Environmental Conditioning

IV. Planting

V. Juvenile to Adult transition maintenance

VI. Long-term Maintenance

I. Introduction

When selecting a reference site for restoring ecosystems, it is important to devise a reference site using both a historic reference, and observing similar sites and observing its success there. *Calycanthus* has traditionally been a California native to the riparian environment (Ferris 1968), and a common plant found along streams and river ways in today's riparian ecosystems (Brenzel 2012).

Pesticides and fungicides (Wauchope 1978) and nutrients, mainly Nitrogen, Phosphorous, and Selenium are running off the surface of agricultural fields and into riparian ecosystems. This surface water also increases surface erosivity of streams (Rice 2014). Restoration ecologists are going in and removing invasive species that are flourishing under the nutrient load and restoring classic riparian forest plants that will remove the nutrients from the water, and develop root matrices that will help stabilize riparian banks.

II. Seed collection and storage

Collection will begin from June to August during the end of *Calycanthus'* blooming time (Watershednursery). Collection from *Calycanthus* plants in current reference sites similar to the target site. From each site, ten seeds from ten plants will be collected until enough seed is collected for the size of our target site, and twenty-five percent surplus. If the target site is so large that five-thousand or more seeds need to be collected, fifty seeds from fifty plants will be collected. Seeds will be stored at fifteen degrees Celsius six months to induce germination (Practicalplants). In mid-September, one and a half months prior to planting, seeds will be treated with cold stratification until planting (Practicalplants). Stratification involves placing seeds in a moist 70% peat moss and 30% vermiculite environment from one-to-five degrees Celsius for one-to-two months prior to spring planting, and is required to deactivate dormancy in this species (Practicalplants).

III. Environmental Conditioning

Calycanthus does not have very many specific required environmental conditions, except for one. The soil must be well-drained and moist (Rhs.org). A moist soil environment is essential for development of roots. Soil pH can be anywhere from 6.1-7.5 (Kubitzki 1990), and the genus does not have any known insect or disease problems (Brenzel 2012). *Calycanthus* can tolerate no-to-medium shading; however heavy shading is not advised (Watershed). Soils will be tested for element/nutrient composition for a starting reference point.

IV. Planting

Because *Calycanthus* requires moist soils, if the target site does not have this, it is suggested to plant *Calycanthus* near hardwood plantings on the slope or woodlands that also would need irrigation to reduce costs. *Calycanthus* will need regular irrigation for the first year it is establishing, but will not after developing a mature root system. When planting near the water source, soils are traditionally moist due to the capillary action of soil to move water. As mature plants grow to be two-to-four meters wide (Rhs.org), seeds will be planted in grids three feet apart from another *Calycanthus* plant. When planting *Calycanthus* we will also be planting some Eschscholzia in between the plants, as they share the *Endeodes insularis* beetle as a pollinator (Garvey 2010). Planting will occur during the first rain of the spring season with the stratified seeds to reduce watering costs. Plastic fences made of rebar and plastic netting will be erected around restored areas to prevent herbivores from interfering with recruitment.

V. Juvenile to Adult transition maintenance, First Year

Plants will be watered weekly for ten minutes via a buried drip system. If soil nutrients are lacking, light amounts of nutrients can be added. After growing to three feet tall, the plastic fencing will be removed, and the planted area will be inspected for die-off. These areas will be marked, and replanted through layering and seed next spring. Soils will again be tested for any changes since planting. If the plants have seeded in the first year, new seed will be collected for planting next year. If they have not seeded, we will collect more seed as we did originally from the same sites. Populations of the *Eschscholzia* will need to be monitored as well, as a collapse in the poppies might signal a collapse in the shared pollinator with *Calycanthus*. Seed germination and subsequent stratification preparation preformed for next years anticipated planting.

VI. Long-Term Maintenance, Second Year and After

Areas of die-off surrounded by healthy plants can be restored using layering, as *Calycanthus* sends out suckers in early spring (Practicalplants). Suckers sent into areas of die-off can be pinned into the ground using a paper clip, and propagated directly from the mother plant into the soil without being severed from the mother. This technique is called layering, and is commonly used for plants that send out suckers (Evans 2014). At the end of summer, pinned down suckers will be cut from their mothers if they have developed mature roots.

If there are large areas of die-off, or layering seems inconvenient to the land manager, a fifty percent combination of collected seed from the planted *Calycanthus* will be mixed with fifty percent of the original collected seed prior to planting, and the area will be closed off with rebar and plastic net fencing. The irrigation system and soil will be checked prior to planting to ensure they are not the reason for the die-off. Every year twenty-five percent of plants will have twenty-five seeds collected for future plantings for the first five years.

Monitoring will be defined as a species population count, soil test, test of the irrigation, estimation of pollinators (done while doing population count), and mapping any die-off. The target site's *Calycanthus* population will be monitored, and replanted in this way for five years, and after the fifth year, the irrigation will be shut off. The site will be monitored heavily for the following month, to ensure removal of irrigation will not cause mass die-off (defined as twenty percent or more death after the irrigation is shut off), and then monitored monthly for five more months. If the population seems stable (no die-off detected), the target site will be monitored every six months for the next twenty years.

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Dry small trees/shrubs

Blue blossom (*Ceanothus thyrsiflorus*) ** Joseph Fiorello

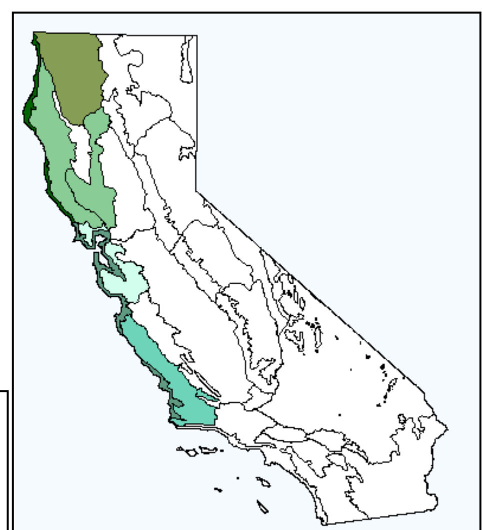
Ceanothus thyrsiflorus (“Blue Blossom”)

“Blue Blossom” sometimes also called “Blue Brush”, is a native to the California coastal region and is prized by many for its rare, true lilac-blue flowers. *C. thyrsiflorus* is a hardy evergreen part of the Euceanothus section of the genus, and is hardy, evergreen shrub that can grow 6-25 ft. tall. Like all species of *Ceanothus*, it is well adapted to drought, although other native shrubs such as *Quercus agrifolia* have been shown to be more efficient in handling water-stress (M. Abril, R. Hanano). This species requires well-drained soils is an important factor in wildfire ecology as its foliage is highly flammable and its seeds utilize fire for heat in order to germinate (USDS Forest Service). All species of *Ceanothus* are crucial members of their communities, in a multitude of California habitats such as a variety of forest types to chaparral and coastal bioregions. The Range Plant Handbook (USDA Forest Service 1937) describes C. thyrsiflorus, along with C. sanguineus and C. fendleri as being among the most important browse species in their respective ranges.

C. thyrsiflorus is best known for its beautiful spring plumage that attracts a long list of pollinators, most commonly honeybees, bumblebees, butterflies and hummingbirds; other native bird species such as the bushtit and quail feed on the seeds that fall in the early summer (Hansen’s). Due to improper fire-control practices, populations of *Ceanothus* have been noted to be in decline (USDA Forest Service). Not only would restoring native populations of this genus intensely beautify California’s surroundings in a drought-sensitive manner, it would also offer a multitude of benefits to many California species.

<u>Distribution/Range</u>

- The range of *C. thyrsiflorus* extends from Southern California chaparral to up along the rest of the entire California coast, into the Eastern San Joaquin-Central Valley and even further up into Southwestern Oregon (Jepson Flora Project).
- This species is established in both forest and chaparral sites and shares its natural range with other species of the genus, such as *C. Cuneatus and*



“Bioregions in which *C. thyrsiflorus* occurs” (Jepson Flora Project 2013).

C. Incanus , though *C. thyrsiflorus* is recognized as being the most important browse species for wildlife in its range (USDA Forest Service).

<u>Growth Conditions and Propogation</u>

- Intolerant to shade, though afternoon shade can be beneficial in especially hot areas (Sonoma County Master Gardeners)
- Tolerant to stress, summer drought, extreme temperatures and very poor site conditions (USDAFS)
- Requires well-drained, sandy soils and will experience root rot in standing water (USDAFS)
- Can be sprouted from seed or grown through cuttings (USDFS)
- Seed is best sown as soon as it is ripe in a cold frame after being treated to heat and soaked for 12 hours (Sonoma Country Master Gardeners)
- Best planted in fall before winter rains to establish root growth (Sonoma County Master Gardeners)
- <u>Do not water in the summer</u> except for infrequent soakings during the first summer (SCMG)
- Specimens can live up to 12 years (USDFS)
- Tolerant of maritime exposure though slow to establish in most-exposed conditions (Practical Plants)

<u>Reproduction</u>

- Hermaphrodite flower clusters, fragrant smell, blooms March-May (Sonoma County Master Gardeners)
- When ripe, seeds are ejected from their pods and fly shorts distances, making successful collection of viable seeds difficult (USDA Forest Service)
- Species of the genus are estimated to store between 47,000 to 29.2×10^{6} /hectare of viable seeds in the duff layer (soil) in a single season (USDS Forest Service)
- Although not essential, fire is the most common and effective way of germination (USDA Forest Service)

- Only a fraction of produced seeds are stored in the soil, in chaparral regions 90-99% of all seeds are mainly eaten by rodents, in addition to birds and harvester ants (USDA Forest Service)
- *Ceanothus spp.* seeds have been shown to remain viable after long periods, shown in a lab to germinate after up to 24 years in dormancy (USDS Forest Service)
- Birds and ants act as seed dispersal agents
- Need of disturbance for germination ((USDA Forest Service)
- All species of *Ceanothus* can readily hybridize with each other (Sonoma County Master Gardeners)

Fire Management

- Stands of *Ceanothus* die off after 70 years without fire suppression (George, M.R.; Alonso, M.F.)
- Fires are necessary in oak-woodlands to control live-oak stands from shading out *C. thyrsiflorus.*(George, M.R.; Alonso, M.F.)
- Compared to disturbances caused by fire, grazing is long and relentless and not a beneficial disturbance in the event of fire recovery (Forrestel et al.)
- After the 1995 Vision Fire, dense stands of Blue Blossom appeared in areas only scattered with Blue Blossom prior to the fire (Forrestel et al.)
- Rapid high mortality is common among seedlings after a fire event (USDA Forest Service)
- Fall slash burnings have shown to be more effective in producing more seedlings, thought to be due to the wet stratification offered in the winter rain months.(USDA Forest Service)
- Too frequent or intense fire burnings can lead to elimination of the species in the area (USDA Forest Service)
- Intensity of fire is not as crucial as frequency, because seed bank has time to recover (Forrestel et al.)

Ecology and Relationships with Biotic Factors

- Several species of butterfly and moth feed on the leaves of *C. thyrsiflorus* (California Floral Nursery)

- Considered a colonizer or pioneer by many for its quick ground-covering capabilities in open land and its ability to nitrify soil in root nodules that store bacteria (USDA Forest Service)
- Several species of insects can heavily infest and damage seed crop (USDA Forest Service)
- The high protein content in leaves attracts can attract grazers such as elk, sheep, deer and cattle in the spring and summer months (USDA Forest Service)
- In forest sites, fungi such as *Armillaria mellea* can infect roots and girdle them through rhizomorphs (USDA Forest Service)
- In the absence of fire, *C. thyrsiflorus* has shown to be dominated by the maritime shrub *Arctostaphylos pajaroensis* that overtops and shades it (Van Dyke et al)

Human Interaction

- For centuries Native American tribes would practice fire control leading to the mosaic of grassland, chaparral and forests we have today (Forrestel et al.)
- Native Americans also used the foliage as a fragrant soap base that removes dirt but leaves natural oils in the skin due to high saponin content (Practical Plants)
- a green dye is manufactured from the blue flowers (Practical Plants)
- "The Royal Horticultural Society received seeds of Ceanothus thyrisflorus from Richard Brinsley Hinds from the 1837 expedition of HMS Sulphur, making it the first California species introduced into European gardens "

Gaps in Research

- Where exactly will *Ceanothus*?
- Quantitative optimum and extreme values of abiotic conditions such as elevation, site quality, soil moisture and days needed for growth and establishment.
- Age at onset of seed production.

- Duration of viable seed in soil
- Factors that limit Nitrogen fixation for *C. thyrsiflorus*
- Threshold tolerance to summer watering

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Due to the widespread use of *Ceanothus* species in California and their ability to thrive in nutrient poor, drought-laden areas, “Blue Blossom” is hardly considered an endangered or threatened species. However, due to modern fire suppression policies and the ecological effects of land cultivation, native stands of *C. thyrsiflorus* are increasingly rare in California. This leads to the two long term main goals of the project:

- Protecting chaparral land from cultivation and other types development: once land has been cultivated and tilled native species lose their advantage and become subject to increased competition (Keeley,1992)
- Employing low intensity prescribed burnings once stands have reached maturity (every 40-50 years): wildfires alter the allelopathic chemicals in *Ceanothus spp.* seeds that otherwise inhibit them from germinating (George, Roche and Eastburn 2012). By practicing controlled fires, not only are seeds germinated, competitors that are more likely to shade out *C. thyrsiflorus* over time are set back to balanced populations.

<u>Short-term goal:</u>

- provide well-drained soil by clearing sloped soils of invasive species: *Ceanothus thyrsiflorus* requires well-drained soil such as that on hillsides in order to survive

<u>Potentials of goal, trade-offs with prescribed burning</u>

Waiting too long to prescribe burnings allows faster growing shrub species of oak (*Quercus)* and *Arctostaphylos* to outcompete *C. thyrsiflorus* for sunlight. Too frequent or too intense fire schedules could eliminate *Ceanothus* stands (USDA Forest Service 1982) and lead to the conversion from an oak-woodland to oak-grassland (George, Roche and Eastburn 2012).

Because not all species in the Central Valley are aptly adapted to fire, planned fires meant to restore overtaken stands of *Ceanothus* can potentially destroy other important plants to the area. But due to the planned infrequency of implemented fires (40-50 years), biodiversity in the community has time to recover. Additionally, most native species are adapted to some frequency of fire and probably will benefit from such events.

Pre-Monitoring

Because it is unclear whether *C. thyrsiflorus* is the appropriate species for Central Valley, an analysis of the area for native species of *Ceanothus* will help determine what species does best there now.

To ensure the best locations are chosen to promote the establishment of new *Ceanothus* stands, areas of soil with good drainage should be located. Because of the need of fire in managing older stands, chosen areas for the restoration project should be distant from pine forests and human establishments. Sites popular with *Quercus spp.* or *Arctostaphylos spp.* should be avoided as they have been shown to outcompete *C. thyrsiflorus* unless fire disturbance occurs.

During times of heavy rain, it would be beneficial to monitor how well the soil drains and discern appropriate sites from those with inadequate drainage.

Restoration

Due to the difficulty in cultivating *Ceanothus spp.* by seed or cutting, one-gallon saplings purchased at local nurseries will provide the specimens. Due to the ability of this species to produce up to 29.2×10^{6} /hectare of viable seeds, only about 20-30 individuals should be necessary in each location to establish long-lasting stands. The best time to plant them is in the fall before the onset of rain so the Blue Blossom will be able to grow deep roots that deeply penetrate the soil in preparation for hot, dry summers. As the saplings begin to establish, it is necessary to make sure they receive enough water. Give plants 3-4 deep soakings within the first 2 months. In the cooler months the roots are less susceptible to rot because the fungi prefer warm environments.

As already stated *C. thyrsiflorus* requires well-drained soil, otherwise it should be planted on slopes or with the root ball slightly above the grade of the soil (SCMG 2014). Choose spots in full sun, away from trees and other tall shrubs. Plant one specimen for every five feet, plants are expected to branch outward and may reach heights over 6 feet. Once planted, the area should be watered enough to keep soil around roots moist but not waterlogged (between once a week and once a month).

If desired, *C. thyrsiflorus* may be planted in conjunction with other species of *Ceanothus*, including different cultivars of *C. thyrsiflorus* because other native species of *Ceanothus* are also adapted to the Central Valley such as *C. incanus* (USDA Forest Service 1982) and all species are capable of hybridizing with one another (SCMG 2014). It should be noted that deer are attracted to graze on this species and so planting in areas of high deer populations should be avoided, or the prostrate cultivar, *C. thyrsiflorus repens*, should be planted instead because of its smaller leaves (SCMG 2014).

It is important to not use drip irrigation techniques, fertilization and never to irrigate during the summer. Like most native species, *C. thyrsiflorus* is adapted for dry summers and nutrient-poor soils.

Every year after the flowering season (July), inspect plant for seed production. Usually *Ceanothus spp.* will reach maturity after 3-6 years. Once mature, a prescribed burning can help germinate the seeds produced by each plant. Slash-burnings are most effective in the fall right before it rains to ensure proper seed stratification and germination (USDA Forest Service). The following season many seedlings should sprout in the area in the place of the original plants and result in large natural stands of *Ceanothus.* No further maintenance should be required in order for the seedlings to reach maturity.

Monitoring

During the spring the newly planted saplings should be inspected to ensure survival. If young plants show signs of heavy grazing or browsing, the area might have too many deer for the species to establish and the prostrate variety of *C. thyrsiflorus* should be planted instead.
Mature stands should be monitored every five years and a slash-burn subscribed when over 50 percent of a stand becomes woody or composed of dead growth, or when the growth of neighboring species threatens to outcompete the *Ceanothus* for sunlight. This will typically be a period of at least 50 years, as wild scrubs of chaparral have been found to contain healthy stands of *Ceanothus* at least 50 years old depending on the amount of competing species in the area (Keeley 2002). Every year during the fall the amount of carbon stored on average by each stand should be recorded by measuring plant volume, as this is a good indicator of how many seeds will be produced the following year (USDA Forest Service 1982). Years of high seed production are particularly suited for fire disturbance. The amount of nitrogen present in the soil following a fire and every year thereafter in the *Ceanothus* stands would also be beneficial to record because little is known about the nitrogen-fixing capabilities of this species.

Concerns

It is uncertain how well this species can withstand cold, winter temperatures, although other species of *Ceanothus* are capable of growing in high elevations with snow. During the first winter especially, temperature freezes might be too harsh for young saplings to establish, requiring planting to be done perhaps a month earlier or in areas not in low points where cold air will not collect.

As stated already, areas with high deer populations might not be suitable for *C. thyrsiflorus*. However, it is recognized that to some extent of grazing is beneficial if not necessary for optimal growth.

To best prevent root rot in the first months of establishment, cover soil with organic mulch and soak plants at the end of the day when it is cooler.

Research questions

What species of *Ceanothus* will grow best in areas of the Central Valley? It would be important to find out whether old stands experience die-off due to changes in soil, changes in neighboring species abundances, or just due to old growth? How long can stands grow without prescribed fires?

If some stands were weeded out of competing shrubs while similar stands nearby were not, this would determine whether it is the shading effect of competitors or another factor determine the longevity of *Ceanothus* stands.

How long should management wait to prescribe burnings?

This can be answered by differentially managing disturbances in different locales and comparing the vitality and size of the stand in the next five years. Will the new stand be bigger than if no fire occurred?

Can this species be hybridized with another to make it more adapted to poory-drained soils?

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California buckeye (*Aesculus californica*) Alanna Burhans

California Buckeye

Aesculus californica

Classification

Kingdom: Plantae
Phylum: Tracheobionta
Class: Magnoliopsida
Order: Sapindales
Family: Hippocastanaceae
Genus: *Aesculus L.*
Species: *Aesculus californica*
(USDA 2012)

Background and Justification
by Ken Cheetham

Aesculus californica (California Buckeye) is a species endemic to California. It is largely distributed throughout California, from the costal range and stretching as far east to the Sierra Nevada (Howard). It also spans from Northern California down to Los Angeles County. Its ability to live in such a wide array of places demonstrates it can tolerate a variety of conditions (Howard, USDA 2012). It can grow on dry slopes, in canyons, and along streams and riverbeds. It is able to tolerate large amounts of drought but is also adapted to places that get more frequent rainfall during winter months. There is no specific data on how much rainfall or waterlogging it can handle but it cannot tolerate being submerged in water (Howard). Because of its ability to grow on slopes and near water this tree is commonly used at restoration sites, even though it is toxic if ingested by most animals and humans. Planting of this tree helps with erosion control and reduces loss of the landscape (Howard). *Aesculus californica* has been shown to be effective in riparian restoration sites in areas like Central Valley, where it can help with soil loss. However for the plant to be effective at this task it need to be able to become established. Lastly, the Buckeye has large inflorescences that are pretty when in bloom and these attract butterflies and hummingbirds that feed on the trees' nectar. This makes *Aesculus californica* an attractive plant to use in areas that are frequently visited (Calflora).

Goal

The goal is to decide if *Aesculus californica is* suitable for a site and/or to choose the ideal location for planting the tree on a restoration site.

FACT SHEET

LIFE CYCLE

Growth Characteristics

- *Aesculus californica* is a deciduous shrub or tree that grows to approximately 12 meters high. At maturity it has a wide rounded crown. (USDA 2004)
- Has a fairly short span where it has foliage and blooms. It is one of the first shrubs to produce leaves in May and one of the first to loose them in July. (USDA 2004; Calflora)
- Has large inflorescences (USDA 2004)

Reproduction

- Honeybees are important in their reproduction cycle. (Howard)
- In natural conditions the *Aesculus californica* reproduces by seed. Between the months of November and mid-February a single tree can produce up to 100 seeds. The seeds do not disperse very far and are viable for up to a year. When temperatures stay below 40 degrees Fahrenheit for more then 2 months the seeds may get a fungal infection. (Howard)
- When propagating the California Buckeye seeds, they should be collected between September 1st and December 1st. The husks will need to be removed from the seeds and then stored in moist conditions in the refrigerator. Do not store dry. When ready to propagate soak them in water for 24 hours, and afterwards soak them in a 5% bleach solution for 1 minute. After rinsing the seeds with water, one should place them into freezer bags filled with sterile perlite. Place the bags in the refrigerator for 6-8 weeks. When the radicals emerge they are ready to be sown in standard potting soil, one plant per container. It should take about 21 days for the Buckeye to become established with a 90% survival rate. (Young 2001)

RANGE AND DISTRIBUTION

- *Aesculus californica* is endemic to California. (Howard)
- It grows in Coastal Ranges spanning from Siskiyou County to Los Angeles County. As well as the Cascade Range and the foothills of the Sierra Nevada. Finally it spans from Shasta County to Kern County and is found in the Central Valley. (Howard)

HABITAT AND ASSOCIATIONS

- It is found in Mediterranean climates, where there are cool moist winters and hot dry summers. (Howard)
- Grows in many different environments like dry slopes, in canyons, and along waterways. For example in the Central Valley it is found along streams and riverbanks (Howard)
- Can handle seasonal flooding. (Buckeye 2012)
- It also appears in mixed evergreen forests as understory shrubs. (Howard)
- In California Buckeye communities and chaparrals, the *Aesculus californica*

emerges as a climax indicator. (Howard)

- There are several communities in which *Aesculus californica* are dominant or co-dominant and these are California Buckeye woodland and oak woodland. They are also occasionally dominant in chaparral communities. (Howard)
- In the Sierras Nevada foothills, their leaves shed in the late spring to early summer. (Howard)
- It appears in grasslands and the individuals are widely dispersed. (Howard)
- In coastal areas where the soil stays moist for longer periods of time, the leaves won't shed until fall. (Howard)
- They are associated and tend to grow with poison oak (*Toxicodendron diversilobum*) (Howard).

REQUIREMENTS

- The wet season needs to last from 4 to 9 months and rain from 13 to 85 inches. (USDA 2012)
- During the summer the temperature must reach over 100 degrees Fahrenheit for several days. (Howard)
- Root depth needs to be a minimum of 36 inches. (USDA 2012)
- Needs a minimum of 175 frost-free days. (USDA 2012)
- Grows in areas with very low salinity. (Calflora)
- Is suitable for several kinds of soil: sandy, sandy-loam, or gravelly-loam soils (Howard)
- Soil pH must be between 5.5 and 7.5. (USDA 2012)
- Grows between an elevation of 0 and 4000 ft. (1,219). (Howard)

TOLERANCES

- Does not handle anaerobic environments such as being submerged in water. (USDA 2012)
- Has a high drought tolerance rating. (USDA 2012)
- Is able to handle some amount of fire. (USDA 2012)
- Has intermediate shade tolerance. (USDA 2012)
- *Aesculus californica* cannot survive with any salinity. (USDA 2012)

INTERACTIONS

Pathogens

- *Aesculus californica* is a host for a fungus called *Phytophthora ramorum*, also known as sudden oak death. The fungus infects the leaves and branches. (Rizzo 2002)
- It is also a host for a bacterium called *Xylella fastidiosa* that causes Pierce's Disease. (Calflora)
- Susceptible to fruit tree leafroller pests and bark beetles. (Damask)

Wildlife

- *Aesculus californica* is only moderately poisonous. The poison is mainly abundant in seeds and flowers and is extremely toxic to honeybees. (USDA 2004)

Even though it is one of the main pollinators. (Howard) These trees should not be planted any where near bee yards. (USDA 2004)

- The only wildlife known to eat the seeds are squirrels, for example the California ground squirrel (Citellus beecheyi). (USDA 2004) It is also toxic to all classes of livestock. There have been cases where the California Buckeye has induced abortions in cattle. (Howard)
- There are several species of butterflies and hummingbirds that benefit from the *Aesculus californica*. They eat the nectar from the flowers. (Calflora)

Humans

- Several parts of the Buckeye including the bark, leaves, stems, fruit and seeds have been known to have a detrimental effect on humans if ingested. They contain glycosidal compounds that can decrease the number of red blood cells in the body and weaken the central nervous system. (Howard)
- Many indigenous tribes utilized several different parts of *Aesculus californica*. They would cook and eat the seeds (only poisonous in raw form). Cut up seeds were mixed with water and used for medical purposes. The bark was used when treating snakebites. Young shoots were used to make fire kits and finally the seeds were sometimes crushed in pools of water to stun or kill fish. (USDA 2004)

MANAGEMENT OPTIONS

- In areas where there is erosion like streams, riverbanks or steep slopes *Aesculus californica* can be used to keep the soil in place. (Howard)
- Grazing is not a manageable way to keep California Buckeye in check because its toxicity is harmful to animals. (Howard)
- Using fungicides or botanical oils that are suited for a particular problem can treat fungal infection. To prevent fungal problems avoid overhead watering and destroy infected parts of plants (Damask)
- The best ways to deal with pest are to do preventive measures by not stressing out the plant and applying insecticides before there's a problem. (Damask)

KEY KNOWLEDGE GAPS

- Information on disturbance regimes.
- Things that threaten *Aesculus californica* survival.

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Part II

A. Goal:

Establishing and maintaining the California Buckeye (*Aesculus californica*) in Central Valley restoration site by:

II. Locating suitable habitats and locations with in a site.

The California Buckeye is an endemic species (Howard) to California and can be found all over the state a variety of communities. This is an important first to identify the what kind of community that one wants to place the buckeye in because within that community there may be more suitable locations for it to have its best chance of establishing. In the Central Valley placing the Buckeye near streams and riverbanks is preferred because that is where they are naturally found in here (Howard). Its is also important to keep in mind that Poison oak (*Toxicodendron diversilobum*) tends to grow with the Buckeye (Howard) so it should not be placed right next to frequented walking path.

III. <u>Properly collecting and propagating seed (timing and technique).</u>

This is an important step that should be done once a restoration site has been identified. Like stated previously Buckeyes are found in many different communities ranging from dry slopes to along waterways (Howard). Collecting seeds from locations that match your site will be beneficial because the they will have the desired traits that are need to best survive. The seed need to be collected during the September to December. To start the propagation process the seed need to be properly stored in a refrigerated space. Knowing when your site needs to be planted is a very important goal because Buckeye seeds cannot be stared dry. They immediately need to be prepared for the propagation process and starting this process to soon could lead to root binding.

IV. <u>Monitoring post planting</u>

Monitoring should be done after planting to make sure the seedling take hold and are not diseased with any fungal infections. To prevent the infections do not use overhead watering and remove any infected parts of the Buckeye. It is important to monitor to make sure the buckeye is not under duress because this can lead to many pests that will decrease its survival rate. If possible apply insecticides can be a preventative measure. (Damask)

V. <u>Providing Appropriate Pollinators.</u>

Honeybees are the primary pollinators for the California Buckeye. Planting them in areas where there are high numbers of honeybees would be beneficial to the Buckeye but is harmful for the bee population. Honeybees find the Buckeye to be very poisonous. This should be kept in mind when looking at your site because if it is located next to a be yard the buckeye should not be used or planted sparingly. It will end up having negative effects on the bee yard if planted in high amounts. (USDA 2004)

B. <u>Restoration plan:</u>

- **I. Introduction**
- **II. Locating suitable sites**
- **III. Collecting and Propagating Seed (techniques and timing)**
- **IV. Monitoring post planting**
- **V. Providing Appropriate Pollinators**
- **VI. Research necessary for plan**

I. Introduction

During the restoration process there are several criteria that must be met to give *Aesculus californica* its optimal chances of survival. The most critical condition that needs to be met is making sure your site has suitable conditions for the growth and persistence of the buckeye. Secondly, it is very important to properly time the collection and propagation of seed. Then once the propagules have been planted at a site temporary monitoring is best to help prevent major's losses from pest or fungi. Finally, it is important to keep in parasitic relationship that the California Buckeye has with is main pollinator.

II. Locating suitable sites

There are many things that need to be taken into account when deciding if your site is suitable for the *Aesculus californica,* such as climate, soil and topographical characteristics. As well as looking at what plants are associated with it. There are many aspects of climate that need to be taken into consideration. The *Aesculus californica* to live in conditions where there is a wet season of 4 to 9 months and has at least 13 to 85 inches of rain. The conditions must allow for at least 175 frost-free days and several days over 100 degrees Fahrenheit (USDA 2004; Howard). If this is suitable soil testing need to take place to identify salinity, pH and texture. Buckeyes grow in soils with very low salinity this is key thing to take note of because this is something they are very sensitive to. They also grow in acidic soil with a pH of 5.5 - 7.5 and prefer sandy, sandy-loam or gravely loam soils (USDA 2004; Howard). In the central valley, sites that favor the restoration of *Aesculus californica* are along streams, riverbanks, canyons and dry slops (Howard). They and can be good choice of plant if there erosion problems because they are capable of living on slopes. Finally, California buckeye tends to be associated with Poison oak (*Toxicodendron diversilobum*). This can be both a positive and negative feature. If you are wanting to promote poison oak in a location of your restoration site, for example to keep pedestrians on paths of prevent their access to certain areas, this could be a positive feature. On the other hand if site is prone to many pedestrian in a more residential scene keeping poison oak away from paths maybe want is needed meaning the buckeye should be set back from the path (Howard).

III. Collecting and Propagating Seed (techniques and timing)

When it comes to propagating *Aesculus californica* timing is a key part of this process. So deciding your planting schedule need happen before you can even start collecting the seeds. The reason for this is that the seed cannot be stored dry. Collection of the seeds should take place between September 1st and December 1st. once collected the husks are removed and the seeds need to be stored in a moist refrigerated environment (Young). This is not a long-term way of storage and must be propagated shortly after. When ready for propagation the seeds need to soak in water for a 24-hour period and then put into a 5 percent bleach solution for 1 minute. Once rinsed the seeds are placed in plastic bags filled with sterile perlites and are places back in the refrigerator for 6 to 8 weeks. Once the radicals emerge they can be sown in single plant container filled wit standard potting soil. When the specimens reach there desired size they can be planted in the site and will take about 21 days to establish (Young).

IV. Monitoring post planting

Monitoring the California buckeye after planting is an important step. They are susceptible to pest and fungal infections. Going out on a regular basis while they are first establishing in the site is need to help catch or prevent pest and fungal infections. Fungal infections are typically due to overhead sprinkling so if this type of irrigation is being used at the site it is important to make sure that directly hitting the buckeye seedling. This will help prevent infection. If there are pest problem its best to remove the infected leaves and branches as soon as possible to prevent it from spreading. Another option, if possible, is to use insecticides (Damask).

V. Providing Appropriate Pollinators

Bees are an important pollinator for many species including the California buckeye. But the relationship between the two is really only beneficial for the buckeye. Honeybees find buckeyes to be poisons can survive long after collecting its nectar. Having a populations of bee near or in the restoration site is good for the Buckeye but because of this negative relationship between the to species it is best not to plant them near bee yards. It will end up killing off all the bees in the bee yard (USDA 2004).

VI. Research necessary for plan

Further research that would be necessary for this restoration plan is to look into exact extent of monitoring that need to take place. How frequently and how many months or years. Knowing more about the negative effects Buckeye has on bees is important because this could effect the pollination of other species in the area. Finally finding information on irrigation time and the duration it may be needed to help establish the Buckeye at a restoration site is needed.

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California rose (*Rosa californica*) Ellie Marin

ROSA CALIFORNIA (CALIFORNIA ROSE)

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Rosidea
Order: Rosales
Family: Rosaceae
Genus: Rosa L.
Species: californica

BACKGROUND AND JUSTIFICATION:

Rosa californica (common name: California rose) is a native understory, woody, dry shrub occurring normally near riparian zones in woodlands and chaparral throughout California (USDA, 2014). It is a deciduous angiosperm that can tolerate drought and moderately tolerate flooding (USDA, 2014). Despite these tolerances, the California rose is at risk due to the destruction and alteration of riparian systems and plant communities (Katibah, 1984). California rose is also vulnerable to takeover by invasive plant species which are better at establishing themselves afterward or tolerating a disturbance or stress event and might shade out the California rose, including Himalayan blackberry, Arundo, and Blue gum eucalyptus (http://www.plantright.org/regions/central-valley). California rose is also susceptible to diseases transmitted by mites (Katibah, 1984). Streams are altered to transport water to urban centers, and with those alterations come the inability for native plants to thrive (Robert et al., 1997). Stream alterations include damming and diverting which can limit the available water for the California Rose; development along riparian zones also leads to the alteration of the stream by changing the landscape through species removal and alteration of the stream path, affecting the soil. With the loss of its habitat, the loss of the California rose might eventually follow.

California rose completes various ecosystem functions. California rose is important in the support of both agriculture and the environment. Importance of the California rose is in its support of various wildlife species, some of which are endangered and some of which are important pollinators such as insects and birds (USFWS, 2014). California rose provides habitat and protection for the endangered Riparian Brush Rabbit as well as various important bird, bee, and butterfly species (USFWS, 2014). As a flowering plant, California rose strongly facilitates pollination within the ecosystem, supporting the pollinators as its own genes spread in a mutualistic relationship with the pollinators (Katibah, 1984). California Rose also serves a role in stabilizing the slopes upon which it resides along riparian systems; it limits the erosion potential in the area due to its well-established roots and perennial growth (Doherty et al., 2006). The California Rose has the ability to perform these ecosystem services that would be far more costly if humans had to resort to performing them with human technology. Near the last quarter or so of the 1900s, California rose's environment faced growing degradation and destruction, slightly decreasing the abundance of California rose; however, the future of the California rose will be threatened if the destructive actions continue (Kelch & Murdock, 2012). However, in recent years, conservationists have made this species and the ecosystem where it survives a concern (Kelch & Murdock, 2012). Restoration practices are needed to ensure that this species continues to benefit humans and the ecosystem (Kelch & Murdock, 2012).

<u>FACT SHEET:</u>

Project Goal:

- To facilitate the reintroduction of California rose in disturbed areas where invasive Himalayan blackberry, Arundo, Scarlet wisteria, Blue gum eucalyptus, Saltcedar, and Russian olive have been introduced and riparian ecosystems have been degraded.

Growth characteristics:

- California rose is a woody shrub and undergrowth species that grows to an average of five feet tall but can get as high as 9 feet (USFWS, 2014).
- The rate of growth is moderate – about 1 to 2 feet yearly. As a shrub, it spreads, forming a thicket. California rose is a deciduous plant, dropping its green leaves (Stanford, 2014).
- California rose is a perennial dicot species (USDA, 2014).
- The shrub has straight, slender prickles with a curve at the tip. California rose leaflets can take on a variety of appearances, with simple or grandular-compound teeth and pinnate venation (Najda & Buczkowska, 2013).

Reproduction:

- California rose reproduces by rhizomes or seed. Pollinators include butterflies, bees, and songbirds (Crepin, 1896).
- Rose hips appear in late summer to early fall. The rose hips produce yellow seeds which attract various pollinators. Seeds are disperse afterward (Cole, 1956).
- California rose can also be planting by cuttings.
- It has conspicuous, flowers that bloom in the late spring and early summer (Crepin, 1896).
- California rose can self-fertilize (Cole, 1956).
- Flowers have five petals that can be various shades of pink (Cole, 1956).
- The flowers are hermaphroditic (Elias & Dykeman, 2009).

Range:

- California rose is distributed throughout California with the exception of the High Cascade Range and High Sierra Nevada Range – above 6000 feet (USDA 2014).
- It also does not grow in the deserts or in other areas without a Mediterranean Climate.
- California Rose can be found as far north as Oregon and as far South as Baja California.
- California Rose grows in the following counties within California: San Diego, Riverside, Orange, San Bernardino, Los Angeles, Ventura, Kern, Santa Barbara, San Luis Obispo, Monterey, Tulare, San Benito, Fresno, Madera, Mariposa, Merced, Santa Cruz, Santa Clara, San Mateo, Stanislaus, Toulumne, Calaveras, San Joaquin, Alameda, San Francisco, Contra Costa, Solana, Sacramento, Yolo, Napa, Marin, Sonoma, Lake, Sutter, Colusa, Lake, Mendocino, Glenn, Nevada, Butte, Tehama, Plumas, Shasta, Trinity, Siskiyou, Modoc (USDA, 2014).

- California Rose grows in the following counties within Oregon: Glackamas, Yamhill, Jackson, Josephine (USDA, 2014).
-

Habitat:

- California rose normally inhabits areas near riparian systems and other moist areas throughout California (Bendix, 1999).
- Due to the thorns, California rose faces little threat from mammal herbivory.

Succession:

- Following the initial grass colonization in an area, California Rose will, as a shrub, replace non-woody plants that replaced forbs and grasses (Katibah, 1984).
- Following disturbance events that facilitate grass colonization in an area, California Rose will, as a shrub, replace the woody plants that replaced the forbs and grasses (Doherty et al., 2006).

Requirements:

- California rose does well in slightly moist soils and moderate sun with more needed near the coast and at high elevations (Campa, 1950).
- This shrub does not grow well in water logged soils for extended periods of time (Roberts et al., 1997).
- This shrub‘s light requirements vary depending on the amount of water and the location of the plant.
- California Rose can do well in all soil pHs but does particularly well in soils with a pH from 4.5 to 8 (Calflora, 2014).
- California Rose grows best in soils that have a largely clay composition but can thrive in sandy loam to clay loam soils (Calflora, 2014).

Tolerances:

- California rose can tolerate drought-conditions but usually only after it is well established. As a riparian zone plant, it can also tolerate seasonal flooding (Wildflower Center, 2014).
- California naturally thrives in a Mediterranean Climate that can be classified as semi-arid; therefore, the shrub usually thrives in soils that are on the dry side (Campa, 1950).
- California Rose has no tolerance for calcium carbonate that might precipitate (Wildflower Center, 2014).
- Due to the thorns and thicket-forming nature, California Rose has a high tolerance to herbivory (Cole, 1956).

Wildlife Interactions:

- Many species of birds and butterflies rely on the California rose for food; a mutualistic relationship exists since they pollinate the California Rose (Cole, 1956).
- Additionally, rodent species such as the endangered Riparian Brush Rabbit utilize the shrub for habitat and protection; the thorns and thick growth provide protection from other animal species (USFWS, 2014).

Plant Interactions:

- California Rose can associate with the Delta Tule Pea (*Lathyrus jepsonii var. jepsonii).* This pea plant has been known to grow within and above the thickets which the California rose so densely creates (Witham & Kareofelas 1994).

Human Interactions:

- Humans frequently utilize California Rose in native plant gardens or arrangements due to their fragrant and attractive flowers (Najda & Buczkowska, 2013).
- Humans utilize the California rose to provide cover for small mammals and birds such as quail
- Native Americans used the fruit for medicinal purposed for years, and some other humans currently eat the flower of the California Rose for its abundance of vitamins and minerals. It has also been incorporated into dietary supplements and into essential oils. (Open Space Authority, 2014). California Rose is utilized for treatment of cold symptoms and digestion issues (Elias & Dykeman, 2009).
- The rose hips of the California rose are sometimes made into rose water, jams, tea, fruit leather, soup, and syrup and are rich in Vitamin C (Wildflower Center, 2014).

Threats:

- Alterations of riparian zones due to human water diversion, damming, and stream movement threaten the California Rose's habitat (Roberts et al., 1997).
- California rose is susceptible to various pathogens and pests such as spider mites, caterpillars, whiteflies, apids, and thrips, small insects. It is also susceptible to fungal outbreaks if under overly dark or moist conditions (Cole, 1956).

Propagation Requirements:

- California Rose can provide erosion control by stabilizing hillsides (Calflora, 2014).
- California Rose propagates most successfully by container.
- Seed germination requires 2 years due to warm periods following cold periods needed to mature that embryo. Scarification followed by a few months in peat may possible expedite this process (Plants for a Future, 2014).
- California Rose can be planted from seed propagation or cuttings (Wildflower Center, 2014).
- This plant benefits from pruning during the winter time. Within about two to three years of establishment, they will likely have had their roots reach the water table, and the California rose requires little to no human care (Stanford, 2014).

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Restoration Plan for California Rose

The restoration of California Rose to California's Central Valley is vital in order to support native animal species such as the Brush Rabbit, quail, butterflies, and songbirds. The first goal of California Rose restoration ought to be to conduct a survey in order to gain knowledge of existing patches of California Rose. The second goal should be to determine areas that have great potential to support introduced California Rose. The third goal should be to alter areas that could have potential to support introduced California Rose but currently require habitat modification such as removal of invasive species or chemical, geological, hydrological, or topographical modifications. California Rose should be revegetated based on the conditions prescribed in the following sections. These goals will be accomplished through transplanting individual California roses to appropriate or appropriately restored habitat. Success will be measured by the persistence of or growing of California rose habitat patches, the decrease in topsoil lost, and the increased resilience of the restored habitat to takeover by invasive species.

Revegetation Preparation: In preparation of restoration of California Rose in the wild, seeds ought to be carefully collected throughout July and August while the fruits are deep red and the collected seeds are hard (Young, 2014). Germination requires about two years due to the need of warm periods after cold spells, although scarification and storage for a few months can possibly expedite this process (Young, 2014). California rose seeds ought to be grown in D40 sized containers in a controlled greenhouse until the individual California Rose's roots firmly plug the container bottom (Young, 2014). After shoveling loamy soil, ideal for California Rose, into racks filled with the containers, the racks should be tamped to limit the empty space between soil particles which could lead to water loss (May, 2010). Seeds ought to be planted to a 1-2 inch depth. When the height of the plant equals the height of the container, it is ready for pruning or sowing if it is the right time for sowing: beginning of April (Young, 2014). This typically takes two years after collection for these seeds to germinate. These methods combined with greenhouse care during initial growth will ensure that individual California Rose species are off to a good start, and California Rose tends to have a high survival rate when it comes to replanting; they usually take 1-2 years to reach the water table, and management can turn to monitoring (May, 2010). To increase the potential for California Rose success from replantings, hybridization with nonnative cultivated roses that are not native can be helpful (Circuit Rider Productions Inc., 2003).

Conservation:

California rose is currently largely growing in Western dogwood thicket habitats along riparian zones (Geologic Information Center, 2014). We can analyze the ways in which California Rose is being threatened and the conditions that it thrives in. There might be specific areas where California Rose resides where it is witnessing increased growths, and there might be areas where it currently resides where it is experiencing reduced growth. Comparing the various patches and analyzing the differences between there conditions will aid in the development of a plan to increase California Rose presence across the Central Valley (Harris et al., 2006). Influencing factors that ought to be considered include microclimate, soil and water chemistry, water quality and movement, nearby plant species, proximity to developed areas, competitive species, hillside orientation (if applicable), geology, mutualistic relationships, pollinator and herbivore abundance, and soil properties.

Conservation of these existing patches ought to then commence. Removal of Arundo, Blue gum eucalyptus, and Salt cedar can aid in California rose growth facilitation. If management plants for other native species conflict with the required management of the

California Rose, then buffer zones will be required to ensure that these two systems can both be restored (Harris et al., 2006). Indeed, if two native species that require opposing restoration plans reside in the same place, they are likely not evolved to be a part of the same ecosystem, and, therefore, management plants ought to be carried out in separate physical areas.

Focus on conserving existing patches of California Rose should initially place greatest emphasis on the sites that are likely to continue hosting the species and, more importantly, the areas with the greatest patch size and other plants which naturally thrive in the same community as California rose, including Western sycamore, Toyon, White sage, and Prickly-pear (Harris et al., 2006). By conserving larger patches of the California rose's habitat and initiating restoration plans that will make those patches increasingly larger, patch strength is more likely. Focus should then be gradually shifted to the smaller patches of current California Rose that surround the larger patches. It is likely that larger patches of California Rose will require less active restoration, and the presence of a large patch will contribute to higher gene flow into the smaller nearby patches.

Reintroduction:

After focusing time, energy, and funds on the conservation of current California Rose patches in the California Central Valley, focus ought to be placed on the areas which are likely able to support the species. Introduction of California Rose species into these areas ought to commence, given that there are no conflicting restoration plans as described in the previous conservation section. Surveys should be conducted to assess hydrology, microclimate, soil, geology, water quality, shading, and current plant community in order to determine which areas that have great potential to host California Rose. Of those potential areas, the ones that currently experience the least amount of human disturbance and are likely to continue doing so ought to be considered first for vegetation of California Rose; this is due to the fact that human development and disturbance can very quickly alter these site characteristics (Harris et al., 2006). Similar to the methods utilized for conservation, reintroduction of California Rose ought to commence beginning with focus on the development of a large patch followed by the development of smaller nearby patches. Since the California Rose is a woody shrub that can reproduce quickly with the help of pollinators, the focus of patch establishment will increase the likelihood of pollination (Harris et al., 2006). Lone species are less likely to be pollinated due to their isolation from other shrubs and their visiting pollinators (Seifan et al., 2014). Conducting reintroduction in this manner is beneficial for many reasons. For example, this method does not require a large area of suitable habitat. Habitat modifications have made vast expanses of undisturbed habitat rare in the Central Valley, and, therefore, taking advantage of the suitable habitat patches will increase the potential for California Rose reintroduction (Harris et al., 2006). Revegetation actions should be followed as described in the previous Revegetation Preparation section. As a clarification, this is meant to be conducted in areas which currently do not host any serious threats to California Rose such as an invasive plant or animal species.

Habitat Modification:

The last area of focus of the restoration plan for California Rose is perhaps the most challenging: areas which have the potential to be suitable habitat for the California Rose, namely near riparian systems, but have been altered in such a way so that the area no longer has that potential (Harris et al., 2006). Due to runaway agricultural development, damming, and the aqueduct systems, many riparian areas in the California Central Valley have been drastically altered. This renders the restoration of California Rose by means of habitat modification particularly daunting. Since California Rose provides the ecosystem service of stabilizing slopes, thrives in riparian systems, and can tolerate seasonal flooding, the first places which ought to be surveyed for California Rose introduction after habitat modification are the minimally altered portions of riparian systems within the Central Valley. In order to carry out restoration into disturbed areas, removal of invasive species that threaten the growth of the California Rose must occur (Harris et al., 2006).

Removal of the aforementioned invasive species that reside in suitable California Rose habitat is not easy due to the aggressive nature and rapid reproduction of the plants (United States National Arboretum, 2008). However, since invasive plants occur in so many places throughout the Central Valley, this task of removal is likely necessary.

Transplanting:

Ideally, the reintroduction of California Rose by transplant in fall – in time for the wet season—along riparian zones and on hillsides would lead to stabilization of the soil that could then facilitate the reintroduction of other native species that also naturally thrive in those types of ecosystems. The California rose would need to be irrigated via water-efficient drip irrigation or surface watering until about one year after transplanting. In order to aid in the restoration of California Rose, assessments of pollinators within an area would occur. This will likely occur in areas where nonnative or native flowering plants already occur. By reintroducing California Rose in close proximity to these plants, there is a greater likelihood that California Rose will be able to be pollinated; this means that the period of intense restoration intervention would be less intensive, and mere management and monitoring can occur earlier. Once the removal of invasive species occurs, which is no easy task, in order to keep them at bay, buffer zones of management ought to be established around the native California Rose individuals that have been established.

Since invasive plants can spread quickly, monitoring the area 100 feet around the California Roses will assist in the preservation of revegetated California Rose.

Management and Monitoring:

Management of the revegetated and conserved patches of California Rose ought to occur until the patches begin to reproduce and spread on their own. Transplanted California Rose that was germinated in the manner previously discussed in the Revegetation Preparation section will likely require watering, winter pruning, and competitor (such as the Delta tule pea) removal for the first year or so (Young, 2001.) Increased patch growth can be measured by increased physical space filled by and the persistence of native California rose plant community. Increase in number of patches can indicate success if this phenomenon is occurring simultaneously with the persistence of or growth of patch size, as previously described. The continued stabilization of soils following a heavy rain or flooding event can be measured by the loss of topsoil; once less topsoil is lost from erosion or runoff than previous flooding or heavy rain events of similar magnitude, restoration has begun experiencing success. These measures are indicators that management can be weaned and monitoring may take over. Depending on the soil and topography of the site upon which California Rose is transplanted, more frequent watering, pruning, and soil movement may be required to ensure that the California Rose is establishing itself in the correct manner as to carry out the ecosystem function of soil stabilization (United States National Arboretum, 2008). Monitoring of revegetated California Rose ought to continue for several years. How long monitoring ought to continue is becoming less and less predictable due to global climate change (Harris et al., 2006). Since climate change is leading to biome shifts, microclimates within the Central Valley might alter ecosystems. Conditions that California Rose thrives in might change. The drought of 2013 was one of the worst droughts in

California history (Wang et al., 2014). For events like these in the future – as well as intense rain events that will likely occur – management and monitoring might become more and more important.

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Silver bush lupine (*Lupinus albifrons*) Alexander Rodriguez

Lupinus albifrons

Common Name: Silver Bush Lupine

CLASSIFICATION

Kingdom: Plantae
Phylum: Tracheobionta
Class: Magnoliopsida
Super Order: Rosanae
Order: Fabales
Family: Fabaceae
Genus: *Lupinus* L.
Species: *Lupinus albifrons* Benth.
(Young 2001)

BACKGROUND AND JUSTIFICATION

The *Lupinus albifrons* or more commonly known as the Silver bush lupine are a perennial flower having a normal life cycle of around two years that grow to heights and widths of 3 to 5 feet. It is native to both California and Oregon its range is from Southern Oregon to Northern Baja. Also it should be noted that the *Lupinus albifrons* is not an endangered shrub.

The Silver bush lupine has a multitude of important roles that it can play such as being able to attract beneficial insects such as bees and butterflies which are native pollinators of L. albifrons. It also should be noted that it plays an important role as a host for the endangered Mission Blue Butterfly. *Lupinus albifrons* is known to be used for erosion control as well as restoration purposes since it can use nitrogen-fixation for low maintenance landscape purposes. Silver bush lupine has a very appealing fragrance and vibrant beauty that have been known to be favored by humans along walk and bike paths. The planting and introduction of the Silver bush lupine alongside other natives would help to stabilize slopes as well as bring in more diversity by the attraction of pollinating insects and fixing nitrogen to enrich the soil. The *L. albifrons* provide a stabilizing force in ecosystems once introduced due to a combination of its roots that help stabilize soil preventing erosion, attraction of pollinators increasing biodiversity, and the ability of nitrogen fixation.

Fact Sheet

Life Cycle

Growth Characteristics

-Grows to a height and width of around 3-4 ft. and is Perennial (having a normal life cycle that exceeds two years.) (Annie 2013)

-*L. albifron* flowers in March or April in a single burst of blooming, and seeds are dispersed in early May. (Torres-Lezama 1989)

Reproduction

-Mortality studies carried out in wild populations revealed a low seedling survivorship, which was largely attributable to drought. (Torres-Lezama 1989)

-It has been shown that Seedlings from larger seeds which are considered equal or greater than 30 mg emerged earlier and grew much more rapidly. (Torres-Lezama 1989)

-Lupinus albifrons seeds germinate 14 days after planting. (Torres-Lezama 1989) Their germination can be stimulated by scarifying seeds by nicking them with a sharp knife. (Koomas 2003)

-In a study they found a significant increase of seed pod production following visits from insects visits and found that this increase was attributed to induced self-pollination by insect tripping (depressing of the keel petals). (Torres-Lezama 1989)

-The main mode of seed dispersal is by being carried and dispersed by small rodents such as mice. The seed type is a legume and is know as a high protein source and is attractive to small rodents.

Range and Distribution

-Lupinus albifrons range varies from Southern Oregon to Northern Baja. (Young 2001)

-It has been found as native in areas in which there is an 8" to 35" rainfall average. (Young 2001)

-Lupinus albifrons has been surveyed to being found in rocky and sandy places that are below 4,500 ft. (Torres-Lezama 1989)

-Lupinus albifrons are typically found in multiple plant communities that include coastal sage scrub, chaparral, northern coastal scrub, foothill woodland, and yellow pine forest.

Growing Conditions

-It will allow for some water collecting in the summer but it is better for this plant to be on the dry side. (Wilson 2013)

-Silver lupine needs to be planted a little above soil grade in sunlight with access to good drainage during the late fall to take advantage of winter rains and it grows well in lean soil. (Wilson 2013)

-Soil Ph levels are found to be from 6 to 8 and by USDA 6 to 10 (Torres-Lezama 1989)

-The Silver Lupine is tolerant to cold up to -10 degrees when it is planted. (Young 2001)

-Lupinus Albifrons is known to tolerate some sitting summer water but it is suggested that it be kept on the dryer side with adequate drainage. (Wilson 2013)

INTERACTIONS

Wildlife

-Host for the endangered Mission Blue Butterfly. (Annie 2013)

-Attracts Beneficial Insects, Bees, Butterfly, and Other Insect Nectar (Wilson 2013)

-A food source for snails and slugs in communities (Wilson 2013)

-When plants are young they may not have built up enough of the alkaloids that gives them a bitter taste and deters deer. So protection of young plants until they can be established is essential. (Annie 2013)

-Seed loss of the Silver Lupine to various predations is small. (Torres-Lezama 1989)

Plants and Pathogens

-The Silver Lupine seedlings that were large (greater or equal to 30mg) showed a strong ability to compete with annual exotic grass, and were found to be more likely to emerge than seedlings from small seeds (equal or less than 28mg). (Torres-Lezama 1989)

-There are no diseases that were observed as significant. (Wilson 2013)

THREATS

-Past field observations have hinted at a possibility of grass competition on the Silver lupine to suppressing its establishment. (Torres-Lezama 1989)

-Loss of habitat is a serious threat since it takes time for the Silver bush lupine to establish and needs protected habitats to survive if there are many herbivores in the area.

MANAGEMENT POINTS AND FACTORS TO CONSIDER [SUB SECTIONS]

Possible uses

-It is known to be used for erosion control once established in a community (Wilson 2013)

-*Lupinus albifrons* is a very low maintenance plant once established into a community (Wilson 2013)

-*Lupinus albifrons* has the potential use for nitrogen-fixation for low maintenance landscape purposes. (Torres-Lezama 1989)

Germination

-It was shown that only seedling from larger seeds (< or equal to 30mg) possess enough competitive ability to establish in closed grass stands. (Torres-Lezama 1989)

-To stimulate see germination in the silver lupine you can bury seeds under bare soil and grass litter, since this helps naturally scarify the seeds which you can also perform by hand using a sharp knife to knick the seeds (Torres-Lezama 1989)

Transplanting

-A process that was suggested for establishing silver lupine instructs that Seedlings should be transplanted "14 days after germination from original containers to individual 2" by 7" tubes which contain a standard potting mix of peat moss, fir bark, perlite, and sand. The Length of this process is around 28 days. (Torres-Lezama 1989)

-It should also be noted that survival averages of transplant survival averages around a 75% (Torres-Lezama 1989)

-Suggested methods of fertilization include using Nutricote NPK two months after transplanting the plant. (Torres-Lezama 1989)

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Part II. Goals and Management plans focused on Lupinus albifrons

A. **Goals**

1. Conserve existing patches

This goal as stated is to conserve the existing patches of *Lupinus albifrons* in order to make the increase in population of this species more prevalent at this site. Success would be measure by being able to conserve existing patches for *L. albifrons*. Preserving the existing patches of *L. Albifrons* helps with our aim to overall maintain and increase *L. albifrons* population because it is a very low maintenance perennial plant once established into a community (Wilson 2013). There is also a need to take into consideration the flowering time of *L. albifrons* in case there is a desire to use fire or flooding as a management for neighboring species. Since *L. albifrons* flower in March or April in a single burst of blooming, and seeds are dispersed in early May there would need to be an avoidance of fire treatment during these times (Torres-Lezama 1989). These implications of course apply if there are already existing patches of *L. albifrons* present on the sites in question. If this is not the case then we simply proceed to prioritize our second goal for management of *L. albifrons* on this site.

2. Establish viable patches

Establishing viable patches consisting of scrubland plant community, which can also be categorized as reaching mature standards (average patch size described in the next sentence), which also directly helps to increase the amount of patches that *L. albifrons* are capable of using in order to increase population sizes of the species. In order to establish more viable patches which have an average patch size that spreads ~5-7 feet, an average height of 5-6 feet, and a spacing of 5-7 feet between we can maximize the ideal situations for *L. albifrons* at the sites in question (Gold 2014).

Factors that need to be considered for this goal are that the *L. albifrons* needs to be planted a little above soil grade in sunlight with access to good drainage during the late fall right before winter starts (Wilson 2013). This time frame would be aimed around November to catch the beginning of the fall showers. Also the *L. albifrons* needs to have plant protectors surrounding it in order to keep pests such as slug and other predators from preventing proper establishment. This goal is important because this can increase the spread of the population of *L. albifrons* which is beneficial to the continued success of the species due to the fact that by covering more locations the plant will have more access to pollinators and potential for wider seed dispersal.

3. Creation of a Monitoring protection plan

When *L. albifrons* are young they have not built up enough alkaloids to give them a bitter taste that deters deer and other pests from eating them and research has been unclear at exactly what point these develop but they indicate that this occurs around 2-3 months after seedlings have developed (Torres-Lezama 1989). The goal is to have a successful growth of L. albifrons after transplantation onto the site, monitoring, and protecting the patches of L. albifrons for up to 3 years in order to properly determine successful establishment. In order to achieve this we need to allow the L. albifrons to grow to a state in which they are no longer juveniles on the first transplant therefore possessing the alkaloids which would take around 3 months of growing time in a greenhouse. Therefore a close monitoring and plant protection of the early development of the shrub would be highly beneficial and drastically increase its chance of survival and once established *L. albifrons* require low maintenance (Wilson 2013). With a generation of a protection plan for the early stages of the plants germination and growth you can increase the chance of establishment and survivorship of *L. albifrons*.

A. **Restoration Management Plan for *Lupinus albifrons***

The initial step that should be taken is to determine the locations on the site that are suited to be patches for Lupinus albifrons. There would need to be a measure of the soil ph since the levels that Lupinus albifrons are found at are from 6 to 8 Ph and by USDA 6 to 10 (Torres-Lezama 1989). Also sites in the sunlight and with access to good drainage are needed since Lupinus albifrons are known to tolerate some sitting summer water but it is suggested that it be kept on the dryer side with adequate drainage (Wilson 2013).These sites would at minimum need ~10-14 feet of spacing between each of the shrub patches due to the fact that on average the shrubs grow to be ~5-7 feet long and ~10-14 feet would provide ample adequate spacing (Gold 2014). An assessment of the wildlife surrounding these sites is necessary since past field observations have hinted at a possibility of grass competition on the *L. albifrons* to suppressing its establishment (Torres-Lezama 1989). Another favorable attribute to take into consideration is the presence of foraging mammals since it has been found that seeds are often carried and dispersed by small rodents such as mice you would want to increase dispersal rates by choosing locations that are known to have a lot of small rodent activity.

After locations have been chosen there are two ways to proceed with introduction of *L. albifrons* to these new locations. One option is to order seeds that come from plant nurseries in which the conditions are similar to the sites. A method that is used is to grow these seeds in the greenhouses would be to sow the seeds into 2"x7" tubes which have a mixture of peat moss, fir bark, perlite, and sand. The dimensions are that the seeds are planted two times its diameter in regards to its depth. These containers are then watered with an automatic irrigation system the length of this process is around 28 days, after that seeds are sown in June. In this situation the percent of germination success is about 65% (Young 2001).

The second option that can be taken is to take seeds from already present *L. albifrons* preferably seeds that were large (greater or equal to 30mg) in which they were shown to have a strong ability to compete with grass, and were found to be more likely to emerge than seedlings from small seeds (equal or less than 28mg) (Torres-Lezama 1989) and plant these seeds on these locations by scattering them on the location and using a rake to rake them in. These seeds would be planted a little above the soil grade in lean soil within late fall to take advantage of winter rains. Checking on these seedlings once to twice a month until sprouting is advised with giving the plant around one inch of water at these times (Wilson 2013). This part of the process would be for the first 4-5 months until after their alkaloids develop fully. The difficulty is to monitor the progress of these seeds since the legume seeds are small possessing a color that blends into the background. This option is much more difficult since instead of the assurance of a transplant operation the seed growing on the site is subject to being eaten by animals, carried off from intended location by wind or rain, and failing to sprout at all. You would gauge this by the percent of the patch that is filled and if the patches are over 60% filled by the end of the first perennial cycle then this would be considered a success.

In both options to protect the growth of *L. albifrons* it should not be given fertilizer since the fertilizer can kill the symbiotic relationship with *L. albifrons* and the nitrogen fixating rhizobia in the soil (King 2014). *L. albifrons* is vulnerable to snails, caterpillars and slugs in which can be eaten by ducks, turtles, and predatory snails or you can also use handpicking to get rid of these pests. For protection from these pests you can go with the first introduction option and grow the Lupinus albifrons in a greenhouse until it has built up alkaloids, this can be around 3 to 4 months from seedling development, that give them their bitter taste in this situation the transplant survival average is at 75% (Young 2001). Therefore increase establishment growing the seedlings in a greenhouse and transplanting to the site is favorable. To improve the speed of germination you can scarify seeds by nicking them with a sharp knife (Koomas 2003). This plant after being established into a community *L. albifrons* is a very low maintenance plant and would not require much monitoring after this establishment which includes setting up a drip irrigation system to keep the soil in a lightly damp state when there are dry spells but turned off during rainy times in order to prevent drowning the roots. You would use this irrigation system for the first year and can remove it the summer after transplantation has occurred.

Monitoring of the patches to view success over 3 years would be ideal with checking in on the patches 1-2 times a month to view progress over the first 6 month of each year since they come into reproductive age following the first year of establishment during this time you will log neighboring plants conditions and soil quality at each patch. You would want to monitor during 3 years because of the nature of the average life cycle being perennial and concluding around 2 years of living. Therefore 3 years would be appropriate so that the patches can be assessed after the parent generation has died off. The needed stable establishment of *L. albifrons* and to see the success of the first few generations to make sure they are constantly maintaining adequate survival to maintaining desired patch sizes.

Research that can be done to improve this plan is site research regarding conditions such as frequencies of fluctuations in natural conditions (such as fires or floods) since mortality studies carried out in wild populations revealed a low seedling survivorship, which was largely attributable to drought (Torres-Lezama 1989). Also there is little data on the development of alkaloids in this species and if more information is provided you can obtain a better timeframe for growing the *L. albifrons*. This allows the development of a more accurate management plan.

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Western redbud (*Cercis occidentalis*) Erik Grijalva

Project *Cercis occidentalis* (western or California redbud)
Part 1: Project Background and Justification
Background and Justification
Cercis occidentalis (western or California redbud, also *Cercis orbiculata*) is a native California deciduous shrub whose range extends into Arizona, Nevada and Utah. It is a close relative of *C. Canadensis* (eastern redbud) which is more commonly used in horticultural applications. Both species provide year-round interest: showy pink to purple flowers in spring, burgundy seed pods in summer through fall, and unique heart-shaped light green leaves in summer that turn bright yellow in fall. This leguminous (Fabaceae, Caesalpinioideae) shrub can reach 20 feet in height and attains a dense, rounded form at maturity. *C. occidentalis* rarely forms uniform stands across its range, generally establishing as scattered members of a shrub communities or open woodlands. As a component of a native plant community, *C. occidentalis* contributes to soil stabilization via a dense root network which can withstand both periodic flooding and drought conditions once established. It also provides nectar to both native and introduced bee species and other pollinators, may fix nitrogen for soil enrichment, and has historically been extensively used by Native Americans as material for basket weaving. Additionally, its dense branching structure often provides cover for nesting birds.
C. occidentalis has a generally stable population across its range which is somewhat enhanced by propagation and trade in native plant restoration and horticultural applications. A difficulty for restoration projects is obtaining sufficient stock for inclusion into planting designs. Many available plants are small (and expensive) and may therefore be difficult to establish. The seeds evolved to respond to the heat provided by fire scarification, and where fire has been excluded from the landscape, seed germination must be assisted. Inclusion of *C. occidentalis* in a restoration planting palette provides many ecosystem services in the form of a tough, beautiful plant that can tolerate a variety of soil and environmental conditions. Additionally, *C. occidentalis* can provide aesthetic interest on the borders of restored habitats and potentially allow for restoration of historic cultural practices into restoration design. The overall goal of my interest in *C. occidentalis* is to provide support for inclusion of the species in restoration design.

Literature Review: Species attributes and ecosystem services
 Nitrogen fixation – *C. occidentalis* is a nitrogen-fixing legume that forms a symbiosis with *Rhizobium* bacteria. An early-branching member of the pea family (Fabaceae, Caesalpinioideae), *C. occidentalis* does not form root nodules as do later-branching legumes (Fabaceae, Papilionioideae). However, the N-fixing ability of California redbud allows the plant to survive in N-limited sites, contributing nitrogen-rich leaf litter to the organic layer of soils. This may provide increased habitat availability for associated restoration plantings, but may also provide a competitive advantage to invasive plants over natives adapted to N-limited soils. (Liang and Harris 2005, Adkins 2012)

 Pollinator support – *C. occidentalis* can provide an important early-spring source of nectar for around 40 spp. of both native and introduced bee species. Bumble bees (*Bombus spp*.) orchard mason bees (*Osmia spp*.) and European honeybees (*Apis mellifera*) may use this resource along with various species of flies, beetles, butterflies and other insects. Integration of

C. occidentalis into restoration planting schemes can enhance habitat for pollinating species. (Andersen 2002, Kremen et al. 2002, Andersen 2006, Hauser 2006, Long and Anderson 2010)

 Soil stabilization – *C. occidentalis* has a dense, interconnected root system that is tolerant of some inundation in well-drained soils that do not have standing water. As such it can be an important component of the upper edge of riparian corridors. Additionally, once established, the root system can survive prolonged drought. Plants can be found growing in rocky outcroppings and steep, dry exposed areas. *C. occidentalis* may therefore play a role in stabilizing soils in restoration settings, including clay and alkaline soils. (Andersen 2002, 2006, Hauser 2006)

 Cover for birds, mammals, insects – The thick, sometimes dense network of stems, leaves and previous-season seed-pods found in mature plants of *C. occidentalis* provide shelter and nesting support for various bird species. (Long and Anderson 2010)

 Cultural services

Horticulture – California redbud is most prized for the splash of early spring color provided by magenta or pink pea-like flowers that precede leaf unfurling on bare branches. The cordate (heart-shaped) leaves begin as lime-green and turn a darker blue-green over the course of the growing season, eventually turning a bright yellow in the fall. The seed pods begin as a light apple-green and move through burgundy to a charcoal grey after leaf-drop. Plants can grow up to Plants respond well to pruning and can be kept in both tree-like and bush forms. Plants can grow to 20 feet or more in optimal conditions and be cut to the ground to force growth of new shoots or the re-establishment of the entire plant. *C. occidentalis* can fit well in xeriscape applications in well-drained soils or as a background planting in mixed perennial borders. It is resistant to most pests and infections, though it may be susceptible to oak root fungus in overly wet soils. (Brenzel , Bornstein et al. 2005, Baldwin et al. 2012)
Basket weaving – the young shoots of *C. occidentalis* were highly prized by some Native American tribes for the wine-red branches. As branches age, the bark turns grey. Stands of the plant were induced to produce new vigorous shoots either through selective cutting of the plants, coppicing or via application of fire. Wild growth in redbud produces relatively stiff, brittle branching architecture, whereas new growth is generally straight and exhibits flexibility in terms of the elastic and tensile strength properties coveted for bending in basket weaving. Baskets may have required 25-50 2-meter shoots each, depending on the type of basket constructed (cooking, seed gathering, sifting), an amount much more difficult to obtain from wild, uncultivated plants. Tribes that utilized *C. occidentalis* in this way include Yosemite Miwok, Pomo, Wukehumni Yokuts, Yuki, Northern Maidu, and Mono. There is also evidence that the Patwin (and other Wintun), native to Solano County, utilized redbud shoots in the same way.(Anderson 1999, Anderson 2000)

 Fire – *C. occidentalis* readily re-establishes after fire, resprouting from root crowns from mature plants or from seed stored in a seed bank. Fire was used by Native Americans in *C. occidentalis* habitat for many purposes, including for production of basket making materials. The hard outer layer of the seed requires heat to break seed dormancy, and indicates that the plant likely adapted to periodic fire over its range. (Anderson 1999, Andersen 2002, 2006, Hauser 2006)

 Propagation and Establishment– *C. occidentalis* is a fire-adapted species and the hard seed coat requires heat scarification to break embryo dormancy. A typical way to simulate fire in propagation is to soak *C. occidentalis* seeds in boiling water (93°C, 200°) water that is allowed to subsequently cool overnight. This process is repeated, and the seeds are then immediately planted in a planting medium, or chilled under peat for up to 2 months. Young plants are provided fertilizer to speed growth. Plants are ready for outplanting after 7 to 8 months. *C. occidentalis* shoots have been shown to respond well to formulations of rooting hormone, rooting an average of 58% of the time. However, propagation by seed is a more cost-effective approach for restoration applications that require larger numbers of individuals. Once outplanted, young plants may require supplemental irrigation for summer months for optimal growth. (Pooler and Dix 2001, Andersen 2002, Keeley 2005, Andersen 2006, Hauser 2006, Palmerlee and Young 2010, Adkins 2012)

 Management – *C. occidentalis* should require little management once established, especially in ‘wild’ or ‘natural’ restoration applications. It does respond well to fertilization and targeted summer watering within the first 5 years of growth, but it is not required. Pruning or coppicing are documented ways to manage unruly growth or produce new red shoots where a more formal restoration border or cultural product is desired. Pruning should be done in fall, winter or early spring when the plants are dormant. Flowers form on the previous season’s growth, so flowering will be diminished in the year following pruning. If desired, plants can also be shaped into small trees through selective pruning of side shoots in young plants. (Andersen 2002, Bornstein et al. 2005, Hauser 2006, Adkins 2012)

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Part 2: Project Goals and Management Plan

Ecosystem Background

California’s Great Central Valley has been highly modified from historic conditions that existed prior to European-American occupation. Agriculture, industry and urbanization have transformed the vast majority of the valley into a managed landscape that little resembles the ecologically complex river valley and delta it once was. These modifications have introduced exotic species, changed hydrology, modified animal and plant communities, introduced high levels of nutrients and toxins, and overexploited most available resources. The landscape that exists today contains only a scattered few remnant patches of habitat that preserve some of the ecological character of the historic valley. Restoration of areas historically used for agriculture or other intensive activities provides an opportunity to steward ecological resources toward a sustainable, native-rich and biodiverse future more able to adapt to changing climates and land-use patterns.

Within that overarching restoration structure, this project examines the contribution of a single species, Western Redbud (*Cercis occidentalis*), to restoration of disturbed communities across the Central Valley. Historic distributions of *C. occidentalis* within the valley proper are difficult to come by, but current distributions, the adaptable characteristics of the plant and extent of Native American cultural use of the species indicate that *C. occidentalis* was a significant component of many ecological communities across the valley. Where these communities exist in fragmented form or where restoration activities are planned, *C. occidentalis* is a species that can provide a suite of ecological and cultural benefits to enhance the performance of restoration projects.

Project Goal

Inclusion and establishment of sustained populations of C. occidentalis on restoration sites.

Populations of *C. occidentalis* are well-distributed within California, especially along the Coast Ranges and Sierra foothills that surround the Central Valley. As such, the species does not require any specific conservation or restoration based on rarity or threatened status when considered statewide. However, given the heterogeneity of the habitats in the valley before the advent of large-scale land conversion, it is reasonable to assume that the species played a larger role in upper riparian and upland habitats that bordered the complex network of waterways within the valley than is currently the case. *C. occidentalis* is generally not absent from native restoration planting palettes in the valley, but could play a more prominent role as a component of shrubby understory or mixed woodland plantings throughout the Central Valley, especially in the central and north-central portions. (Andersen 2002, Hauser 2006, Baldwin et al. 2012)

Restoration Plan

I. Propagation

II. Establishment

III. Monitoring/Mainenance

IV. Research

V. Conclusions

I. Propagation

Seed Collection

Redbud seed is produced from legumes that mature in late summer to fall. The seed pods persist on the plant through the following growing season, but the seeds are generally released by mid-winter as the pods dehisce. Seeds are mature after the somewhat fleshy, burgundy seed pod dries and turns brown. Seed can be collected via breaking open the dried seed pods and separating the hard individual seeds from the interior. Seeds can be stored for future use in paper bags kept in cool, dry environments out of the sun. It is important to carefully choose donor sites for seed collection. The areas around potential restoration sites may provide the greatest opportunity to incorporate localized ecotypes into the planting palette but several factors must be considered before any particular individual or population of plants is chosen as a donor site. If *C. occidentalis* can be located in proximity to the planned restoration site in a similar habitat type, it can be considered a potential candidate as a source population for propagules used in restoration.

However, since redbud is often incorporated into horticultural applications that stress plant traits that may differ from the habitat requirements of the site (flower color, flower size, leaf shape, growth form, etc.), plants proximate to restoration areas may have origins in populations from other locations within the species range (or may even be individuals of the closely related, and similar appearing, species *C. canadensis,* Eastern Redbud). If possible, a historic analysis of land-use in the area (ex. former farmhouse, garden, park) may point to transport from distant locations. If one can be reasonably assured that the nearby population is of a localized origin, the number of plants present should be analyzed carefully. There is no specific rule on how many plants might constitute 'enough' to accommodate seed harvest, but as a rule-of-thumb, no more than 10% of the seeds on a site should be taken in a 7-10 year timespan. For a single harvest event, or where there are few plants present, a conservative approach would only allow for less than 5% of the seed crop to be harvested.

Scarification

Once seeds have been collected they can be prepared for propagation. *C. occidentalis* is fire-adapted and therefore requires heat scarification to end seed dormancy and enable germination. In restoration settings where prescriptive fire is incorporated as an ecological restoration or management tool, redbud seeds should be broadcast in targeted fire areas prior to the prescribed burn. This may be especially beneficial where the planned burn precedes a rain event or the rainy season to allow newly establishing seedlings sufficient moisture. Where site conditions preclude use of fire, several techniques are available for scarifying the hard seed coat of redbud and breaking dormancy. The simplest method is to put seeds in a pot and pour boiling water over them until they are covered. The water is allowed to cool and the seeds sit in the water for 24 hours when the process is repeated. Any seeds that float are considered non-viable and removed. After the second 24-hour period has elapsed, the seeds are ready to plant, or they can be chilled for up to several weeks in peat. Other methods for scarification have been suggested that include nicking the individual seed coats with scalpels (or similar), soaking in a strong acid overnight, or placing the seeds in a paper bag and setting the bag on fire. Some sources recommend up to 3 months of cold stratification in moist soil following scarification treatments, while others forgo this step (Keeley 2005, Andersen 2006, Hauser 2006, Palmerlee and Young 2010, Adkins 2012).

Seedling management

Once scarified, the seeds can either be directly outplanted to the restoration site or grown in a nursery setting in a well-drained, sterile nursery soil mixture. The soil should be kept moist until germination, when the soil should be allowed to dry down to avoid fungal infestation. When plants have two true leaves they can be transplanted to larger containers. Though redbud is a N-fixing plant, it can benefit from fertilization during early growth, especially in a container. Plants are generally ready for outplanting after 7-8 months.

Horticultural work with *C. occidentalis'* close genetic cousin *C. canadensis* has developed processes for using softwood cuttings for propagation. *C. occidentalis* itself has been shown to respond moderately well to rooting hormone under controlled conditions. Research on *C. canadensis* from commercial growers on the east coast indicates that hardwood cuttings are much less successful material for rooted cuttings. Once rooted, plants can be cared for under the same conditions outlined above for plants generated from seed (Pooler and Dix 2001, Keeley 2005, Palmerlee and Young 2010).

II. Establishment

C. occidentalis occurs in a wide range of ecological settings within its range. As such, it can generally tolerate the disturbed settings found most restoration sites. Soil preparation should not be necessary prior to outplanting as redbud occurs on many types of soils including the clay soils typically found in the Central Valley. Siting of plantings should concentrate on sunny areas though it can tolerate limited shade where it responds with less flowering. Sites along seasonal watercourses, dry, shrubby slopes, streambanks, and foothill woodlands are among the areas where it will thrive. Elevations in the Central Valley are generally at the lower end of redbud's range of 400-5000 feet, though suitable localized habitats, soils and exposures within this range serve to expand the area able to support the species (Bornstein et al. 2005, Andersen 2006, Hauser 2006).

Seedlings should be planted at the start of the rainy season in October or November to take advantage of higher soil moisture levels through the winter season. Where rains are limited during drought conditions or late arrival, plants will benefit from supplemental irrigation during the first year or two of growth. After the first year, established plants may not require additional water, but will still respond to additional allocations of water with increased vegetative growth. Plants may also benefit from fertilization during the first year or two of growth, though it is not required as the plants are nitrogen fixers.

In natural environments, redbud generally occur in mixed stands with other shrubs, in open woodlands or as individual plants, though they are known to occur in uniform stands on occasion (Hauser 2006, Baldwin et al. 2012). In a restoration setting, spacing of plantings can be tailored to the goals of the restoration project. The considerable horticultural value of the species can allow for a solid, denser planting distance (2-4m on center) for a high visibility border or woodland transition, which also provides habitat value for animal species that utilize the woody thickets provided by the plant's branches. In other applications, plants can be interspersed with other shrubs, situated on the edge of open grasslands or forb-planted areas at wider spacing distances.

III. Monitoring and Maintenance

Redbud plants can be maintenance-free once established, requiring little supplemental water and no fertilizer. However, they are susceptible to fungal infections during wet conditions, especially during the first year or two following germination. The US Forest Service identifies a fungal canker (*Botryospaeria ribis* and *B. dothidea*) as a particular concern. Plants may also be periodically grazed by deer, birds and other animals, especially when the leaves are freshly emerged in the spring. Caterpillars can also be a problem on western redbud, as can the fruit tree leafroller. Both can be effectively controlled with *Bacillis thuringiensis* (BT) formulations (Hauser 2006).

To assess for survivorship of plantings and any subsequent impacts to the health of the plants, a monitoring program should be implemented to track the condition of the site and the plants themselves. Pre-planting, the sites should be assessed for soil characteristics, exposure and plant species composition to determine the suitability for redbud in the planting palette. Especially important in this initial monitoring is to locate areas containing tree species that will develop extensive shading canopies at maturity. These areas may support redbud during the early stages in restoration, but as the plants become shaded as the tree species mature, redbud is likely to be

outcompeted and decline. This characteristic would fit well when successional patterns incorporated into restoration design, but not if a persistent redbud component is desired.
In the first two years of growth, plantings should be assessed for overall vigor, shoot number, plant height and cover, impacts from grazing or insects, evidence of fungal infection, and other metrics to assess the health of the plants. Soil samples should also be taken annually to assess changes to soil composition. Assessments of the amount and color of the flowers can also be made (relatively sparse, lighter-colored flowers indicate sub-optimal lighting conditions). Monitoring should be done at least twice yearly for the first two years, then annually thereafter. Mortality should be noted and, where possible, a causal hypothesis suggested. If site conditions are determined to be sub-optimal for *C. occidentalis*, inclusion of the species in the planting palette should be re-evaluated. If mortality can be attributed to transient, one-time events, or to easily managed stressors, replacement plants should be installed on the site.
Management of plants on the site may also include trimming, pruning or coppicing of the plants if horticultural or cultural values are incorporated into the restoration design. Redbud responds well to pruning, and plants can be shaped into specimen trees to highlight restoration edge areas or focal highlights. If plants are incorporated to provide Native American basketmaking supplies in the form of new, vigorous shoots, mature plants can be coppiced (cut to the ground) every 3 years to provide the colorful new growth prized for this art form (Anderson 1999, Anderson 2000).

IV. Additional Research

Increased understanding of propagation techniques. Side by side trials of scarification techniques on seeds in terms of germination success, outplanting success and long-term plant characteristics would both inform *C. occidentalis* restoration across the plant's range and could also be easily incorporated into restoration plantings across sites.
Improvement of soils. Specific contributions of *C. occidentalis* to N-levels in soils, and soil improvement trajectories from organic matter contributions. This work would provide a quantified justification for including redbud in restoration plantings, and could be tracked over long-term timescales at restoration sites. Various restoration soil types could also be incorporated into this type of research (Liang and Harris 2005, Hauser 2006).
Provision of pollinator support. As one of the earliest blooming spring plants, C. occidentalis has been suggested as a significant contributor to pollinators early in the growing season. Which species utilize redbud, what proportion of contribution is made by the plant relative to other plant species and how pollinator populations respond to varied levels of redbud plants would illuminate another aspect of *C. occidentalis*' role in ecosystem function. Plant numbers and locations could easily be configured to answer these research questions as part of a restoration effort (Andersen 2002, Kremen et al. 2002, Bornstein et al. 2005, Hauser 2006).

V. Conclusions

C. occidentalis plantings can be easily incorporated into most restoration settings within the Central Valley. The plant is an adaptable and low-maintenance member of plant communities throughout its range and provides ecological, aesthetic and cultural resources. Propagation techniques are relatively simple and can be accomplished by experienced and novice growers alike. The conditions observed at the Solano County Resource Conservation District restoration sites indicate that *C. occidentalis* would fit well within the ecology of the sites. The adaptability of the plant allows for integration with other restoration goals for the sites in terms of plant diversity, pollinator support, soil improvement, sediment control and general provision of habitat. Establishment of redbud has a high likelihood of success in these restoration settings, and should be seriously considered as a component of planting design.

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Poison oak (*Toxicodendron diversilobum)*- particularly focus on ecological role of this (e.g. wildlife habitat) Joel Friesen

The Ecology of Pacific Poison Oak

Taxonomic Classification:

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Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Rosidae
Order: Sapindales
Family: Anacardiaceae
Genus: *Toxicodendron*
Species: *diversilobum* (Torr. & Gray) Greene (syn. *Rhus diversiloba*)
Common Name(s): Pacific poison oak, western poison oak
(USDA, 2014)

I. BACKGROUND AND JUSTIFICATION

Pacific poison oak is reviled by nature-goers and more than a few restoration ecologists because of the severe rash that it causes in the estimated eighty to eighty-five percent of people that are allergic to its oils (DiTomaso, 2009). For this reason, its inclusion in restoration plans for degraded, damaged, or destroyed sites has been minimal. However, evidence in the literature suggests that poison oak serves important ecological roles. Indeed, poison oak is one of the most versatile and resilient California native plants and is currently undervalued for its erosion control and food and habitat provisioning capacities.

II. FACT SHEET

A. Range and Distribution
   1. Occurs in California, Nevada, Oregon, and Washington, as well as British Columbia (Howard, 2014)
   2. Distributed from sea level up to 5,000-foot elevations (DiTomaso, 2009)
   3. Is the most widespread shrub in California, being found in fifty of California's fifty-eight counties (Eaton & Sullivan, 2013)
   4. Not an endangered species nor is it protected at the federal or state level (Howard, 2014)

B. Habitat Characteristics

1. Found in mixed evergreen forests, woodlands, chaparral, coastal sage scrub, and riparian zones (Howard, 2014)
2. Tolerates a wide range of microclimates, soil types, moisture gradients, and light intensities, but is most often associated with shallow, well-drained, acidic soils and sloped topography (Howard, 2014)
3. Thrives in disturbed sites, including roadsides (DiTomaso, 2009)

C. Growth Characteristics

1. Grows as a multi-stemmed climbing vine (10-30 ft) or as a shrub (2-6 ft) depending upon presence of support structures (Gartner, 1991)
2. Vines have adventitious roots and may smother or break supporting plants, sometimes killing them (Howard, 2014)
3. Develops a shallow yet extensive rhizome root system often several feet in diameter which prevents topsoil erosion (DiTomaso, 2009)

D. Biotic Interactions

1. Is the most important black-tailed deer (*Odocoileus hemionus columbianus*) browse in some regions of California (Howard, 2014)
2. Horses, woodrats (*Neotoma sp.*), pocket mice (*Chaetodipus sp.*) and to a lesser extent, cattle, sheep, goats will browse on leaves and stems, which contain high concentrations of phosphorus, sulfur, and calcium (Barkley, 1937; Howard, 2014)
3. Acts as nesting site in oak woodlands for California towhees (*Pipilo crissalis*) (Benedict, 2009) and the federally endangered least Bell's vireo (*Vireo bellii pusillus*) (Benedict, 2009; Gray & Greaves, 1984)
4. Studies have linked poison oak woodlands with higher overall bird diversity and density in California (Hehnke & Stone, 1979)
5. Drupes are a food source for California quail (*Lophortyx californica*), red-shafted flickers (*Colaptes cafer*), Lewis woodpeckers (*Asyndesmus lewis*), Nuttall woodpeckers (*Dendrocopos nuttallii*), yellow-billed magpies (*Pica nuttallii*), olive-backed thrushes (*Hylocichla ustulata*), California thrashers (*Toxostoma redivivum*), Fox sparrows (*Passerella iliaca*), golden-crowned sparrows (*Zonotrichia atricapilla*), white-crowned sparrows (*Zonotrichia

leucophrys), bushtits (*Psaltriparus minimus*), Oregon juncos (*Junco hyemalis*), ruby-crowned kinglets (*Regulus calendula*), Northern mockingbirds (*Mimus polyglottos*), red-breasted sapsuckers (*Sphyrapicus ruber*), Audubon warblers (*Dendroica coronata auduboni*), cactus wrens (*Campylorhynchus brunneicapillus*), wrentits (*Chamaea fasciata*), hermit thrushes (*Catharus guttatus*), Swainson's thrushes (*Catharus ustulatus*), oak titmice (*Baeolophus inornatus*), and spotted towhees (*Pipilo maculatus*) (Barkley, 1937)

6. Drupes are reported to be a food source for scrub jays (*Aphelocoma californica*), wild turkeys (*Meleagris gallopavo*), chickadees (*Poecile sp.*), waxwings (*Bombycilla sp.*), and finches (Fringillidae) (Eaton & Sullivan, 2013)
7. Flowers are reported to be pollinated by soldier beetles (Cantharidae), long-horned beetles (Cerambycidae), checkered beetles (Cleridae), burrowing bees (Anthoporidae), and sweat bees (Halictidae) (Eaton & Sullivan, 2013)

E. Reproduction

1. Spreads by seed, ground layering of stems, or by underground rhizomes; plowing acts to propagate rhizomes (Howard, 2014)
2. Digestion of seeds by birds aids in both dispersion and germination (DiTomaso, 2009)
3. Fires of low to moderate intensity (<200 kcal/sec/m^2) also enhance germination rates and promote vigorous re-sprouting from root crowns and/or rhizomes, but fire is not required for regeneration (Howard, 2014)
4. Sexual propagation protocols call for soaking dried seeds in sulfuric acid for 3.5 hours prior to sowing (Evans, 2001)
5. Asexual propagation protocols call for sticking 2-inch long softwood or semi-hardwood cuttings in a coarse rooting medium under mist for 4-6 weeks (Evans, 2001)

F. Key Gaps in Knowledge

1. Climate change should extend the range of Pacific poison oak beyond 5,000-foot elevations. How will this movement into higher elevations alter the

ecosystem dynamics at these elevations and the ecosystem services that Pacific poison oak is able to provide?

2. To what degree might Pacific poison oak be able to out-compete invasive species in disturbed sites?
3. In restoration sites, how densely should Pacific poison oak be planted to ensure that it does not smother neighboring species?

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GOALS:

A. To outline restoration sites for which Pacific poison oak plantings may be appropriate

B. To provide guidelines that can be used to promote establishment of Pacific poison oak stands

C. To detail management regimes to keep established stands from encroaching upon land with agricultural or recreational value

A. APPROPRIATE SITE TYPOLOGIES

Pacific poison oak (*T. diversilobum*) is a species that causes a severe rash in an estimated eighty to eighty-five of humans that come in contact with its oils and therefore should be used with extreme caution in restoration applications (DiTomaso, 2009). Although *T. diversilobum* exists naturally from sea level to five thousand-foot elevations as a member of a variety of plant communities, including mixed evergreen forests, oak woodlands, chaparral, coastal sage scrub, and riparian zones, once established it has the potential to smother slower-growing species (Howard, 1994). Much like its East Coast relative, poison ivy, Pacific poison oak exhibits a vining growth habit when provided with vertical support in the form of surrounding trees, shrubs, or even utility poles (Gartner, 1991). For this reason, it is not a suitable species for restoration sites that are intersected by utility lines or sites with associate species that cannot tolerate intense competition for light or the stress of physically supporting this vigorously climbing species.

Within mixed evergreen forests, associate species include Pacific madrone (*Arbutus menziesii*), sugar pine (*Pinus lambertiana*), bigleaf maple (*Acer macrophyllum*), tanoak (*Lithocarpus densiflorus*), California bay (*Umbellularia californica*), and chinquapin (*Chrysolepsis chrysophylla*) (Howard, 1994). Oak woodland associates include valley oak (*Quercus lobata*), interior live oak (*Q. wislizenii*), Monterey pine (*Pinus radiata*), Coulter pine (*P. coulteri*), bigcone Douglas-fir (*Pseudotsuga macrocarpa*), and California walnut (*Juglans californica*). Chaparral associates include toyon (*Heteromeles arbutifolia*), chamise (*Adenostoma fasciculatum*), and California scrub oak (*Quercus dumosa*). Coastal sage scrub associates include California sagebrush (*Artemisia californica*), coyote brush (*Baccharis pilularis*), and sugar sumac (*Rhus ovata*). Lastly, riparian zone associates include bigleaf maple, California sycamore (*Plantus racemosa*), white alder (*Alnus rhombifolia*), boxelder (*Acer negundo*), willow (*Salix spp.*), California blackberry (*Rubus vitifolius*), toyon, and wild grape (*Vitis spp.*)

Given the proclivity of Pacific poison oak to occupy disturbed sites, including rangelands and roadsides, it would not be advisable to use this species in restoration sites that border fallow agriculture land or land adjacent to transportation or recreation corridors (Eaton, 2013). Generally, the use of Pacific poison oak is limited to wildlife habitat restoration projects (Evans, 2001). When used appropriately, Pacific poison is invaluable for its versatility as well as for its role as a provider of food and habitat to a host of species, which are listed in Part I of this report.

B. ESTABLISHMENT

Pacific poison oak is easily propagated by seed or stem cuttings (Evans, 2001). Fruits are collected in late summer and scarified for three-and-a-half hours in sulfuric acid, after which they are rinsed overnight in water and then promptly sown in flats containing equal parts (by volume) perlite, vermiculite, coarse sand, and sphagnum peat moss. When kept under a shadehouse in slightly moist conditions, seeds take about three weeks to germinate and six to nine months until seedlings can be transplanted into restoration sites.

The best time to take cuttings is when plants are dormant in the winter, although even contact with dormant stems without leaves can result in skin irritation (Evans, 2001). For this reason, protective equipment should be worn when taking cuttings or collecting seed (e.g. long sleeves and gloves). Softwood or semi-hardwood cuttings with one or two nodes should be taken and stuck in a rooting medium containing three parts (by volume) course sand, perlite, and vermiculite respectively, and one part sphagnum peat moss. Under humid greenhouse conditions, roots should form on cuttings after four to six weeks. Once they are well rooted, both seedlings and cuttings benefit from applications of Osmocote (18-6-12) at a rate of 2.7 kg/m^3 as well as inoculations of the vesicular arbuscular mycorrhiza *Glomus intraradices* (sold by Grolife) at a rate of 6 kg/m^3. It should be noted that the literature does not comment on how these treatments impact the survivability of the plants once they leave the favorable greenhouse environment and enter the often-harsh conditions of the restoration site.

Documented methods to promote the in-situ establishment of Pacific poison oak are few and far between in the literature. Observational studies indicate that prescribed fires of low to moderate severity (<200 $kcal/sec/m^2$) enhance the establishment of Pacific poison oak seedlings while also reinvigorating mature stands through resprouting of root crowns and underground rhizomes, but little more has been published about how to encourage establishment (Howard, 1994). This lack of information may be due to the fact that so much focus has historically been directed at the control of this species and not at its promotion, or alternatively, because the hardiness and versatility of the species is such that prescribed manipulations of site characteristics are unnecessary. While Pacific poison oak prefers sites with shallow, well-drained, acidic soil and sloped topography, it is tolerant of a wide range of microclimates, soil types, moisture gradients, and light intensities (Howard, 1994).

C. MANAGEMENT OPTIONS

In the state of California, loss of income due to exposure to Pacific poison oak is covered by Worker's Compensation Insurance, which reflects the considerable economic impact of this species while also indicating the need for more effective management strategies (DiTomaso, 2009). In natural ecosystems, Pacific poison oak is not a pest, but when it is found growing near residential areas or encroaching upon disturbed sites, it may need to be controlled mechanically, chemically, or culturally. Ingestion of seeds by birds is the primary dispersal mechanism of Pacific poison oak, although individual plants will form clonal colonies often several feet in diameter via rhizomatous growth. Therefore, the most effective way to counteract long-range dispersal is to remove young seedlings that germinate in undesirable locations. Hand pulling of seedlings is best done when the soil is moist in late fall or early spring. Pacific poison oak plants over two months old resprout readily from rootstocks, so the entire root and stem should be removed whenever possible (DiTomaso, 2009). Introducing browsing sheep and goats can be an effective way to prevent stands from flowering and producing seed and also can reduce the biomass of stands dramatically. On a U.S. Forest Service plot in Oakland, for instance, when six hundred goats were released on each hectare of land, Pacific poison oak biomass decreased by sixty-six percent, which is significant considering the propensity of the species to act as a ladder fuel in forest fires (Howard, 1994)

Mowing is a moderately effective control measure if it is done at least four times throughout the growing season (DiTomaso, 2009). However, any type of brushraking, bulldozing, or plowing is not advised as it will only divide rhizomes into individual propagules, each of which will then resprout. Prescribed burning can be effective at high intensities, but given that those areas under active management are often near residential areas where high intensity fires could prove deadly, this too should be discouraged. Furthermore, the skin irritant found in Pacific poison oak's oils does volatize and can cause severe respiratory irritation (Howard, 1994).

Chemical management strategies include foliar, basal bark, and/or stump applications of any of the following herbicides: glyphosate, triclopyr, 2,4-D, dicamba, and imazapyr (DiTomaso, 2009). Foliar sprays are most effective when leaves are mature and the plants are in their flowering stage between April and June. Basal bark applications can be made any time of year, whereas stump applications should be made during periods of active growth on cut stems one to two inches above the soil surface.

Cultural control of Pacific poison oak consists of establishing plant cover at sites that may be susceptible to invasion (DiTomaso, 2009). This involves regularly irrigating landscape or agriculture crops and keeping the soil under cultivation because Pacific poison oak thrives in ruderal-type sites with low levels of competition. In terms of biological controls, options are limited given that Pacific poison oak is indigenous and as a result, potential biocontrol agents are already present.

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Sub-Shrub
California blackberry (*Rubus ursinus*) Chloe Bombardieri

Part 1: Literature Review and Fact Sheet

Source: D.L. Smith, 2005

Background and Justification

California blackberries can be found in habitats along the California coast and river systems in the central valley (Calflora, 2014). This native species is an excellent competitor in shaded, wet environments such as riparian areas or coastal forests (River Partners, 2014). This species can be invasive and dominant in unmanaged environments but it is also an important habitat and source of food for many native species. California blackberry provides low ground cover for small mammals, which are protected by the thorny vines of the plant. They also provide nutrients for a wide variety of animals by producing pollen, nectar and blackberries and allow the plant to spread to a large area (River Partners, 2014). Specifically, blackberries provide food sources for native birds such as California quail, sharp-tailed grouse and others, along with black-tailed deer and elk and other ranging organisms (Tirmenstein, 1989). California blackberries are also excellent at growing in disturbed areas and areas with poor soil quality and may be a good choice to prevent soil erosion and secure riverbanks (Tirmenstein, 1989).

Since *Rubus ursinus* is a dominant competitor and an early successional species and tolerant of unexpected conditions there is no concern of it becoming endangered. Another consideration for California Blackberries is the berries that they produce; they are commercially cultivated and very popular. They do not require strenuous management and are easily propagated so that they will provide nutrients and enrich the soil with leaf litter and fallen fruit.

General Characteristics

- *Rubus ursinus* is a shrub with a low, trailing growth pattern, when it mounds it can reach heights of 5-6 meters.
- The vines of *Rubus ursinus* are thorny and green but develop into woody stems at maturity. They have deep green leaves with small white flowers that develop at the end of a vine in groups of 2 to 15 and eventually develop into berries (Tirmenstein, 1989).
- California blackberry is found in multiple, deteriorated habitats but require adequate soil moisture in order to become established and succeed. They thrive in low floodplains and mixed riparian forests (River Partners, 2014).

Life Cycle

- Flowers bloom from February to May and are visited by native bees, bumble bees, and hummingbirds which spread pollen for sexual reproduction (Calflora, 2014).
- *Rubus ursinus* can also reproduce asexually and vegetatively very successfully, and this is some of the reasons why *Rubus ursinus* can spread quickly and widely (Tirmenstein, 1989).
- Vegetative propagation can be achieved through root clippings or tip-layering, and placing these cuttings in 32°F in moist soil, though there is a possibility of root rot or other infection when transplanting from unknown plants (Vossen, 2014).
- Seeds are hard and embryos are dormant for extended periods of time so germination occurs when natural conditions are replicated, a period of 90 days of warm conditions, 86° to 68°F followed by colder conditions of 36° to 41°F for another 90 days. These conditions often occur in the warm summer months and cold winter months in the central valley, the seeds are often viable for years before germination(Tirmenstein, 1989).
- Seed dispersal occurs when animals and birds consume the blackberry fruit, which are mature from green and sour to sweet and black at maturity and contain seeds in each drupelet of the berry (Tirmenstein, 1989).
- *Rubus ursinus* flowers from April to June, Fruit ripens from June to August and seeds are dispersed from July to September (Tirmenstein, 1989).
- The plant does not produce flowers or fruit in its first year, instead the vines only grow leaves and are called primocanes.

Range and Distribution

- *Rubus ursinus* is found on the West Coast of North America, as far north as British Columbia in Canada and as far south as California's border with Mexico, it extends as far east as Idaho and as far west as the coast (USDA, 2014).
- In California, *Rubus ursinus* are most common on the coast and along rivers and deltas, this is mostly due to their need of moist soils and seasonal climates (Calflora, 2014).

Growing Conditions and Tolerances

- Conditions for *Rubus ursinus* are wide ranging, they can withstand temperature ranging from 28°F low in winters, and 96°F highs in the summer, they need a minimum of 12 inches of rain per year, but in general they rely on deep roots reaching a water table and thus are found coastally and along rivers (Calflora, 2014).
- California Blackberries are often found in open prairies, canyons and previously disturbed areas, such as logged or burned areas. They do not require a specific soil texture and can survive in relatively infertile soils, they can withstand a pH range of 5.4 to 8 (Tirmenstein, 1989).
- *Rubus ursinus* can also withstand flooding from fresh and brackish water periodically (Tirmenstein, 1989).

Successional Status

- California blackberry is able to establish itself in infertile and heavily disturbed soils so it is an early successional plant (Tirmenstein, 1989).

- *Rubus ursinus* is especially dominant in formerly logged and burned areas, and it remains dominant and in high abundance for about 5 years after a disturbance. Following that, it can be found as a remnant species in mature, secondary successional forests (Tirmenstein, 1989).
- California blackberry is tolerant of fires, and can re-establish itself due to its extensive root system. However, it cannot withstand very severe and intense fires that harm the soil structure, in that case seeds can re-establish the plant (Tirmenstein, 1989).

Interactions

- California blackberry thickets provide good habitat and cover for many species including, nesting birds, mammals such as rabbit, squirrel, black bear and beaver also use it for cover (Tirmenstein, 1989).
- The leaves of *Rubus ursinus* are unpalatable to most domestic livestock, but some deer have shown a preference for it (Tirmenstein, 1989).
- The berries of *Rubus ursinus* are delicious at maturity and are eaten by several bird and mammal species such as California quail, ring-necked pheasant, ruffled grouse, raccoons, squirrels, chipmunks and humans (Tirmenstein, 1989).
- Beneficial species to California Blackberry are the animals which eat its fruit and disperse its seeds, also hummingbirds, bumble bees, and native bees which use the pollen and nectar from the flowers and pollinate neighboring plants (Calflora, 2014).
- Pests of blackberries are more cause for concern for agricultural blackberries but red berry mites, spider mites, raspberry horntails and crown borers can negatively affect *Rubus ursinus*.
- Humans use *Rubus ursinus* agriculturally; the berries are widely used in pies, jams and other goods. Native Americans also ate ripe berries in the late summer and dried them to make teas and medicines (Tirmenstein, 1989).

Management

- California blackberry can be controlled with mechanical means; the most effective is multiple tillages. Mowing and burning are ineffective because the plant can branch out from cut vines and re-establish itself from roots alone when burned (Pest Notes, 2010).
- Biologically *Rubus ursinus* is difficult to control, in some cases introducing diseases such as blackberry rust has somewhat controlled blackberry plants, though not completely controlled it.
- Yellow rust, Orange rust, Leaf and Cane spot, Crown gall, Dwarf virus, die-back, Verticillium wilt, Armillaria root rot, and Phytophthora root rot are all viral and fungal diseases that can affect *Rubus ursinus* (Vossen, 2014).
- Various chemicals such as Glyphosphate, Dicamba, Triclopyr and Round-up can control *Rubus ursinus* with relative success (Pest Notes, 2010).

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Project Part 2
California Blackberry *Rubus ursinus*

Goals:

1: Short Term: Establish productive California blackberry (*Rubus ursinus*) at our restoration site.

California blackberry is a common plant in native Californian riparian areas, establishing a collection of *Rubus ursinus* can help secure soil and prevent erosion from the river and play a role as a primary successor to help develop the habitat.

2: Long Term: Monitor and manage California blackberry and prevent over dominance at the restoration site.

Since vegetative propagation and seed spreading through animals is very common in California blackberry, it could be classified as an invasive species if it was not native, management is important to prevent California blackberry from dominating the entire habitat and pushing out other target species. This should be measured by

3: Potential Demonstration Garden: The appeal of blackberry fruit and low maintenance management would make it a good choice for a community garden.

California blackberries have the potential to thrive and be productive and useful to a community after an initial trellis system is built and irrigation added.

Restoration Plan:

The introduction of *Rubus ursinus* would be most beneficial if it occurred very early in the site restoration. Since California blackberry is highly tolerant of poor soil conditions and low nutrients there is not a lot of physical preparation that needs to occur at the site so it can go in early. Once established California blackberry will drop seeds, fruit and leaf litter to enrich the soil, and will also attract animals to further enrich the soil with fertilizer, which may prepare the site for further restoration efforts. With this in mind, California blackberry should be introduced to an area in the site with moist soil, preferably near the river and should be done between November and April (Vossen, 2014).

Short Term (0-12 months):

There are multiple ways that California blackberries can reproduce so there are various ways to introduce it to the restoration site including vegetative propagation with stem or root clippings and seed germination (Tirmenstein, 1989). Vegetative propagation occurs quickly and usually more successfully than seed germination which may be beneficial since it can be established quickly and restoration can focus on other species more readily. To achieve vegetative propagation you must acquire stem or root trimmings. We would also need to consider the source of the trimmings, ideally we could use local ecotypes that can be found in the surrounding areas but we could also introduce genetic diversity by using a seeds from a nursery. Root trimmings are preferable since they are often more successful than stem trimmings, the trimmings should be the thickness of a lead pencil or larger and then cut into six inch lengths to be placed into the soil (Vossen, 2014). This can be done on site throughout November to April or it can be done in a nursery and transplanted at the site in early April through June (Vossen, 2014). During this time, the trimmings need to be kept in moist soil so the area should be irrigated regularly, such as two times a week when using sprinklers or daily for an hour using drip irrigation, in this case it would be more convenient to propagate the plants in a nursery since the plants do not need irrigation when matured (Vossen, 2014). The potential drawback to vegetative propagation is the potential for disease from the original plant, such as leaf and cane spot, yellow and orange rust, and Armillaria root rot, which can remain on the trimmings and infect the new plant for restoration (Vossen, 2014). Also, since there is no guarantee that the original plant is genetically pure, the trimmings may not be the native *Rubus ursinus* and that could affect interactions with other species on the site. Native California Blackberries can interbreed with invasive Himalayan Blackberries and the offspring is a hybrid that does not contain the complete genetic diversity of the native blackberry, so using these hybrids does not preserve native genetic diversity. Depending on where you collect seeds you may also have this genetic problem through seed germination, though you could avoid this by getting seeds from a nursery, or from a trusted source in local habitats. Seed germination would be best accomplished in a nursery, then grown to seedlings for about six months to a year and transplanted to the site. To germinate the seeds must be in 86° to 68°F conditions for a period of 90 days, followed by colder conditions of 36° to 41°F for another 90 days, these conditions naturally occur in the summer and winter months in California but the seeds should be monitored nonetheless because the seeds are hard and embryos are dormant so germination is not always successful (Tirmenstein, 1989). After germination they can be treated the same way as vegetative propagation. Also, *rubus ursinus* does not produce berries in its first year; so you can avoid this by using seedlings and propagating off site for a year before planting (Vossen, 2014). This way the plants are productive faster so that succession and nutrient cycling can occur faster as well.

Once seedlings have been acquired through vegetative propagation, seed germination, or buying seedlings from a native nursery they need to be placed at the restoration site and monitored. When planting, the seedlings should be approximately 2 to 4 feet apart into shallow holes, and then watered to set the soil. The seedlings should be monitored and potentially irrigated weekly to ensure that the plants have rooted and have established themselves successfully, if the soil moisture is high then irrigation is unnecessary. If the blackberry plants are planted in riparian zones or very close to the creek there is no need for irrigation (Tirmenstein, 1989). Once the vines have started to branch out and the plants have reached 2 to 3 feet in height monitoring can slow to monthly, this monitoring does not need to be intensive, it can consist of looking at the plants to make sure they are alive and producing which would be easy if there were other plants in the area that needed more intensive care. After the plants produce berries, which should ripen after the first year in the late summer months of July to September then the short-term goal has been achieved and our goals should shift to long-term management.

Long Term (1-5 years):

Once established, California blackberry requires very little management to produce seeds and berries and tends to thrive without any further maintenance (Tirmenstein, 1989). At this stage, managing and monitoring goals should focus on vine growth and how other plant species are interacting with *Rubus ursinus*. Since California blackberries can grow quickly and can outcompete with many plants for sunlight and water, they are a threat to dominate the restoration site. Every summer, during August or September when the blackberries are ripened, managers should inspect the *Rubus ursinus* plants and see whether or not they are controlling the area and negatively affecting other target species. Monitoring the growth pattern of the blackberry plants and pruning the plants in the winter so that they are growing in a shrub shape, instead of uncontrolled vines, can prevent domination. There is a danger that the blackberry plant will vine out and cover the ground, suppressing the surrounding plants and preventing new growth by covering the ground (Pest Notes, 2010). If California blackberries have taken over, managers should follow up in the winter months, after some of the leaves have fallen from the plant and remove the new sprouts and invading plants. This can be achieved by digging out the plants or using a rototiller, making sure to go over the area multiple times to ensure the plants cannot propagate. You could also use chemical control such as Glyphosphate, Dicamba, Triclopyr or Round-Up, but in a sensitive restoration site, I would recommend mechanical control since it has less negative side-effects and is the most effective form of control for *Rubus ursinus* (Pest Notes, 2010). Maintenance and restoration goals in the long term would be to promote the establishment of secondary successor plants by increasing soil quality and increasing nutrient cycles. The blackberry plants would only need to be monitored twice a year, in late August when the plant is producing berries, and again in the winter to prune and encourage other plant species to grow and become established.

Demonstration Garden:

Finally, California blackberries would be an excellent candidate for a demonstration garden, the berries produced are popular and the community would appreciate them. Thornless hybrid species are used commercially, including some hybrids with *Rubus ursinus*, so the demonstration garden could be used to determine whether local genotypes could be successful agriculturally (Finn, 2013). To create ideal conditions for California blackberries in a demonstration garden you would need to build a two-wire or three-wire trellis at about 6 to 7 feet tall that could be in a raised planter box or simply in between rows of raised soil (Vossen, 2014). Since the soil conditions would be drier than along a river, the plants would have to be irrigated regularly. Under normal conditions they should be watered two times a week by heavy sprinkler or daily for an hour by drip irrigation, which would be easier to manage, irrigation should be increased if conditions were especially hot or windy, or if the fruit was ripening (Vossen, 2014). After the plants were planted, in early spring from March to April, they should be guided toward the trellis and should produce fruit after a year. In the long-term these plants should be pruned yearly by trimming the canes from the previous year (Vossen, 2014).

Future Research:

These restoration goals could help to analyze the question of how quickly can California blackberry establish itself in a habitat. Also, since California blackberry often colonizes areas after they have been burned and is identified as a primary successional species, you could analyze the secondary species that colonize after or alongside California blackberry by monitoring it within the site. Another area of research could be to observe the effects of the additional leaf litter and fallen berries in the soil under and around *Rubus ursinus* and compare it with a control plot of soil without any litter.

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California fuchsia (*Epilobium canum*) Grace Amico

The Management, Biology, and Impact of *Epilobium canum*, the California Fuchsia on its Ecosystem

<u>Background and Justification</u>

The California fuchsia, *Epilobium canum,* is an eye-catching perennial native that thrives in dry climates (Plant, 2009). *E. canum* can grow into several forms from large bushy shrubs to single-stemmed plants. It is a garden favorite due to its habit of blooming in the late summer to fall (July-November), adding splashes of color from bright red to pink or white in an arid landscape. *E. canum* is one of the only members of the Onagraceae family to grow from herbaceous to woody (Beidleman, 2003). One third of these species thrive in California, and the plant is well known throughout the western side of North America. The California fuchsia can often be found growing on rocky slopes and hills. This is possible because the California fuchsia sends out spreading rhizomes as it grows (Bloom, 2014). This shrub is also very ecologically important because of its close relationship to hummingbirds. *E. canum*'s tubular flower shape has evolved for hummingbird feeding and therefore has become an important food source (Boose, 1995). A species of bee also benefits from the nectar by drilling holes into the flower petals (Plant, 2009). Two subspecies that are worth taking a look at are *Epilobium canum* 'Calistoga' and *Epilobium canum* 'Schieffelin's Choice' (Hot, 2014). Both subspecies are drought tolerant, prefer full sun, and can grow in poor quality soil.

<u>Literature Review</u>

1. *Species characteristics*
    - *E. canum* is known for its tubular bright red to red-orange flowers and pale gray-green leaves that grow opposite of each other. (Beidleman, 2003).
    - Each flower is about two inches long and contains four petals and sepals (Plant, 2009). The leaves are usually thin and lance-like. They grow to be about an inch long and can also be slightly hairy like the stems.
    - Seeds are spread with the use of seedpods that can be seen growing alongside the scarlet flowers.
    - It is a densely spreading subshrub that can be found growing on dry slopes and ridges (UC/JEPS, 1993).
    - May grow up to three feet tall (Plant, 2009).
    - Grows from rhizomes (Bloom 2014).
    - *Epilobium canum* 'Calistoga' has rounder leaves than most California fuchsia subspecies (Hot, 2014). It is an attractant of hummingbirds and can spread to about three feet. It prefers a habitat with full sun, can grow in poor soil, and is drought and deer resistant.
    - *Epilobium canum* 'Schieffelin's Choice' grows prostrate and can also spread to about three feet. It prefers growing in full sun and poor soil and is deer resistant. It can survive temperatures down to 25 degrees F and may be slightly invasive. Best to plant in arid, nutrient-poor soils to keep it from growing too rapidly.
2. *Ecology and Impact*

- The California fuchsia is an important pollinator for hummingbirds and some bee species (Boose, 1995).
- The bright color of the flowers in late summer and fall attract hummingbirds and offer food during times when there are few blooming plants.
- *Epilobium canum* can often be found growing on rocky slopes and ridges with the help of its rhizomes (Beidleman, 2003).

3. *Management*
    - *E. canum* can often have an invasive growing habit due to its rhizome growth so it is beneficial to grow the shrub in dry environments with poor soil quality to avoid it getting out of hand (Schmidt, 2012).
    - In the winter after it is finished flowering, the California fuchsia should be trimmed back almost to the ground. This will allow the plant to create new growth in the spring.
    - Cuttings made from the plant are also easily propagated in the late fall.
    - After the initial planting, California fuchsias only need to be watered once a month to thrive (Hot, 2014). Over-watering may cause the soil to become too acidic for the shrub.

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Part 2

A. Goals:

The California Fuchsia (*Epilobium canum*) is a California native that is well known for its fall color. Its resistance to drought and attractiveness to pollinators like hummingbirds makes it a good choice for the Central Valley climate and worth restoring and conserving. To begin the process, existing populations of *E. canum* must first be noted. After recording the initial populations, more populations of California fuchsia will be established in the area. This will help provide a sufficient number of populations that could eventually become self-maintaining. Lastly, it is the hope that after the California fuchsias have become established they will provide a food supply for hummingbirds and other pollinators like butterflies and bees. In order for this to be ensured, the populations must be monitored in order to upkeep optimum vitality.

1. Find and record already existing *Epilobium canum* populations.

This initial step would involve taking note of where and how many populations of California fuchsia have already established in the chosen area. By recording this information, it can be more easily determined what kind of environment this plant can survive and thrive in. It is more likely that a new addition will have a greater chance of establishing if it is planted in a place where other *E. canum* individuals are growing with vigor. By locating preexisting populations it would also be possible to take seeds and cuttings of individuals that have already proven capable of establishing in the area.

2. Plant more California fuchsia in sites around the area where they are likely to establish.

The goal here is to increase the number of viable California fuchsia populations. This can be done both by planting seeds and cuttings from cultivars suited to the climate. It is important to keep in mind the habitats that *E. canum* is most likely to thrive in, like rocky crevices or dry slopes in full to partial sun (Plant 2009, In 2014). During this process, it will be important to return to the site of each new population several times a year to document how they are taking. This kind of documentation may need to take place for about three years, which is the average time it takes for *E. canum* to reach maturity (California 2014).

3. Continue monitoring both initial and new populations of California fuchsia. Take note of plant vigor as well as popularity with pollinators like hummingbirds, bees, and butterflies.

After maturation, monitoring should continue for another few years to confirm that the new adult plants are producing seeds and propagating by rhizomes. It is necessary that new generations can also be established for the restoration effort to last. The presence of hummingbirds and other pollinators will be a sign that the plants are a part of the surrounding community and ecosystem. One of the reasons *E. canum* is so important to the area is due to their place as a major food source of hummingbirds, especially during their migration (Boose 1995, Plant 2009). The nectar that attracts the hummingbirds will also attract many species of butterflies and some bee species.

B. Restoration Plan:

Source

It would be best if seeds for the California fuchsia populations came right from the source, meaning they were harvested from plants already adapted to the proposed area. The limiting factor to this plan of action depends on how many populations are actually in the area. It should not be assumed that there is enough of an established California fuchsia population to supply a suitable number of seeds without drastically diminishing the plants' future generations. To combat this issue, seeds should also be collected from subspecies that are capable of thriving in similar climates. In California, *E.* canum can be found growing naturally on the entire coastline and all along the Sierra Nevada mountain range (CalFlora 2014). These plants can also be found bordering the Central Valley. Two such subspecies capable of growing in the Central Valley are *E. canum* ‘Calistoga’ and *E. canum* ‘Schieffelin’s Choice’ (Hot 2014). Both thrive in climates with full sun and are drought tolerant and resistant to damage by deer. ‘Calistoga’ may be the better option however, since ‘Schieffelin’s Choice’ can grow to be invasive.

Another option is the ‘John Bixby’ cultivar, a more easily managed plant but less tough plant with a rounded shrub form (O’Brien 2007). A third option would be to use a mixture of these cultivars and lay down certain cultivars in places where they are more likely to beneficially contribute to their environment. For example, ‘Schieffelin’s Choice’ could be planted in the harshest areas to keep it from growing too wild, while ‘John Bixby’ could be grown in areas featuring more shade. This option allows for a pleasing mixture of cultivars that will, in effect, also provide more flexibility in where *E. canum* can be established.

<u>Method</u>

Two methods of planting could be used in this scenario: with seeds and with cuttings from rhizomes. When collecting seeds, it is necessary to not collect more than ten percent of the plant’s seeds. There should also not be more than two cuttings made per healthy, mature plant. These precautions are kept to ensure that the plant continues to produce new generations in the upcoming years.

The seeds will simply be scattered in the fall on the recently tilled area that they are needed (O’Brien 2007). Root cuttings will be made in the early summer when new growth is still soft, and then rooted in a greenhouse offsite (Schmidt 2012). Once the cuttings have formed viable roots they should be planted in the fall at about three feet apart, which is the average width of an adult California fuchsia, and about fifteen centimeters deep (Hot 2014, CalFlora 2014).

Before planting however, all roots must be checked for root mealybug, a pest that is difficult to manage once discovered and can caused significant root damage to the plant, which may lead to death (O'Brien 2007).

The soil should not need to be amended due to *E. canum*'s ability to grow in very nutrient-poor soils (Schmidt 2012). As was previously stated, it is actually better for the plant to be grown in soils that are more "difficult" to keep them from growing too wild too fast. The California fuchsia can actually survive in soils with a pH between 5.4 and 8.2 (CalFlora 2014).

The area that *E. canum* should be planted should be rocky and on hillsides or slopes at less than a 3000 meter elevation (UC/JEPS 1993). It can grow easily with several different plant community types, especially with other shrubs and grasses (Schmidt 2012). They are especially desirable for a restoration area needed erosion control. Their deep-rooted underground roots, rhizomes, help keep the soil in place as the plant grows.

After planting seeds and cuttings, *E. canum* only needs irrigating at most once a month during the initial few years before maturation (Hot 2014). These plants are not accustomed to frequent watering and can grow after a year with no additional watering at all; therefore it would be overkill to install an irrigation method. It is also imperative that the sites be visited for weeding, especially in the spring, until the plants have somewhat matured. In the areas that have been seeded, not planted with cuttings, weaker-looking California fuchsias should also be weeded out until there is eventually about a three-foot spacing between plants. This particular weeding should last a couple of years until the plants are decently spaced and have had time to establish a complex root system in the soil.

Monitoring and Evaluation

The sites should be monitored at least once per season the first two years after planting to be weeded. After this period, monitoring should occur at least once per year, preferably in the early summer and/or late fall. This will be to record if the plants are exhibiting new growth (early summer) and if they are flowering (fall-late fall). It should be noted how many plants are showing signs of maturation around the two and three year marks. This includes the growth of seedpods among flower clusters and meeting the average plant height and diameter depending on cultivar (Plant 2009). If the density of the new California fuchsia populations is below 50% establishment, then additional plantings and seedings should take place in the following fall. This should continue every couple of years until the plant cover is at an appropriate standard of density and fullness.

After the third year, note the percentage of plants that are flowering and if there are any pollinators visible. After a majority of California fuchsia have matured and begun producing flowers and viable seeds, the number of hummingbird and other pollinator sightings should increase. Pollinator activity should be recorded during each return to the site for monitoring. It should also be noted how many new plants are growing from rhizomes versus seedpods (clones from rhizomes should be clumped with parent plant).

There do not seem to be many issues that plague *Epilobium canum.* It is a fast-growing plant, relatively disease-free and has adapted to tolerate hardy climates (California 2014). However, one issue that may occur is leafhopper invasion (O’Brien 2007). These insects have a life cycle that matches up with the growth and bloom period of the California fuchsia (late summer to fall). If a leafhopper infestation is discovered, they are difficult to control with nonchemical pesticides. At large populations these insects can easily kill an adult California fuchsia. It was discovered that leafhopper infestations usually occur on plants that have been growing in areas with more shade, however. To keep this from occurring, seeds and cuttings should be mostly planted in areas with full sun and less than partial shade.

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Forbs

Mule's ear (*Wyethia* sp.) Chenoa Wilcox

Background and Justification

The *Wyethia* species native to Solano and Yolo Counties of California are *Wyethia helenioides* and *Wyethia angustifolia*. These native perennial herbs provide resources for native butterflies, habitat for birds and small mammals, and potential ecosystem benefits such as soil stabilization via rhizomatous growth (http://www.calflora.org/; http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/; http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/; http://www.wildflower.org/plants/result.php?id_plant=WYAN; Matthews, 1993). Unfortunately, there is little information about the state of *Wyethia* species in Solano and Yolo counties and across California. However, some inferences can be made. Because of the general trend away from fires in California, many ecosystems are shady and overgrown, which is not conducive to growth of *Wyethia* (The Jepson Manual, 2012; http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/; https://www.inaturalist.org/taxa/narrowleaf_mule-ears; http://www.theodorepayne.org/mediawiki/index.php?title=Wyethia_angustifolia; http://www.wildflower.org/plants/result.php?id_plant=WYAN). These ecosystems may be lacking species that would benefit the native butterfly community or stabilize soil in areas such as riverbanks, and planting *Wyethia* may greatly benefit the ecosystem and its functions. Other ecosystems, however, may be heavily grazed, which tends to promote the prevalence of *Wyethia* (Mueggler and Blaisdell, 1951; Matthews, 1993; http://www.sacsplash.org/post/narrow-leaf-mules-ear). Where *Wyethia* is prevalent, management actions to decrease abundance may result in greater habitat and species diversity in the ecosystem by breaking up monotypic stands of these herbs (Matthews, 1993). The state of these species in California, therefore, depends on the state of the ecosystem in consideration. The following section of this document is a literature review of the information available on the two *Wyethia* species native to Solano and Yolo counties, with some additional information on closely related *Wyethia* species.

Literature review

Species of consideration for Solano/Yolo Counties (http://www.calflora.org/):

- *Wyethia helenioides*
- *Wyethia angustifolia*

Ecosystem requirements:

- Require full sun/open habitat (The Jepson Manual, 2012; http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/; https://www.inaturalist.org/taxa/narrowleaf_mule-ears; http://www.theodorepayne.org/mediawiki/index.php?title=Wyethia_angustifolia; http://www.wildflower.org/plants/result.php?id_plant=WYAN) or minimal shade, as in a mixed-oak forest understory (http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/; https://www.inaturalist.org/taxa/50799-Wyethia-helenioides).

- Drought-tolerant (http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/; http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/), except when establishing (http://practicalplants.org/wiki/Wyethia_angustifolia).
- Tolerate winter lows around freezing and summer highs up to 100°F (http://www.calflora.org/).
- Require a wet season of approximately 5-8 months with about 20-75 inches of rain (http://www.calflora.org/).
- Grow at elevations of approximately 40-1960 meters (http://www.calflora.org/).
- Tolerate clay, sandy, and loamy soils (http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/; http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/)
- Do not grow in saline soils (http://www.calflora.org/), but can grow on serpentine soils (Harrison et al., 2006).

Phenology and life-cycle information:

- Bloom March-July (*W. angustifolia*) and March-May (*W. helenioides*) (http://www.calflora.org/).
- Perennial flowering plants (http://www.calflora.org/).
- Grows 1-2' tall (http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/; http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/), or as tall as 3' in some horticultural environments (http://www.sacsplash.org/post/narrow-leaf-mules-ear).
- Dies back each winter (http://www.theodorepayne.org/mediawiki/index.php?title=Wyethia_angustifolia; www.wildflower.org/plants/result.php?id_plant=WYAN) and regenerates the next year from a large taproot (http://www.sacsplash.org/post/narrow-leaf-mules-ear).
- Can spread via rhizomatous growth (http://www.wildflower.org/plants/result.php?id_plant=WYAN).
- May monopolize soil moisture early in the season (Matthews, 1993).

Responses to abiotic factors:

- Generally considered unpalatable to, and therefore unaffected by, grazers for most of the year, except when leaves or inflorescences are new in early spring (Matthews, 1993), at which time the plants may not have a high tolerance for grazing (http://www.sacsplash.org/post/narrow-leaf-mules-ear).
- Closely related species (*W. amplexicaulis*) is controlled by application of Triclopyr or 2,4-D early in the blooming period (Matthews, 1993).
- Mowing can destroy these plants (Field Guide to the Rare Plants of Washington, 2011).
- Fire does not seem to be harmful to closely related species (Matthews, 1993).

Relevant management concerns and interactions with other species:

- Resource for native butterflies (http://www.calflora.org/; http://www.theodorepayne.org/mediawiki/index.php?title=Wyethia_angustifolia), bees (http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/), and birds (http://www.watershednursery.com/nursery/plant-finder/wyethia-helenioides/).

- Historical methods of rangeland management included removing *Wyethia* and replacing it with desirable forage species (Mueggler and Blaisdell, 1951).
- Closely related species are known to not compete well with invasive weeds, especially tall oatgrass (Field Guide to the Rare Plants of Washington, 2011).
- Seeds are a desirable food source for rodents (http://www.sacsplash.org/post/narrow-leaf-mules-ear).
- Closely related species (*W. amplexicaulis*) can form dense stands by spreading rhizomatously to prevent erosion, and grows well on gentle or moderately steep slopes (Matthews, 1993).
- Dense monotypic stands of *W. amplexicaulis* may provide good cover for birds and small mammals, but provide little habitat diversity and can exclude other animals (Matthews, 1993).
- May spread somewhat agrressively on clay soils (Matthews, 1993).
- Closely related species (*W. amplexicaulis*) are potentially useful in recolonizing mine-spoils (Matthews, 1993).

Propagation notes:

- Seeds require cold stratification over 90-120 days for proper germination (www.wildflower.org/plants/result.php?id_plant=WYAN).
- Should be seeded in early spring (http://practicalplants.org/wiki/Wyethia_angustifolia).
- Seedlings do best when transplanted into individual pots as soon as they are large enough to handle (http://practicalplants.org/wiki/Wyethia_angustifolia).

Current state of *Wyethia* in California:

- A closely related species (*W. amplexicaulis*) is reported to dominate in some heavily-grazed environments (Matthews, 1993).
- The two native species of concern for Solano and Yolo Counties, *W. angustifolia* and *W. helenioides* are noted to hybridize in the San Francisco Bay area ((The Jepson Manual, 2012.)

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Susan Harrison, Hugh D. Safford, James B. Grace, Joshua H. Viers, and Kendi F. Davies. 2006. Regional and local species richness in an insular environment: serpentine plants in California. *Ecological Mono*

Goal #1: Increase density of *Wyethia* in California's Central Valley to bolster native butterfly resources.

Objective: Plant stands of seedlings or rhizomes into open areas.

Performance standard: Have three stands of *Wyethia* at each site, covering at least five square meters.

Goal #2: Use *Wyethia* to control erosion at sites where vegetation has been removed.

Objectives: Plant *Wyethia* on slopes where vegetation (esp. nonnative plants) has been removed when possible.

Performance standard: Have stands of *Wyethia* from previous goal placed on banks where erosion is a concern.

RESTORATION PLAN

METHODS

1.) Collection: Seed or rhizomes should be collected from as many sites as possible throughout Yolo and Solano counties, in order to have the least significant impact on local populations. These local populations are expected to be relatively small, perhaps with only a few individuals at any given location due to the prevalence of nonnative grasses, and overharvesting of seed or rhizomes from one location may decimate the population (1). In addition, small populations at collection sites means that the genetic diversity of a site is inherently low.

2.) Planting: Increasing the density of *Wyethia* via seeding may not be a safe strategy for *Wyethia* introduction to a site because seeds are a desirable food source for rodents (2). Growing seed in a greenhouse for transplantation abates the threat of consumption by rodents, and harvesting rhizomes for planting may also be a viable option (3-4). If seed is grown to transpant individuals in spring, seeds should be cold-stratified for 90-120 days prior to planting (4). Rhizomes or seedlings should be planted into open habitats where they can have full or nearly full sunlight (4-9). The plants should grow no larger than 2' wide, so 4 per square meter should be an adequate planting density, with some mortality easily colonizable by remaining plants (6, 10). Areas should be planted relatively evenly, allowing *Wyethia* the ability to form a monotypic stand that will hopefully afford some protection from invasive grass competition and double as erosion control (3). Plants will need additional water for 1-2 years after planting to aid establishment (11).

PROJECT TIMELINE

The temporal scale of this project will vary with the spatial scale desired. Generally speaking, all transplanting of seedlings should be done in early spring, between March (in warmer, lower elevation sites) and May (in cooler, higher elevation sites) (11). If rhizomes were harvested, planting should occur sometime in winter to allow the plant enough time to sprout in the spring. Planting should not occur earlier (for seedlings) or later (for either planting strategy) to maximize survival of the *Wyethia* planted. If not all of the sites where restoration is desired can be planted in one season, planting should re-occur the following spring. Habitats most important as butterfly resources should be planted earliest.

SITE PRIORITIZATION

Restoration work should focus on areas that are important for native butterfly habitat (6, 9, 10, 12). Efforts should be made to plant three stands of *Wyethia* per site to provide ample resources for butterflies. Stands should be five square meters or larger.

Separate research on native butterflies will lend insight to the spatial scale of *Wyethia* restoration required to significantly impact butterfly habitat resources. In these areas, increasing the density of *Wyethia* will create a more suitable environment for butterflies and other native species (3).

MONITORING

Monitoring of the sites should occur in the fall for the year of planting and the two years following to assess how many individual plants survived the first summer, as plants die back in winter and will not be easily assessed for viability (4, 9). Sites should also be assessed for survival in the spring following initial plantings, to ensure that sites with high mortality of *Wyethia* individuals can be replanted quickly to maintain the desired level of butterfly support. If a site needs to be replanted, monitoring should resume as if the site was initially planted in the latter year to continue efficient assessment of survivorship and management actions.

Management action to replant should be taken if more than 25% of the planted rhizomes or transplanted seedlings do not survive to grow the spring following planting. Because there is no information on survival rates in the field, it is important for monitoring efforts to be vigilant and management action efficient.

If one method of planting (rhizomes or transplantation) is not producing viable plants the year following planting (less than 25% survival), the site will be re-planted the following year using a different strategy. If neither strategy is producing viable plants, seeding can be carried out as a last resort.

POTENTIAL PROBLEMS, RISKS, UNCERTAINTIES

Due to the fact that little is known about restoration efforts with *Wyethia*, there are many potential problems that could arise. The biggest problem is likely to be failed establishment of plants at the site. One method of planting may not be effective at some sites, or the planting time may not be conducive to perennial growth of these species. Additionally, if sites are analyzed for survivorship at the wrong time, it may look as though no plants have survived at a site due to the winter die-back and dormancy of *Wyethia* (4, 9). For this reason, it is important to maintain the multiple sampling times (described earlier) in the first year.

RESEARCH REQUIRED PRIOR TO IMPLEMENTATION

Prioritization of key butterfly habitat is critical to the progression of this project (6, 9, 10, 12). Timelines for completion, planting methods (use of rhizomes or transplantation of seedlings), and planting densities may also need to be adjusted, depending on the level of degradation at sites of concern for native butterflies.

Some site-specific research will need to be carried out prior to implementation of this resporation plan. *Wyethia* does not grow well on saline soils, but serpentine soils would be acceptable for this project (13). Additionally, fire does not seem to significantly harm *Wyethia*, but grazing may be detrimental to the plant's establishment (2, 3). After establishment, grazers tend to find the plant unpalatable, but the seasonal dieback of this plant with respect to grazing sensitivity has not been thoroughly examined and could pose a recurrent challenge (4, 9, 14).

If there is adequate time before plating of restoration sites, trials of seed and rhizome growth of *Wyethia* in greenhouses to evaluate germination rates would be extremely useful. This would allow planting efforts to use only the most effective method of survival. Transplantation trials to look at field survival would provide similarly useful information on what densities in the field would result in sustainable stands that would not require more planting efforts.

ASSOCIATED RESEARCH

This project has the potential to assess native butterfly restoration through population monitoring. This project can also assess the viability of using *Wyethia* for erosion control in urban habitats.

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9.) http://www.theodorepayne.org/mediawiki/index.php?title=Wyethia_angustifolia (Accessed: Apr 11, 2014).

10.) http://www.watershednursery.com/nursery/plant-finder/wyethia-angustifolia/ (Accessed: Apr 11, 2014).
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Showy milkweed (*Asclepias speciosa*) Jamey Wilcher

A. <u>Background and Justification</u>

Showy milkweed, scientific name *Asclepias speciosa* Torr., is part of the milkweed family, and is of special ecological significance because it is the only species of plants on which monarch butterflies will breed(Pleasants and Oberhauser, 2013). Milkweed provides critical habitat for this iconic species both in the Midwest and in California, and is considered a native plant for most of the United States and southern Canada west of Michigan(County, PLANTS*)*. The monarch butterfly has two primary migration paths- one between the midwest, southern Canada and their overwintering grounds in Mexico, and one to and from the beaches of California and summer breeding grounds west of the Rockies (Luna and Dumroese, 2013). This second path in particular makes the presence of milkweed in as many places as possible along their western migratory route critical to butterfly survival. Milkweed is also an excellent attractant for other pollinators, including "native bees, honey bees, butterflies, beetles, flies, and hummingbirds" (Borders, 2013). The milkweed population in the United States began to fall dramatically with the introduction of genetically modified Roundup™ ready crops between 1996 and 1998. Since 1999, there has been a 56% decline in midwestern milkweed populations due to increased use of herbicides and urbanization (Pleasants, 2013). Milkweed populations in CA are also declining due to urbanization and herbicides, and appear to have disappeared from about half of their native CA range. (Luna and Dumroese, 2013).

B. <u>Literature Review</u>

Characteristics:
General:

- *Asclepias speciosa is a perennial forb. It grows from roots up to 18 inches deep, usually to a height of up to 5 feet (Borders, 2013), (Bring Back... Asclepias, ND).*
- *Showy milkweed has rhizomatous roots capable of sprouting into new plants if damaged or collected correctly for propagation. This feature encourages growth of milkweed plants in small, dense patches.(Bookman, 1983), (Pleasants and Oberhauser, 2013).*
- *The life span of milkweed plants varies by species and can be between 3 and 100 years; however, the longevity of most species is unknown. (Bring Back... Details, ND).*
- *Showy milkweed grows in soils ranging from dry to moist with a variety of textures spanning the spectrum from sand to clay, but requires full sunlight. (Borders, 2011)*
- *Showy milkweeds can be found in a variety of plant communities, "including wetlands, meadows, savannah, and forest clearings, as well as disturbed sites along roadsides, railways, and waterways." (Borders, 2011)*

Reproductive:

- *Showy milkweed flowers May through September, then dies back to the ground.(Borders, 2011).*
- *It produces an average of 630 seeds per stem, and these are most commonly distributed by wind, and possibly distributed by water. (Ulev, 2005)*
- *Showy milkweed can also reproduce asexually by sprouting from sections of the*

rhizomes. (Ulev, 2005)

- *Natural seed establishment rates are high. (Borders, 2013)*

Distribution:
Native:

- There are over 130 species of milkweeds native to North America. (Luna and Dumroese, 2013)
- These species are distributed across the continent mainly west of the 100th meridian, and are only endangered in Iowa. *(Bring Back... Details, ND),* (Ulev, 2005)

California:

- Showy milkweed is native to, and currently documented in the California counties of: Inyo, Mono, Fresno, Maiposa, Tuolumne, Alpine, Amador, Calaveras, El Dorado, Placer, Nevada, Sierra, Butte, Glenn, Colusa, Yolo, Solano, Marin, Sonoma, Lake, Mendocino, Tehama, Shasta, Lassen, Plumas, Trinity, Humboldt, and Siskiyou. (Borders, 2012).
- California has 15 of the 130 milkweed species native to the U.S., the most important for monarch hosting being showy milkweed (A. speciosa Torr.). (Luna and Dumroese, 2013).

Ecological impacts:

- Showy milkweed provides crucial breeding habitat for monarch butterflies in California.
- It has abundant nectar, which also attracts a variety of other invertebrates, including wild native bees, and other beneficial insects like "mite-eating ladybeetles, minute pirate bugs, hover flies, and parasitic wasps" that prey upon agricultural pests. (Borders, 2011).
- The nectar in Milkweed plants also attracts pollinating birds such as hummingbirds (Borders, 2011).
- The milkweed species in general has been proven toxic to grazers, and most grazers will avoid it unless they are confined in an area where milkweed is the only plant available for consumption. (Ulev, 2005).
- Common milkweed pests include "Lygaeus and Oncopeltus spp., milkweed longhorn beetles (Tetraopes spp.), and oleander aphids (Aphis nerii)." (Borders, 2011).

Ecosystem Services:

- Showy Milkweed can be used for stream bank stabilization. (Borders, 2013)
- It can also be used for riparian vegetation cover, pest management, and attraction of agricultural pollinators. (Borders, 2013)
- This plant can also be used to begin restoring vegetation to disturbed sites, beginning the process of succession in areas such as roadsides. (Borders, 2013)

Tolerances:

- Showy milkweed establishes quickly in recently disturbed areas. (Ulev, 2005)
- However, it is mainly an early successional species, and can be out-competed by

later-successional species that block sunlight or take up nutrients more quickly than milkweed. *(Pleasants and Oberhauser, 2013).*

- *Milkweeds as a species are intolerant of herbicides, and have been lost in 58% of their range in the mid-west due to increased use of herbicide-resistant crops. (Borders, 2013), (Pleasants and Oberhauser, 2013).*

- *There is little information on the fire tolerance of showy milkweed; however, fire during the dormant season promotes straight stem growth and increases the number of flowers in Mead's Milkweed, which is closely related to showy milkweed. (Ulev, 2005)*

- *Showy milkweed is drought-tolerant. (Borders, 2011)*

- *Showy milkweed does well in moist environments, and often colonizes floodplains, which implies a resistance to flooding and inundation, however, there seems to be little research on the subject. (Ulev, 2005).*

Propagation:

- *Showy milkweeds are self-incompatible, and must exchange pollen with a different individual to successfully sexually reproduce. (Ulev, 2005).*

- *Follicles containing seeds form and rupture by the end of summer, which is when collection should occur in order to harvest the most viable seeds. Plants should be monitored near the end of the season to ensure timely seed collection before the follicles split completely and seeds are blown away. (Luna and Dumroese, 2013).*

- *Seeds for showy milkweed should be stored in a cool dry place, and can be stored up to three years, although germination success decreases slightly over time. (Luna and Dumroese, 2013)*

- *To grow: Plant seeds in containers 98-200ml in volume, 1.5-2" diameter, and 4-8.5" deep, 5-7 months before they are intended to be transplanted to a site; will grow in commercial seedling mix soils, hand-water. Plants can be moved to an outdoor growing area after reaching the desired height indoors. They should be planted in the restoration site during the fall or early spring, when rains will follow in the next few weeks. (Luna and Dumroese, 2013)*

- *For seeding directly into the ground, the soil should be free of large dirt clumps, gently packed; for successful establishment from seeds over larger areas, soil should be smooth and seeds should be pressed firmly onto the ground, which can be done with a roller or a tractor. (Borders, 2013)*

- *Showy milkweeds can also be propagated vegetatively by removing a section of root from the upper underground portion of a dormant plant and placing it in suitable moist soil. Sprouting occurs regardless of whether there is a visible shoot bud on the transplanted section of rhizome. (Luna and Dumroese, 2013).*

Maintenance:

- *Showy milkweed is an early successional species, and so periodic mowing of the site every 2-3 years may be required to prevent late-successional encroachment. (Bring Back...*

Details, ND)

Human Interactions:

Native American:

• *Native Americans used showy milkweed especially to form fibers used in nets or clothing. Various other species of milkweed have been harvested for edible seed pods or root tubers, and the sap has been used to cure warts, ringworm, and bee stings. (Borders, 2013)*

Current:

• *Butterfly milkweed (*A. tuberosa*) has "pleurisy roots," which are used to make an over-the-counter drug sold to treat lung inflammation. Milkweed floss is also buoyant and was used in life preservers during WWII, and is currently used in hypo-allergenic bedding. (Borders, 2013)*

Expanded Literature List- Showy Milkweed

Database: ProQuest- Environmental Sciences and Pollution Management, Search: Asclepias speciosa (OR) Showy Milkweed

• Kaul, R. B., Rolfsmeier, S. B., & Esch, J. J. (1991). The distribution and reproductive phenology of the milkweeds (asclepiadaceae: Asclepias and cynanchum) in Nebraska. *Transactions of the Nebraska Academy of Sciences*, *18*, 127-140. Retrieved from http://search.proquest.com/docview/16226767?accountid=14505 on 4/14/2014
This article contains information about the habitat type, range and flowering and fruiting phenology of two different species of milkweed in Nebraska.

• Martin, R. A., & Lynch, S. P. (1988). Cardenolide content and thin-layer chromatography profiles of monarch butterflies, danaus plexippus L., and their larval host-plant milkweed, asclepias asperula subsp. capricornu (woods.) woods., in north central Texas. *Journal of Chemical Ecology, 14*(1), 295-318. Retrieved from http://search.proquest.com/docview/14885142?accountid=14505 on 4/14/2014
This article contains information about the interaction between monarch butterflies and milkweed plants, focusing on the levels of the toxin cardenolide in the butterflies and their host plants.

• Bookman, S. S. (1983). Costs and benefits of flower abscission and fruit abortion in asclepias speciosa. *Ecology, 64*(2), 264-273. Retrieved from http://search.proquest.com/docview/13590570?accountid=14505
This article presents the results of a study on the energetic costs and benefits of surplus fruit and flower loss in showy milkweed, with information about its general habitat and characteristics.

Database: Encyclopedia of Life, Search: Asclepias speciosa or Showy Milkweed

• Asclepias speciosa Details. *Encyclopedia of Life.* Retrieved from

http://eol.org/pages/581271/details on 4/14/2014
This reference contains a summary of information about Showy milkweed plant including its distribution, propagation, preferred climate, habitat, and soil types, water requirements, interactions with other plant and animal species, its uses in restoration and management, and useful disturbance regimes to encourage growth.

Database: Web of Science, search: Ecology and Evolution of Reproduction in Milkweeds

- Anurag A. Agrawal 2004. Resistance and Susceptibility of Milkweed: Competition, Root Herbivory, and Plant Genetic Diversity. Retrieved from: http://dx.doi.org/10.1890/03-4084 on 4/14/2014.

This article summarized a complex manipulation of milkweed ecology investigating the combined effects of root herbivory by *Tetraopes* beetles on milkweed success and its effects on surrounding grassland, and attempts to create a manual for milkweed ecological under various environmental conditions.

- Braman, S. K., & Latimer, J. G. (January 01, 2002). Effects of Cultivar and Insecticide Choice on Oleander Aphid Management and Arthropod Dynamics on Asclepias Species. *Journal of Environmental Horticulture, 20,* 11-15.

This article presents the findings of a study on the effects of five different insecticides on aphid control in a variety of milkweed species, attempting to determine which species-insecticide combination produced the healthiest plants with the most monarch butterfly larvae.

- Pleasants, J. M., & Oberhauser, K. S. (2013). Milkweed loss in agricultural fields because of herbicide use: Effect on the monarch butterfly population. *Insect Conservation and Diversity, 6*(2), 135-144. http://www.mlmp.org/results/findings/Pleasants_and_Oberhauser_2012_milkweed_loss_in_ag_fields.pdf

This article contains information on the relationship between monarch butterflies and milkweed plants, and the current decline in both the mid-western milkweed population and the accompanying decline in the monarch butterfly population. It examines the primary reasons for milkweed decline in the mid-west and the ideal spatial distribution of milkweed plants for monarch use.

Database: USDA NRCS “PLANTS database”, Search: Asclepias speciosa

- County Distribution: *Asclepias speciosa* Torr. - showy milkweed ASSP in the state of California. *Plants.usda.gov.* Retrieved from http://plants.usda.gov/java/county?state_name=California&statefips=06&symbol=ASSP on 4/14/2014.

This interactive graphic shows the native distribution of showy milkweed from the global scale to the USA county level.

- Young-Mattthews, A, and E. Eldrege. 2012. Plant fact sheet for showy milkweed (A*sclepias speciosa).* USDA- National Resources Conservation Service, Corvallis Plant Materials Center, OR and Great Basin Plant Materials Center, Fallon, CA. Retrieved from: http://plants.usda.gov/factsheet/pdf/fs_assp.pdf on 4/14/2014

This fact sheet provides information on the uses, restoration, ethnobotany, toxicity, status,

weediness, establishment, and management of showy milkweed.

• Parks, Recreation, and Preserves Division. 1994. Iowa's threatened and endangered species (20 October 2002). Iowa Department of Natural Resources, Iowa. Retrieved from: http://plants.usda.gov/java/threat?stateSelect=US19&statelist=states on 4/14/2014.
This page provides a list of Iowa's threatened and endangered species; according to the USDA NRCS PLANTS database plant profile for showy milkweed, this is the only state where milkweed is considered a threatened species.

Database: Google, Search: “Milkweeds in California”

• Borders, B. 2012. A Guide to Common Milkweeds of California. The Xerces Society for Invertebrate Conservation. Retrieved 4/26/14 from: http://www.xerces.org/wp-content/uploads/2011/10/CA-milkweed-guide_XercesSoc6.pdf
This article summarizes the native distribution of the most common species of milkweed in California by county. I have often compared it to a SEEDS map of current milkweed distribution in CA found here:
http://arcmapper.sc.egov.usda.gov/output/Counties_hyborea1v27561032106617.jpg

• Borders, B. 2013. Pollinator Plants of the Central United States: Native Milkweeds (Asclepias spp.). The Xerces Society for Invertebrate Conservation. Retrieved 4/26/14 from: http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mopmcpu11905.pdf
This article contains useful ecological information about milkweeds in the United States, including milkweed benefits to species other than monarch butterflies.

• Borders, B. 2011. California Pollinator Plants: Native Milkweeds (Asclepias spp.). The Xerces Society for Invertebrate Conservation. Retrieved 4/26/14 from: http://www.xerces.org/wp-content/uploads/2011/03/xerces-nrcs-california-milkweed-guide.pdf
This article contains detailed information on the distribution and characteristics of milkweed species common to different parts of California, including information on flowering season.

• Luna, T. and Dumroese, R. K. 2013. Monarchs(Danaus plexippus) and milkweeds(Asclepiasspecies): The Current Situation and Methods for Propagating Milkweed. *Native Plants, 14(1):* 5-15. Retrieved from:
http://www.fs.fed.us/rm/pubs_other/rmrs_2013_luna_t001.pdf
This a literature review that summarizes current monarch butterfly populations and population changes in the U.S., with emphasis on factors affecting their survival, including weather and loss of habitat. It includes detailed sections on milkweed ecology, habitat, and propagation.

• Bring Back the Monarchs: Asclepias speciosa. ND. MonarchWatch.org. Retrieved 4/27 from:
http://monarchwatch.org/bring-back-the-monarchs/milkweed/milkweed-profiles/asclepias-speciosa
This webpage includes a general description of milkweed characteristics, including root depth for showy milkweed.

- Bring Back the Monarchs: The Details. ND. MonarchWatch.org. Retrieved 4/27 from: http://monarchwatch.org/bring-back-the-monarchs/campaign/the-details
This article provides information on monarch population, milkweed habitat, and milkweed propagation, with sections on restoration, ecological interactions, and lifespan.

- Ulev, E. D. 2005. Asclepias speciosa. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Retrieved 4/27/2014 from: http://www.fs.fed.us/database/feis/
This article contains detailed information on distribution and occurrence, botanical and ecological characteristics, fire ecology, and management of showy milkweed.

Milkweed Restoration in the Central Valley

Goals:
Overall:
The general goal for Showy milkweed restoration in the Central Valley is to increase its abundance, especially in corridors of monarch butterfly migration. This includes everywhere between the Northern half of the Rocky Mountains and sites along the California coast stretching from San Diego to Bodega Bay. (Marriott, 1997) Although the Monarchs tend to breed during the summer in the mountains, they require nectar from milkweeds along their migration route to be able to survive the journey to their overwintering grounds*(Luna and Dumroese, 2013)*. There are few tradeoffs to broadly installing showy milkweed. It grows in dense patches and, although according to some it has potential to become an invasive weed, it doesn't tend to dominate, needs little water or nutrients, and attracts the broadest spectrum of beneficial insects out of 43 perennial wildflowers tested in a Washington State University study(James, 2011)(Borders, 2011). The threshold amount of milkweeds in a stand that will be beneficial to butterflies and other insects is as small as ten stalks, which makes restoration easier because it does not need to occupy large amounts of space in order to provide the benefits for which it was introduced(Pleasants, 2013). However, milkweed is toxic to grazers because of high levels of cardenolides in the tissues, and so should not be planted in barren rangeland areas where animals may be forced to resort to it for sustenance. However, most grazers purposefully avoid eating it if there are other options, and so it should not be excluded from otherwise productive rangeland areas(Borders, 2011). Feedbacks to installing milkweed may include the attraction of pollinating birds and insects, which may help the milkweed proliferate, however, insects that pollinate milkweed would also be likely to pollinate other angiosperms, resulting in increased general ecosystem health(Borders, 2011). Showy milkweed is resilient, and able to sprout new stems from its rhizomitous roots after disturbances such as fire, grazing, or mowing*(Luna and Dumroese, 2013)*. However, there are insects that prey on milkweeds, such as milkweed longhorn beetlesv(Tetraopes spp.) and oleander aphids(Aphis nerii), which should be considered as potential risks to milkweed success(Borders, 2011). Including these considerations, restoring milkweeds in the Central Valley is a manageable restoration project with many benefits and few drawbacks.
Short-term:
Ensure Showy Milkweed is on the species list of plants to be added to wild wetland, meadow, and grassland restoration sites throughout the Central Valley. A couple local locations to contact include restoration projects conducted at the Consumnes River Preserve, Yolo Bypass Wildlife

Area, Cache Creek Preserve, and North Davis Riparian Greenbelt Greening Project. These projects may be able to increase the abundance of milkweed in their species mixes or sites, or add it to their species lists if it is not already present. Showy milkweed is common in riparian zones but will survive in a variety of environments (see info sheet for details) and so will be an appropriate plant to install in many areas(Borders, 2011). This restoration goal has the benefit of possible wide implementation without requirements for creation of a new organization to bring milkweed to each of these sites. Presence of milkweeds in wild restoration sites has the same tradeoffs, interactions, and feedbacks as dicussed above; however, the risk of milweed toxins poisoning livestock is lower in these areas.

Long-term:

Expand restoration projects to include adding showy milkweed in more widely distributed locations, such as roadsides, margins in and around agricultural fields, and public parks. Work can also be done on promotion and framing of milkweed as a beautiful plant and an asset to private gardens. A study by Pleasants and Oberhauser in 2012 found that monarch usage of milweeds in agricultural fields was 3.89 times higher than in non-agricultural settings, and so milkweed presence in agricultural settings especially should be increased for maximum benefit to the butterflies. This may not be a feasible goal in many cases becuase the presence of milkweed stands in fields reduces the amount of area that can be used for crops*(Pleasats, 2013)*. However, this assessment does not take into account the beneficial role pollinators attracted to milkweeds provide in agriculture(Borders, 2011). Milkweed should also not be added to fields of hay or alfalfa intended for livestock consumption, as it is toxic unless highly processed(Borders, 2011). Milkweeds added to roadsides have potential to make those habitats beneficial to native pollinators in the midst of invasive grasses that have spread heavily into those recently disturbed locations. Roadside locations are also typically devoid of agricultural use, and addition of milkweeds to these locations can help create wildlife corridors through urban areas. However, more research should be done on whether it is ultimately beneficial to place milkweeds along roadsides as intended habitat for monarchs because of potential risks posed by cars to the butterfly population. Milkweeds in horticultual settings such as public parks and private gardens and yards may be the one of the most effective way to restore broad distribution of milkweed plants because of the prevalence of these types of habitats in urban areas across the central valley. These locations are largely removed from grazers, high volumes of fast-moving cars, and are on smaller scales where climate and soils can be more easily manipulated to benefit milkweeds and foster growth of native communities with more regular maintenance. Drawbacks of planting in these locations might include difficulty in distributing milkweed seeds and plugs to many separate people, and difficulty spreading information to a wide population cogent enought to cause public action and internalization of the need to increase milkweeds to a degree strong enough for people to bring plants home and care for them. Milkweeds also may not be as traditionally aesthetically pleasing as other horticultural flowers like roses, and so may not be favored in public spaces. Human-milkweed interactions that could make this goal more feasible are the popularity of monarch and other butterflies for which humans will tolerate or enjoy the presence of milkweeds, especially in butterfly gardens.

Restoration Plan:

For restoration of showy milkweed in the Central Valley, establishment in many diverse locations is preferable to limitation to only riparian habitats or only roadsides, etc. One of at least two distribution patterns may be desired: sporadic patches established throughout the site, or establishment of one large patch dominating a portion of the site. This will depend on size and location of the site, and availability of sunlight and water. Small restoration sites on the order of half an acre or so may want to limit milkweeds to one area to avoid possible weedy expansion from crowding out other species with shade from their large leaves. Larger sites may want patches spread throughout to ensure that there is butterfly habitat available at intervals frequent enough to be found, possibly meaning within comfortable view, although there does not seem to be information available on the optimum spacing of showy milkweed stands for butterfly habitat.

Milkweeds can be propagated either from seed, from root clippings, or from transplanting seedlings or plugs grown in a greenhouse. For effective restoration of either spatial configuration a combination of seeding and transplanting of plugs will ensure the highest rate of establishment; in a Janke study through Kansas State University, an average of 55% of seedlings planted survived to maturity. Seedlings should be planted about one foot by one foot apart to prevent crowding. Showy milkweeds have been reported to produce an average of 158 seeds per gram, or 115 seeds per large fruit follicle, while each plant has around 6 follicles per stem; therefore, seeding should be generous to ensure adequate establishment; 690 seeds/m2 would closely mimic natural seed release rates from milkweed plants positioned one foot apart*(Luna and Dumroese, 2013)*. Seeds for direct seeding as well as for propagation for transplantation should be collected from other showy milkweeds currently living successfully in similar conditions in the central valley to where they will be placed in a central valley restoration site. This will ensure that they are able to survive this area's Mediterranean temperature and precipitation patterns. Seeds from a remnant or other suitable reference population near the chosen site would be ideal. However, other similar sites may be used; one such location is the CA native plants section of the UC Davis Arboretum, which has a healthy showy milkweed stand. Seeds collected should not exceed 5% of those present in the population. Seeds should be sown in September or October, and pressed lightly into the ground to ensure contact with soil*(Ulev, 2005)*. To attain seedlings, *seeds should be planted in containers 98-200ml in volume, 1.5-2" diameter, and 4-8.5" deep, 5-7 months before they are intended to be transplanted to a site; they can be grown in commercial seedling mix soils, and hand-watered. The young plants can be moved to an outdoor growing area after reaching the desired height indoors.* Seedlings should be transplanted from early fall through the spring, during a period likely to be followed with rain within a few weeks*(Luna and Dumroese, 2013)*. Seelings from historically moister locations may need additional water until they are firmly established.

Milkweeds are an early successional species that can not tolerate shade. Therefore, in order to maintain a milkweed population, the ecosystem must be maintained in an early successional state. This can be accomplished by burning or mowing the site to prevent woody encroachment every 2-3 years; since milkweeds are capable of re-sprouting from the roots, these techniques will not harm them*(Bring Back... Details, ND)*.

Monitoring of the site should be done before, during, and after any restoration attempt. For Showy milkweed restoration, a vegetation survey and photographs of the planned location of milkweed installation should be done during the spring prior to the work beginning to determine whether there is a remnant or reference population and for records against which to judge the success of the restoration attempt. During this season, the milkweeds present will be readily visible and likely flowering. Once restoration has begun, the same type of monitoring should occur in early late fall and mid-spring for two years, after which time seedlings should be firmly established and reproductively mature, and during the mid-spring for up to three years thereafter to ensure continued survival of the population*(Ulev, 2005)*. In case of complete failure of the population to establish during the first year, site conditions should be re-evaluated and more extensive small-scale testing should be done to determine the cause of failure. Changes may have to be made to to improve drainage in the soil or to increase light through removal of nearby vegetation. If only twenty five percent of the population establishes the first year, an additional round of seedling transplants may be warranted to raise the total, along with re-evaluation of the site conditions to determine the cause of failure. However, if half or more of the desired amount of milkweed esablishes, time and natural processes may take over to increase milkweed cover in later years due to its ease colonizing diaturbed areas*(Luna and Dumroese, 2013).*

Despite showy milkweed's tenacity and ability to survive a wide range of environmental and soil conditions, there are still some problems and uncertainties that milkweed restoration may encounter. The most general would be the unsurety that the chosen milkweed species would be able to survive in the particular conditions of the restoration site. This uncertainty could be minimized through the performance of smaller-scale field tests. Some specific potentially questionable conditions inability for the plants the amount of light they need, for example if a beloved old tree or stand of trees dominates and shades the site milkweed restoration may be impossible. If I encountered this problem, I would suggest relocating the milkweed restoration aspect of the project, or thinning the stand of trees to allow more light to come in. Constantly waterlogged soil may also drown the plants due to generally low oxygen levels in inundated soil, although they do tolerate some moisture. To solve this problem I would work of the hydrology of the site to try to get it to drain better. Another problem is that, with decreasing abundance of milkweeds including showy milkweed across its eastern and western ranges, it may be difficult to find reference sites or collect enough seeds to be effective. If I encountered this problem I might consider spending two or three years collecting enough seeds to be able to carry out the project and have a light buffer in seed numbers in case of failure. Similarly, if restoration is planned for a drought year, the lack of rain could delay planting of seedlings until it is too late, in which case I would hold them over until the following fall, or install more extensive, costly irrigation.

Some research questions that could be considered to improve this plan would be targeted research on the optimal stand density and spacing for milkweed health and maximum monarch butterly habitat west of the Rockies, as well as more extensive, purposeful studies on fluctuations in the range of milkweed plants and the effects of central valley agriculture on their extent. Scientists could also do research on the advisability of creating milkweed stands on busy roadsides or center dividers and see if there is any safe/unsafe cutoff for density and speed of traffic to the monarch butterflies the milkweeds would attract. Research could also be done on the exact water requirements and tolerances of showy milkweed.

For the purposes of creating an exact restoration design that would simultaneously be a research experiment, I will say I am working on a level, square two-acre site with plenty of sun in an area with the southern sections of soil tending towards sandy and the northern sections towards clay-ey. The site recieves adequate winter rainfall during the to support a mature milkweed population. It is also in a popular monarch butterfly travel corridor. I would plant at least 18 stands of milkweed, three at the center of the north and south ends of the site and three on each side towards the center on the east and west sides, and six more more scattered in the middle. The stands all would be composed of an equal proportion of seeds to plugs, however, there would be the same amount of extra water added to one stand out of each group of three stands at the different locations, and water witheld from one stand under a shelter with a clear roof. The third would be a control. My strategy for propagation, maintenance, and monitoring would follow the guidelines I discussed for successful central valley milkweed restoration above, with the only variations stemming from soil and water conditions across the site.

My restoration design would allow me to determine the exact effects of varying soil and water conditions on milkweed plants to see whether they do equally well within their range of tolerated soils and water requirements, or whether there is one treatment that is particularly ideal. If I had a larger site with the same gradients of conditions across it I would do at least two more replicates of the treatments in each location in order to have more reliable data.

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Janke, R. (2004). Farming a Few Acres of Herbs: Butterfly Milkweed/Pleurisy Root, Kansas State University. Retrieved from: http://www.ksre.ksu.edu/bookstore/pubs/mf2623.pdf
This article contains general information about milkweeds including suggested spacing between plants.

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This a literature review that summarizes current monarch butterfly populations and population changes in the U.S., with emphasis on factors affecting their survival, including weather and loss of habitat. It includes detailed sections on milkweed ecology, habitat, and propagation.

Marriott, D. (1997). Where to See the Monarchs in California: Twenty-five Selected Sites. California Monarch Studies, Inc.. The Monarch Program. Retrieved 5/7/14 from http://www.monarchlab.org/Lab/Research/Topics/Migration/casites.pdf
This article contains details about the monarch butterfly's Western migration route and locations of some of their overwintering sites in California.

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This article contains information on the relationship between monarch butterflies and milkweed plants, and the current decline in both the mid-western milkweed population and the accompanying decline in the monarch butterfly population. It examines the primary reasons for

milkweed decline in the mid-west and the ideal spatial distribution of milkweed plants for monarch use.

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This article contains detailed information on distribution and occurrence, botanical and ecological characteristics, fire ecology, and management of showy milkweed.

Yarrow (*Achillea millefolium*) Gevork Arutyunyan

Achillea millefolium (yarrow) Plant Restoration

Achillea millefolium (yarrow) has various beneficial impacts on the environment. One of those is that is attracts many different species of native pollinators that can thus pollinate other plants in the area. Yarrow also attracts predatory and parasitoid insects that prey upon pest insects, thus providing another benefit to the environment around it. Yarrow also has numerous medicinal benefits to humans. Yarrow is hemostatic (stops bleeding), inhibits bacterial growth, helps tissues heal, and is anti-inflammatory. Yarrow is also good for soil erosion control due to its system of rhizomes. Yarrow populations are not in decline. They can however still be used and planted in restoration sites to help with the overall restoration goal for the above mentioned reasons. Establishing a yarrow population at the restoration site is our intended goal.

Literature Review by Topic:

Importance of goal:

- Attracts insects that prey on pest insects (Wildflower.org 2014)
    - A. Attracts lacewings that prey on aphids, caterpillars, cottony cushion scale, Insect eggs, spider mites, and thrips. (Sustainable Baby Steps 2013)
    - B. Attracts ladybugs that prey on aphids, mealybugs, mites, and pest eggs (Sustainable Baby Steps 2013)
    - C. Attracts trichograma wasps that prey on Alfalfa caterpillar, Armyworm, Bagworm, Borers, such as corn, peach, and squash, Cabbage looper, Cankerworm, Coddling moth, Corn earworm, Cutworm,Tomato hornworm, Wax moth (Sustainable Baby Steps 2013)
- Attracts native pollinators in area.(Wildflower.org 2014)

- Has medicinal value to humans including; hemostatic (stops bleeding), inhibits bacterial growth, helps tissues heal, and is anti-inflammatory (Bioweb.edu 2011)
- Native Americans used it for tooth, ear, and headaches. Also as eyewash. (Forrest Service)
- Good for erosion control due to rhizomes. (Forest Service)

Establishing plant:

- Optimal time to plant: Spring (Old Farmer's Almanac 2013)
- Soil preference: dry to medium, well-drained sandy loam soil. (Missouri botanical garden)
- Plant in full sun (Old Farmer's Almanac 2013)
- Plant seeds in 12-15 inch hole. (Old Farmer's Almanac 2013)
- Space plants 1-2 feet apart when planting. (Old Farmer's Almanac 2013)
- Add 2-3 inches of mulch to each plant. (Old Farmer's Almanac 2013)
- Propagation (SFGate.com)
    1. Division. Do not divide established yarrow when in bloom. Loosen soil around established yarrow plant. Cut the plant in half with a shovel. Dividing multiple times is o.k. Each segment should have 3 shoots. Dig a hole where the new plant is to be planted big enough to accommodate root ball. Cover the roots and water until soil is moist.
    2. Stem Cuttings. Best done in late spring and summer. Stem should be new and healthy with 3-4 buds. Look for 6 inch long stem. Remove with sheers. Plant in pot that is well drained with potting mix. Potting mix should be peat moss and

vermiculite. Keep between 20-60 degrees Fahrenheit in sunny area. Once 1 inch roots begin to form, can be transplanted. Do not add fertilizer with this method.

3. Seeds. Best done in late winter. Fill seed tray with even mix of peat moss and vermiculite. Place seeds on top of mix. Sprinkle/dust seeds with mix. Wrap tray in thin plastic. When spring arrives, plant seedlings with above instructions from Old Farmers Almanac in dry to medium, well-drained sandy loam soil.

- Competitor plant: *HORDEUM VULGARE*L. A barley plant. Reduces seed production and rhizome (Bourdot, Field, White 1985)

<u>After Establishment:</u>

- Pests: aphids, powdery mildew, rust, and stem rot (Old Farmer's Almanac 2013)
- If receive less than 1 inch of water through rain, then should be watered manually (Old Farmer's Almanac 2013)
- Tolerates: Deer, drought, dry soil, and air pollution (Missouri botanical garden)
- Fire issues: Has low potential for ignitability. Generates rapidly after a fire due to rhizomes and mycorrhizae. (Forrest Service)

<u>Other important fact:</u>

Yarrow was used at a roadside restoration site in Massachusetts along with 11 other plant species. The plants were seed grown sods and the soil was infertile and shallow with direct exposure. After 4 years, yarrow was one of 3 surviving plants at the site. (Forest Service)

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Project Part Two: Yarrow

Our main goal is to establish a population of yarrow and to ensure the population survives in the long term. The short term goal is to just plant a population of yarrow. To do this, we need to first propagate yarrow plants. The source of the yarrow plant seeds can be any population of *Achillea millefolium* found in the wild that best matches the new growing region. No more than 10% of the seeds at the site should be collected. Once the seeds have been collected, the planting should be done in spring. The seeds should be planted 1-2 feet apart. Each seeding will need 2-3 inches of mulch (Old Farmer's Almanac 2013). The soil preference is dry to medium, well-drained sandy loam soil (Missouri botanical garden). The seeds also need to be in direct exposure to sunlight (Old Farmer's Almanac 2013).

Before restoration, it is important to inspect the area for barley species since yarrows main competitor is a species of barley (Bourdot, Field, White 1985). It is also important to see if the site has the soil type preferred by yarrow. Since yarrow prefers direct exposure to sunlight it is important to make sure there are areas that are sunny enough for the plants. Other than these, yarrow is very durable and does not need much done pre-restoration.

In the long term, we are looking at having a cover rate of at least 10% after one year at the planned planting site and at least a 50% survival rate after one year. In order to keep the plants alive, if there is less than one inch of rain in a week, then we should water the plants artificially (Old Farmer's Almanac 2013). Once the plants are established, no pollinators need to be introduced to the site to assist in pollination. This is due to the fact that yarrow attracts a very large number of native pollinators in an area (Wildflower.org 2014). Due to the high tolerance of yarrow to drought, the plants do not need to be monitored frequently. The plants also do not need to be inspected on in the event of a fire due to the fact they germinate fairly quickly after a fire. Yarrow is also very tolerant of grazing and therefore does not need to be monitored if grazing does occur in the area. Yarrow also has its own system of rhizomes which assist in its survival (Forrest Service). Due to the high tolerance of yarrow to various threats and its large rhizome system, a monitoring regime of once a year is sufficient. Over the summer, a more frequent monitoring regime (such as once every month) can be established. However, as mentioned, due to yarrows high tolerance to drought, this may also not be necessary and can be done only as a precautionary measure. The main reason for increased monitoring in summer can be to ensure the plants are receiving enough water. The monitoring can be conducted by any staff member of an organization.

If for any reason we do not have any establishment after 6 months, we will shift our focus from planting seedlings to planting stem cuttings due to stem cuttings having a higher survival rate. Again the reference site for the original yarrow plants can be any wild area with similar growing conditions. The cuttings will again need to be planted 1-2 feet apart and have 2-3 inches of mulch added. If the species does establish in small populations with seedlings after 6 months but the population is not big enough, we plan to plant more seedling to ensure we meet our target goal of having at least 10% cover at the site after one year. This time however the seedlings will come from the established plants at the site. This is because those surviving plants will be the best suited for that specific site and therefore their seeds will have the greatest chance of survival at the site.

There are other areas that can impact the survival of yarrow. The pests of yarrow that can impact their survival are aphids, powdery mildew, rust, and stem rot (Old Farmer's Almanac 2013). Aphids can be controlled through various brand name organic solutions that deal with them. An example of one would be Safer Brand End All Insect Killer. If powdery mildew were to establish, neem oil and jojoba oil can be to eradicate them. An example of a brand name oil spray is Saf-T-Side Spray Oil. No oils should be applied to the plants if the temperature is above 90 degrees Fahrenheit. Plant rust will also need to be addressed through a commercial spray. Bayer Advanced Disease Control for Roses, Flowers & Shrubs Concentrate is a commercially available solution that can help treat rust. For any of the commercial treatments, the amount of their use will depend on the amount of infected plants. Each plant should also receive the recommend amount on the respective labels of the products. The frequency of use and usage schedules should also be determined with information on the labels. Stem rot can be dealt with by manually removing the affected stems.

One of the greatest uncertainties of planting yarrow is if the species will wind up outgrowing and out-competing some of the other plants in the area and thus dominating the site. Due to yarrows high dispersal rate and rapid growth, there is a possibility that yarrow can wind up being weed-like in an area (Forrest Service). Yarrow is also considered a founder species. Since founder species have a high tendency to spread really quickly, it is safe to assume that yarrow does have the potential to overrun an area. Also, each flowering plant can produce several thousand achenes (seed carrying fruit). With the viability of the seeds exceeding 90%, it can be imagined how quickly and widely yarrow can spread (Forrest Service).

In the event that yarrow does appear to be dominating in an area, pesticides might be the only option of controlling them. This is due to the fact that yarrow does have a high tolerance to fire and grazing, which are mechanisms that are used to control other problem species. However, yarrow also has a high resistance to pesticides as well and there are specific pesticides that will need to be used. Verdone Extra and Westland lawn weed killer are just some of the pesticides that can be used (Lawnweeds.UK). If it is worried that the yarrow will take over a site, a monitoring regime of once every four months should be sufficient to stop any early stage invasions. If we do begin to kill off some yarrow, we should only kill off the portion that goes over the targeted goal of 10% of cover.

The main competitor for yarrow is a barley species called *hordeum vulgare l*. This species reduces the reproductive success of yarrow (Bourdot, Field, White 1985). However, it is not known if it is only this specific species of barley that does this or if all species of barely do this. Therefore some experiments and research questions that can be further inspected is to see how well yarrow does with any barley plants that will be planted at the site. This can be done in controlled environments in some kind of container. Ideally the artificial environment should mimic the natural one of the site as much as possible. It is important to see and inspect the dynamics of yarrow with any barley species before the two can be planted at any site together. If there will be experiments conducted on some plants, it will be best to test some other features as well. One test can include testing the various pesticides to see which one works best incase yarrow does become a pest at the site. The yarrow plants can also be deliberately infected with their various pests to see which treatments work the best. If after testing it is determined that barley is not a good species to plant yarrow with but barley still needs to be planted at a site, it would be a good idea to put as much distance between the yarrow and barleys as possible. One of the tradeoffs of having yarrow might even be to not plant any barley at a site that contains yarrow.

The successful restoration of yarrow can lead to a positive feedback to the organism around it. Yarrow attracts a large number of native pollinators in an area that can also pollinate nearby plants. The pollinators themselves will see a benefit as well. Yarrow is also known to attract organisms that prey on pest species (Wildflower.org 2014). Due to its extensive rhizome system, yarrow can stabilize the surrounding soil as well, which will be an added benefit to the organisms around it. These interactions can make yarrow a valuable species in any restoration work where they are suitable to plant.

In the short term, our main goal is to just plant and establish a yarrow population. However in the long run we are hoping for 10% cover of the site within one year. The amount of monitoring that needs to be done depends on what the monitoring is for, such as pests and so on. There are various actions we need to take if we are not meeting our target goal, such as planting cuttings if we have no growth after six months of planting seeds. We would also need to monitor for any pests and handle them with commercial solutions. With yarrow, it is also important to monitor to see it does not become weed-like and dominate an area. Depending on experimental results we also need to make sure that either barley plants are not in the area or are spaced far away from yarrow. Due to yarrows ability to attract many pollinators and predators of pests, it will be worth the effort to make sure there is a sable yarrow population at the site.

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Lupines (*Lupinus sp)* Mandy Royal

Project Background and Justification

The Lupinus genus is a nitrogen fixing legume with a mychorrizae relationship and is native to California, found in almost all plant communities (CalFlora 2014). Lupines are known for their silvery palmately divided leaves and erect whorls of blue to purple flowers. The specific varieties of interest in this project are Broad Leaf Lupine (*Lupinus latifolius var. columbianus*), Common Broad Leaf Lupine (*Lupinus latifolius var. latifolius*), Arroyo Lupine (*Lupinus succulentus*), Bicolor Lupine (*Lupinus bicolor*), Summer Lupine (*Lupinus formosus*), Chick Lupine (*Lupinus microcarpus var. microcorpus*), and Sky Lupine (*Lupinus nanus*). The large variety of lupines provides one with plants that are both annual and perennial; this group of lupines provides a bloom time ranging from February to October, which is especially important for insects and birds (CalFlora 2014). Lupines also provide critical habitat for butterflies like the Mission Blue and Boisduval Blue butterflies (Weiss, Murphy 1990), and is a main source of pollen for bumble bees. Lupines are critical in the support of native insects; however, the plant is highly poisonous to animal like cows and goats due to the alkaloid contents (Forest Service 2014). The consumption of lupines among cows can cause crooked calf disease, and goats can have stillborns. Lupines have an extensive rooting system making them adapted to fire and mowing, and they are a source of erosion control (Forest Service 2014). Lupines are also early successional species allowing them to establish after disturbances like fire or volcanic activity, building the basis for a growing plant community. Lupines are used for rehabilitation and strengthening of habitats because it has a nitrogen fixing ability, high survival rate, and an ability to spread quickly and grow in poor soil (Wu, Kruckeberg 1985).

Fact Sheet
Lifecycle

Specific Variety Conditions

Common name	Latin Name	Habitat	Perennial or annual	Bloom time	Soil pH	Soil salinity	CaCo3 concentrations	Soil water holding capacity
Broad Leaf Lupine	***Lupinus latifolius var. columbianus***	Riparain	Perennial	April -March	6.8	non-saline	low	high
Common Broad Leaf Lupine	***Lupinus latifolius var. latifolius***	Riparian	Perennial	April-March	6.8	non-saline	low	high
Arroyo Lupine	***Lupinus succulentus***	Riparain to grassland	Annual	Feburary-May	5.7-8.2	non-saline	low	high
Sky Lupine	***Lupinus bicolor***	grassland	Annual	March- June	5.2-8.2	non-saline	low	low
Summer Lupine	***Lupinus formosus***	grassland	Perennial	June-October	05.3-7.0	non-saline	Prefers no concentrations	low
Chick Lupine	***Lupinus microcarpus var. microcorpus***	grassland	Annual	May-June	6.1-8.4	Slightly saline	low	low
Bicolor Lupine	***Lupinus nanus***	grassland	Annual	March-May	5.4-7.7	non-saline	low	low

Plant Description
These lupine varieties height can range from 1-4 feet tall with an erect inflorescence that has many whorled pea-like flowers that can be 4-12 inches tall. Flowers of the given varieties range from blue to purple. The leaves are palmately compound with 5 to 10 elliptic leaflets. Leaves tend to be a grey green to a dark green (Forest Service 2014).

Reproduction: All the selected Lupine varieties can regenerate through seeds or rhizomes. Rhizomal reproduction is when the root systems has root sprouts, or root fragments break off and create a new plant. Lupines have genetic variation due to each plant producing up to several hundred seeds (Brown 2010). Genetic variation is important in lupines, decreasing the likelihood of deleterious alleles negatively impacting the population,. Lupines produce their first bloom their second year of life. Lupine's bloom starts from the bottom to the top allowing for the production of pods at different times; the most mature found at the bottom and youngest at top (Brown 2010). The seedpods can produce up to 10 seeds and once the pods reach maturity they pop open (best to harvest before pods have matured). Seedpods can open with such force they can expel the seeds up to 16 feet (Brown 2010). Seeds are water or gravity dispersed and some lupine species do make a seed bank (not clear if all do). Untreated seeds should be planted during late fall or winter; lupines require cold weather for the development of their roots, and take a few months to germinate (Palmer 2014). Treated seeds produce the most germination success and is the fastest growing method. The treatment begins with scarifying the seeds, then soaking seeds in warm water for 24 hours, and finally planting the seeds in early spring to late summer (Palmer 2014).

In the greenhouse, seedling survival averages around 90%.(Forest Service 2014). However, transplanting of lupine is not recommended because the development of tap roots; if lupine are transplanted too late in life and the tap root is broken and the plant will not survive. Once established lupine can take over a swath of land due to their nitrogen fixing ability and mycorrihzae relationship allowing them to out compete other plants (Forest Service 2014). Lupine are insect pollinated by honeybees, bumblebees, butterflies, and hummingbirds. Bee visits have shown to improve seed set by increasing both self- and cross-pollination (Karoly 1992).

Mycorrihzae Relationship: *Lupinus* is a nitrogen-fixing legume that requires mycorrihzae. The relationship with the bacteria builds upon the lupines rooting system; the extensive rooting system helps with erosion control. The mycorrhizae species, Bradyrhizobium, when inoculated with lupine seeds extends the rooting systems of the plant (Kurlovich 2002). The mycorrhizae's extension of the rooting system makes phosphorus more available allowing for increased nitrogen fixation (Kurlovich 2002). Besides erosion control this relationship in the roots helps lupine to tolerate poor soils, drought, and disease because they tolerate stress better. The need of mycorrihzae when restoring lupine is often overlooked and should be taken into account (Baird 1989).

Nitrogen Fixing Ability: Lupine are successional species allowing them to inhabit poor soil, and through fixing nitrogen they make the soil habitable for other plants (Forest Service 2014) . Lupine's ability to fix nitrogen comes from the symbiotic relationship between rhizobia and lupine's root systems. The rhizobia forms nodules on the roots and perform nitrogen fixation that is readily available for the lupine to grow and out compete others (Kurlovich 2002). Having the ability to fix nitrogen allows the plants to grow and thrive in poor nutrient environments. Lupines are often the first plants to sprout after a volcanic explosion. They improve the soil quality by fixing nitrogen and catching nutrients blown by the wind, creating lands of fertility (Forest Service 2014). It has been found that due to the lupine's ability to fix nitrogen they can inhabit sites with high levels of copper, and with time and nitrogen fixation lupines can make the site tolerable for other plants; they alter the ratio of nutrients in the soil to tolerable levels (Wu and Kruckeberg 1985). Addition of fertilizer or excess nitrogen can potentially kill lupine because the addition gives the plant more nitrogen than it needs (King 2014).

Fire Ecology: The rooting system in lupines allows them to withstand fire. However, the fire return for the species of lupines differs depending on what habitat they are adapted to. The riparian species Broad leaf , Common Broad leaf, and Arroyo lupine have a disturbance fire regime of 35 to 200 years (Forest Service 2014). The grassland adapted species, Bicolor, Summer, Chick, and Sky lupine, have a disturbance fire regime of 10- 25 years (Forest Service 2014). Fire is not directly needed for lupines; however, fire has shown to have benefits for lupine allowing them to be more abundant and produce more flowers (Forest Service 2014). Research is being done to see if the combination of mowing, cutting, and herbicides can be used in place of fire (Forest Service 2014).

Habitat: Broad leaf, Common Broad leaf, and Arroyo lupine are riparian species requiring sites with more water but they cannot handle full inundation. Bicolor, Summer, Chick, and Sky lupine are grassland species requiring full sun and will not tolerate excess water (CalFlora 2014). All the listed lupine species prefer sandy loam soil and are found most commonly in disturbed sites like after a fire, volcano, or human disturbance (sides of roads, mine sites, etc) (Forest Service 2014). With the exception of the riparian varieties, the lupines do well with little to no water once established (CalFlora 2014). When starting from seeds, lupines require a constant moist soil until their taproot has fullydeveloped; taproots can be up to a couple meters long (Kurlovich 2002). Spatially, lupines do well in clumps but are more successful when about a meter apart from each other (Moore, Harrison, Elmendor 2011). Most commonly, in the wild lupine are found in large clusters; however, with a greater distance apart lupine are more likely to have more successful seedlings and survival for long periods of time.
Lupines have higher survival rates in areas with moderate canopy and ground cover and reduced litter cover (Pavlovic, Grundel 2009). Given these requirements and lupines ability to shade other plantsout, plants that can handle these conditions are Irises, Columbines, Poppies, and Purple Needle grass(Russel 2014). Lupines tend to have a high tolerance of pollution and do well in urban areas (King 2014).

Interactions

Insects: All listed varieties benefit native bees, bumble bees, hummingbirds, and butterflies (CalFlora 2014). Butterflies like Mission Blue, Painted Lady, West Coast Lady, and Common Sulfur butterfly are dependent on lupine for food and larvae habitat (Tree of Life Nursery 2014). Insects are required for the pollination of lupine. Bumble bees most frequent lupine for pollen. *Lupinus formosus* is critical habitat for endangered butterfly species, Mission Blue, due to its later blooming period (Weiss, Murphy 1990). By having a mix of lupines varieties one can create a long bloom period creating a longer food source for insects. (Kremen et al. 2002).

Plants: The removal of lupine from a habitat can cause increased annual weed invasion due to the nitrogen rich soil. Lupine removal might be performed for a disturbance regime, or if lupine becomes weedy affecting other native plants. Also invasive annuals can be a problem if they beat the lupines to germination in the spring. When lupines are established in a habitat their leaves shade out competition and most of the nitrogen they fix is only available to them, preventing an invasion (Maron Jefferies 1999). Only some of their nitrogen is released into the soil while the

plant lives; the soil gains most nitrogen after the plants death. Lupine is known as an increaser plant in that when in a habitat it
increases overall plant diversity (Maron Jefferies 1999).

Animals: Lupines are considered toxic to many animals due alkaloids in the plant. Black tail deer are known to eat the plant with no known repercussions. Birds and rodents eat the seeds. For grazing animals its not good for them to eat lupine, it has been known to cause birth defects in cows, horses, and goats. Humans can have children with birth defects from lupine if they consume cow or goat milk during their pregnancy from an animal that has consumed lupine (Kilgore 1981). Usually grazers will ignore lupine, but when stresses like pregnancy cause them to eat the plant. Pregnant cows and goats that eat lupine can have stillborns, or crooked calf disease in cows (Kilgore 1981). When highly grazed the plants will have produce less inflorescences to adapt to the grazing. Lupine is not resistant to trampling but can handle some (Forest Service 2014).
Human: Native people used lupine seeds to make tea to help with urination. Lupine provide an ascetics value making it a popular ornamental plant (Forest Service 2014). Lupines are widely distributed in gardens for their beauty and ability to attract beneficial pollinators; hundreds of lupine varieties are spread throughout the United States (CalFlora 2014). Due to lupine's nitrogen fixing ability, lupine is used as a cover crop in orchards and in fields for crops like wheat or spinach (Kurlovich 2002).

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A. Goals for *Lupinus* species

The *Lupinus* genus thrive in poor quality, slightly acidic soil making it an early successional legume that is able to fix nitrogen due to its relationship with rhizobia (CalFlora 2014, Kurlovich 2002). The mycorrhizal relationship on the *Lupinus* roots creates an extensive rooting system that prevents erosion and enriches the soil by promoting a higher nitrogen fixing rate due to mycorrihzae making phosphorus more readily available (Forest Service 2014). Establishing a genetically diverse community of *Lupinus* by collecting from mulitple reference sites in Yolo and Solano county will allow for the species to grow in riparian and grassland habitats, and provide wildlife with a blooming time from February to October (Kremen et al. 2002). Maintaining the population of *Lupinus* will require a disturbance regime of mowing, herbicides or a combination of both, and spatial heterogeneity of plants to prevent the spread of disease will allow for lupine's optimal survival (Moore, Harrison, Elmendor 2011).

Objectives

Establishment Phase:

- Plant a mixture of seven native *Lupinus* species (riparian and grassland forms) that will reduce erosion, enhance native vegetation, and provide a food source and habitat for wildlife(CalFlora 2014)

  Riparian Species: Broad leaf lupine (*Lupinus latifolius var. columbianus)* and Common Broad leaf Lupine (*Lupinus latifolius var. latifolius)* are riparian varities; they are faculative wetland species meaning they occur in riparian areas but can tolerate non-riparian conditions. Arroyo Lupine *(Lupinus succulentus)* is a faculative riparian species allowing it to grow in either riparian or non-riparian areas (USDA 2014). These three species should be planted near a water source but far enough away that the plants are not inundated for long periods of time, no more than a couple of hours a day during wet season (USDA 2014). Planting depends on site topography and water specifics.

  Upland: Bicolor Lupine (*Lupinus bicolor),* Summer Lupine *(Lupinus formosus),* Chick Lupine *(Lupinus microcarpus var. microcorpus),* and Sky Lupine (*Lupinus nanus)* are upland species and will not occur in riparian areas. These four species should not be planted near water, best planted in a high, dry area with full sun (USDA 2014).
- Install a drip irrigation system to keep soil moist for plant recruitment and establishment.
- Enrich mycorrhizae fungi population at planting site with the addition of water and organic matter to soil. Or inoculate seeds with the mycorrhizae species Bradyrhizobium before planting (Kurlovich 2002).
- Monior recruitment success rate for three years, checking once a month between Feburary to October. If after three years one does not have 50% of recruitment then one needs to reevlaute site or planting methods to see if possible errors were made (Forest Service 2014).

Maintenance and monitoring phase:

- Maintain newly established *Lupinus* populations by not spraying pesticides or herbicides at site, chemicals can kill the rhizobia or mycorrhizae relationship on the lupine's roots (King 2014). Lupine's are self-sustaining after establishment. Ensure the plants are providing a food source and habitat for wildlife having a flowering rate of 75% will provide a food source for pollinators and habitat for butterfly larvae (Forest Service 2014).
- Develop an optimal disturbance regime of mowing or herbicide application promoting a healthy population of *Lupinus.* The riparian lupine varities have a fire regime of 35 to 200 years, while the upland species of a fire regime of 10-25 years (Forest Service 2014). Research by the Forest Service has shown that mowing is the best alternative for fire, but each site differs on disturbance success and wildlife. If time and funds allow, one should experiment with mowing and herbicides to see which method is best for the specific site. One also needs to take into consideration other wildlife needs(if butterflies are in larvae stage) when performing a disturbance regime.

B. Restoration Plan

Implementation

Task 1: Collection of seeds

Collection of *Lupinus* seeds will need to take place during the spring to fall after the flowers have bloomed and the pods have matured (Dean 2014). The seedpods can produce up to 10 seeds and once the pods reach maturity they pop open (best to harvest before pods have matured). Lupine's bloom starts from the bottom to the top allowing for the production of pods at different times; the most mature found at the bottom and youngest at top (Brown 2010).Lupines produce their first bloom their second year of life. According to CalFlora, all seven species are widely distributed in Solano and Yolo county (CalFlora 2014). Collection times will differ due to the range in blooming times (*Lupinus latifolius var. columbianus*: April to March; *Lupinus latifolius var. latifolius:*April to March; *Lupinus succulentus:* February to May;*Lupinus bicolor:* March to May; *Lupinus formosus:* June to October; *Lupinus microcarpus var. microcorpus*:May to June; *Lupinus nanus:* March to May). Genetic variation in each variety, for long term survival, requires a collection method of five seeds from ten plants per population (seed pods can produce up to 10 seeds) (Forest Service 2014). For the survival of the collection populations, collect less than 5% of seeds at one time. The wider range of populations one can collect from will ensure genetic variation. Having genetic variation among the lupine will prevent deterious alleles and will help plants to adapt better to changes in the environment.

Task 2: **Preparation of the site**

Before starting this project the site should be readied for the requirement of a *Lupinus* population. First, one should clear site of debris and control weeds(preferably with fire). *Lupinus* seeds require full sun and moist soil for establishment, weeds could reduce soil moisture and sun exposure for the seeds. Lupine have higher survival rates in areas with moderate canopy and ground cover, and reduced litter cover (Pavlovic, Grundel 2009). Depending on site location mycorrhizae may be limited; *Lupinus* require a mycorrhizae relationship (Baird 1989). To add this relationship one should prepare the soil with the addition of organic material, and water which will promote mycorrhizae health and abunance (Harlequin's Gardens 2014). If the site lacks mycorrhizae purchasing a mycorrhizae product from Organica Biotech, Plant Health Care, Inc., Mycorrhizal Applications, Inc., BioLynceus and Eco-Cycle Compost Tea will provide one with the healiest product (Harlequin's Gardens 2014). Native lupines do best with the seeds are inoculated with the species Bradyrhizobium (Kurlovich 2002).

Task 3: **Design/install of irrigation system**

California's environment is unpredictable, and with *Lupinus* seeds requiring a constant moist soil a irrigation system should be installed. The drip system will be a slow drip, placed on below the soil, below the soil is required so a disturbance regime can go through. This will allow for a constant moisture but prevent water logging of the soil (Dean 2014). The system should be built in the same location as seeds. The moist soil will also support mycorrhizae allowing for a relationship to form among the roots and fungi (Harlequin's Gardens 2014). Irrigation will be needed also for recruitment years after a disturbance regime.

Task 4: Preparation of seeds/seedlings

Depending on the budget and time frame of the project one can use untreated seeds, treated seeds, or transplantings.

Untreated Seeds:Planting of untreated seeds should take place during late fall or winter, *Lupinus* requires cold weather for the development of their roots, and can take a few months to germinate (Palmer 2014). If fall or winter planting time is missed, then before planting seeds place them in a refrigerator for seven days to simulate a cold period, and then plant them during spring (Palmer 2014). Untreated seeds are the least expensive method in impleteing lupine, but this method takes the longest time to see growth. Untreated seeds usually do not germinate until a year after being planted. This method can be beneficial if one has a timeline of planting in the fall before winter rains.

Treated Seeds:Treated seeds produce the most germination success and is the fastest growing method. The treatment begins with scarifying the seeds,then soaking seeds in warm water for 24 hours, and finally planting the seeds in early spring to late summer (Palmer 2014). One problem with this method is if there is a long rainy season causing the site to be too muddy, it could prevent the planting of the treated seeds.

Seed Inoculation: Given site conditions, seeds will need to be inoculated with mycorrhizae. Inoculating requires soaking seeds for two to fours in water, and once drained add the choosen mycorrhizae. Exact amounts of mycorrhizae depend on the number of seeds. A rough estimate would be 50 seeds per 2 tablespoons of mycorrihzae (Harlequin's Gardens 2014).

Transplanting: The least successful method of growing *Lupinus* species is with transplanting. *Lupinus* species are transplanted most successfully when they are "very young due to their long, fragile taproots" (Palmer 2014). For the best results, grow the seeds in peat pots because they survive better when roots receive little handling. Transplanting method assumes one is using treated seeds, and should be transplanted in the spring. This method is the most expensive and labor intensive method of establishing a lupine population. Lupine can also be propagated through cuttings, but this method is not recommended because it has a low success rate (Dean 2014).

Task 5: **Planting**

After one has prepared their seeds or transplants one is ready to plant. The location of the plantings should be a sandy loam, slightly acidic, moist soil (CalFlora 2014). Also important for survival is having a deep soil so the plants can have a long tap root. *Lupinus* species have extensive rooting system and would grow well in highly eroded areas (Wu, Kruckeberg 1985).

Untreated Seeds: As stated early, untreated seeds should be planted in late fall or winter; also it should be noted that planting untreated seeds during the spring can delay growth for up to a year.

Treated Seeds: Treated seeds should be planted in early spring to late summer.

Treated and Untreated Seeds: A minimum number of 700 seeds per acre and a maximum of 2700 per acre should be applied to the planting site (*Find the Best* 2014). When planting either seeds they should be planted ¼ to ⅛ inch deep, and spaced 15 to 24 inches apart (Dean 2014).

Transplanting: Transplantings should be planted in early spring to late summer. The spacing of the plant is critical for long term success of the *Lupinus* population because it reduces the spread of disease and reduces intraspecies competition (Moore, Harrison, Elmendor 2011). For the transplantings, dig a hole 1 1/2 times bigger than the size of the pot, and make sure to place the seedling so the structure from which the leaves grow remains above ground (Palmer 2014). This planting method will help with the survival of seedlings.

Task 6: Monitoring of plant requirement

Monitoring the success of the *Lupinus* species will take a few years to measure its true success. *Lupinus* species have a high seedling survival rate up to 90% when in a greenhouse, but in nature the survival rate decreases (Forest Service 2014). The first spring will not be a good indicator of success because seeds germination can be delayed due to climate variations (Palmer 2014). By the second spring one should have a requirement of at least 50%; however, the sign of a successful population is if the plants are self seeding and spreading across the environment, inceasing their population at a rate of 10% a year(Forest Service 2014). This level of success will not be noticeable till the third spring. Note: these numbers could vary given environmental conditions like drought or El Nino.

Risks: If the site fails to produce such a population one should first check pesticide use; pesticides have the ability to kill lupine (King 2014). Check herbicide use: herbicide use can kill the mycorrhizae and without mycorrhizae survival among lupine is rare[Note: this is differs from an intentional disturbance regime, see task 8] (Harlequin's Gardens 2014). Chemicals like glyphosate or triclopyr kill lupine (Mahoney 2014). Invasive weed managemant involving pesticides should happen a year before lupine establishment. Some research has found the combination of mowing with herbicides could be a suitable disturbanc regime for lupine[See Areas of concern]. If one has a sporadic requirement of *Lupinus* populations this could be due to the soil; a soil too rich in clay lupine cannot tolerate (Dean 2014).

Task 7: Maintaining Lupinus populations

After one has established a population of *Lupinus* varieties monitoring should occur every five years from spring until late summer. Once at the end of the month from March until October will be need to monitor the blooming of each variety (CalFlora 2014). Monitoring will include checking the health of the population by seeing if the plants are blooming, creating seeds, and providing habitat for wildlife like the *Mission Blue, Painted Lady, West Coast Lady and Common Sulfur butterfly* (Weiss, Murphy 1990). Having butterflies, bees, bumblebees, and humingbirds at one's site is a sign of success, but does not need to be monitored unless lupines are not producing seeds. If pollinators are not pollinating the lupine flowers, flowers change color after being pollinated (Blue with have tints of purple, purple with tints of pink, etc.), one needs to address why pollinators are not coming to the site. One would need to advise with a pollinator expert. Lupines can spread very quickly, taking over a swath of land, removal of lupine may be required for the health of other native forbs (Forest Service 2014). Removal of lupine is based on the sites goals, if one wants biodviersity eveness, then one should remove lupine when it outcompetes other plants, or threatens other natives establishment. There is no exact measurement of when to remove lupine; it depends on site prefeneces.

Task 8: Creation of a disturbance regime

Fire: The *Lupinus* genus are plants that do best with a fire disturbance regime. A fire regime of around 20 years for upland and riparian species is considered best; however, fire is not the safest option in urban areas (Forest Service 2014). A disturbance should be performed late summer or fall, after the plants have flowered and before winters first rains (Forest Service 2014). Lupines are adapted to surface fires by having a extensive rooting systems that withstands fire, and are able to sprout from vegetative breakages. Fire also rejuvenates lupine populations because they prefer disturbed sites due to "nitrogen volatilization during fire and nitrogen loss from thatch burn-off"(Forest Service 2014).

Non-fire Regimes: Instead of fire, lupines have shown to have the same response to the combination of mowing, cutting, and herbicide application (Forest Service 2014). The best method found has been complete removal through mowing. Like fire the removal of the top cover and leaving roots intact has shown to produce lupines with increased flowering. Problems have arose with too much herbicide use because it can completely kill the plants. Experiments are being performed to see what amount of herbicides mixed with mowing provide the highest flowering rate (Forest Service 2014). This process reduces vegetation cover, but allows for a larger recruitment the following season (Forest Service 2014). The disturbance regime is subject to change depending on the monitoring results; if there are high numbers of butterflies using the plants disturbance should be delayed (NatureWorks 2014).

Areas of Concern and Further Research:

Toxicty:A problem *Lupinus* plants pose are that they are highly toxic. In an urban area they are beneficial in that they can tolerate high levels of population (King 2014), but if consumed by certain animals or people it is poisonous (CalFlora 2014). Lupine has shown to cause harm to grazing animals like cows and horses, but has no known effect on deer, rabbits, and chipmunks (Forest Service 2014).Humans can have children with birth defects from lupine if they consume cow or goat milk during their pregnancy from an animal that has consumed lupine (Kilgore 1981). When planting lupine in urban areas one needs to be cautious of possible wildlife or humans that might consume the plant.

Disturbance Regimes: The area of most concern is the disturbance regime, not too much is known on the exact effects of fire and whether mowing, cutting, and herbicide application can completely make up for fires. Studies have shown that lupines after fire have increased flowering and germination, but these results varied with biome type (Forest Service 2014). Mowing and herbicide use has been used to maintain *Lupinus* population sites by recreating the structural damage of a fire, but not enough research has been done to shown if the lack of burning will later affect *Lupinus* requirement (Forest Service 2014). Different disturbance techniques could be used at this site to discover which technique provides the most recruitment.

Preventing invasives: One problem the disturbance regime of lupine can cause is an increased invasion of weeds. Lupines are adapted to fire, but the other forbs at the site may not. Bringing a disturbance regime could cause a removal of native forbs and grasses and replace them with invasive species (Maron, Jefferies 1999). Once the lupine have been removed, they create a nitrogen rich soil that is quickly taken up by invasives. A study has found that lupine are able to recover, but natives that were once there might are not able outcompete the invasives; those natives that do recover are smaller than the natives that use to occupy the site (Maron, Jefferies 1999). To combat this issue one should plant natives that have disturbance regimes like Purple Needle grass and other pernnial bunch grasses or forbs.

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Poppy (*Eschscholzia californica)* Matthew Valle

***Eschscholzia Californica* (California Poppy)**

1. Distribution & Habitat
    a. The California poppy is native throughout California and both North into Washington and South into Mexico (Montalvo 208).
    b. Poppies are known to thrive in both naturally and artificially disturbed environments (Leger & Rice 257).
    c. Poppies are known to occupy environments that have natural fire regimes such as the Southern Californian chaparral (Montalvo 208).
    d. Poppies are tolerant of sunset zones 1 – 24 which covers most of California (Brenzel 310)
    e. Poppies grown in riparian environments do not generally grow in soil that is kept moist, rather they grow on sandbars away from the water or on well drained gravely soils near the water (Moise & Hendrickson 20).
    f. Poppies are a good species to plant under oak trees because they do not need a lot of water and can tolerant the fringes of the canopy where more light gets through (Brenzel 73)
    g. Poppies are known to be found living in oak communities and vernal pools in the Sacramento valley (River-Friendly Landscaping).
2. Habit, Morphology, & Tolerances
    a. E. *Californica* is an herbaceous plant with finely divided bluish-green leaves that emerge basally. The plant can grow to be 1 foot tall and 1.5 feet wide. Flower color depends on the variety but is generally orange or yellow. A characteristic unique to the family is two fused sepals that fall off when the flower opens and a characteristic unique to the genus is a protruding rim at the top of the receptacle. Flowers close under low light conditions. (FGP and Brenzel 310).
    b. The fruit is a dehiscent capsule which varies greatly in seed number and can spread seed up to two yards (NRCS 2).
    c. Poppies enjoy adequate light and water and are adapted to a variety of different soil and climatic conditions. They do not however fare well under strong competition for resources (NRCS 3,4).
    d. In a seeding experiment poppies were shown to have a strong positive correlation with nitrate concentration and were shown to have both a negative and positive correlation with organic matter concentration in different years. (Montalvo & Mcmillan 60, 61)
    e. Variations in morphology of the perennial varieties include a stout coastal form that grows in mounds and a taller inland form that grows more spread out (Leger & Rice 258 and FGP).
3. Life History

a. Poppies are outcrossing species pollinated by bees and beetles (FGP and NRCS 1).
b. Poppies bloom and seed from spring to summer (Brenzel 310).
c. Southern California poppies have naturally dormant seeds which are dropped in the spring of their first year and delay germinating until the winter rains (Montalvo 208).
d. <u>Perennial vs. Annual Varieties</u>
    i. Although the poppy is found in many different habitats in California, from the coastal redwood forests to the desert, it changes its life history strategy across moisture regimes, acting more like a perennial as water becomes less available (NRCS 3-4).
    ii. Perennial varieties are common in coastal and inland regions where conditions are not severe and storing energy in the root system is a reasonable survival strategy. Annual varieties are more likely to grow in dry regions or those with harsh winters (FGP).
    iii. Of the many varieties of E. *californica* the most prominent feature between them is how vast their root system is with the perennial varieties being more robust and having a thicker tap root than annual varieties (NRCS 3).
    iv. Annual varieties of the California poppy should be considered for arid, shallow, aerated soils while perennial varieties are better suited for deep well drained soils for healthy tap root growth (NRCS 4).

4. <u>Pests</u>
    a. Common gardens in California have shown that a moth known as Neoterpes edwardsata and a caterpillar known as Lepidopteran feast on poppy flowers and can become pests (Leger & Forister, 312).
    b. Slugs and snails are known to eat young poppy plants (Leger & Forister, 312).
    c. Poppies can be the target of many insects and diseases however they are generally not lethal unless abiotic conditions are not ideal (water logged soil) and then the plant can suffer significantly (NRCS 5).
    d. Livestock may graze on the plant depending on the age of both organisms however there is also the possibility for livestock to find the plant to be toxic (NRCS 5,6)
    e. Poppies are deer resistant (Brenzel 57)
5. <u>Propagation</u>
    a. <u>Selecting Seed</u>
        i. Both annual and perennial seeds of Wild E. *californica* populations were shown to exhibit dormancy while seeds from cultivars did not. It was further demonstrated that smoke along with a moist cold treatment was the best method for breaking dormancy of wild seeds. It is suggested that

using naturally dormant seeds has advantages for restoration in environments where individuals whose seeds are dormant are more likely to produce successful offspring or in areas where fire management is prevalent. If fire management is not a viable option but wild seed is still preferred over domestic seed liquid smoke is useful for breaking seed dormancy in the absence of actual fire (Montalvo 207 &225).

ii. Wild seeds are generally less prone to delayed germination due to light than seeds from cultivated varieties. This is not always true however and depends on the traits of the source population and commercial method of stock increase. Whether or not the seeds to be used are inhibited by light may play a role in determining the best planting depth for ample germination (Montalvo 210 and Montalvo & Micmillan 64).

iii. Choosing a wild seed type that is adapted to the area of interest is ideal because dormancy will likely be broken naturally and because cultivated seed may not fare as well under natural conditions. Natural seed is generally more expensive than cultivated seed. If dormancy is not likely to be broken naturally smoke or cold moist stratification can be used (NRCS 4) .

b. Seeding Methods

i. Montalvo & Micmillan did an experiment comparing different seeding methods along with different ripping depths in order to determine the best planting method for poppies. Although results were somewhat varied it is was generally determined that imprinting and drilling were superior to hydroseeding, especially in dry years, and that overall imprinting was superior to drilling (Montalvo & Mcmillan 60, 61, 63, 64, 65).

ii. In Montalvo's & Micmillan's experiment both 20-cm and 40-cm soil ripping depths showed promise under different conditions but success is likely to vary with varying susceptibility to light induced germination inhibition. Soil ripping in general was shown to produce higher plant densities than occurred in the absence of soil ripping (Montalvo & Mcmillan 60, 61, 63, 64, 65).

iii. The NRCS suggests a half inch planting depth for non light-inhibited varieties and between a quarter to an eight inch planting depth for species that are light inhibited (NRCS 4).

iv. Seeding in the fall right before natural germination promoting conditions such as rain occur is ideal (NRCS 4).

v. Amount of seed to be used should vary depending on the planting goals but can be in the range of 3 to 4 pounds per acre (NRCS and Brenzel 310).

c. Greenhouse and Field Methods

i. Collect mature seed from brown capsules from mid spring to mid fall and store under dry conditions at room temperature (Young).
ii. Poppies should only be transplanted if they are very young however seeds can be sown in flats at the end of September and then transplanted to containers about two weeks after germination. Potting mixes can be found on Betty Young's website (NRCS 4 and Young).

6. Invasive Status
   a. Poppies can become invasive in non-native Mediterranean environments (Leger & Rice 257).
   b. It has been shown that invasive poppies have acquired traits that make them more resistant to herbivory than populations in their native environment (Leger & Forister 311, 14).
   c. Plants from invasive populations in non-native habitats have been shown to be larger and more reproductively successful than native non-invasive populations when grown in a common garden environment (Leger & Rice 261 and Leger & Forister 315).
   d. The Poppy's ability to grow under a variety of conditions and susceptibility to competition likely contributes to its invasive properties (NRCS 4).
7. Management
   a. Little management is generally needed for perpetuation however making sure to plant poppies in a well aerated soil and relatively clean seedbed with plenty of sun and little competition is important. Fertilizer high in nitrate can be applied however poppies are tolerant to low nutrient conditions (NRCS 5).
   b. Do not apply herbicides with any of the following ingredients after germination has occurred: pendimethalin. DCPA, oxyfuorfen, dicamba, and pronamide (NRCS 6).
8. Other
   a. E. *Californica* is the California state flower and is commonly used in restoration (Montalvo 208).
   b. Poppies can be used for erosion control (NRCS 1) .
   c. Poppies have traditionally been used by Native Americans for medicinal, cosmetic, and culinary pursuits (FGP).

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Eschscholzia californica: Restoration Plan for the Central Valley

1. **Goals**

1. Establish substantial, self-perpetuating stands of California poppies that are adapted to the Central Valley environment. Seed will be from local, wild populations ensuring physiological adaptation to abiotic conditions. Wild poppies produce seed with natural dormancy which will produce future generations.

2. Add aesthetic value. Poppies in the Central Valley are perennial and capable of producing beautiful orange flowers from February through October (TWC Staff).

3. Service the biological community. Poppies attract both insect pollinators and birds and also serve as food for insects (NRCS 1).

2. **Site Preparation & Seeding**

Evaluations of competitor species, soil characteristics, and local hydrology will be made in order to predict the viability of planting poppies in a given area. Poppies are known to grow in various Central Valley habitats including vernal pools and foothill woodlands however to increase the probability of establishment we will take measurements to ensure a proper microenvironment (Elkhorn Slough). Poppies are not good competitors, they are generalists that do well in recently disturbed and low-competition sites, so it is important to pick an area that is not overrun with other species (Leger & Rice 257). It should be noted that the soil will be ripped prior to planting, killing competitors however the seed bank will remain and should be considered a potential problem if competitors germinate before the poppy seeds. Abiotic conditions are not as much of a concern, poppies do well under varying light, nutrient, water, and soil regimes however they prefer well drained soils of sand to clay loam and may be sensitive to high levels of organic matter (NRCS 3,4 and Montalvo & Mcmillan 60, 61). The site will be evaluated for soil type and the level of soil saturation, soil should drain readily and should not stay saturated for extended periods (NRCS 4). In considering hydrology, poppies do not grow in riparian areas unless they are on gravely soils that provide plenty of aeration or on sandbars (Moise & Hendrickson 20).

Wild seed will be tested for response to light, germination rates, and will be exposed to germination enhancing techniques to help determine the best planting methods. The seed will be collected from local, self-perpetuating populations in order to increase chances that the plants are adapted to local conditions and have an appropriate dormant state that will aid survival (Curtis, NRCS 4). Because smoke treatment was shown to increase germination rates of wild Southern California species our seeds will be germ tested with and without the treatment to see if treatment significantly increases germination (Montalvo 225). The species we are interested in may not respond in the same manner as the Southern Californian species however if we find that germination rates are significantly higher in treated samples we can assume that dormancy has been broken and that treatment is beneficial. If rates of germination do not improve significantly under treatments, then the wild seed will still be used but will not be treated. If the seeds are found to be significantly inhibited by light then planting depth will be deeper, at one half inch depths and if they were not then planting will be shallower, between one eighth and one quarter inch depths (NRCS 4). Soil ripping was shown to be significant in all years of the Montalvo & Mcmillan study however the optimal depth of soil ripping varied by year for unknown reasons (60, 61, 63, 64, 65). We will use the presence of light inhibition to decide the depth of ripping, with ripping occurring at 20-cm depth if the seeds are significantly light inhibited and a 40-cm depth if the seeds are not significantly light inhibited.

Planting will occur in the fall, soil ripping will occur right before seeding and seeding will be done by imprinting. Fall planting is preferred because rains in the central valley occur in the winter so the seeds should be planted before extensive winter rains occur (NRCS 4). Soil ripping will be performed by a tractor with blades spaced 25-m apart and is to happen on the same day and immediately before seed sowing as was done in Montalvo's and Mcmillan's study (54). Imprinting is a method of seeding that involves a tractor pulling a rotating drum that places seeds in triangular divots in the ground which helps to channel water and organic matter towards the seed and promotes gas exchange between the air and the soil (Imprinting). Imprinting appears to be a good choice because *Eschscholzia* is a poor competitor and may benefit from being fed resources and because imprinting was also found to be the preferred method of planting in Montalvo's and Mcmillan's seeding experiments (Montalvo & Mcmillan 60, 61, 63, 64, 65 and NRCS 4). Their experiments took place in a Southern California valley with sandy loam soil and 34cm of average annual precipitation(Montalvo & Mcmillan 53, 54). The Central Valley varies greatly in rainfall, from 5cm – 30cm annually, however as this is within the native range of poppies and because poppies are reported to propagate well in dry conditions, the study results have a reasonable chance of applying to our situation (NOAA, Heather). Assuming that poppies are the only thing being planted the amount of seeds used will be 3 pound per acre (NRCS 5).

3. **Establishment & Management**

During the first year of germination, poppies will be monitored periodically for growth progress, population density, and competitor density, and in the long run for population density and recruitment. In promoting establishment, irrigation is not necessary and may be harmful because poppies are adapted to germinating in dry conditions which gives them an advantage over competitors such as grasses (Ricci & Eaton 60). Directly after seeding, monitoring of growth progress, competitor density, and poppy density will occur at regular intervals to determine and anticipate problems. The normal function of poppies is to put down a tap root, develop a basal rosette of highly divided leaves and produce flowers in march, if these criteria are met and individuals show no sign of malnutrition or disease, they will be considered to be growing normally (NRCS 2,5). The signal for a healthy population is difficult to determine exactly, although we know poppies enjoy somewhat dense populations, we found no information on the exact densities of poppies that should occur during normal establishment (Leger & Rice 258). Because poppies are poor competitors we find it important to monitor competition to help determine the best course of action if it appears the poppies are being overrun (NRCS 4). For the purposes of long term monitoring of population recruitment, a bi-annual monitoring plan will be implemented for an indeterminate amount of time. Plants will be monitored once after winter rains to measure germination rate and once in March during first flowering in order to determine how many plants made it to maturity (NRCS 3 and TWC staff).

If establishment does not meet expectations or competitors are abundant, our response will depend on the degree to which the poppies are affected by low densities or poor health. Germination is most likely to occur during or directly preceding the winter rain which means that a complete failure of germination should be dealt with in the following season. The next season, the area can be re-seeded and supplemented with nitrate fertilizer, which was shown to increase percent cover in poppies (Montalvo & Mcmillan 60, 61). Poppies are expected to do well under the conditions provided, however if undesired plants germinate and establish before the poppies they may struggle to establish themselves (Ricci & Eaton 60). Herbicides containing DCPA, oxyfuorfen, dicamba, and pronamide may adversely affect poppies if used post-germination however it seems prudent to use herbicide in cases of low poppy-germination and when undesirable plants are abundant (NRCS 6). If establishment is not complete but competitors are also not in abundance, monitoring into the following year will provide information on whether or not supplemental planting should be done to bolster population number. We hypothesize it may be necessary to plant more seeds in the years directly following the initial planting because even if the poppies reach maturity and produce seeds quickly the seed bank may not be large enough to continue the population. Seeding method in this case could not be by imprinting as this requires a tractor and would damage the existing system but and it is unclear what the most suitable method would be.

The main uncertainties we anticipate is how well competitors will do in the planting year, how well seeds will germinate, and how to determine a healthy population. Excessive rains can be bad for poppies by waterlogging the the soil in certain places and promoting competitor species that do better in wet years. Eschscholzia does well under dry conditions; it was found that in dry years *Eschscholzia* did better than grasses however in wet years the grasses did better, signifying precipitation can affect the competitive advantage of poppies (Ricci & Eaton 60). Disease is not expected to be a concern, however unhealthy conditions such as wet soil will make the poppies more susceptible to pathogens (NRCS 5). Because the seeds are wild and were only subject to germination tests in the lab, there are many unknown variables affecting their survival in a new habitat. If our treatments do not break dormancy then we are hoping that the winter rains will and that germination is high enough to establish a population. Despite our research it is still unclear exactly how to determine what a healthy stand of poppies will look like and how to determine if they will be able to perpetuate themselves. Only careful monitoring after planting will reveal whether or not the population is stable.

4. **Missing Information & Research Potential**

Further research that would be helpful in implementing this plan includes data on healthy densities of *Eschscholzia c.* populations in the wild, the size a population must be to perpetuate itself, expected germination rates, and management options for competitors. There are sources on the amount of seed to use per acre but little information on what the goals of these projects were and what kind of communities the plantings will create. It is also difficult to determine the desired plant density; plants in the wild are known to grow in close proximity to one another, however when attempting to determine if our project was a success, there is not a solid standard to compare plant density to (Leger & Rice 258). It appears that most sources believe that poppies will be able to establish themselves given the correct environment, and so identification and control of potential problems like weed species is not addressed. It would be beneficial to possess a detailed restoration attempt in which obstacles such as invaders were experienced and dealt with. Lastly it is important to have a standard for germination rates that is appropriate for re-seeding natural areas because wild seed is not expected to have the high germination rate cultivated seed would have despite being preferred for restoration of natural areas.

We suggest that this project be used as an opportunity to explore the viability of re-seeding using natural seed and to help understand how population size and structure contribute to the perpetuation of the population. By coupling initial germination rates in the field along with long term monitoring of recruitment and population density there is the opportunity to learn how germination rate relates to population stability. In addition the data we collect on breaking dormancy will be beneficial for further restoration projects in the Central Valley in determining how to make wild seed more viable. Further environmental monitoring such as soil, precipitation, and competitor densities can further help explain nuances between our site and others. In achieving this end the plantings should be monitored periodically for years after the initial planting in order to keep an eye on population densities and recruitment.

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Grass/sedges

Purple needle grass (*Nassella pulchra*) Sarah Anderson

Purple Needle Grass

Nesella Pulchra

Background & Justification

Nesella pulchra (purple needle grass) is a California native bunch grass that is extensive and wide spread. *N. Pulchra* is most commonly found in upland valleys and foothills. This bunchgrass has been known to provide erosion control and organic matter to the soil in the long term. This grass is well adapted to droughts as its long roots allow it to tap into deep water sources. *N. pulchra* was adopted as our state grass in 2004 because it has historical and social importance[1]. Something interesting about this bunch grass is that it can have close community ties with lupines, as the lupines provide leaf litter which increases the amount of carbon in the soil which will then increase the nitrogen production from soil bacteria[2].

<u>Literature review</u>

LIFE CYCLE

Growth Characteristics

- *N.Pulchra* is well adapted to grassland habitats. The spring flowering perennial bunchgrass grows at a slow rate reaching full maturity to produce seed after 2 years of healthy growth.
- Caespitose perennial native bunchgrass. Can grow to 60-100 cm tall.
- If the leaves are cut or fragmented, the plant will spread vegitatively. If there is low disturbance by fire or grazing littler can accumulate creating less dense populations but with larger individuals.
- Rooting depth is 64cm and has arbuscular mycorrhizal rooting system.

Reproduction

- Purple needlegrass is wind pollinated. Plants can regenerate either asexually by tillering and bunch fragmentation, or via seed dispersal. Seed burial is facilitated by the sharp pointed seed and long awns which twist as they dry, driving the seed into the soil[1].
-

Seed Banking: Low (compared to annual grasses)

Seed production: 2-year old plants are able to produce seed, and healthy stands can produce 227 pounds per acre (200kg/ha). Defoliation during the growing period will reduce seed production (March through May) in spring.

Germination: Fire might increase germination and emergence in the 1st postfire growing season. Annuals will decrease germination due to competition.

on Leached litter, fresh litter, and topsoil	80-93.7% germination rate
seed collected in summer and germinated in petri dishes	30-75% germination rate

- Seedling establishment requires more than 20% germination to have more than 1% survival of seedlings.
- Seedling survival is heavily dependent on climate; generally individuals greater than 0.8 inches (2cm) in diameter will survive drought.
- Removal of annuals provides more water to seedlings and can increase seedling productivity and density from 88 to 90%

RANGE AND DISTRIBUTION

- Central valley and foothills. This grass prefers slopes.
- Restricted to semi-arid soils because it can't be inundated for extended periods[3].
- Purple needle grass occurs on the west side of the Coast Ranges from northern Baja California north to the Oregon border. The species also occurs in the Central Valley and foothills of the Cascade Range and Sierra Nevada, and on the Channel Islands[3].
- *N. pulchra* will do well in zone 9b USDA hardiness zone with an annual extreme minimum temperature of 25 to 30 (F)

HABITAT AND ASSOCIATIONS

Community

- Purple needle grass can be found in a variety of plant communities. It is most prominent in the prairie or valley grassland[3].
- Species associated in grassland community with *N. Pulchra (See Table 1: Plant Associations)*[3].

Climate: Mediterranean Climate, mild wet winters, hot dry summers with drought.

Season: 7-11 months long, 205 – 325 frost free days.

Precipitation 5.9 inches to 19.7 inches (150-500 mm) Peaks in October through March and from late April to early May.

Soil: Purple needle grass is well adapted to soils with high clay content. This grass is often found growing in mounds where claypans are within 7.9 inches of intermounds and 25.6 inches below mounds. Deeper soils give purple needle grass an advantage over annual grasses[3].

SUCCESSIONAL STATUS

- For those that are in favor of placing *N. pulchra* in a climax successional status argue that the bunchgrass was more predominant pre-pioneer years of the early 1800s.
- Others disagree and place *N. pulchra* in a primary successional status[3].
- The grass is well adapted to disturbances by fire and grazing, but not at great frequencies or intensity[3].

GROWTH REQUIREMENTS

- Rooting depth 2 to 6 feet (minimum)[1]
- Seed depth 0.25 inch to 0.5 inch The pure stand recommended drill seeding rate is 9.5 lb pure live seed (PLS) per acre for approximately 25 seeds/ft^2. This is based on 115,000 PLS/lb[1].
- For broadcast applications the pure seed rate is 15 lbs/ac. Planting 1 lb/acre yields approximately 3 seeds/ft^2.[1]
- Plant in early spring
- Fall dormancy improves germination
- Can mix seed with other native perennial grasses. Do not mix with annual seed.

TOLERANCES

- Purple needle grass is well adapted to heavy clay soils.
- Well tolerated in drought once established
- Seedlings are moderately to severely intolerable to snail herbivory.[4]
- Gophers can become problematic if not under control and can clear stands of grasses.[5] If gophers are in the area it is recommended to remove or deter the gophers from entering the area that is being restored. Once grasses are established no need to remove or further deter gophers, as the full grown and healthy grasses can tolerate some moderate disturbance.
- This grass once established is well tolerated to grazing in low frequencies. If disturbance is high in the area, then further management will be required to fend off weeds that would establish in the highly disturbed areas. Weeds are a problem because they can easily out-compete the grasses for resources. High disturbance will encourage more establishments by annual weedy plants. [6]

- *N.pulchra* productivity decreases with greater water stress, which suggests that this grass is best suited for marginal biomes/habitats or in mixed communities.[7]
- Purple needle grass relies on healthy bacterial and fungal communities in the soil, and anything that destroys or diminishes these communities is harmful to the productivity of this grass. It has been seen that the use of glyphosate or chemicals containing glyphosate will reduce bacterial and fungal communities that are important to the success and survival of purple needle grass. It is advised to reduce the use or eradicate these chemicals as they persist in the soil and can damage the bacterial and fungal communities.[8]

INTERACTIONS

Wildlife

- Gophers and livestock grazing animals can provide an importance disturbance to the perennial grass habitat. They are beneficial if the disturbance is low, and in low frequency. The grazing from cattle will increase the nutrient cycling and can help spread the grass vegetatively .
- Snails prefer to eat the seedlings.

Humans

- Native Americans harvested the seed for food. Some of the blades of grass can be used in basketry.[1]

THREATS

- Land-use change is a huge threat to remaining stands of purple needle grass.
- There is no special legal status

MANAGEMENT OPTIONS

- Remove weedy non-native annuals from area that is to be restored, so that there is greater chance of survival of purple needle grass.
- Plant with other perennials and forbs that are found within healthy native grass communities. (see table Plant associations).
- Control snail and gopher populations that seems fit to the area being restored. (during seedling development)
- Can be planted on slopes for erosion control, but needs to be at proper density to be most effective.
- Can use fire in low intensity and frequency to encourage growth and survival the following year.
- Reduce use of glyphosate as weed killer if at all possible.

TABLE 1: Plant associations		
Perennial	**Annual (that replaces perennial)**	**Forbes**
oatgrass (Danthonia californica)	wild oat (Avena fatua)	fiddleneck (Amsinckia spp.)
California fescue (Festuca californica)	slender oat (A. barbata)	shooting star (Dodecatheon spp.)
tussockgrass (Nassella lepida)	ripgut brome (Bromus diandrus)	goldenpoppy (Escholzia spp.)
beardless wildrye (Leymus triticoides)	soft chess (B. hordeaceus)	lupine (Lupinus spp.)
melicgrass (Melica spp.)	mouse barley (Hordeum murinem)	malacothrix (Malacothrix spp.)
	rattail fescue (Vulpia myuros)	phacelia (Phacelia spp.)
		sage (Salvia spp.)

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GOALS

- Increase biodiversity
- Provide a vibrant native grass community
  - Ensure longevity of native grass populations

<u>Increasing biodiversity of native grasses</u>

Collect seed from a bunch grass community which is dense and diverse. A dense community is approximately 5 to 7 bunches per square meter. A diverse community will include other native grasses, lupines, and native forb species (e.g. ca poppy). Ideally the collection patch should have a diversity of 5 to 10 different native plant species if collecting from/for central valley restoration[1]. Only Collect 5% of the total seed produced from each population; sampling from approximately 50 to 100 plants[5].

For *Nassella pulchra* its gene flow is very limited as because it has low seed dispersal[1]. So its highest diversity can be found within a patch of purple needle grass. Diversity between patches are not as significant.

If the remnant populations of the native grasses are too small, consider collecting a very small amount of seed to be given to contract growers in order to perform a seed increase[1].

A typical seeding density for a single species of perennial native grass is 60 seeds per square foot or 600 seeds per square meter[1]. When making a seed mixture the individual percent live seed per species varies in density within a community[1]. This varies from site to site, so it is best to survey a reference community and note the relative density of grasses to forbs throughout a season and adjust the seed mix accordingly.

Providing a vibrant native grass community

Maintenance and pre-planting measures should be conducted throughout the restoration of native grasses. Pre-planting practices may require the removal of the topsoil if there is little to no native grass seed bank[2]. By removing the topsoil there is less competition with weedy neighboring plants, and ensuring better establishment by the native grasses[2].

If fire, grazing, or other natural disturbances are not available to the site due to urban locality or restrictions to access, then maintain the grasses by mowing annually. Generally the natural ecosystem of native grasslands requires a 3 to 5 year fire disturbance[1]. Fire helps to reduce the exotic populations, and helps to push back shrub encroachment[1].

Ensure longevity of native grass population

Monitor the site frequently during establishment to adjust control for weeds.

Irrigation may be necessary initially for root establishment. Once roots are established, the irrigation should be reduced, and allow the plants to adapt to the environment. Prolonged irrigation will cause the plants to become dependent on the irrigation as a source of water. Do not irrigate past the normal precipitation amounts of the region, and if there is adequate precipitation do not irrigate. The average precipitation for the central valley is 5 to 16 inches annually; rainfall is usually in the winter and early spring[6].

A measure of restoration success is when the restored site resembles the diversity and complexity of a remnant/reference site. After the site has been restored, long term monitoring should be conducted every 5 years to see if any further maintenance is needed.

RESTORATION PLAN

The restoration project should be completed in phases as to organize and mark progress of the project. The phases should include evaluation of the site, preparation for planting, planning and plant establishment, and long term monitoring and management. Throughout all the restoration project phases manage for weeds, and adjust the project as necessary.

Phase one, evaluating the site will provide essential information to see if the site is adequate for native perennial grassland communities to be established. The soil, topography, hydrology, climate, current vegetation, and disturbances should be known from the site in order to properly prepare the site in phase two. Once the site is evaluated, determine if the site is adequate. Follow the part one of this report to see if the site follows the requirements for the successful establishment of native grasses. If there are some characteristics of the site unfavorable for establishment, make note of these differences and see if adjustments can be made to the site. For example, if the most limiting factor for grass establishment is inadequate nutrients, find which nutrients are most limiting, and see if this site is still viable for grasses.

Phase two, preparing the site for planting. Use appropriate weed control methods. Depending on the size of the site, chemical or mechanical weed control methods can be used. Mechanical methods are recommended for smaller sites, as it usually is more labor intensive and potentially expensive. Chemical methods of weed eradication can be more efficient while possibly toxic and hazardous[7]. Using too much herbicide, applying herbicide at the wrong time and at the wrong rates can make herbicide implementation complex. In addition, chemical weed control tends to persist in the soils, and may have detrimental consequences in creating more herbicide resistance[7]. The type of chemicals needed for weed control varies depending on the type of plants being eradicated[7]. Since grasses react similarly to the same kind of weed control chemical, it is advised to control for weeds a season prior to planting, as the chemicals persist, and may be detrimental to the establishment of native grasses[7]. Consider prescribed goat or cattle grazing as an alternative method to eradicating weedy grasses along with supplemental irrigations to flesh out the invasive seed bank[1]. If the site is heavily invaded remove the topsoil[2].

In addition, keep in mind the potential seed dispersal from adjacent exotic populations which could spread into the restoration site[8]. To help prevent more seed from encroaching into the restoration site, make a buffer zone around the site. A buffer zone will help to reduce the invasive seed from transferring[8].

If the soil has low vegetation coverage place native mulch to protect the soils from erosion. Also if the soils are hard clays, and soil aggregation is not adequate, a light till will help the seeds to establish.

Phase three, planning and plant establishment. Once the site is mostly under control in terms of weeds and the soil is moist after the last winter frost, it is time to begin seeding and planting. Plan out the where to plant the grasses and forbs, buffer zones, and potential trees prior to planting. This will help to determine how to irrigate and manage the restoration site throughout the project. Within the restoration specific site plan, provide a map of the area, including major soil features, and water sources. If the terrain is particularly hilly, include a topography map.

Once the layout is finished, gather volunteers and begin planting. Plant the grasses no deeper or higher than the soil level of the plugs. Seeds should be planted shallow approximately 0.5 cm to 1 cm, but with enough soil to protect from herbivores[3]. Irrigate the seeds or plugs as needed. For water use efficiency, use direct drip irrigation lines. If planting seeds, the seedlings should emerge within a week to two weeks[1]. If planting plugs for smaller sites (aprox. < 2 acres), plant each plug approximately 12 to 18 inches apart, radially[1]. If the site required erosion control adjust plug plantings to have a higher density. Plant the young forb plants next to the grass plugs.

Between the newly planted plugs and forbs place native straw or covering to help limit erosion, insulate the soil, and lower evaporative losses, and to further suppress weeds[1]. For the larger seeding restoration projects also cover the site with a light straw or mulch after seedling emergence.

Long term management practices

Once seedlings have emerged, monitor for signs of herbivory by snails[9]. Control for any weeds. The balance of carbon and nitrogen can be altered to favor the establishment of native grasses by immobilizing the nitrogen in the soil. To do this add carbon, timed mowing, timed livestock grazing, prescribed fires, herbicide application, and supplemental irrigation[1]. A low cost solution to adding more carbon to the soil is adding sawdust, this acts as a light mulch and provides carbon, which is taken up for energy by microbes which then immobilize nitrogen.

When the grasses are well established and in adequate densities, management should not be heavily required. However, if the restoration site is within an urban area, there are restrictions to fire as a management tool, use alternative methods that are available. Again, the native grasses do best with a fire disturbance at least once every 5 years[3]. Fire disturbance will also help to reduce the intensity of future fires. If mowing is the preferred control for weeds, frequent mowing will favor the non-native forbs over exotic grasses[1]. Yellow star thistle is one such forb that does well in heavily mowed areas[1]. Mowing also will have no effect on the native grasses in a short term, but if mowing is timed correctly it can be an effective weed management tool[1].

Knowledge gaps in restoration management

- Detailed evaluation of soil and restoration
- Evaluation on cost-effective strategies

- Better definitions of restoration success for small and broad-scales
- Better tracking and monitoring for restoration projects
- More information on genetic variability on specific native grasses and their community interactions.

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Plant species- exotic invasives (focus on control of these species)

Herbaceous species

Exotic annual grasses- Marina LaForgia

Part I: Annual Invasive Grasses Fact Sheet

Background and Justification

Invasive annual grasses are a permanent fixture throughout California grasslands and are often the biggest obstacle in restoration (Stromberg et al. 2007). The invasion of California by these annuals dates back to the 1800s and it is not generally known what was dominant in these sites before these grasses invaded. It is thought that perennial bunchgrasses dominated wetter portions of the state while annual forbs dominated drier portions (D'Antonio et al. 2007), however without a clear reference community, this uncertainty only adds to the difficulty of restoration. Most of the exotic annual grasses are native to Europe or Eurasia and include *Bromus diandrus* (ripgut brome), *Bromus madritensis* (red brome), *Bromus hordeaceus* (soft brome), *Avena* species (slender and wild oat), *Horduem murinum* (foxtail or hare barley), *Taeniatherum caput-medusae* (medusahead), and *Aegilops triuncialis* (barbed goatgrass). These species, having co-evolved with humans, are pre-adapted to disturbance and often outcompete native species. Their rapid spread is now thought to have been triggered by an intense drought in mid-1800s that occurred on a backdrop of long-term, year round grazing by cattle and sheep (D'Antonio et al. 2007). These invasive grasses colonized California in four phases, with *Avena* species establishing before the 1860s, *B. hordeaceus*, *B. diandrus*, and *H. murinum* becoming more dominant in the 1860s and 1870s, *B. madritensis* in the late 1800s, and the finally the most recent invaders, *T. caput-medusae* and *A. triuncialis*, colonizing in the late to early 1900s (D'Antonio et al. 2007). These invaders all have large economic as well as ecological costs. Economic costs include reduced revenue from shorter grazing windows, the direct cost of management and control, and the indirect costs of ecological damage remediation (D'Antonio et al. 2007). Ecological costs include reduced diversity, competition with natives, increased fire frequency, and facilitation of other invaders (D'Antonio et al. 2007). While a goal of the complete eradication of many of these grasses is infeasible, limiting their establishment and spread in sites is still possible.

1. **Species characteristics**
   - Most invasive annual grasses are cool season annuals with relatively short-lived seed banks (Eviner and Firestone 2007). Because most of their life cycle occurs over the cool, wet part of the year they do not need to develop deep roots and thus concentrate their roots into the top 30 cm of soil (Eviner and Firestone 2007). Warm season perennials and other annual forbs that are active later in the dry season are able to take advantage of deeper soil water with deeper roots (Eviner and Firestone 2007).
   - The life cycle of most invasive annual grasses (Eviner and Firestone 2007)
     - Germinating rains typically occur early in the fall (late September to mid-November)
     - Growth slows down as temperatures fall in late December and remains low until mid- to late February when temperatures increase and plant and microbial activity starts up again.

- In early spring, annual grasses are finished with belowground biomass accumulation and, as temperatures begin to rise, they rapidly increase aboveground growth.
- Plant growth continues until soil moisture is depleted shortly after rainfall stops in mid-spring.
- Plants then begin to set seed and often senesce by early May

- Studies have shown that annual grasses are much faster to respond to fall rains, often germinating one to two weeks earlier than most natives (Reynolds et al. 2001).
- Seed densities can reach as high as 300,000 per square meter (Young et al. 1981), but they average about 60,000 per square meter (Bartolome 1979). About 90% of these seeds germinate with the first few days of a significant rain. Even with 50-70% mortality, plant densities by the time of seed set are still extremely high and range from 8,000 to 20,000 individuals (Heady 1958).

2. **Abiotic site characteristics**

2.1. *Nutrients*

- Invasive annual grasses can occupy compacted soils and highly disturbed soils in both high and low fertility systems (D'Antonio et al. 2007). Sites most commonly invaded include roadsides, rangelands, old crop fields, agricultural areas, and natural areas (DiTomaso and Healy 2007). Some invasive grasses are even tolerant of serpentine soils, like goatgrass (DiTomaso and Healy 2007).
- Sites dominated by invasive annual grasses create a large flux of nitrogen into the system. After germination seedling densities can reach 60,000 individuals per square meter (Bartolome 1979). By seven weeks later, 50-75% of these die and their highly labile biomass is easily decomposed and returned to the system (Bartolome 1979). This doesn't occur in native-dominated systems where seedling densities are much lower.
- Addition of nitrogen to soil should be avoided in restoration because this generally favors invasive grasses as they are strong competitors and fast growers (Stromberg et al. 2007). To decrease nitrogen in soils, carbon can be added. By stimulating microbial activity, this effectively immobilizes a large portion of the plant-available nitrogen in the soil (Stromberg et al. 2007).

2.2. Fire

- Although fire is a historically important component in California grasslands it is difficult to determine what level of fire is normal. For instance, fires burn a lot faster and more intensely through invasive grass dominated systems than through perennial systems (Reiner 2007). Grasslands typically burn between May and November when it is the driest (Reiner 2007).
- Exotic annual grasses often leave dense stands of dry thatch by May, increasing fuel load, which can lead to more intense fires (D'Antonio et al. 2007). Additionally, fire frequency often increases in annual-invaded grasslands due this consistent, annual build up of thatch and small window for native perennial re-establishment post-fire (D'Antonio and Vitousek 1992).

2.3. Precipitation and Soil Moisture

- Invasive annual grasses typically concentrate their roots into the upper 30 cm of soil while native bunchgrasses typically have deeper roots that allow them to access soil water resources later in the season (D'Antonio et al. 2007). In areas that are invader-dominated there is often an unused resource pool deeper in the soil that has facilitated invasion by later-season invaders with deeper roots to establish such as yellow star-thistle (Gerlach 2004).

- Annual invaders may be more susceptible to drought than native perennials due to shallower roots (Corbin et al. 2007).

2.4. Climate change

- The effect of climate change on invasive species is most clear in terms of warming. California is expected to warm 1.7-3.0 degrees Celsius within this century (Dukes and Shaw 2007). Warming during winter months has been shown to accelerate flowering in invasive species, leading them to senesce earlier while natives are not as quick to respond (Cleland et al. 2006).
- Interactions with precipitation are less predictable because climate models of future precipitation vary from intense decreases to moderate increases (Dukes and Shaw 2007). Because of the unpredictable nature of precipitation in the future it is difficult to say whether climate change would facilitate invasion (Dukes and Shaw 2007) however the timing of precipitation will be an important factor. Increased winter droughts would negatively affect invasive annual grasses while more frequent rainfall would positively affect these grasses (Stromberg et al. 2007).

3. Biotic interactions

3.1. Competition with natives

- One potential reason for invader dominance might be seed limitation of natives. Seedling densities of *Nassella pulchra* were found to be 5 times higher in plots that were seeded with an additional 5,000 seeds per square meter as compared to unseeded plots (Hamilton et al. 1999). Invasive annual grass seedlings however can range from 20,000-40,000 individuals per square meter by the beginning of winter (Eviner and Firestone 2007).
- Native perennial grasses are most vulnerable during the seedling stage and invasive annual seedlings easily outnumber perennial seedlings. These fast growers are able to shade-out the perennial bunchgrass seedlings while they are still developing their roots. Once temperatures increase, native grasses switch to adding aboveground biomass, however they are extremely light-limited by the already-tall invasive grasses and the roots die off (Eviner and Firestone 2007).
- While annual invasive grasses are highly competitive, a well-established perennial bunchgrass community, such as those dominated by *Nassella pulchra*, have been shown to limit establishment of annual grasses (D'Antonio et al. 2007). Any type of disturbance on top of this however, such as soil disturbance or fire, can trigger a phase shift to invasive-dominated systems. (D’Antonio et al. 2007).

3.2. Microbial community

- Highly disturbed sites dominated by invaders often lack a diverse microbial and fungal population that many native species rely on. Thus, repeated tilling can lead to long-term alteration of the soil microbial community (Stromberg et al. 2007). While tilling can be an important method in limiting invaders, it is important to re-establish this interaction between native plants and the soil community by inoculating plugs with healthy, local soil (Stromberg et al. 2007).

3.3. Pathogens

- Pathogens play and important role in invading species. Often a species is able to invade a site because it lacks natural enemies (Keane and Crawley 2002). In addition to this release from enemies, invaders can have a negative effect on natives by acting as disease facilitators. For example, stands of *Avena* species and *B. hordeaceus* attract certain cereal aphids more than native stands (Malmstrom et al. 2005). These aphids transmit yellow dwarf virus leading to increased infection rates in stands with the invaders. Because the infection is not transmitted by seed, annuals are able to escape the disease, while it persists longer in native perennial populations (Malmstrom et al. 2005).

4.Control

4.1. Mechanical control

- Mechanical controls like hand labor, mowing and clipping, tilling, and removing thatch are not very practical and can be very expensive albeit effective (DiTomaso et al. 2007).
- Hand labor is more common post-restoration for follow-up management but is often only feasible with a large group of volunteers. This allows for the targeted removal of invasives and maintenance of native-dominated systems and thus is recommended on much smaller scales (DiTomaso et al. 2007).
- Mowing is typically used on larger scales and is mostly used for roadside maintenance however this is not generally an effect method for eradication and only works to limit seed production and thus spread. The optimum time to mow is during the flowering stage before seed development however mowing when the soil is wet can have the opposite effect, stimulating rapid growth and seed set (DiTomaso et al. 2007). Negative effects of mowing include disruptions of late-season native plant activity and reduction of forage for livestock (DiTomaso et al. 2007).
- Tilling sites controls invaders by plowing under live plant parts. Like mowing, tilling must also be done when the soil is dry to decrease the chance that invaders will regrow (DiTomaso et al. 2007). Negative effects of tilling involve soil erosion, disruption of microbial community, and direct harm to native species. This is often only a good method when restoring a site from scratch before reseeding or planting is done (DiTomaso et al. 2007).
- Thatch build-up is a problem in invaded communities not only because it limits native seedling establishment but also because leads to more intense fires. For example, Kyser et al. (2007) found that removing thatch of medusahead, which decomposes slowly due to the high silica content in leaves, can effectively reduce competition of the invader with the native community.

4.2. Chemical control

- Chemical control of invasive annual grasses is often considered the most economical option however there are relatively few herbicides that target annual grasses and not native grasses (DiTomaso et al. 2007). Herbicides used on these grasses include gylphosphate and imazapic. Glyphosphate is a nonselective herbicide that is useful in controlling most invasives however also harms natives. It is applied post-emergence and leaves no soil residue behind. This is generally recommended in sites that are highly disturbed where complete removal of invasive grasses is necessary before restoration can happen. Imazapic has been shown to be very effective mostly on annual grasses including medusahead, downy brome, ripgut brome, barbed goatgrass and other annuals, however it is also nonselective and thus can negatively affect native grasses (DiTomaso et al. 2007). It is mainly used pre-emergence but can also be applied post-emergence to seedlings (Kyser et al 2007). When using Imazapic it is important to remove thatch first because the herbicide sticks to the leaf litter, which reduces its effectiveness (Kyser et al. 2007).

4.3. Other types of control

- Grazing, like fire, has been a historically important component of California grasslands. Even before the arrival of cattle and sheep, native herbivores were abundant grazers (Jackson and Bartolome 2007). Evidence is mixed on the effectiveness of using grazing as a tool to limit invaders and promote natives (Hayes and Holl 2003).
  - The most important factor to consider when using grazing as a management tool is timing. Intense grazing of invasive grasses early in the season can reduce invasive grass seed set. For example, sheep grazing in mid-spring has been shown to reduce medusahead cover by more than 80% the following year (DiTomaso et al. 2007). Rotating livestock throughout a site to create short and high-intensity grazing can effectively control specific weeds throughout the growing season but this often requires fencing and can be logistically difficult (DiTomaso et al. 2007).
- Prescribed burning can be a good management technique for controlling invasive grasses however this varies depending on site, species, and season (Reiner 2007). Use of fire should be monitored at the small scale to look at effects before implementing a larger plan.
  - Annual invasive grasses are most susceptible after fire season begins when flower structures are in the fuel bed or exposed to direct flames. It is best to burn when invasives have not yet dispersed but natives have, making this technique difficult in stand with mixed early season invasives and late-season natives (DiTomaso et al. 2007). Burning can effectively rid a site of thatch and is most effective for species with long-awns where the seedheads do not shatter after maturing like ripgut brome, medusahead, and barbed goatgrass (DiTomaso et al. 2007).
  - Betts (2003) investigated the effects of burning on medusahead, ripgut brome and barbed goatgrass dominated plots and found that burning increased the probability that these sites would transition to *Avena* species, *B. hordeaceus*, and *Trifolium* species, which are likewise nonnative but considered to be relatively more desirable invasives.
  - There is also evidence that annual burning can increase native forb cover and decrease annual grass cover however once burning stops, invasive grasses typically rebound within 2-4 years so this may not be a good long-term management technique (Reiner 2007).

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Part II: Goals and Management Plan

Invasive Annual Grasses in the California Central Valley

Goals

The goals of invasive annual grass management will vary depending on the site, size, and level of invasion. In some cases, such as in a heavily invaded site, a practitioner's goal may be to completely eradicate the current population in order to properly prepare the site for native species planting. In other sites that are not as heavily invaded, it would not make sense to do broad scale eradication as this would also harm the natives in the site. In this case effectively reducing spread of current invader populations will be the best goal. Although the short-term goals in these cases may differ, in the long-term the goals converge. In both cases, the long-term goal is to establish a diverse and abundant native community that can outcompete and limit the establishment of incoming invaders.

Restoring from a denuded landscape may be more economically feasible than eradicating smaller populations of invaders mixed in with natives. It is generally more cost-effective as well as easier to completely eradicate a plant population at a particular site than it is to tip competitive balances between invasive grasses and native species however it is often difficult to get native populations to establish before reinvasion. Because of this it is generally more important to limit the spread of these invaders, focusing management on populations that have high growth rates rather than monocultures with lower rates of spread. A site that has a low background rate of invasive annuals may be only a few years away from a community dominated by invasive species. When one invader makes a site more suitable for other invaders to establish, this is called an invasional meltdown (Simberloff 2006). For example, a site invaded with annual grasses that wipe out the native perennial bunchgrass population leaves a reservoir of deep water available in the soil. This makes the establishment of yellow starthistle easier as it doesn't have to compete with the later season bunchgrasses for this water (Gerlach 2004). Once the site reaches this stage it can become harder and harder to push it back to a previous stable state without long-term management efforts. This is an important consideration in choosing which sites to restore and how to use resources.

Restoration and Management Plan

While plans will vary depending on the species and cover of invader present, these general guidelines will assist with basic eradication planning and should be adapted to the site-specific characteristics. Often project goals are constrained by limited funds and available personnel. However, a well thought out plan that takes advantage of natural environmental variation can save practitioners time and money. Due to site variability in both abiotic and biotic conditions, predicting how each eradication attempt responds to individual and various combinations of management techniques is extremely difficult. Detailed digital records should be kept and analyzed in order to determine the effectiveness of each case study. This will add to the knowledge base and make future management easier.

For heavily invaded areas it is recommended to use a combination of tilling and herbicide to eradicate invasive grasses. The advantage of managing a heavy invasion is that it is often more cost-effective than selectively managing invaders at smaller scales. For large areas that are dominated by a variety of invasive annual grasses, repeatedly tilling and flushing the system with water in early September, before fall rains begin, and then applying a nonselective, post-emergence herbicide such as glyphosate will usually eradicate the majority of the seedbank (DiTomaso and Healy 2007). Because annual grass seeds have low dormancy and high germination the fall after seed set, this can be effective in eliminating the seedbank (Eviner and Firestone 2007). It is important to ensure the invasive seedbank is completely flushed out before planting natives. Any surviving invaders will be highly competitive with native seedlings and may shade out the natives thus preventing the establishment of a healthy native bunchgrass population (Eviner and Firestone 2007). Also, young plugs of native bunchgrasses often require more water than the drought-tolerant adults. This can be especially dangerous if there is still a seedbank of invaders in the soil, as any available moisture can cause germination and allow for reestablishment of invaders (Reynolds et al. 2001).

For areas that are not heavily invaded, small-scale herbicide use in conjunction with mowing is recommended. Fire and tilling are not recommended as disturbance like these would likely kill both native and invasives and could lead to an increase in invasive cover over time (D'Antonio et al. 2007). In order to control invader populations, post-emergence herbicide such as glyphosate should be selectively applied to invaders post germination in the fall. This can be applied more widely when early fall rains occur. Because invaders typically germinate up to a couple weeks earlier than native bunchgrasses (Reynolds et al. 2001), the widespread application of a post-emergence herbicide should not effect the dormant native populations. Mowing of the invasive populations the following spring should be done during the flowering stage before seed production, typically in early April, however it is important to do so when the soil is dry to avoid regrowth (DiTomaso et al. 2007). Together with herbicide application, this will greatly reduce the seedbank and spread of the population. In addition to these management techniques, the native population of bunchgrasses should be enhanced by plug planting and dispersing seed to give the native species a competitive advantage over the incoming invasive population (Stromberg et al. 2007).

In remote areas grazing and burning can be more easily incorporated into a management plan. Fire is most useful for species whose seedheads do not shatter. Because the seeds of ripgut brome, medusahead, and goatgrass stay on the seedhead after maturing, burning of the site in the summer when most aboveground biomass has senesced can reduce invader cover the following year (DiTomaso et al. 2007). This type of burning, fueled by the fine thatch of grasses, can create a high intensity fire that can kill the seeds aboveground while leaving the native seeds unharmed in the seedbank (D'Antonio and Vitousek 1992, Reiner 2007). Fire in this case could help transition an area from less desirable, to more desirable invaders (Betts 2003). Fire can also promote establishment of invaders and should be used with caution. Therefore before burning a site, smaller scale burns should be done and monitored. Long-term use of fire to manage a site is not recommended as it limits the ability of strong perennial bunchgrass populations to establish and often, once stopped, invasive grasses are quick to take over (Reiner 2007). If grazing is a feasible option, such as in pastures and rangelands, short-term intensive grazing early in the season can effectively limit invader seed set (DiTomaso et al. 2007). Timing is also extremely important when considering grazing as a management tool. Grazing must be done early enough before seed set, such as in February and early March, however grazing a site too early can allow the invader to recover and set seed (DiTomaso et al. 2007). Both cattle and sheep are good candidates for grazing species, although sheep are more typically used to control forbs ((DiTomaso et al. 2007). Use of grazing requires strong partnership and cooperation with ranchers as it is logistically intensive to coordinate. If the site to be restored is in an urban environment, and grazing and fire should not be used. Often urban environments are constrained by nearby private property in the form of private residences and business. These areas are more difficult to manage because they are often highly disturbed and subject to a lot of foot traffic. They may however be smaller than rural sites, making hand-weeding an option. In these cases, tools such as mowing, tilling, and herbicide application should be applied as stated above.

Management techniques will vary depending on the species of invader. Sometimes eradication of all invaders will not be feasible and one invader may be preferred over another. The more recent invaders medusahead and barbed goatgrass have some of the most detrimental impacts on California central valley grasslands, while older invaders like *Avena* have more moderate impacts (DiTomaso and Healy 2007). Once established, medusahead and barbed goatgrass are extremely difficult to eradicate. Therefore, with limited resources, sites should selectively manage to limit the spread of these invaders. Medusahead has deeper roots and thus can access deeper water later in the season (DiTomaso and Healy 2007). To manage this grass a combination of techniques is necessary, including tilling before seed sets, and slow, hot burns (DiTomaso and Healy 2007). Other herbicides, like imazapic, are effective options and can be applied pre- or post-emergence (Kyser et al. 2007). In this case it is important to remove the thatch by tilling or mowing before application otherwise the herbicide sticks onto the thatch and reduces the effectiveness of application (Kyser et al. 2007). Goatgrass on the other hand can survive burns and can even increase with grazing and thus these techniques should be avoided (DiTomaso and Healy 2007). Some invaders, like soft brome, ripgut brome, red brome, and medusahead, require a thick layer of thatch to germinate, which can suppress native seed germination (DiTomaso and Healy 2007). In these cases, eliminating the thatch in the fall by tilling or mowing will be an important step in promoting native seed germination. Other invaders however, like species of *Avena*, do poorly with a layer of thatch and cannot establish under these conditions (DiTomaso and Healy 2007). In sites that require small-scale management of *Avena*, applying a layer of mulch in between established natives could successfully prevent germination.

Post-exotic management will require monitoring and it is recommended that native plugs be planted as soon as possible post eradication to prevent re-establishment of unwanted invaders. Often invasive grass monitoring can be done alongside monitoring of plug establishment and survival. The fastest and easiest variable to measure is percent cover of each species in a square meter plot. Transects that bisect the site can be established in year 0, before management application, and percent cover of a plot should be taken every 5-10 meters, depending on the length of the transect. The establishment of permanent transects will make monitoring of the site each year easier. Percent cover should be done before and after management application to follow the progress of the site and should continue twice annually, once to capture the early-season species in March/April and again in May/June to capture the late season species. Ideally, this should continue until native abundances stabilize. Additionally, it is important to monitor a wide-range of ecosystem variables along with species cover such as precipitation and temperature, which can usually be acquired through online databases. If resources allow, other variables such as soil moisture, nutrient levels, and microbial activity are also important correlates to keep track of. Monitoring these variables in addition to the site progress will allow practitioners to tease apart why some methods work well in combination in one area but not in another area, or similarly, why the effectiveness changes from year to year.

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Fennel (*Foeniculum vulgare)* Ale Hoyos

History, Biology, and Management Strategies of the Invasive *Foeniculum* Vulgare

Background and Justification:

Fennel is the common name for the invasive species *foeniculum vulgare.* Fennel is a perennial herb, about 4-10 feet tall. This invasive plant is native to southern Europe and the Mediterranean region; there it was used as a spice and for medicinal purposes (California Invasive Plant Council, 2014). Currently, in California fennel is found in areas with Mediterranean climates. Dense populations have been found in fields around the San Francisco Bay, Santa Cruz Island, Palos Verdes Peninsula, and Camp Pendleton; it is also scattered throughout the fields of Sacramento, Salinas, and San Joaquin valleys and foothills (California Invasive Plant Council, 2014). Fennel is spread very easily, seeds get stuck on tires, shoes, clothing, and it is also dispersed by animals. Invasive fennel has brought a series of negative consequences along with it. Fennel tends to invade areas in which soil has been disturbed. This invasive plant species is particularly aggressive in areas that undergo plowing, medium-heavy grazing, and areas that have been recently abandoned (California Invasive Plant Council, 2014). Consequently, it disturbs and inhibits the growth of native plant species. Fennel outcompetes the native plant species for light, nutrients, and water. Once fennel is established, it is very difficult to control and can build up rapidly (California Invasive Plant Council, 2014). Eliminating the invasive fennel will allow rare and native species to grow again and thrive in an environment that was once theirs. Native species would not have anything competing for natural resources with them. Controlling and/or removing this dominant invasive plant is expected to lead to a richness in native plant diversity (Ogden and Rejmanek, 2005). Not much is known about the introduction of fennel from Europe and Mediterranean regions, to the United States. However, it is known that it has occurred in California for at least 120 years (California Invasive Plant Council, 2014).

Literature Review

Goal: To create a suitable environment for reestablishment of native species by removing invasive fennel in grasslands.

Physical Site Characteristics:

- Plowing has brought many negative effects along with it, and has been associated with the loss of much of California's perennial grasses. Getting rid of farmed fields makes it easier for invasive species to quickly become established (D'Antionio et al. 2007).
- Other human influences such as introduction to road construction, grazing, and fire have been known to be major sources of degradation in grasslands also. Road construction increases the spread of invasive species and loss of native species by enabling and making seed dispersal easier (D'Antionio et al. 2007). With the arrival of humans, came the usage of fire in areas where grasslands thrived; soon enough, grass-dominated areas were burned (D'Antionio et al. 2007). Some invasive species however are resistant to fire.
- Human impacts have been one of the main reasons for the degradation of grasslands. Invasive species represent the single greatest impediment to grassland restoration in California (D'Antionio et al. 2007).
- Species that are introduced are highly competitive. Invasive species maintain a very large soil seed bank, and can overwhelm native seedlings after it rains (Reinheart and Callaway 2006). The replacement of perennial grasses with annual grasses has also increased the deep soil water availability; this then provides good conditions for invasive species to grow.
- *Foeniculum Vulgare* hosts mutualiusm between invasive Argentine ants and three aphid series. This relationship can influence herbivory rates. As a result, invasive *Foeniculum Vulgare* spreads successfully (Dibble, 2009).
- Climate change has proven to greatly influence the growth and production of fennel. Abnormally hot summers and droughts have prevented reseeding of fennel plants (Cavaliere, 2009).
- Fennel seeds can stay in the soil several years without germinating; and germination can occur at almost any time of the year (California Invasive Plant Council, 2014).

Control and Management:

Manual Methods:

- Manual methods of controlling this invasive species have been the most effective when infestations have been light. Manual methods are typically preferred over plowing because it minimizes soil disturbance (California Invasive Plant Council, 2014). As stated before, fennel tends to grow in areas where soil has been disturbed, and it is better to minimize the chances of it spreading further.
- Another form of physical control of fennel would be cutting, mowing, or chopping. However, these methods have not been shown to be very effective, as they do not get rid of the roots; and just allows fennel to grow back (California Invasive Plant Council, 2014). In addition, cutting while plants are producing seeds will promote dispersal.

Fire Resistance

- One of the better methods for reducing fennel in large areas would be burning the area and then spraying with herbicide. Fennel can be fire resistant, that is why having the herbicides to spray after, and makes this method effective. This method provides a successful removal of about 95-100 percent (California Invasive Plant Council, 2014).

Biological Methods:

- Grazing has shown to only be effective in areas that are not very dense and where the fennel is young. Grazing where fennel is older and denser has shown to not be very effective, as the fennel spreads further. Areas now that are very dense have been formerly known to be cattle pastures (California Invasive Plant Council, 2014).

Chemical Methods:

- Experiments were conducted using glyphosate and triclopyr for the control of fennel. Each herbicide was sprayed alone, and then with different combinations to test the effectiveness. After the 6 week evaluation, researchers noticed that the herbicides did keep the fennel under control, while not significantly harming the native purple needlegrass (Bell, Easley, Goodman, 2009).

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Restoration Plan for Invasive Fennel

Goal: To create a suitable environment for reestablishment of native species by removing invasive *foeniculum vulgare* in grasslands.

Physical Control:

Invasive fennel (*Foeniculum vulgare*) has the capacity to reproduce from both its crown and its seeds. The seeds germinate at almost any time of the year, but plants generally do not flower until 18 months to 2 years. Once a plant is established, flowering stems are produced from the perennial crown each spring (Parsons 1973). Flowering commences in May and could continue into September. Seeds are produced during the summer and autumn, and the flowering stems die back during winter to be replaced by new growth in late winter. Some stems stay alive towards the base and produce new leaves from nodes along the stems during the winter. New leaves are also produced in winter at the base of the plant (Parsons 1973). In order to obtain the results that we want, the first goal that needs to be achieved would be to manage invasive fennel and decrease the overall density and abundance of invasive species (fennel) at sites in need of restoration. One of the ways that this could be done would be by removing the invasive fennel manually. This would be most effective in regions where fennel grows in smaller patches. Efforts for invasive eradication should begin in the spring. This should be done while the patches are still small, but also as a preventative measure for the further spread of invasive fennel. Manual methods are typically preferred over plowing because it minimizes soil disturbance (California Invasive Plant Council, 2014). Small seedlings can be hand pulled when soil is soft or loose; whereas mature fennel plants are difficult to remove due to the large tap roots which can reach depths of up to 10 feet (Noxious Weed Control Board 2014). This method may be effective in areas where the fennel is not very dense. Small patches of fennel can be removed manually; putting a bag around the top of the plant where the seeds are will prevent unwanted spread and spillage of any seeds while pulling them out. The plant can reestablish itself from small pieces of roots or bulbs, so it is critical to remove them completely, without spreading seeds or leaving behind any roots or bulbs. Fennel tends to grow in areas where soil has been disturbed, and it is best to minimize the chances of it spreading further. Another form of physical control of fennel would be cutting, mowing, or chopping; but these methods are not recommended. These methods have not been shown to be very effective, as they do not get rid of the roots; and just allows fennel to grow back (California Invasive Plant Council, 2014). In addition, cutting while plants are producing seeds will promote dispersal.

Chemical Control:

An additional goal would be to vacate ecological niches in which native species can establish. This would be a more feasible goal in sites where fennel is less dense. However, in areas where fennel has been very dense and hard to remove, more drastic actions need to be done. It has been noted that fall burns (November-December) followed by herbicide sprays the following two springs can reduce fennel cover 95 to 100 percent (California Invasive Plant Council, 2014). A 2% solution of amine-based triclopyr, plus 0.025% v/v Pro-Spreader surfactant are known to remove this invasive plant after fire (Ogden 2005). For reducing fennel in large areas with dense stands, this method is effective, but costly, compared to manual removal while the plants are still small (California Invasive Plant Council, 2014).

Since invasive fennel occurs in areas with a Mediterranean climate, many fennel infestations occur in the central and southern regions of California; where the areas they occur in need restoration; these would be areas that have highly disturbed soil, have low ecological quality, feral animal disturbance also promotes germination and spread of seeds. Removing fennel would increase native plant biodiversity. A goal related to this would be to restore the physical site conditions which would prevent fennel re-infestation, and would support the planting of native plant species of that area. In order to see if this is at all possible, one would have to evaluate the site in need of restoration to see how much fennel cover there is. Areas with minimal fennel cover could be the easiest to reintroduce and increase native plant biodiversity.

The Restoration Plan:

In general, eradicating invasive fennel in areas where fennel is very dense would be much too costly and time consuming. Because of its strong competitive abilities and persistent seed bank, management becomes very difficult. One plant can produce thousands of seeds in the first year; seed output can then increase greatly in the second year. Although not a specific time was given, many sources suggested that invasive fennel's seed banks last a very, very long time, making it much more difficult to nearly impossible to clear them out completely. With species like invasive *Foeniculum vulgare*, the best method of approaching management is simply to avoid the further spread of this noxious weed. This can be done by providing a prescribed burn and then later spraying with herbicide. A study conducted in the Santa Cruz Islands found the greatest decrease in fennel cover and a significant increase in native species richness and diversity with a stem removal treatment or prescribed burn, and a winter herbicide application (Ogden 2005). Eradication for invasive broadleaf species such as fennel should begin in the spring. However, this is only if it is removed mechanically. Spring burns are dangerous and not recommended. It does not burn well in the spring (California Invasive Plant Council, 2014). It primarily affects gaps in coastal scrub stands, rather than intact stands. Fennel has high fueled moisture content and the shading of the herbaceous layer increases ignition temperature. This translates to much higher ignition temperatures and greater intensity and duration of the fire (California Invasive Plant Council, 2014). The bulk of eradication should be completed by the fall before native planting. Monitoring for fennel should occur every 2 weeks during rains, once every 2 months in summer. Mechanical and spot treatments should be done during this time. The monitoring should be continued for at least 5 years or as funding allows. Lower frequency if emergence is lower.

Despite many negative consequences that invasive fennel may have, it also has a few positive traits. In addition to being a medicinal plant and a very popular spice in many cultures, *Foeniculum vulgare* serves as a host for many pollinators, butterflies, bees, and many other insects (Ecological Landscaping Association, 2014). *Foeniculum vulgare* and other non-native plant species provide nectar sources for butterflies and other insects that land on them. There are several options to providing a better habitat for these pollinators but still control the invasive fennel. The best practice, which will benefit the most species of butterflies, is to mow meadows no more than once per year, in the late fall. Keep the mower height at least 4 to 6 inches off the ground, since larvae will be over-wintering near the ground at the base of plants, and leave the cuttings in place to decompose over the winter (Ecological Landscaping Association, 2014). Black swallowtail butterflies, which range from Eastern North America from Ontario south to Gulf coast, west to Colorado plains and central Texas, are very much attracted to fennel (Texas A&M Extension, 1993). They are known to take nectar of flowers from fennel as a food source as well as other plants (Butterflies and Moths of North America, 2014). Their caterpillars also use fennel as a food source and habitat. The consumption of fennel acts as a repellent against predators such as birds, because they do not like the taste of the caterpillars, since the toxins absorbed from the host plants make the caterpillars foul tasting (Texas A&M Extension, 1993). In general, the removal of fennel would not harm the swallowtail butterfly because they are not limited to consuming fennel. They have a wide range of different host plants from which they feed upon as well.

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Italian thistle (*Carduus pycnocephalus)* Efrain Delgado

Italian thistle

carduus pycnocephalus

Background and Justification:

Carduss pycnocephalus is an invasive species that originated from Europe. It is now a pest in not only the United States but also Australia, New Zealand, South Africa, Pakistan, Iran, and parts of Europe. It arrived in California around the 1930s and has since become a major weed problem. Because of its ability to germinate quickly in areas of disturbance it's often found in very dense patches that are then hard to get rid of. From its ability to dominate susceptible areas, this plant has made it difficult for areas of restoration to be successful with their plans. It is able to be successful in different habitat types, which makes it more difficult to contain. Many types of control strategies have been used such as mechanical, chemical, biological, and cultural methods.

To this day it stands in the way of re-establishing native conditions in restoration target areas because of its intense presence. It is important to get a good understanding of how to deal with this species, as it will be a big threat to any efforts made in reintroducing native species that may not be able to compete without the proper control methods in place. Eradicating the plant will also serve to improve the overall resistance of the area that it is occupying.

Species characteristics and Natural History:

- The Italian thistle is a winter annual broadleaf weed. The plant can grow to be up to 6 feet tall with spiny-winged stems
- The flowers bloom from around May to June in either solitary or in clusters of more than 5. The fruits that the thistle produces are gray on the outside portion and are yellowish or tan on the inner portion.
- The seeds are designed to use the wind as their medium for seed dispersal with the help of their large pappus and small size. It is estimated that they can travel at least several hundred meters (Parsons 1973).

Range

- It originated in western and southern Europe but is now widespread throughout temperate parts of the world. It has especially spread rapidly throughout California (Dunn 1976)

Habitat

- The thistle thrives in disturbed areas where interspecific competition is less intense (Goeden 1974). It is seen in high density in the coastal areas and pops up as a weed in pastures, ranges, roadsides, rural areas, fallow cropland, ditchbanks, etc (Goeden and Ricker 1978). The thistle's ability to blanket areas with its overwintering rosettes can severely reduce the establishment of other plants. This happens because of the leaves' ability to become erect in dense stands (Parsons 1973)

Growth and Development

- Germinates in the fall, overwinters as a rosette and flowers in late spring. Seed has no after-ripening requirement and germinates over temperatures ranging from 2-30 degrees C. Reproduces *only* through seed (Washington State Noxious Weed Control Board). The rate at which is germinates is very high with it's range between 83-96%. They germinate over alternating temperatures. They're even known to germinate with freezing temperatures during the daily cold period (Evans et al. 1979). The seeds are thought to be able to survive in the soil for up to 8 years while it awaits optimum conditions to germinate (Parsons 1973).The growth of the thistle is favored by the presence of more nitrogen as opposed to phosphorus or potassium. It also favors higher pH levels (6.5) (Bendall 1975).

Control and Management:

Mechanical

- Thistles are pioneer species so a dense ground cover with a closed canopy can help prevent establishment and reduce infestations (Bendall 1973)
- Other studies have also shown that continuously grazed pastureland is more susceptible to thistle development than rotationally grazed or nongrazed pastureland (Feldman, et al. 1968)
- Data collected from Nebraska has shown that mowing musk thistle within 2 days of anthesis of the terminal blooms will prevent seed production while preventing regrowth. But if mowing is done once 4 days have passed after anthesis then production of significant amounts of viable seeds is seen (McCarty et al. 1975)
- The downside to this type of approach is that the uneven maturity of thistle stands would require more than one treatment to happen per season (Trumble et al. 1982)

Chemical

- 2,4-dichlorophenoxyacetic acid (2,4-D) is the most commonly used chemical for this group (Coartney et al. 1968). This herbicide is quick to make its way throughout the plants structure and interferes with plant functions such as respiration, synthesis, enzyme activity, stomata operation, and cell division (Klingman 1961). Other herbicides used on this species is picloram, dicamba, silvex, and MPCA. In some cases these have been seen to be more effective than 2,4-D but 2,4-D continues to be the one most widely used. The maturity of the thistle also plays a big role in the effectiveness of the herbicide (bigger plants being less susceptible) (Trumble et al. 1982). To get thistle numbers low enough to where cultural techniques can be the main controlling factor, several years of herbicide use seem to be required (Higgins 1966)

Biological control by natural enemies

- Interest in using biological means of control has garnered attention in the past 15-20 years. There has been a wide variety of thistle-feeding insects that have been released in North America in order to see which may be able to play a role in the future with thistle control. One thing that does lack with this is the knowledge of impact of herbicides or cultural controls on biological control agents of thistles (Trumble et al. 1982)
- One thing that *is* known with biological controllers is that as the number of different species increases within an area, the potential for integrating successfully chemical and biological techniques without loss of biocontrol agents decreases. So if chemical application is being planned for, natural enemies of the thistle should be selected with the compatibility of integrated pest management kept in mind (Trumble et al. 1982)

Management Programs:

- The management program used at Ring Mountain Preserve, CA includes hand pulling and cutting to rid the area of the plant. It has proven to be the most effective during the spring and early summer (Wolley 1986)

Monitoring Requirements

- Extensive monitoring is essential is determining whether the control measures are being effective. It is almost necessary to have constant and longer term monitoring because of the plant's potential to have seeds that go dormant for up to 8 years.

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Goals

1) Identifying best removal strategy:

When it comes to invasive plants such as the Italian thistle, it can be difficult determining how exactly you'll be removing it so that it is effectively dealt with. We would like to find a strategy that can sustain the absence of the plant through the possible combination of chemical, biological, and mechanical removal. Because of the variability of the environmental conditions of the plant, the process needed to find the best strategy will take time and experimenting with.

2) Establishment of effective monitoring system:

Creating a monitoring system that will ensure that newly restored environment will not be susceptible to being re-invaded by the thistle. This will be influenced by how large of an area we will have to deal with and also with the physical conditions surrounding the newly eradicated areas. We will be able to get relatively quick feedback from the plant on this since the Italian thistle will have not trouble coming back into the area in a matter of a couple years if things are not done correctly to keep it out. This monitoring system would have a mitigation plan ready to go in case it is seen that things are not going as well as anticipated. Say there are patches beginning to be seen on the edges of the restoration area, it would be important to have a plan ready to go in order to take care of the situation in a timely matter.

Restoration Plan

For our plans to be the most effective we need to take into account its growing/seeding season. The Italian thistle germinates in the fall, overwinters as a rosette and flowers in late spring (Washington State Noxious Weed Control Board). Since it is already so dense in the area we are dealing with, preventing the establishment of more of it should be one of our concerns. Since it is only able to spread through seed dispersal, finding a way to eliminate its seed production will be important. A way to do this is to go into the area slightly before the plant beings to flower, which is late spring, to cut it down so it isn't able to produce any seeds. We can then follow it with a round of chemical treatment in an attempt to kill the plant down to the root. The chemical most likely used will be 2,4 dicholorophenoxyacetic acid (2,4-D). Because the thistle is a sturdy plant, one round of chemical treatment will not be enough so repeating this process for 3 or 4 years will be the best thing to do to ensure that it won't sprout back up after we leave that area alone.

The use of biological control can be considered but considering that this plan will be integrated into a larger plan, bringing in other species into the window wouldn't be the best idea since the organism might have a negative effect on other parts of restoration plan. Also, in order to use biological control as effectively as possible, we would have to experiment with which insects are the most effective for the thistle given its conditions. In order to find out if this would be a type of control we can use, we can set up smaller locations where chemical and mechanical removal are not used so we can then attempt to see if the insects have the ability to effectively deal with the weed. If we see that it has the effect we want then we can proceed to include it into our larger scale plans by looking for a herbicide that will not kill off the insect. To do so I believe some experimentation will be needed since not too much research has been made on insect compatibility with commonly used agriculture herbicides.

Once this is done a monitoring process should be established where the numbers of the thistle are maintained and brought to the restoration groups attention if it shows signs of getting out of hand. Since reporting a large area's worth of plant establishment over a long period of time can be time consuming and ineffective to do on a constant basis, we can have the designated monitor person report back to group only when they see that the thistle is making a strong reemergence into the area. In the beginning of the restoration plan, monitoring should happen at a high rate (2-3 times a week) with a gradual decrease as time goes by. The monitoring can begin right after the treatment and depending on how effective the eradication efforts are, the monitoring should last around 5 years if possible. But, the Italian thistle seeds are known to go dormant for up to eight years so as the duration of monitoring should be flexible enough that it can be extended if the need for it to be arises.

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Woody species

Himalayan blackberry (*Rubus discolor*) Joshua Bertuch

Himalayan Blackberry

Rubus armeniacus

Background and Justification

Himalayan blackberry (*Rubus armeniacus* or *Rubus discolor*) is an invasive perennial shrub in Riparian habitats. Historically it was introduced as an agricultural crop but has since escaped into the wild, where it tends to aggressively outcompete native flora. It is both an effective competitor and difficult to manage by virtue of its physical characteristics and growth patterns. It is an important management goal because biodiversity of both plants and animals is reduced in areas where Himalayan blackberry becomes dominant and Riparian habitats are among the most diverse ecosystems in California. Hence, reducing numbers of Himalayan blackberry could indirectly increase the numbers of a wide range of desirable native species. Not only does it reduce biodiversity through competition, but Himalayan blackberry also damages Riparian habitat structure by preventing the growth of trees thereby decreasing the amount of large woody debris (logs, etc.) which accumulates in streams and is important for the creation of microhabitats(Bennet 2006).

<u>Fact Sheet</u>

Life Cycle & Growth

- *Rubus discolor* can self-pollenate or can be pollenated by bees to produce seeds; a blackberry thicket is capable of producing up to 13,000 seeds in a square meter. Seeds can remain viable in a seed bank for several years (Bennet 2006)
- *Rubus discolor* can also sprout vegetatively from the tips of shoots when they reach the ground, as well as from the root crown after a disturbance such as fire or grazing.
- Himalayan blackberry grows via a single cane in its first year, which will not yet flower but can reach lengths of up to 10 meters (Soll 2004)
- During the second year it will produce side shoots which will then flower (Stannard 2014)
- At any shoot which touches the ground will form roots, in addition to root suckers and seedlings, with proliferation resulting (Bennet 2006)
- Root stock is perennial and will produce new shoots if simply mowed over (Soll 2004)
- Canes are biennial and will eventually die. New shoots use dead shoots for structural support and quickly a thicket is created which is impenetrable to light and animals (Bennet 2006)

Habitat

- *Rubus discolor* lives in disturbed riparian zones along streams and pools with adequate sunlight (it cannot survive in full shade). (Stannard 2014)

- It can also live along roads, train tracks, and other disturbed sites as long as there is adequate soil moisture.
- Himalayan blackberry can tolerate a wide range of soil textures and pH. (Soll 2004)
- It can also tolerate periodic flood events of both fresh and brackish water. (Soll 2004)

Ecosystem Interactions

- Himalayan blackberry grows fast and quickly outcompetes most early successional riparian natives for light, space, and water. (Astley 2010)
- Himalayan blackberry provides food for birds and small mammals in the form of its berries which are highly prized for their sweetness.
- It also provides shelter for small birds and mammals by the creation of thickets which are impassable to larger animals.
- *Rubus* discolor also provides soil stability with its roots and makes the edges of streams resistant to erosion, but not as efficiently as the native Riparian trees and shrubs which *Rubus armeniacus* outcompetes (Bennet 2006)
- The dense thickets created by accumulated old and new growth are impassable by large mammals, reducing their foraging ability in these areas (Bennet 2006)

Management

- Physical removal is difficult because of the spiny stalks which can cause injury and deep, expansive roots (Soll 2004)
- Mowing alone is not enough due to the ability of roots to grow new shoots (Soll 2004).
- Mowing can also spread prickles from the shoots of the plant to nearby bike paths and become a hazard to cyclists.

- Herbicides such as glyphosate (Roundup) must be used to kill sprouts every year for at least 2-3 years after removal due to a large seed bank which can endure eradication from fire, herbicides, and physical removal. (Stannard 2014)
- Biological controls are available such as *Phragmidium violaceum* (fungal rust). *P. violaceum* defoliates Himalayan blackberry and prevents rooting, but does not always kill (Astley 2010)

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The key goal of this restoration project is the complete removal of Rubus discolor from riparian habitats. Complete removal is necessary because without it Rubus discolor will quickly reclaim recovered land due to its prolific growth patterns which include large seed banks, production of root suckers, and the ability of shoot nodes to take root once in contact with the ground. Due to the variety of ways in which Rubus discolor reproduces, an even wider variety of management strategies are required for any measure of success. Management strategies necessitated will include physical removal (via manual volunteer labor or mechanical means, the latter of which is highly destructive to soil), chemical herbicides such as glyphosate (which carries various ecological risks), biological controls (such as pathogen *Phragmidium violaceum)*, and the reestablishment of native plant populations.

In order to limit the growth of Himalayan blackberry it is important to completely kill and physically remove of all mature individuals as well as return every year for at least 2-3 years to kill young individuals. Success in this is defined as the eradication *of R.* discolor thickets and the prevention of their reestablishment over the next several years. This is because the ability of both the roots and shoots to reproduce leads to a high reproductive potential for any individual plant. However, it is difficult to remove Himalayan blackberry from the landscape because the shoots quickly grow and die, creating nearly impenetrable thickets of tangled, dry, woody shoots. Additionally, all shoots are covered in spines making manual removal hazardous and is not recommended unless proper tools and protective gear is available. There are also difficulties below ground which complicate physical removal; roots form large storage masses which can survive the death of the attached shoots and are resistant to uprooting. Machinery can be utilized for these purposes. This method is the time costly and has the possibility of damaging soil structure and causing erosion. Volunteers with hand tools are the recommended removal method due to lower disturbance and lower cost of using a bulldozer, which can cost as much as $400 per day.

Killing the shoots of Himalayan blackberry is also possible by utilizing fungal rust (*Phragmidium violaceum*). *Phragmidium violaceum* has been found to selectively kill Himalayan blackberry without affecting agricultural blackberry crops. However this method is not without limitations; fungal rust does not kill all individuals of Himalayan blackberry, leading to a possible resurgence of individuals resistant to Phragmidium violaceum. Additionally, widespread utilization of this control method may carry the hidden danger of mutation of Phragmidium violaceum into a pathogen which is no longer selective to only Himalayan blackberry and can attack agricultural blackberries and native blackberries (*Rubus ursinus*), leading to economic damage. It is also unknown how *Phragmidium violaceum* may affect other native and non-native vegetation. Release of this pathogen into plant communities without proper knowledge of its full effects could cause more harm to the communities than Himalayan blackberry itself. However, if these interactions are found not to exist the benefits of utilizing *Phragmidium violaceum* would outweigh the disadvantages.

After an area has been cleared of Himalayan blackberry it must be treated with an herbicide such as glyphosate (Roundup) every year for at least 2-3 years to kill emergent seedlings which will germinate from the seed bank. Without herbicide treatment the seedlings will quickly grow and begin to root clones until finally producing flowers, fruits, and more seeds. This method also carries environmental concerns which must be considered such as what effects the spraying might have upon other vegetation in the area (both native and non-native) and unknown interactions with other pesticides or pollutants already present.

After all Himalayan blackberry plants have been removed and all seedlings have been eradicated native plants such as *Rubus ursinus* and *Calycanthus occidentalis* can be reintroduced to the area. These should be fast growing and create deep shade when fully grown, which will help prevent reintroduction of Himalayan blackberry due to its intolerance for full shade.

Insights gained in the management of Himalayan blackberry here in California can aid in efforts elsewhere on the West coast, where Himalayan blackberry has gained a foothold in riparian regions. Removal of this invasive species is important for improving biodiversity in a wide range of habitats, including the most productive ecosystems in California.

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Native Wildlife species
Reptiles and amphibians
Western pond turtle *(Emys/Clemmys marmorata)* Ali Zarreen

Background and Justification:

The Western Pond Turtle (*Emys marmorata*) is a reptile species that is native to the North American west coast with its distribution ranging from as far up north as Puget Sound, Washington, through Oregon and California, ending up in Baja California (Buskirk 2002). It is a slow growing and long lived species that used to have a great array of genetic variation throughout the state of California, but is now only limited to parts of California (Spinks 2005). *E. marmorata* has been under review as a candidate to be listed as an endangered species, and is now considered a "species of special concern" (Reese 1997 & Lambert 2013). This species is unique in the fact that by way of its large home ranges it employs the use of various habitat types, from aquatic to upland terrestrial, throughout its life (McAllister 1999). Due to habitat loss and fragmentation, the entire population of this species, from Washington to California, has declined by 80-85% since the 1850's (Buskirk 2002). Also, the Western Pond Turtle is in competition with invasive turtle species for suitable habitat and having further habitat degradation occur by invasive plant species that can alter both the terrestrial and aquatic environments (Lovich). Then, what habitat does remain for *E. marmorata* to compete for, is being polluted by wastewater runoff from human developed areas, which is negatively altering the health of the turtles (Meyer 2013 & 2014). In order for this turtle species to return to historic numbers, habitat conditions must be improved in order to support its unique life cycle.

Literature Review:

<u>Morphology:</u>

- 130 – 170 mm adult carapace length (Buskirk 2002)
- Dark brown to olive carapace color (Buskirk 2002)
    - Can have black radiating line markings in each shield of the carapace (McAllister 1999)
    - Can contain specks of yellow or gold (McAllister 1999)
- Yellowish plastron (Buskirk 2002)
- Flesh is gray or brown and can have a mottled appearance (Buskirk 2002)
- Sexual Dimorphism
    - Males have larger heads and pointier snouts (Buskirk 2002)
    - Females have deeper and rounder carapaces (McAllister 1999)
    - Males grow to about 130mm and females reach 145mm (Lovich)
        - Size dimorphism may vary geographically. Northern areas (i.e. Washington) tend to see larger males, whereas the opposite is seen in Southern areas (McAllister 1999)

<u>Behavior:</u>

- Thermoregulation to maintain body temperature around 95 degrees F (Lovich)
    - Employ both terrestrial and aquatic basking depending on weather conditions (McAllister 1999)
- Males aggressively compete with one another for optimal basking sites (Buskirk 2002 & Lovich)
- Easily disturbed by human presence (Lambert 2013)

- Employ torpor during winter months, November – February (Reese 1997)
- Estivate at high temperatures, usually summer months May – August (McAllister 1999)

Habitat:
- Various intermittent and permanent wetland habitats, but streams are preferred (Lovich).
- Optimal basking sites should be readily available (Lovich).
  - Logs, snags, large rocks
- Aquatic habitat must have riparian buffer (Buskirk 2002 & Lambert 2013)
  - Needed for over-wintering, thermoregulation, and foraging
  - Native sedges are optimal for providing shade while still allowing for movement (McAllister 1999).
- Must have access to upland grasslands
  - Needed for nesting sites (Buskirk 2002)
  - Specific characteristics of this site that make it preferential for nesting are the sparse vegetation and dry soil that make it easy for females to dig a hole (McAllister 1999).
- Large home ranges
  - Males average 2.42 acre (Lovich)
  - Females average 0.62 acre (Lovich)
  - Juveniles average 0.89 acre (Lovich)

Diet:
- Omnivorous and opportunistic feeders (Buskirk 2002)
- Algae, macrophytes, terrestrial native plants (Lovich)
  - *Alnus* species have been noted as important because their catkins are a preferential food source (Nachman 2011)
- Small and/or weak fish, insects, small frogs (Lovich)
- Scavenging behavior has been observed (Buskirk 2002)
  - Feeding on carrion
  - Juveniles feeding on coyote scat
  - Traveling to houses near creeks and eating dog food

Reproduction:
- Sexual maturity at 6-7 years of age or carapace length of 120mm (Lovich & McAllister 1999)
    - Life span of 50 – 70 years (McAllister 1999)
- Copulation from February to November (Buskirk 2002)
- Nesting from late April to early August (Lovich)
- Clutch size is 1-13 eggs per female (Buskirk 2002)
  - Females can lay up to 2 clutches per year (Lovich)
- Incubation period is 80-126 days (Buskirk 2002)

- Sex determination during incubation is dependent on the temperature of the environment (Lovich).

Threats to Species:

- Urbanization and agricultural land use are the main culprits for the decline in *E. marmorata* populations. The alteration of land use and land cover has destroyed habitat that was originally used by the turtles for nesting and over-wintering activities (Spinks 2003). Fragmentation caused by human construction of roads results in decreased genetic variation and it directly decreases the population by increasing the chance of the turtles becoming road kill (mostly females searching for nesting sites) (Reese 1997 & Spinks 2003). The turtles also require habitats with well-established vegetation for shade as a way to thermoregulate, and as protection from predators (Buskirk 2002), so it would be negatively impacted by any grazing activities or fire.

- The Western Pond turtles are also in competition with the invasive Red-Eared Slider turtle species. The turtles are competing for habitats suitable to bask in order to thermoregulate (Lambert 2013). The invasive turtle species gain access to more optimal basking habitat in disturbed areas because they are less timid around humans, while the native pond turtles tend to give up basking sites more easily when scared by humans (Lambert 2013). Other characteristics of the slider turtle that make it a better competitor are the fact that it is larger, an even greater generalist, and reaches sexual maturity faster than the native species (Thomson 2010). Invasive turtle species also are potentially carrying a respiratory disease that could be fatal to the native pond turtle (Lovich).

- Also, in areas where the invasive plant species *Tamarix ramosissima* (Saltcedar) occurs, western pond turtle populations decline (Lovich). The Saltcedar grows in dense patches that alter the terrestrial habitat and make it hard for the turtles to move through (Lovich).

- A temperature dependent incubation process could cause a skewed sex ratio in the future as climate change progresses. The warmer the climate and the environment get, the more females that will be born per clutch than males (Lovich). This will cause population declines over time.

Possible Solutions:

- A head-starting program has been started in order to supplement the existing native, wild turtle population (Spinks 2003). Hatchlings are collected right after exiting the nest and raised in captivity for 1-2 years to increase their chances of survival before being reintroduced into the wetland (Spinks 2003). If a greater variety of genetic material is needed, then individuals from different regions can be chosen based on phylogeographic data and introduced to the restoration site (Spinks 2005).

- During restoration, removal of any Saltcedar plants will make huge improvements to the habitat. In order to give the native pond turtles an advantage over the invasive sliders to optimal basking habitat, the structural conditions of the restored creek bank should be steep and stop the sliders from seeing or feeling threatened by humans, but still allowing humans to get a good view of the turtles (Lambert 2013). Many opportunities are created by giving the public visual access to the turtles. Simply by raising awareness of the turtles' presence creates an educational opportunity on what this species needs and what the public can do to help them. By showing them the organism, they can better connect with its vulnerabilities and should be more supportive of restoration efforts.

- It is said that a turtle could need up to 500 meters of undisturbed terrestrial habitat from the water channel for the turtle to complete its land activities without disturbance (Thomson 2010). That seems a bit of an impossible notion in an urbanized area. But, this brings up the idea of how far the walking/biking path should be away from the water way. The further away it is, the better it is because it would keep the fragmented habitat out of the potential home ranges of the turtles, and it would help the turtles not to see and be frightened by humans (Thomson 2010 & Lambert 2013).

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Restoration of the Western Pond Turtle (*Emys marmorata*)

Goals:

1. **Increase survival rate of female turtles searching for nesting sites.**

Habitat used for nesting sites differs drastically from the riparian habitat that these turtles are found in. Females lay their eggs to incubate in a nest chamber that they dig. In order for the females to burrow these chambers, the ground must be flat and dry without the root system of dense vegetation so they can have access to at least 10 cm of soil (Nachman 2008). Females can travel up to 100m or more looking for optimal nesting sites (Lovich). The path from the riparian area to this open, grassland area can be fragmented by roads, increasing the amount of female deaths caused by cars. This also leaves juveniles vulnerable to cars and even more so vulnerable to predators on their way back to the riparian habitat. The establishment of a corridor from riparian habitat to nesting habitat can increase both female and juvenile survival. A successful breeding season should have all gravid females that leave to nest, return to the stream. Average nest success rate is currently 15% due to nest predation and juvenile mortality (McAllister 1999). The first step is to at least double that rate using predator defenses and the head-start program. To maintain a self-sustaining population, I would set a goal of 70% nest success.

2. **Decrease populations of the invasive Red Eared Slider turtle (*Trachemys scripta elegans*).**

T.s. elegans is an invasive turtle species that has been deployed into the environment by human activities. Its presence in this habitat results in decreased fitness, loss of weight, and increased mortality of *E. marmorata* (Cadi 2004). The invasive sliders out compete the pond turtles for basking sites, obstructing their chances for proper thermoregulation (Lambert 2013). The sliders population also grows faster than that of the pond turtle's because sliders reach maturity faster and lay more eggs per clutch than pond turtles (Thomson 2010, Bettelheim 2011). There has also been evidence of interference competition by the sliders for females; male sliders have been observed pursuing females in water ways (Cadi 2004). Two things can be done about this threat. *T.s. elegans* can be captured and eradicated from the restoration area. Head-starting *E. marmorata* juveniles will increase their likelihood of survival to maturity, therefore the native population has a better chance of increasing (Spinks 2003). Or, the riparian buffer zone can be altered and managed to better meet the habitat needs of *E. marmorata*, giving it the chance at competitive dominance. Due to *T.s. elegans* faster life span, evidence of coexistence has not been seen. The goal for initial removal efforts will be total eradication. Monitoring will be used to ensure that all have been removed and/or no more have been introduced. If that is the case, traps will be used to remove individuals that have been seen.

3. Increase genetic diversity of *E. marmorata*.

Urbanization and other land use has fragmented the natural distribution of the western pond turtle, effectively separating and isolating large communities into small populations (Buskirk 2002). The lack of genetic variation in a population can lead to inbreeding depression and can have negative fitness consequences in the long run. Individuals from southern populations can be translocated to the Central Valley to increase genetic variation (Spinks

2005). Corridors can also be used to connect fragmented habitat between populations and allow for natural contact.

Restoration Plan:

Restoring optimal riparian habitat.

Urbanization can cause riparian buffer zones to become narrow, sparsely vegetated, and lacking any solid or stable structures near the water's edge. The turtles prefer terrestrial habitat that has dense native riparian vegetation cover for thermoregulatory processes and protection from predators and off-shore basking sites (Buskirk 2002). Also, it is thought that steeper sloped stream banks are preferred in order to employ evasive maneuvers at a faster rate when necessary (Lambert 2013). A habitat design using these characteristics is intended to optimize habitat for the western pond turtle, thus giving it a greater advantage when competing with *T.s. elegans*.

The bank should protrude from the water at a gentle slope, 30 degrees, for 15 m before beginning to flatten out. Then continue the riparian zone for another 50 m across the flat land. If a recreational path is necessary, then the aspect of mid-slope will have to be accounted for (Lambert 2013). In this case, the slope should protrude from the water at the same 35-45 degree angle and have a small plateau after 10 m. The shelf of the plateau will be small, 3-5 m in length, before continuing the additional 5 m at a smaller angle of 25-30 degrees. At that 15 m mark, the path can be constructed, allowing people to enjoy seeing the turtles without the turtles being interrupted by them. Then, after the path, the riparian zone can be continued on flat ground for 50 m.

Any variety of vegetation can be planted on the stream bank as long as they are species native to California and are naturally a riparian habitat species. Invasive plant species can degrade terrestrial habitat by growing too densely (Lovich). Any invasive plant species will be eradicated and can be replaced with native sedges and woody species. Ideally, tree and shrub species belonging to the *Alnus* genus would be planted because alder catkins make up a big portion of their plant diet (Nachman 2011). It would also be worth the effort to choose plant species that have high water filtration abilities. Agriculture and urban runoff can be harmful to the western pond turtle and adversely affect its health (Meyer 2013 & 2014).

The last aspect of turtle habitat that has to be incorporated is the availability of basking sites. This can be done in many ways: large rocks along the water's edge, logs or snags in the center of water ways, or man-made basking platforms (Lambert 2013). To give the turtles a variety of sites at different parts of the water way, we will be using a mixture of non-vegetated patches adjacent to the water way, shore-side rocks, and natural logs/snags depending on the size of the water way (Roe 2007). The number of rocks arranged will depend on the length of the water way, but they will be dispersed randomly along one side of the water way. The opposite bank will have the snags or log embedded in it and protruding into the water. This arrangement provides many different mediums that disperse heat differently for the turtles to bask on.

Constructing corridors

Corridors can be used for connecting riparian habitat to nesting grass land habitat or to other water ways containing populations of *E. marmorata*.

For nesting habitat, a constructed corridor will be up to 500 m long (perpendicular to the water way) and at least 100 m wide. These measurements account for the lengths a female is willing to travel to find an optimal nest site (Buskirk 2002). The best way to choose where to construct the corridor would be to collect observational data on the most common path females attempt to take to the nesting habitat and supplement it with historical data of female migration. The corridor should be complex by using a variety of native vegetation that naturally transitions from riparian to grassland habitat and that can be self-maintained (Fischer 2000). The start of the corridor, from the riparian zone, should have larger and denser vegetation. As the female turtle moves along the corridor, the vegetation should become less dense and smaller until it leads her into the nesting habitat zone. Low fencing, no taller than 1 foot, can be used to ensure they do not burrow nests outside of the protected zone. Fencing can also increase nest and juvenile survival by acting as protection from some predators (Spinks 2003). Once a clutch is laid, a nest cage will be installed around it to keep nest predators out. If the corridor is not in some way enclosed, then you can have problems with not only predators, but people coming across turtles, as well. If a person sees a turtle on dry ground, their instinct might be to pick it up and take it back to the water way. The community will have to be educated about and involved in this project in order for them to understand the appropriate ways to behave around the turtles. "Turtle crossing" signs can also be placed in areas with heavy traffic; it will make the public aware of the turtles and can also be aesthetically attractive.

A corridor can also be used as a means to connect two habitats that contain isolated populations of *E. marmorata*. *E. marmorata* can live in a variety of aquatic habitats and with such large home ranges, they may be able to migrate between habitats if they were not fragmented (Lovich, Nachman 2008). If there is another aquatic habitat located within 1000m of our restoration site, building a corridor to connect the two sites would increase the heterogeneity of their habitat options. This will increase the buffer zones around the habitats, allowing greater protection of core habitat from pollution and edge effects over time (Roe 2007). With this option, the corridor should be wide enough to enclose both habitats and encompass nesting habitat. If there is already an existing population of *E. marmorata* at the second sight, then the corridor construction will allow for natural gene flow. Increasing genetic variation will prevent long-term, deleterious effects from occurring within the population.

Combatting the Red Eared Slider

The design of the restoration site should help the western pond turtle achieve competitive dominance over the invasive slider. Increasing the population of *E. marmorata* so they outnumber the number of *T.s. elegans* in a given area is another way to achieve competitive dominance. A head start program will be used to increase the survival rate of juveniles (Spinks 2003). With an enclosed nesting site with the corridor design, eggs can be monitored. When juveniles begin to exit the nest, they can be collected and transported to a captive breeding area where they will be raised for a year, then reintroduced to the restoration site. During the first year, the juveniles will be raised in an environment where they will learn foraging behaviors. They will not be handled by humans in captivity. They will be kept in closed areas that resemble outdoor habitats. It will have the vegetation and a small pond with small fish in it so they can learn to forage for their food and not have to be hand-fed. This way, when they are reintroduced to the restored site, they will not have a reliance on humans.

Another option is to actively remove red eared sliders from the environment by trapping them. This will be an option that is more expensive and will require more effort. Basking traps can be used, but that will not differentiate between capturing the native and invasive species of turtles. Research will have to be done prior to this method in order to determine a more targeted way to capture only red eared slider turtles. But, even then, extirpating the invasive turtles may be an ineffective effort if continuous introduction into the environment continues through the pet trade (Pitt 2005, Thomson 2010). Community involvement will be key in preventative measures.

Outreach and education to locals about the invasive species threats can reduce the amount of introductions into the environment. Getting community involvement with the restoration project through volunteer opportunities will help the public become more invested in the project and the native turtles.

Monitoring:

Success of this restoration site will result in an increase of *E. marmorata* population, an increase of genetic variation within the population, better health of adult individuals, and a decrease in *T.s. elegans* population. Once a year, a population count will be taken after the turtles emerge from hibernation. Basking traps will be used to capture turtles of both species, and they will be marked in order to retrieve density measures. Blood samples will be taken from the native turtles, the introduced *E. marmorata* turtles, and some *T.s. elegans* turtles to keep genetic information of record. Shell notching methods will be used to mark adult turtles, and shell painting will be used to mark juveniles released from the head start program. *E. marmorata* turtles will also be given physicals to determine that their health is improving. The annual measurement will also be able to determine how many juveniles from the head start program have survived each year. To ensure that genetic variation is increasing, juveniles taken into the head start program will be genetically tested to determine whether mating is occurring between the introduced and native individuals.

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Birds
Hawks (red-tailed, red shoulder) ** Kelsey Ray

Background and Justification

Red-tailed and Red-shouldered hawks were particularly successful in North America due to their ability to tolerate a wide range of conditions (Preston 2000). They range from North America into Central American and winter south from southern Canada (Tesky 1994). Breeding bird surveys indicate Red-shouldered hawk populations are declining in the parts of the midwestern and northeastern United States but stable elsewhere (Sauer et al. 2008). This is caused by the clearing of forests to accommodate agriculture and the degradation of wetlands and foraging areas (Strobel and Boal 2010). The California woodlands are a good example of the impact of urbanization and land degredation because of low survivability of seedlings (Tietje et al. 1997). This degradation can limit the number of acceptable nest sites for hawks (Tietje et al. 1997). Raptors are an integral part of an ecosystem because of its huge influence on trophic interactions. They maintain the predator and prey balances between trophic levels by feeding on small rodents, birds, and other such prey species (Sekercioglu 2006). It is important to differentiate between Red-tailed and Red-shouldered hawks. While they may be similar in diet and reproduction, their habitats differ greatly. Because more and more forests are being cleared, Red-shouldered hawks are losing their habitat while Red-tailed hawks gain it due to their preference for open spaces (Tesky 1994).

Hunting Habitat

Red-Tailed Hawk

- Red tailed hawks like to hunt in large, open areas surrounding by woodlands (Tesky 1994)
  - Often decidious or coniferous forests with large trees with wide canopy
  - Places that they frequently hunt in include grasslands, agricultural fields, and rangelands (Tesky 1994)
- They usually avoide dense woodlands since a large open area is utilized (Tesky 1994)
- Prefer to hunt and forage close to their nesting sites
  - Within 3 meters of the nest (Tesky 1994)
- Needs perch sites in order to forage
  - Minimum 10 perches in a 40 acre area (Tesky 1994)

Red-Shouldered Hawk

- Red-shouldered hawks prefer a more dense hunting ground.
  - This includes semi-open areas with stands of trees spread out through the area
  - They thrive in edgelands as well
    - Such as riparian areas (Tesky 1994)

Reproduction

Nesting Habits:

Red-Tailed Hawk

- Red-tailed Hawks prefer nest trees with higher tree diameter at breast height (dbh), height, and maximum canopy width (Tietje et al. 1997)
    - dbh should be around 85 cm (vs. an average of 62 cm for non-nested trees)
    - height should be around 20 m tall with the nest height being about 15 m high (Tietje et al. 1997)
    - canopy should spread about 11 m (trunk to dripline) (Tietje et al. 1997)
- Red-tailed hawks nest at or near the edge between woodland and a large, open clearing (Moorman and Chapman, 1996)
- nest-access is very important
    - preference for an open canopy and taller trees (Moorman and Chapman 1996)
- steep slopes along a hilly landscape (Tietje et al. 1997 and Moorman and Chapman 1996)

Red-Shouldered Hawk

- Red-shouldered hawks prefer a greater area of bottomland habitat with nests located in large stands in a hardwood habitat - riparian forests being dominant (Moorman and Chapman 1996)
- They prefer larger trees with a low percent canopy cover thats closer to water(Moorman and Chapman 1996)
- tree species is of little significance, as long as the size, location, and canopy provide protection (Tietje et al. 1997)
- usually nests within <1 km of a water source
    - stream, pond, etc (Crocoll and Parker 1989)
- spatial distribution between mating pairs should be 1 pair for every 200 hectares (Crocoll and Parker 1989)

Both Species

- minimum distance between Red-tailed and Red-shouldered hawk nesting sites should be greater than or equal to 650 m to limit encroachment (Moorman and Chapman 1996)
- mature forests with larger trees therefore it is important to maintain mature and larger stands (Moorman and Chapman 1996)
- Wetland and riparian forests provide nesting sites as well (Moorman and Chapman 1996)
- Active nest sites are found from January to June (Moorman and Chapman 1996)
- Distance between intraspecific nest sites in a woodland area with successful hawk populations was on average 0.84 km apart (Tietje et al. 1997)

Constraints:

- In some cases, nests fail with causes unknown (Moorman and Chapman 1996)

Breeding:

Red-Tailed Hawk

- Age of sexual maturity: 2 years of age (Tesky 1994)
- Season: End of January all the way to September

    - Most lay their eggs during February in warmer places such as California (Tesky 1994)
- Clutch Size: lay 2 to 4 eggs that are incubated 28-34 days. May lay replacement clutch within 3-4 weeks if the first one doesn't survive (Tesky 1994)
- Fledge: 42-46 days. May remain in nesting territory for 30 days or more (Tesky 1994)
- average longevity of a mature hawk is 6 to 7 years but may live up to as much as 16 (Tesky 1994)

Red-Shouldered Hawk

- Season: roughly April-August
    - Nesting begins in April and May and eggs start to hatch in June (Crocoll and Parker 1989)
- Clutch Size: 2-3 eggs (Crocoll and Parker 1989)
- Fledge: 30-32 days after hatching (Crocoll and Parker 1989)
- Average length of life of a mature hawk is 6-7 years (Tesky 1994)

Diet

Red-Tailed Hawk

- Diet is very flexible (Strobel and Boal 2010)
- Opportunistic eaters with a variety of prey,
    - prey usually the size of a jack rabbit or smaller (Tesky 1994)
    - Constraint: They also prey on domestic animals that are small enough
- correlates with latitude (Strobel and Boal 2010)
    - northern latitudes: abundance of mammals and limited number of amphibians
    - southern latitudes: more amphibians and less mammals
        - different latitudes have different climates, vegetation, and pattterns (Strobel and Boal, 2010)
    - in drier conditions, prey is primarily mammalian
    - in moist conditions, amphibians and invertebrate prey are dominate

Red-Shouldered Hawk

- different prey types have different nutritional advantages
    - mammalian prey taken by Red-shouldered hawks is 30% heavier and more nutritional than amphibian prey (Strobel and Boal, 2010)
        - includes voles, mice, snakes, and rabbits
- Red-shouldered hawks breeding in areas with larger and more nutrient rich prey can rear large broods and have higher quality young.
    - however, productivity (the allocation of time to activities such as nestling defense or average number of nestlings produced by successful nests) is not affected by prey type (Bednarz and Dinsmore 1985)

Migration

- migrate individually

- western hawks migrate during the spring starting in February and March
  - could be correlated to the emergence of ground squirrels in April
- (Tesky 1994)

<u>Vulnerability for Both Species</u>

- current deforestation practices for livestock grazing eliminates suitable nesting sites and affects rodent populations (Tietje et al 1997)
- Predators
  - studies don't show much predation on hawks specifically but based on other raptors' predators they may be vulnerable to great horned owls and golden eagles (Tesky 1994)
  - on the ground, coyotes, bobcats, skunks and crows are potential threats (Tesky 1994)
- Urbanization
  - Red-tailed and Red-shouldered hawks can tolerate housing developments and such as long as there are suitable nesting trees, perch sites, and adequate clearings or open ranges for hunting
    - Red-tailed hawks in particular are resilient since the clearing of land provides them with their preferred hunting habitat
      - however, this can affect small prey populations (Tesky 1994).
    - Red-shouldered hawks are well adapted to urban environments and therefore have a high tolerance of anthropogenic noise
- Fire
  - not much vulnerability to small fires that don't affect nesting sites
  - they actually flourish due to the availability of prey after the fact
    - as long as the fire stays away from the canopy with potential nesting sites, fire isn't a major issue (Tesky 1994)
- Clear Cutting
  - Clear cutting forests can be very detrimental to hawk populations nesting in the area
    - Destroy nests and future availability of nesting grounds
    - Never want to cut down a nesting tree or forest with nesting trees
  - For hawks not nesting in the area, clear cutting can provide great foraging grounds and prey availability

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Restoration Plan

Goals:

- A key goal in the restoration of Red-tailed and Red-shouldered hawk populations is establishing a thriving habitat on the ground in order to support the diet of both species.
    - We can do this by promoting native shrubs and grasses to provide habitat for small mammals and reptiles.
        - These include small rodents, snakes, amphibians, and many other small prey (Strobel and Boal 2010).
    - Central California is home to a variety of native grasslands and shrubs so I don’t believe there will be a problem providing small mammal and reptile habitats. The grasslands will provide hunting grounds for the hawks while the concentrations of shrubs provide shelter for the prey. These interactions will provide a balanced trophic interaction.

- We need to provide adequate hunting ground and foraging sites for both the Red-tailed and Red-shouldered hawk.
    - Red-tailed hawks hunt in open spaces with low grasslands (Tesky 1994).
    - Red-shouldered hawks hunt in smaller open spaces interspersed with trees (Tesky 1994). The Riparian forest along a basin would be adequate.
    - Many sites in Central California consist of open clearings surrounded by some woodland and used to consist of dense riparian forests (Rottenborn 2000). It would not be unfeasible to restore native grasslands and riparian forests using those as reference sites.
- Maintain or plant tall growing and overhanging trees to provide high perches for both species.
    - California can support these tall mature trees as long as they are maintained and protected.
- Provide adequate nesting sites for both species that will promote survivability.
    - Red-tailed hawks choose trees with a wide diameter and a lot of canopy to protect its nest (Tietje et al. 1997). The trees should be planted or maintained between the edge of the woodland and open grassland (Moorman and Chapman 1996).
    - Red-shouldered hawks utilize riparian forests as their nesting sites and so a riparian forest should be maintained with tall, sturdy trees (Rottenborn 2000).
    - A study conducted in California about the successful nest sites of Red-shouldered hawks in urban areas states that they preferred to nest in non-native Eucalyptus trees (*Eucalyptus spp.*)(Rottenborn 2000). If Red-shouldered hawk populations don’t establish within the existing woodlands, I suggest planting

Eucalyptus trees.

- It wouldn't be impossible to maintain mature and tall trees in the Central Valley as long as they are protected. Red-shouldered hawks are particularly used to urbanization in California and are a little more adapted to it (Rottenborn 2000).

Restoration Plan:

My restoration plan would start by surveying spots in Central California that would provide an adequate habitat for Red-tailed and Red-shouldered hawks. This habitat would need to accommodate the Red-tails tendency for wide, open areas surrounded by woodland and high perch sites (Tesky 1994). Red-shouldered hawks prefer an area punctuated by stands of trees so a denser woodland area would be best (Tesky 1994). These areas would have to be maintained year round; meaning mature trees need to be protected to provide nesting sites and grasslands and shrubs maintained for food. Red-tailed and Red-shouldered hawks nest in trees with large diameters, large canopies, and tall height so mature stands of trees should be used (Tietje et al. 1997). In order to maintain hawk populations over time, seedlings should be protected so they can grow into trees suitable for hawk nesting.

After introduction of the hawks I can monitor the success of the species by counting and measuring the success of nests in both habitats. I can use a mechanized hawk call to try and illicit a territorial response in order to locate the individuals and follow them to their nesting site (Rottenborn 2000). Then, I can use binoculars or spotting scope to monitor the nest to see whether there are babies or a nest failure. If the nest is viable I would monitor every 3-4 days until fledglings. I can increase the monitoring time to every 2-3 days when as they grow older in order to count and estimate the population (Rottenborn 2000).

In the Red-shouldered hawk site, if populations aren't as high as we want or they failed to establish in the area we can try to plant non-native trees such as, Eucalyptus. Being non-native, these trees tend be taller and fuller than their competition and therefore more appealing to Red-shouldered hawks. (Rottenborn 2000). It is important to plant or conserve tall, sturdy trees in the area in order to establish successful nesting sites. Another option to improve both Red-tailed and Red-shouldered hawk populations would be to institute strong bottom-level trophic interactions. This involves planting grass and shrub species among the site in order to promote more small mammals and herptiles. This will not only attract more hawks but it will also maintain hawk populations over long periods of time.

Both species of hawk are avid hunters that hunt small mammals and reptiles, namely herbivores (Strobel and Boal 2010). This will help maintain the introduced and growing vegetation at a restored site while sustaining the raptor populations. This interaction will also promote biodiversity through balanced trophic interactions between the raptors, small mammals, native vegetation and insects. In an urban setting, hawk populations can decrease pests in and around urban areas that may nearby. One consideration when dealing with urban settings is the safety of small domestic pets. Hawks have been known to prey on domestic animals small enough to hunt (Tesky 1994).

The small mammal and herptile populations are an example of a threshold, a boundary between two states that can cause a rapid change in the ecosystem if it reached. This means that small a change in the conditions of the environment can cause a rapid change in the ecosystem as a whole. In this case, the conditions of the environment involve habitat for small mammals and herptiles. Therefore, the grasses and shrubs planted at the site must be able to provide adequate habitat and shelter for bottom-level animals for long periods of time in order to sustain the hawk populations. If the sustaining vegetation at a site decreases past a certain threshold, hawk populations will decrease rapidly. This means planting grass species that can handle variability in precipitation and sustain herbivore populations.

The obvious risks and uncertainties associated with this plan involve the underlying conditions of the environment. If a ground population of viable habitat for raptor prey cannot be maintained, then hawk populations will be in serious trouble. Sustaining viable grasslands and surrounding shelter areas is difficult in California right now due to the three years of drought and the variability of precipitation that comes with it. A high tolerance to these types of climatic variations need to be considered when planting the grass species. The attraction of insects and certain mammals and herptiles is also essential in maintaining population. Fire is another risk associated with California right now. However, as long as the nesting sites in the taller trees aren't disturbed, hawks have the ability to flourish when prey are displaced from their habitats (Tesky 1994).

In order to improve my plan the research questions that need to be answered regard the type of vegetation that is most ideal for both hawk species. When restoring a site, manipulating vegetation to best suit the ecosystem needs is essential. More research about ideal ground-level vegetation for preferred Red-tailed and Red-shouldered hawk diet would increase the introduction, establishment, and success of the species. If I knew exactly which grass and shrub species supported which type of small animal I could create a balanced and thriving ecosystem where hawks flourish at the top of the food chain.

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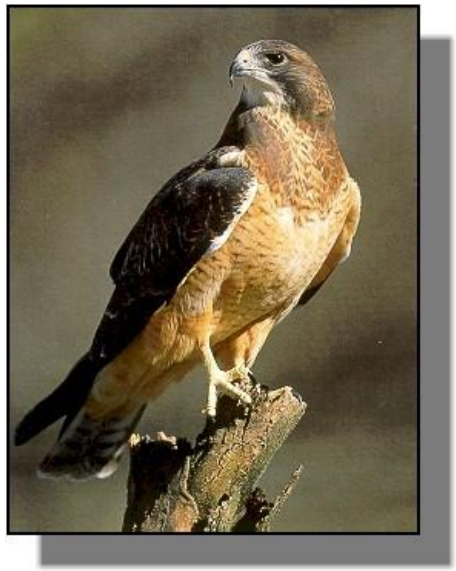
5 June 2014

Swainson's Hawk
Buteo swainsoni



Classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Aves
Order:	Falconiformes
Family:	Accipitridae
Genus:	Buteo
Species:	*B. swainsoni*

Background and Justification

The Swainson's Hawk (*Buteo swainsoni*) is a raptor that can be found in the Central Valley in California and down the coast in areas of Southern California. It thrives in riparian habitats and open grassland where prey densities are high. Swainson's Hawks have lived in the western United States for much of its history, however current population numbers are declining and the species is considered threatened by the US Department of Fish and Game; mainly due to habitat degradation and alteration. Current population size is estimated to be just under 200 breeding pairs (LSA 2004). Urban development has taken away much of the prime land that these hawks used to use for foraging and nesting. The shift of agricultural crops to vineyards and exotic plants make disadvantageous foraging grounds, as these plants are too dense for the hawks to hunt efficiently. Swainson's Hawks are important to the ecosystem to rid agricultural farms of pesky insects like grasshoppers and also to control the population of small mammals like field mice and ground squirrels. If we do not halt our "progress" of urban planning and agricultural alterations and be more aware of the consequences our actions have on the natural world around us, we may cause an even steeper decline of the Swainson's Hawk that other species will eventually fall victim to.

Fact Sheet

Life Cycle

- Growth Characteristics
    - After strengthening their muscles and growing sufficient feathers for flight, the young tend to be partial to small insect prey (Woodbridge 1998)
    - Active during the day

- Young nestlings are helpless and dependent on parents after hatching. They must be fed by the male for first two to three weeks (Woodbridge 1998)
    - Will live 15-20 years in the wild (Woodbridge 1998)
- Reproduction
    - Arrive at nesting areas in March to May (England 1997). Their summer breeding grounds cover North America from the Midwest to the Pacific coast and all the way up through western Canada.
    - Nests are built at the tops of solitary trees, power poles, or in small groves of trees near small bodies of water, such as streams. (Bechard 2010)
    - Lay eggs between April and June (England 1997)
    - Young nestlings are strong enough and have developed enough feathers to leave the nest between June and August (England 1997)
    - Form monogamous pairs (Woodbridge 1998)
    - Clutch size is about 2-3 eggs (Woodbridge 1991)
    - Prefer reproductive nesting sites near riparian habitats (Woodbridge 1998)

Range and Distribution

- Population has decreased by about 90% since the 1940s (SCWA 2007)
- Labeled as a threatened species in 1983 due to habitat loss and decrease in population size (USDFG)
- During summer, they occurs in open habitats throughout the western United States and Canada
- In California, very popular in the Central Valley and Great Basin (Woodbridge 1998)
- Has suitable habitats in Northern California, however temporal differences between Swainson's Hawk and the prey that inhabits the area prevent the hawks from persisting (Woodbridge 1998)
- Migrates to South America for the winter (USDFG)
    - Swainson's Hawks migrating from the western United States will be in South America for 5-6 months. Those leaving from more northern territories in Canada will have a much longer absence, about 7-8 months (Woodbridge 1991)
    - Flocks are typically composed of as many as 5,000-10,000 individuals (Bechard 2010)
    - The adult Swainson's Hawks gather to get ready to start their journey by hunting and storing energy in late August and early September (Bechard 2010)
    - Migration path funnels south through Mexico and Central America to as far south as Argentina (Bechard 2010)
    - Complete travel time is between 50-60 days, each way (Bechard 2010)
    - Leave South America in late February to mid-March to return to northern breeding grounds (Bechard 2010)

Habitat and Associations

- Swainson's Hawks have a preference to open grasslands with few scattered trees or shrubs (Bent 1961)
- Open fields for hunting; adapted to soar and perch while foraging (Woodbridge 1998)
- Does not survive well in high mountain ranges or steep terrains (Woodbridge 1998)
- Needs between 6,500-10,000 acres to forage and nest (Estep 1989)
    - Dependent on distribution and density of foraging habitat (Woodbridge 1998)

- Suitable foraging habitats depend on the prey density and the prey accessibility (i.e. how easy and efficient is it for the Swainson's Hawk to see and acquire the prey)
- Prey reductions are common in habitats that are taken over by exotic species of weed plants (Estep 1989)
- Tolerant to environments with little to no surface water, however these birds thrive when living near water bodies in riparian habitats. This depends on the availability and location of appropriate nesting trees. Preferred nesting trees include (Bechard 2010):
    - Willow
    - Black locust
    - Oak
    - Aspen
    - Cottonwood
    - Conifers
- Tolerant of regularly occurring human activity (Woodbridge 1998)
- Has adapted to agricultural fields, as the increased cultivation activities expose prey, however is not tolerant of vineyards or crops that offer advanced protection to prey. The crops are too dense for the hawk to efficiently hunt in (Swolgaard 2014)
    - Appropriate agricultural fields include:
        - Hay
        - Alfalfa
        - Pastures
        - Grain crops (wheat, rye, etc.)
        - Row crops (cotton, maize, soybeans, sugar beets, etc.)

- Other crops, such as bean and tomato fields, have high prey density, but limited accessibility because they are only available during certain seasons of the year (Estep 1989)

Interactions

- Wildlife
    - Preys on continually abundant, small mammals (mice, voles, ground squirrels, etc.) during the breeding months (March to June) (Woodbridge 1998)
    - Preys on nutritious insects (grasshoppers, crickets, etc.) to store large amounts of energy after the breeding season in late August and early September, before leaving for their month long journey to South America (Woodbridge 1998)
    - Will infrequently prey on other organisms they can get including toads, crayfish, other species of birds when mammals and insects are not available (Woodbridge 1998)
    - Swainson's Hawks will sometimes try to prey on other bird species nestlings if food resources are scarce (Woodbridge 1998)
- Occasionally, Swainson's Hawks will become prey items for large carnivores such as coyotes and bobcats (Woodbridge 1998)Pathogens
    - It is possible to become infected with avian influenza if in extensive close contact with other infected birds. Avian influenza is spread through contact with infected saliva, nasal secretions, and feces. (CDC 2010)
        - "Low pathogenic" strain includes mild symptoms such as ruffled appearance and slight intestinal infection (CDC 2010)
        - "High pathogenic" strain spreads much more rapidly and can cause severe damage to multiple internal organ systems and results in death in 90-100% of cases in under 48 hours.
    - Can be infected with West Nile Virus, but only in rare cases (Bradbury 2009)
        - Symptoms include birds becoming lethargic, weak, and unable to stand, let alone fly. Most birds die within 24-48 hours (Seattle Audubon 2014)
- Humans
    - Swainson's Hawks all respond differently to human interactions.
    - Swainson's Hawks have become more comfortable to forage in agricultural habitats after being supplied with sufficient amounts of prey that live in the fields (Woodbridge 1998)
    - Female Swainson's Hawks tend to protect their nests, especially when incubating their eggs, and leave only when activity is very close by (Dechant 2001))
        - This is a dangerous study because some females have been known to abandon their nests if a threat seems severe enough (Fyfe and Olendorff 1976)

Threats

- Habitat degradation (Loss of foraging and breeding grounds) (USDFG)
    - This has the biggest effect on raptor populations.
    - Large farms are taking business from many of the smaller family owned farms. These farms would have shelterbelts that would protect the farm house from wind and erosion and used to offer appropriate nesting sites.

- Elk Grove has plans to expand into 8,000 acres of farmland. This area has the highest density of nesting Swainson's Hawks (FOSH)
- "Big-money" crops, such as grapes tomatoes, and beets, do not provide suitable foraging grounds for these raptors. Either the vegetation is too dense for the bird to get through or the prey density in that particular crop is too low (Woodbridge 1998)
- A loss of foraging habitat in their wintering grounds in Argentina resulted from the conversion of grassy pasturelands to soybean fields (Cornell Lab of Ornithology)

- Climate change
  - Sea level rise may cause the Sacramento-San Joaquin Delta to flood which would in turn cause salt water to intrude on agricultural farms (FOSH). This would alter the amount of prey living in those fields and in turn affect the Swainson's Hawks that forage there
  - Increasing temperature will put additional stress on raptors
  - Changes in rainfall patterns could cause a reaction in the agricultural areas where the Swainson's Hawks know to forage (FOSH)
- Pesticide poisoning (USDFG)
  - Organophosphate and carbamate insecticides are harmful to Swainson's Hawks who feed on insects near agricultural fields (Woodbridge 1998)
  - Organophosphate poisoning is a problem in Argentina where the birds migrate in the winter. Monocrotophos and dimethoate are used in South America to hinder grasshopper populations. (Woodbridge 1998)
- Decapitation or harm from wind turbines (Erickson 2005)
  - Although we cannot know for sure how many raptors are affected by wind turbines due to scavenging predators, it has been estimated that thousands are harmed or killed every year (Wildlife Society)
  - Most of the wind turbines are located in prime migration paths along the Pacific coast where the most wind blows (CEC)
  - Fourteen wind farms are currently being developed in Oaxaca, Mexico's Isthmus of Tehuantepec. Millions of raptors pass through this isthmus every year and the effects would be severe (FOSH)
- Solar flux burns from solar farms (Clark 2014)
  - Solar farms not only take away potential foraging and breeding habitats, they cause intense feather singing and skin burns that render the birds unable to fly (Clark 2014)

Management Options

- Farmer education programs to encourage alternative forms of pesticide use
  - Offer a "crop bonus" for farmers who switch to more gentle pesticides
  - Offer a sample of the safer pesticides
  - Reimburse them for a percentage of the crops if they lose profit
- International relations with Central and South American countries
  - Education programs to advise against harmful pesticide use and some more humane alternatives
  - Compromises should be extended about the locations and intensities of the wind farms

- Increase public awareness of the declining Swainson's Hawk population and get them involved
    - Teach Elementary and Junior High schools about the importance of becoming sustainable and preserving what pieces of the natural world we have left
    - Offer sustainability and wildlife protection classes at community colleges and local organizations
    - Organize education and information booths at local public outings, such as farmer's markets
- Protect and preserve crucial riparian habitats and agricultural land
    - Keep current on development plans and mitigation in important bird areas such as the Central Valley
- Provide suitable habitats, such as open grasslands with scattered trees for perching and nesting, in close proximity to modestly cultivated areas.

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Introduction

Swainson's Hawks (*Buteo* swainsoni) are raptors native to Central California and most of western North America. They are currently listed as "threatened" by the United States Department of Fish and Wildlife (USDFW) because of various reasons such as loss of habitat, climate change, human ignorance, and alteration of rural environments. Current Swainson's Hawk populations have plummeted down to just 10% of the original population from the 1940s with only about 200 breeding pairs in North America (LSA 2004, SCWA 2007). Urban populations of these hawks are being subjected to constantly shifting agricultural lands and increasing urban development which inflicts harm on their breeding and foraging grounds. Swainson's Hawks have a very important niche in ridding pesky insects from crops and controlling rodent populations around agricultural farms. We must realize the previously unforeseen errors of our ways and halt our progress of urban development and agricultural alteration that affects native animal species. If we do not, we will see an even steeper decline of this species, as well as many others that would inevitably follow.

Overview of Threats to Swainson's Hawks Populations

There are many threats that harm Swainson's Hawk populations, in North, Central, and South America. Habitat degradation and alteration of breeding and foraging grounds are the most influential impact on current populations. Not only are humans encroaching evermore on prime, crucial habitat, we are also causing inadvertent alterations on existing rural and agricultural fields that the hawks have become accustomed to. Climate change, although not an immediate threat, is a slow moving inexorable outcome of our selfish actions. Sea level rise, temperature change, and change in weather patterns are all possible stresses that the raptors have to adapt and acclimate to in a relatively short period of time. Our attempts to hinder the causes of climate change that we have already inflicted on the world and move away from fossil fuels have also proven harmful to the populations of Swainson's Hawks and other species. Poorly thought out placement of wind turbines and solar farms are harming many raptor species and other types of birds. Decapitation and amputation are becoming more and more common as more wind farms are being developed. Skin burns and feather singeing result from birds flying over the solar farms where solar energy is intensified, rendering the birds immobile and unable to fly. Lastly, while not as much of a problem as it used to be, Swainson's Hawks are still affected by pesticide poisoning from pesticides such as monocrotophos and dimethoates, during their migration route on the long journey to their South American wintering grounds (Woodbridge 1998)

Detailed Descriptions of Goals and Management Options to Preserve Swainson's Hawk Populations

<u>Goal: Increase Public Awareness of Declining Swainson's Hawk Populations</u>

Swainson's Hawk populations are declining in North America and not many people are aware of this morbid fact. Because of this lack of awareness, generations after generations harm the environment without even realizing it. In order to stop this way of thinking and regain raptor populations, we need to start education programs in Elementary schools and Junior High schools. Programs and curriculums in a classroom setting would instill the important reasons behind saving animal species and coexisting with them in the overlap of the urban and natural worlds. These formal lessons should be supplemented by real-life, hands on experiences that could foster excitement and enthusiasm in their young minds. If we implant this sense of necessity and pride at a very early age, we may be able to halt, or even reverse, the negative attitude present towards the environment.

In addition to educating our upcoming generations to be more sustainable, we must offer adult education programs in hopes that we can appeal to logic and instill a sense of urgency in a way that is easy and flexible for the typical working person. In order to get people to care about this cause, we must allow them to make a connection with nature. Seeing is believing, and getting people outside and actually seeing these birds in action would inspire them to care and do their part in preserving them. Local organizations such as the Audubon Society and California Hawking Club could offer classes or seminars for basic wild life education and knowledge of current events. Trips to local migration bottlenecks, such as the Golden Gate Raptor Observatory in San Francisco, would allow people to see how graceful and majestic these birds are and motivate them to want to protect them.

Land owners and agricultural farmers must be shown the benefits of having Swainson's Hawks present if they do not already know. Swainson's Hawks control the populations of insects and small mammals in the farmers' crop fields; without them, their crops would suffer much more damage from the pesky pests. Literature and pamphlets can be drawn up and passed out to local farmers to educate them without them having to travel or spend time in a meeting. If we change our way of thinking about the environment from a resource and commodity to coexisting with nature and using the land in a mutual, sustainable way, we can make amends for the damage we have already imposed.

Goal: Prevent Habitat Degradation and Alteration

Swainson's Hawks are relatively generalist species that can survive in several types of habitats. They prefer to soar over large open grasslands and agricultural fields where they have increased visibility of prey items, such as small insects and mammals. Each nesting pair needs between 6,500 and 10,000 acres to comfortably forage and nest without competition (Estep 1989). Overlap between breeding pairs or individual hawks may occur, but will cause increased competition and may result in nutritional deficiency and lack of nesting sites. While they can travel between their nesting site and foraging grounds, they do need a continuous territory, rather than a patchy, spread-out one. Large, open grasslands with scattered trees and devoid of steep terrains must be preserved in order for the hawks to forage adequately. Trees must be transplanted and maintained until they are established and can support themselves.

This large of an open area is becoming more difficult for the Swainson's Hawks to obtain as we intrude on the natural, environmentally sensitive ecosystems for beneficial gain. They are restricted to these wide open lands and tend to deteriorate in mountain habitats and very steep terrains (Woodbridge 1998). Scattered trees and shrubbery offer perches for the raptors to preserve energy and scout out their prey before they strike (Bent 1961). Willows, black locusts, oaks, aspen, cottonwoods, and conifers are suitable perches, however Swainson's Hawks are also commonly found on power lines and towers if trees are not available. They have become tolerant in environments with little to no surface water, however these birds thrive in riparian habitats close to small bodies of water (Woodbridge 1998, USDFW).

Suitable foraging habitats depend on both prey density and prey accessibility. Prey density is the amount of prey items per unit area and prey accessibility is the ease in which the raptors can see and obtain their prey item with energetic efficiency. There is a general guideline for the amount of food to feed to raptors that follows the formula (Ash, 2004-2014):

$$\text{Maintenance Metabolic Rate} = 1.5(78(\text{weight in kg}^{0.75}))$$

On average, Swainson's Hawks weigh two pounds and therefore require 108.74 Kcal daily. Adult mice have a gross energy content of 5.25 Kcal/g and typically weigh around .5 ounce, or 14 grams, and therefore offer 73.5 crude Kcal of energy (Dierenfeld et al., 2002). This means that each hawk would need to eat at least two mice daily to obtain adequate nutrition. This number will vary depending on specific type of prey, such as voles (4.97 Kcal/g), grasshoppers (4.168 Kcal/g), etc., available (DeFoliart, 1992, Dierenfeld, 2002). <u>Small mammal populations must be established in areas where there are none and must be surveyed every three months in order to be sure the prey density is sufficient enough to support the hawk population present.</u>

Swainson's Hawks have become acclimated to agricultural fields as more and more land area is being converted. Alfalfa crop fields offer steady prey levels, however it is at relatively low abundance (Estep 1989). More farmers are turning to "big-money" crops such as tomatoes and grapes in the form of vineyards. These crops are a problem for raptor populations. Tomato and beet fields have high prey density, but only grow during the summer for a few months out of the year (Estep 1989). Vineyards cover the Northern California Coastal area and offer high abundance of prey, but the vegetation offers protection for the prey species as it is too dense for the raptors to maneuver through efficiently (Woodbridge 1998). It is difficult to overcome this problem of dense vegetation: if one were to plant the grapevines too far apart in order to allow the hawks access to the prey below, then more land cover would be needed to supply the vineyard the same amount of grapes.

Urban development and agricultural alterations have had the biggest impact on raptor populations. Swainson's Hawks have become more comfortable to forage in agricultural habitats, as cultivation activities expose vulnerable prey (Woodbridge 1998). However, large portions of the Central Valley and Northern California are being converted from their natural or agricultural states for monetary gain. Elk Grove has plans to expand their city limits into 8,000 acres of farmland; this region has the largest density of nesting Swainson's Hawks in Northern California (FOSH). In addition, large farms that have incorporated smaller farms have taken away many prime nesting trees that were being used by Swainson's Hawks. The smaller farms used to have shelterbelts, small patches of trees around the farm house that offered protection from wind and erosion, which were perfect nesting sites for breeding pairs (USDFW).

Habitat loss and degradation is not only a problem here in the United States, but in the Swainson's Hawks wintering habitats in Central and South America as well. Swainson's Hawks travel through Central America during their migration journey. Millions of Swainson's Hawks and other raptors pass through the Isthmus of Tehuantepec in Oaxaca, Mexico twice a year where 14 wind farms are currently under construction (FOSH). Not only are these large, invasive wind towers directly harmful to birds and their migratory habitats, the developers are clearing the land on which to build with fire, which causes an increase in greenhouse gas emissions contributing to global climate change (AIDA and

CEMDA). In addition, a large portion of the raptors' foraging grounds in Argentina has recently been converted from open grassy pasturelands to soybean fields, leading to a reduction in prey density and abundance and causing competition between the birds (Cornell Lab of Ornithology).

In the big picture of biodiversity, birds are the greatest indicator of the quality of life on Earth. Because of their public appeal and economic value, birds have enormous political power. In order to stop the loss of habitats in the United States and other parts of the world, we must become involved in the political process. <u>It is imperative that citizens keep up on current development plans that could take away even more of the dwindling environment.</u> By paying attention to development projects, we can know if they are acting according to the law, or if they are cutting corners and pushing to get their projects approved. Pushing for infill developments (i.e. developing within city boundaries) instead of encroaching further into the natural ecosystems would impede the theft of land from these raptors.

We know where important bird areas are located, but we must look further and see if there are potentially important bird areas that we can preserve before it is too late. By seeking out sites that are close to suitable habitats, we can potentially alter them in a positive way, making them habitable for raptors. Clearing out abandoned fields and construction and planting trees for nests is one way we could make these positive changes. Fields that are no longer being used are good, safe locations for nesting tree species, such as willows, valley oaks, cottonwoods, and sycamores to promote breeding pairs and a mixture of grasses and sedges to sustain small mammal populations. We must protect this web of locations in order to steady population sizes and return them to original levels. <u>Projects could involve local farmers to plant trees on part of their land as proper nesting and breeding locations</u>.

This would require minimal effort from the farmers and would benefit the birds tremendously by giving them a safe, permanent place to breed.

Liaisons between organizations in the United States and those in Mexico and Argentina could be beneficial to obtaining protection over very large distances. Keeping current on development plans and litigation in Central and South America is also necessary because different countries have different laws and priorities, we must keep in touch with their plans. Swainson's Hawk populations will still diminish if we cannot protect their entire, year-round range.

Goal: Slow and Reduce the Effects of Climate Change

While the threat of climate change is slow-moving, it is a real one for which we must prepare. Greenhouse gas emissions and the burning of fossil fuels have caused many issues such as sea level rise, temperature increase, and changes in global climate patters. While these sound like far-off problems, they are affecting Swainson's Hawk populations swiftly and severely. Once sea levels rise enough, the Sacramento-San Joaquin Delta will flood. The delta islands are not necessarily good foraging or breeding grounds for the Swainson's Hawks, but the displacement of salt water into agricultural farms would upset the balance of prey density and abundance in those farms where the raptors have become accustomed to (FOSH). The increase in temperature around the world would add additional and new stresses to the raptors. Finally, changes in climate patterns such as rainfall would cause reactions in the agricultural regions that support Swainson's Hawks (FOSH). Areas that were once abundant with prey would suddenly be flooded and devoid of any sustenance.

In order to reduce the effects of global climate change, we must change our current way of thinking. By being mindful of the effects of every one of our actions, we can use less resources and stop taking from the environment. By driving less and biking or walking more, we can cut the amount of fossil fuels that are burned and the amount of greenhouse gases being emitted into the atmosphere causing a cascade of other issues, such as global temperature increase, sea level rising, and changes in weather patterns. Public transportation must be organized more efficiently and made available to every person so they have an alternative option rather than drive. Even further, our cities and towns should be planned to be efficient and not rely so heavily on driving to run every errand or go to work every day. These are plans for future development, but they should start now. If we do not begin to realize how severe these effects are already, we too will soon suffer the consequences.

Management Plan

Relocate current Swainson's Hawks to different location if they are in a region with low quality breeding and foraging habitat

Information must be gathered about the nesting locations of current Swainson's Hawks, both individuals and breeding pairs. If there are no appropriate nesting trees (oaks, cottonwoods, sycamores, etc.) at least one must be transplanted and established several years prior to their reintroduction for the hawks to build a nest. Hawks that are in low quality environments with low prey densities or near mountainous terrains must be relocated to proper, open grasslands covering an area of at least 6,500 acres (10 mi^2) each. The Swainson's Hawks that are captured and relocated should always be banded for future identification. After they are banded, surveys for the status of the hawks should be conducted every two months to make sure they are healthy and thriving.

Restore native open grasslands to allow Swainson's Hawks to forage sufficiently and survey these regions for adequate prey densities

While Swainson's Hawks can nest in relatively urban areas, they cannot forage in them. Large plots of land covering at least 10 mi^2 per hawk must be protected in order to support the Swainson's Hawk population. Abandoned fields can be restored to grasslands that are able to support populations of small mammals such as field mice, voles, and pocket gophers. The presence of a variety of small mammals would be necessary for hunting during the day because California voles are nocturnal. However, they would be present in the early mornings to help sustain the Swainson's Hawks' appetite. Small mammals prefer grasslands where they can burrow. They feed off grasses, sedges, and occasionally other flowering plants. Preferred grasses for these small mammals include wild oats, rye, artichokes, and alfalfa.

<u>Establish trees suitable for nesting and breeding.</u>

Regions that are devoid of trees must have several trees transplanted throughout the region to allow the hawks an opportunity to choose their nesting tree. Newly established trees must be given several years prior to the reintroduction of the hawks to grow enough to support a breeding pair and their young. If not established and self-sufficient within three years, transplant new trees to nearby location. In addition, weeds within a two foot radius of the tree will hinder its growth and must be eradicated.

<u>Keep current on political arguments regarding land acquisition in every region of the Swainson's Hawk territory</u>

We must be aware of projects that alter the important habitats from being developed or converted to low quality habitat for Swainson's Hawks before they begin. Examination of monthly reviews for new and existing development plans for counties and cities in the Central Valley should be done to stay informed of possible future construction and alteration. In addition, the status of development projects in Central and South America must be known at all times since the Swainson's Hawks spend half of the year there. Their entire range must be protected in order bring back the original population size.

Conclusion

Swainson's Hawks are just one of the many species that are threatened by extinction. Because of human interference, we have driven populations down to almost nothing compared to what they once were. As we now realize this, it is our duty to right the wrongs we have instilled on countless species. In order to protect and preserve Swainson's Hawks populations we must get involved and increase public awareness of the status of these birds. Without public support, these raptors will likely become extinct out of pure ignorance. Both child and adult education programs will be beneficial to the upcoming generation and those that will follow. Projects that involve the general public, such as farmers planting trees on their land, would provide safe, suitable habitats for Swainson's Hawks to rely on. Preventing even greater losses of crucial foraging and breeding habitats is the next step. In the consumer society we live in today, we must take a step back and focus not solely on our own needs. We must learn to live sustainably and coexist with the wildlife species that have been here long before we were. If we do these things, we may be able to regain the original population sizes and take away the threat of extinction we have imposed on this species.

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Grasshopper sparrow (*Ammondramus savannarum*) Jeffrey Haight
Jeffrey Haight

Grasshopper Sparrow
Ammodramus savannarum
Family: Emberizidae
Order: Passeriformes

Image Source: Wikimedia Commons

Background & Justification

This restoration project would seek to increase local populations of the Grasshopper Sparrow (*Ammodramus savannarum*), a secretive ground-dwelling sparrow native to North America and found seasonally throughout many parts of California (Alderfer 2006; Sibley 2000). Though the grasshopper sparrows in California are not listed as an endangered or threatened at the state or federal level, their populations have demonstrated declines due to the complex impacts of urban and agricultural development, leading to their listing as a "Bird Species of Special Concern (breeding), priority 2" (Shuford & Gardali 2008). Particularly in urban and suburban areas, where higher human population densities and habitat disruption have made human interactions with wildlife infrequent, the presence of songbirds such as the grasshopper sparrow plays an integral role in fostering an appreciation of nature among the local community. In comparison with those described in historic accounts from the earlier 20th century, grasshopper sparrow populations in the Central Valley and the surrounding foothills have demonstrated dramatic decreases in size and extent, though these declines have not been well quantified (Shuford & Gardali 2008). Due mainly to the role of land cover change (e.g. urbanization) as the primary factor driving declines in grasshopper sparrow populations, the restoration project must seek to reach the goal of increasing local grasshopper populations through the on-site creation of grassland habitat necessary for breeding

Fact Sheet

Goal: the promotion of local grasshopper sparrow populations in the area of the restoration site through the provision of higher-quality grassland habitat.

Threats

- Urbanization is generally recognized as the main threat to grasshopper sparrow populations in California, primarily because the land conversion associated with urban development generally decreases the amount and/or quality of existing grassland habitats(Alderfer 2006; Shuford & Gardali 2008)
- Interactions as part of the urban landscape are thought to have additional negative impacts on grasshopper sparrows, though the specific factors and mechanisms involved are in need of further study (Shuford & Gardali 2008). Possible detrimental effects of the urban landscape include inadequacy of habitat on the urban-rural fringe and predation of ground-level nests by urban animals, such as feral cats (*Felis silvestrus*) and raccoon (*Procyron lotor*)(Vickery 1996).

- The grasshopper sparrow is known to be a bird species highly impacted by urban edge effects, so grassland habitats with higher edge-to-size ratio – such as those at the restoration site – should be expected to be poorer at supporting populations of the sparrow (Chace & Walsh 2006). While the actual amount of habitat necessary to support breeding populations of grasshopper sparrows is highly uncertain and varies greatly from system to system, 1.8 hectares of contiguous grassland is the smallest known territory size of a male grasshopper sparrow, meaning <u>at least 9 hectares</u> (22.2 acres) would be required to support a substantial breeding population of 5 mating pairs (SCWA 2009; Zeiner et al. 2008).
- Fire suppression/control activities leading to the encroachment of grasslands by woody vegetation has been additionally noted as contributing factors in declines of grassland bird species such as the grasshopper sparrow (Alderfer 2006; Hill & Diefenbach 2013).
- Information on pathogens and inter-specific competitors affecting grasshopper sparrow population is not generally known (Vickery 1996).

Distribution & Seasonality

- While found year-round across many parts of North America, the grasshopper sparrow is only known to reside in Northern California during the summer months, arriving between March and May and leaving around August and September (Alderfer 2006; Sibley 2000; Zeiner et al. 2008). This seasonality of distribution means that grasshopper sparrows should not be expected to be found at the restoration site during the winter months.
- Breeding season typically occurs from approximately early April to mid-July, so any restoration activities with the potential to negatively impact the ground-nesting sites

found in the restored grassland habitats should be limited during these spring/summer months (Zeiner et al. 2008)

- High year-to-year variability in observed abundances of grasshopper sparrows is generally to be expected due to annual fluctuations in underlying environmental conditions, particularly climate (DeSante & Geupel 1987; Shuford & Gardali 2008). As with many other land birds in the region, grasshopper sparrow reproductive success is positively correlated with annual rainfall – i.e. higher than average annual rainfall will lead to higher than average productivity during the next breeding season, and vice versa (DeSante & Geupel 1987). This close association between rainfall and reproductive success is a major factor leading to the species' high variability in population from year-to-year (Shuford & Gardali 2008).

Reproduction & Breeding

- Grasshopper sparrows build their nests on shallow depressions in the ground at the bases of surrounding grasses and forbs (Shuford & Gardali 2008; Zeiner et al. 2008). These nests are constructed out of grasses and other nonwoody vegetation, are roughly dome-shaped with a side-facing entrances, and are approximately 5 inches in diameter by 2 inches tall (Shuford & Gardali 2008; Zeiner et al. 2008)
- Females typically lay and incubate clutches of 4-5 eggs and have been known to brood as such 2-3 times per year (SCWA 2009; Zeiner et al 2008).
- As previously mentioned, the reproductive success of grasshopper sparrow broods has been found to higher in years immediately following winters with higher-than average rainfall (DeSante & Geupel 1987).

- Grasshopper sparrows sometimes form semi-colonial groups consisting of about 3-12 breeding pairs (Shuford & Gardali 2008; Zeiner et al. 2008).

Feeding & Behavior

- The grasshopper sparrows primarily feed on insects – especially orthopterans, such grasshoppers – and other invertebrates, which make up approximately 63% of their diet during the months of their residence in California (Shuford & Gardali 2008; Vickery 1996; Zeiner et al. 2008). Although pesticides have not been observed to have any direct effects on the grasshopper sparrow, general care should be taken in their application to avoid any negative impacts to the grasshopper populations that serve as the primary food source for the grasshopper sparrow during the spring and summer months.
- The remaining 37% of the grasshopper sparrow diet consists of seeds, of which species of the genera *Polygonum* (knotweed), *Lychnis* (campion), *Avena* (oat), and *Amaranthus* (pigweed) are known sources (Shuford & Gardali 2008).
- Though many of the grasshopper sparrow's feeding and reproductive behaviors involve their secretive movement among nonwoody vegetation near ground level, males of the species have been known to use shrubs as call perches (Alderfer 2006; Shuford & Gardali 2008).

Habitat & Ecological Requirements

- The grasshopper sparrow requires a moderately thick but patchy cover of mixed nonwoody grassland vegetation (grasses and forbs) for ground-level foraging for seeds and insect prey, concealment from predators, and creation of nests (Shuford & Gardali

2008). Increased height of nonwoody vegetation located proximally to nesting sites has been shown to positively affective nesting and fledgling productivity in other regions in the species' range, though exceedingly high grasses may actually contribute to lower reproductive success depending on the predator assemblage found at the project site (Hill & Diefenbach 2013). Although grasses with intermediate heights of at least 16-20 inches (40-50 cm) appear be tall enough to provide habitat with cover adequate for nest building and foraging activities, the grasshopper sparrow's preference of vegetation height is uncertain and highly variable from system to system(Hill & Diefenbach 2013; Shuford & Gardali 2008).

- Unfortunately, as the grasshopper sparrow's ecology has not been well-studied in California, very little is actually known about its specific habitat requirements in the area of the restoration site (Shuford & Gardali 2008). For instance, specific information regarding the California grassland plant species or communities that would create higher quality habitat for this species in the region is noticeably scarce.
- Though the species is notably absent in communities dominated by trees and shrubs, the grasshopper sparrow commonly inhabits environments featuring scattered shrubs – e.g. California Buckwheat (*Eriogonum fasciculatum*) and California Sagebrush (*Artemisia californica*), and the complete removal/exclusion of shrubs and other woody vegetation from the site will not necessarily lead to any increases in reproductive success (Hill & Diefenbach 2013; Shuford & Gardali 2008).
- Light levels of grazing generally appear to be beneficial for grasshopper sparrow reproductive success and population while higher grazing intensities have largely negative effects; however, the level of grazing ideal for maintaining optimal

grasshopper sparrow habitat is unknown and is a subject in need of future study and experimentation (Shuford & Gardali 2008; Vickery 1996).

- Additionally, the occasional prescribed burning of the species' grassland habitat appears to positively affect reproductive success of the grasshopper sparrow by preventing the establishment and spread of detrimental shrubs and invasive plants (Alderfer 2006; Shuford & Gardali 2008; Vickery 1996). If prescribed burning is used, the controlled fire regime should allow for periods of at least 1 year for vegetation to recover to a state preferred by grasshopper sparrows (Vickery 1996).

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Grasshopper Sparrow: Goals & Management Plan

Goals for Grasshopper Sparrow Restoration

In order to reach the overall species-specific goal of the establishment and persistence of local populations of grasshopper sparrow (*Ammodramus savannarum*) in the area of the restoration site through the provision and maintenance of higher-quality grassland habitat, this restoration project and the subsequent management of the site must:

1) **Restore and maintain at least 22.2 contiguous acres (9 hectares) of native grasslands to serve as breeding and foraging habitat necessary for sustaining a substantial breeding population of grasshopper sparrows.**

Before populations of grasshopper sparrows can colonize the restoration site and sustain a substantial population, an adequate population of habitat-providing, native, perennial bunchgrasses and forbs must be established and persist on site for at least 1-2 years (Vickery 1996). Grasshopper sparrows have been found to inhabit a wide variety of open grasslands and similarly-structured habitats – such as agricultural fields – regardless of the whether the herbaceous vegetation present in the system is native or non-native (Shuford & Gardali 2008). However, grasshopper sparrows in California have been found to demonstrate a preference for grasslands dominated by perennial bunchgrasses over those with predominant sod-forming grasses and native grass and forb species would generally be more likely to be well-adapted for persistence under local environmental conditions (Vickery 1996).

When it comes to determining how much overall restored grassland is adequate, the average size of a typical grasshopper sparrow territory is highly variable depending on the system but tends to range between 0.91 and 4.45 acres (0.37 and 1.8 hectares) per male sparrow or breeding pair (SCWA 2009; Zeiner et al. 2008). Although male sparrows in southern California – the closest well-studied grasshhave the smallest known territory of 0.37 hectares, the exact area needed to support a single breeding pair of grasshopper sparrows in the California Central Valley has not yet been measured. Given the largest known territory size (1.8 hectares) and the size of a substantial breeding population of grasshopper sparrows (5 breeding pairs), <u>a minimum patch size of about 22.2 acres (9 hectares) would likely be necessary to support a sustainable population</u> (CITATION). Though the optimal patch size varies considerably from system to system, larger patches can be generally stated to be better for grasshopper sparrow population viability, with patches upwards of 74 acres (30 hectares) being the ideal patch size for many analogous habitats throughout the country (Chace & Walsh 2006; Shuford & Gardali 2008; Vickery 2006). Currently, the geographic extent of the project site is highly limited, meaning it is highly unlikely that the restoration of grassland communities would be able to extend beyond the available area of around only 15 acres (<6.1 hectares). However, grasshopper sparrows present on site would not necessarily have their territories confined to the restored areas if the lands adjacent to the restoration site feature open grasslands or other adequate habitat, as may be the case with the area surrounding the drainage basin site. With these consideration in mind, the restoration project should still aim to establish and maintain the maximum spatial extent of native grasses possible at the site itself.

Like many other ground-dwelling grassland birds, the grasshopper sparrow is highly susceptible to negative edge effects, meaning they have lower rates of survival/reproduction – and thus lower population densities – close to the edges of their habitat patches (Chace & Walsh 2006). Though the exact nature of these edge effects in relation to different adjacent land uses/covers are not known specifically, the viability of grasshopper sparrow populations is generally higher when edges are formed with grasslands and herbaceous agricultural lands (e.g. alfalfa fields) and lower when the bordering landscape is highly urbanized or forested (Chace & Walsh 2006; Shuford & Gardali 2008). To minimize any of these detrimental effects and provide more adequate habitat for the grasshopper sparrow, the project's upland restoration should proceed in a manner that involves the creation of only a few large, round, contiguous patches of grassland rather than numerous smaller, elongated, separate patches

2) Assure the quality of foraging and breeding habitat through the limitation of woody vegetation and the maintenance of sufficient herbaceous cover

Across most parts of its range, the grasshopper sparrow persists only at sites dominated by grasses and other herbaceous vegetation, but not at sites with substantial coverage by trees and shrubs (Shuford & Garaldi 2008; Vickery 1996). In an analogous grassland system in the state of Georgia, the maximum percent cover of woody vegetation tolerated by grasshopper sparrows is 35%, above which the species was completely absent (Vickery 1996). Though the exact thresholds for the maximum tolerable woody vegetation cover is undefined for most systems – including that of the project site - the species generally appears to be somewhat more tolerant of the presence of shrubs in systems located in Western North America (Shuford & Gardali 2008; Vickery 1996).

The presence of woody vegetation in grassland areas at the site should generally be <u>kept minimal</u> in order to avoid reaching the level of cover at which the grasshopper sparrow cannot persist on site (e.g. >35% in Georgia grasslands)(Vickery 1996). However, a limited abundance of scattered shrubs can prove not only tolerable but even beneficial to the species, as shrubs have been known to serve as calling perches for the male grasshopper sparrows (Shuford & Gardali 2008; Vickery 1996). The presence of trees within or adjacent to the grassland, on the other hand, has a consistently negative effect on the grasshopper sparrow – most likely as a result of increased predation – and <u>should generally be avoided entirely</u> (SCWA 2009; Vickery 1996). The above considerations leads to the recommendation that an <u>approximate 25% woody vegetation cover</u> be used as a threshold for the maximum acceptable presence of woody vegetation at the site and the maintenance of this goal.

When it comes to herbaceous cover, the height of the grass and forbs preferred by the grasshopper sparrow is highly variable from system to system. In most grassland breeding habitats, fecundity and survival are typically at their highest when grass and forb cover is longer and taller, as greater vegetation cover offers visual protection from predators such as hawks and cats (Hill & Diefenback 2013; Shuford & Gardali 2008). In systems with different predator communities, such as those featuring nest-predating snakes, high levels of herbaceous cover actually end up have a detrimental effect on grasshopper sparrow fitness (Hill & Diefenback 2013). Based on the assemblage of potential grasshopper sparrow predators possibly present at the restoration site, the ideal foraging and breeding habitat should be characterized by grasses and forbs that allowed to grow as tall as possible wherever and whenever other major management goals do not make it absolutely necessary to set limitations of plant height. It is worth restating, however, that this aspect of ideal height of herbaceous plant cover is highly variable within and between different systems, so the exact role of plant height in the meeting goal of creating an ideal foraging and breeding habitat is still very uncertain and subject to change in response to the results of long-term management.

3) **Avoid impacts to grasshopper sparrow nesting sites by restricting human uses of the grasslands and deferring all high impact management activities – such as the mowing of grasses and the conducting of prescribed burns – so that they do not coincide with the grasshopper sparrow breeding season (April-July)**

Grasshopper sparrows build their small (approximately 5 in. diameter by 2 in. tall), dome-shaped nests on shallow depressions in the ground at the bases of surrounding grasses and forbs, using that surrounding non-woody vegetation as building material (SCWA 2009; Shuford & Gardali 2008; Zeiner et al. 2008). Being a ground-nesting bird makes the grasshopper sparrow highly susceptible to disturbances to its breeding habitat, especially those from anthropogenic sources. Essentially any direct human use of the grassland habitat (e.g. walking through it) has the potential to detrimentally affect the nests of ground-nesting birds, making it necessary to seek to prevent such uses from occurring during the breeding season. While some management activities – particularly light grazing and occasional prescribed burning – could be beneficial to the sparrow when implemented at other times of the year, they could easily result in the displacement or complete destruction of ground-nesting bird nests when put into effect during the breeding seasons of these birds. In order for the grasshopper sparrow to successfully colonize and breed at the site, <u>all avoidable anthropogenic impacts to the restored grasslands must be avoided or kept to a less than significant level</u> for the period of April through July, at minimum.

Your goals are excellent- specific, extremely well justified and well-researched. This is professional quality work!

<u>B. Restoration/Management Plan</u>

I. Restoring and maintaining extent and contiguity of grassland habitat

The mixture of grasses and other herbaceous vegetation planted on-site should primarily be composed of the perennial bunch grasses – such as purple needle grass (*Nassella pulchra*) – that provide a bare soil component that is likely an important characteristic of foraging habitat. Other community components desirable for restoration of grasshopper sparrow habitat include additional native bunch grasses and forbs – such as *Lupinus leucophilus* – as well as some non-native herbaceous vegetation that can provide sources of seed food – such as the wild oat (*Avena fatua*)(Shuford & Gardali 2008). Planting of the necessary herbaceous grassland vegetation at the site can occur through one of two methods: the planting/spreading of seeds and the planting of propagated seedling plugs. The seed planted or used in the propagation should be locally-sourced from the restoration site itself or from nearby sites in Solano County. During planting, the aim should be to create continuous and roughly evenly-distributed populations of herbaceous grassland vegetation.

II. Managing habitat components contributing to reproduction and survival

Once long-term management proceeds following the conclusion of restoration activities, there are two main techniques that can be likely used to maintenance of the grasshopper sparrow's perennial grassland habitat in an urban/suburban setting, namely mowing and grazing. The mowing of grasslands could prove beneficial to grasshopper sparrow if shorter or more intermediate heights of non-woody vegetation led to the greater fitness of the population; as this does not currently appear to be the case, mowing should not play a major role in managing the site's grasslands for this species. Alternatively, the grasshopper sparrow management regime should include some mild level of grazing by cattle or goats, as low levels of grazing has proven instrumental in preventing the spread of woody vegetation, especially in other parts of California and Western North America (Shuford & Gardali 2008; Vickery 1996). In areas of the restoration site where the surrounding urban landscape allows for such activities, managers have the additional option of using prescribed burns, which has been shown to have a positive effect on the reproductive success of the grasshopper sparrow by helping to control the spread of shrubs and invasive plants and maintain the integrity of the perennial grassland community (Shuford & Gardali 2008; Vickery 1996). If prescribed burns are to be utilized, then grassland should be expected to provide preferred grasshopper sparrow habitat after at least 1 year has elapsed since the area was last burned (Vickery 1996).

III. Preventing/minimizing impacts to nesting sites

While generally either beneficial or harmless to the grasshopper sparrow during the non-breeding months (August through March), impactful management practices including mowing, grazing, and prescribed burning should be ceased during the breeding season of April through July, so as to avoid disturbing ground-level nests. Wherever and whenever possible, human movement through the restored grassland habitat itself should additionally be discouraged/prohibited through the use of signage and/or the construction of physical barriers.

IV. Monitoring of Grasshopper Sparrow Population and Habitat

The primary component of monitoring the short- and long-term success of the goals for the grasshopper sparrow during and after the completion of restoration activities is the frequent surveying of its on-site population. Surveying of grasshopper sparrow population abundance should be conducted in perpetuity at a frequency of <u>at least once per year – between April and September – using the line transect method and should occur simultaneously with transect surveys of all other present species</u> (Shuford & Gardali 2008). Though beyond the scope of this project, yearly sampling of local populations should also be conducted at various sites throughout the grasshopper sparrow's range in order to effectively monitor the species' population as a whole (Shuford & Gardali 2008). Additionally, the underlying habitat conditions contributing to the persistence of grasshopper sparrows – i.e. grass height and woody vegetation cover – should also be surveyed <u>continually at the highest frequency</u> feasible to managers and the results of this monitoring should be connected back to the monitoring of the monitoring of the sparrow population in order to evaluate the effectiveness of current management strategies.

V. Uncertainties and Need for Further Research

As has been previously mentioned, the specific ecology of the grasshopper sparrow in the California Central Valley and the region as a whole has been very poorly studied. This means that there is expected to be high levels of uncertainty in the restoration and management of sites intended to support grasshopper sparrow populations. Even within the regions of North America where the species has actually been studied, anecdotal and experimental evidence of the grasshopper sparrow indicates that differences in climate and in the plant and predator communities have made it so that parameters such as ideal grass length and tolerable shrub cover are highly variable from one system to another.

With that said, many of the generalizations that have been made about the effects of management activities on the grasshopper sparrow are capable of being tested through the experimental manipulation of management practices. Though grasshopper sparrow survival and reproductive success are generally highest at some intermediate height of herbaceous vegetation, some light level of disturbance, and some small prevalence of shrubs, it is still not entirely certain what the actual ideal values are for these parameters when it comes to the promoting local populations of the species. Even after the restoration activities are completed, the managers of the site should continually seek to determine reduce these uncertainties by experimenting with the components of the management regime – i.e. intensity, frequency, and timing of mowing, grazing, and/or prescribed burns – and adjusting them according to the resulting effects of these practical experiments on populations of the grasshopper sparrow.

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Burrowing owl (*Athene/Speotyto cunicularia)* Angela Prada-Baez

Burrowing Owl Fact Sheet

Part I:

Justification and Background

Justification:

The Burrowing Owl (*Athene/Speotyto cunicularia)* is a small, white and brown raptor that inhabits the grasslands and deserts of some western states of the U.S., small portions of southern provinces in Canada and few areas in northern Mexico (U.S. Fish and Wildlife Service 2003). They have been listed as Species of Special Concern in the State of California and they are also recognized as a National Bird of Concern since 2008, due to the increase in habitat loss/ fragmentation which they need for foraging, breeding and nesting (Miller et al. 2003, Trulio and Higgins, 2012). Habitat loss and fragmentation have been mainly caused by urban sprawl into the grasslands, agricultural intensification and the decline of small burrowing mammals, hence hampering the livelihood of *Athene/Speotyto cunicularia* (Gervais, et al 2008, Shuford, W. D., and Gardali, T., and editors. 2008). Most importantly these impacts to their habitat in California have been occurring in the past 10-15 years, with the reduction of their natural range by 8%, along with rapid decline in populations. (pers. comm., 2001, using data from DeSante and Ruhlen 1995).

According to Jeff Miller from the Center of Biological Diversity, populations that have been completely extirpated due to urban development include the counties of Napa, Marin, San Francisco, Santa Cruz and Ventura. Other extremely vulnerable owl populations are in the Coachella Valley, Mendocino and Humboldt to name a few (Miller et al. 2003). Two notable areas where larger populations are found breeding and foraging are the Imperial Valley and the Central Valley of California. Population surveys taken in these two areas assert that 71% of the total state's populations live in the Imperial Valley, while 24% reside in the Central Valley and the remaining are scattered throughout the state (Wilkerson and Siegel, 2010). Unfortunately the Imperial Valley has also seen a rapid decline in certain owl populations, with alarming statics stating a decrease of 27% in populations from 2007 to 2008 (Miller et al. 2003).

Important activities to prioritize in the management plan should focus on increasing and keeping a good quality amount of native vegetation such as perennial grasses, that can be used for foraging and nesting, maintaining adequate prey availability such as beetles, crickets, voles and mice, preserving small burrowing mammal populations that dig out burrows for the owls and implementing mitigation practices such as passive relocation when other measures fail or in areas with high levels of disturbance due to urban development. Aforementioned target goals will be further explained in this management plan.

Background

General Information and Behavior:

- Family: Strigidae, Genus: *Athene/Speotyto* Species: *A. cunicularia*
- Burrowing owls are reasonably small (19.5 cm-25.0 cm, ~150 g), long legged, short molted plumage and without ear tufts. Their feathers are colored brown, white, gray, beige and black while their eyes are always lemon-yellow. Their wingspan is somewhat large for their proportion ranging from 51 cm- 61 cm. Males and females do not differ greatly in size, but the female's pigmentation can sometimes be darker (Haug et al. 1993).
- Burrowing owls are somewhat unique in the fact that they are active during the day and night. They spend most of the day perched in proximity to their burrows, sporadically hunting for insects. In the afternoon and dusk, the owls will commence their foraging activities and will get further away from their burrows in order to prey on small mammals (Miller et al. 2003, Estep, Beedy and Sterling 2009, Thomsen 1971)
- Burrowing owls can either be migratory or yea-round residents. Such behaviors vary through their range, with northern populations showcasing migratory behavior and eastern populations lingering in the winter (Brenkle 1936, Ligon 1961, Thomsen 1971, Haug et al., 1993, Rosenberg et al., 2007)
- Not much information is known about the migratory populations, except that they may be responsible for the increase in population density during winter months within year-round resident populations. Also, it appears as if those northern-most populations migrate further down south (Rosenberg et al., 2009).
- Non- Migratory *Athene/Speotyto cunicularia*, are known for their high fidelity to their burrows, with most of them returning to the same location year after year. They use their burrows for: breeding, wintering and foraging (Miller et al. 2003).
- Burrowing owls display monogamous behavior during breeding seasons, and in some circumstances the pair may remain together the entire year (Coulombe 1971)
- Depending on resources and food availability on site, *Athene/Speotyto cunicularia* have been seen nesting in loose colonies, which is advantageous when it comes to defense against predators (Miller et al. 2003).

Phenology

- Burrowing owls reproduce a year after hatching has occurred, but variations on egg-laying dates occur due to geography. For example, the clutch initiation can happen as early as mid-March for populations residing in New Mexico, early to late-April for Oregon and Northern California or as late as mid-May in Saskatchewan (Haug et al. 1993, Martin 1973, Henny and Blaus 1981, Thomsen 1971).
- Nesting Season begins as early as February 1st and continues until the end of August. Latitude and climate can change the date range (Thomsen 1971, Zarn 1974).
- In most areas, pair formation and courtship is initiated in March and April, with some exceptions in California where the process can begin in December and January (Grant 1965, Butts 1973, Thomsen 1971).
- Normally, females will have one clutch per year, unless the first attempt fails. The average number of eggs laid in the burrow is around 7, but with some being larger with 12 eggs. These eggs are laid on the months of March and May (Haug et al. 1993).

- The female incubates the eggs for 3-4 weeks, while the male fetches food and guards the burrow. After hatching the chicks will stay in the burrow chamber for 2-3 weeks, and once large enough they will wait for food by the entrance of the burrow (Miller et al. 2003).
- By the fourth week, the young owls are able to run and forage and by the sixth week they will be able to take flight. Parents will supervise their young until mid-September which also coincides the molting of their plumage. At this point the young owls will disperse to satellite burrows in the vicinity. (Haug et al. 1993, Dechant et al. 1999, Landry 1979).
- Although there are no concise results about burrowing owl longevity, some studies have pointed an average of 5 years to be their life expectancy (Kennard 1975).

Range and Distribution

- Their historical breeding range encompasses a small portion of south-western provinces in Canada such as Alberta, British Columbia and Saskatchewan , various mid-west and western states in the United States extending from Iowa to California and Montana to Texas Not much concern existed regarding the health of burrowing owl populations since they were quite common across their target range. However In most recent years, a reduction on the size of the burrowing owl's range has been the general trend (Klute et al 2003, Miller et al. 2003)
- In CA, the burrowing owl's range encompasses lowlands that move along west and south of north/central California all the way to Mexico. Other smaller populations can also be found scattered throughout the lowlands of the south, Great Basin and Mojave Desert. These distribution patterns vary depending on whether a given population is migratory or not (DeSante et al. 2007, Gervais et al. 2008).
- The Burrowing Owl populations used be quite strong and not of much concern. However, due to urban sprawl and other human activities the populations have greatly decreased over the years. Some estimates show that about 60% of the breeding populations have disappeared (Miller et al. 2003).

Habitat Requirements → Forage and Nesting

- The preferred habitat for burrowing owls can be found in annual and perennial grasslands, deserts, scrublands with low-growing vegetation along with well-drained soils. They favor open areas that sustain burrowing mammal colonies, as they will eventually use their abandoned burrows for nesting and roosting (Zarn 1974, Haug et al. 1993, Dechant et al. 1999).
- Low vegetation and reduced ground cover allow owls to a have a wider view of the area and thus allowing them to easily forage, watch out for predators and guard their burrows. Tree and shrub cover should be no more than 30% of the habitat (Miller et al. 2003, DeSante et al. 1996).

- Foraging can take place in natural and ruderal grasslands where vegetation has been disturbed or manicured (Miller et al. 2003)
- Burrowing owls are known for exhibiting a high tolerance towards human development and activities. They have been found residing in golf courses, campuses, military bases, airports, agricultural fields, city parks, athletic fields, etc… (Dechant et al.1999, Thomsen 1971, Haug et al. 1993).
- Unsuitable site characteristics include: areas with dense canopy and tree cover, tall vegetation and grasses, lack of fossorial mammals such as ground squirrels, badgers and prairie dogs, limited prey abundance and availability and high exposures to chemical pesticides (Desmond et al. 2000, Rosenberg and Gervais 2009).

Burrows for Nesting

- Burrowing owls are the only North American owl that nests and roots in burrows (The California Burrowing Owl Consortium 1993)
- The most important aspect of their habitat is their burrows, weather natural or artificial. These burrows are usually excavated by fossorial mammals like squirrels or badgers. Man-made structures can also serve as burrowing grounds (Rosenberg and Gervais 2009).
- The number of ground squirrels and the density of vegetation have very heavy impacts of the success of the burrowing owl population. If there are not enough ground squirrels and very dense vegetation, less nesting sites would be available for owls to use (Rosenberg et al., 2009).
- Excavated burrows serve as nests, and they usually range from 1 to 3 meters long and have a downward slope of 15 degrees. The shape is that of a J or a U, with the nest chamber located on the widest part (Coulombe 1971).
- In order to prepare the burrow for breeding season, owls often line the edges of their burrows with horse or cow manure, grass, feathers and debris. It is believed that owls do this in order to attract beetles which are part of their diet, to regulate temperature and to simply mask their scent from predators, however no conclusive study has proven this (Thomsen 1971, Martin 1973, Evans 1982, Johnsgard 1988, Voous 1988, Green and Anthony 1989)
- Occupation of a suitable site can be determined least one owl is seen using the same burrow for the past 3 years. Also if their molted feathers, cast pellets, prey remains or excrement is in vicinity to the entrance of the burrow (The California Burrowing Owl Consortium 1993)

Diet

- Burrowing owls are known for being generalists and opportunists that mostly consume arthropods such as beetles and grasshoppers. This diet is also complimented with small mammals such as voles and mice (Estep, Beedy and Sterling 2009).

- Their diet goes through seasonal a fluctuation which typically means that in summer months more insects are more available whereas during the winter small mammals are more abundant (Haug et al. 1993).
- During breeding season, a lack of number in rodents may affect the reproductive success of a mating pairs as most avian species have higher energy demands during these breeding periods (York et al. 2001, Strong et al. 2004)
- Results collected from the study *The Diet of Western Burrowing Owls in an Urban Landscape* by Trulio and Higgins described the composition of cast pellets found in urban areas. The most common invertebrates found were earwigs (48.6%), beetles (27.5%) and grasshoppers (16%). On the other hand vertebrates represented 6% of their diet with California moles, house mice and western harvest mice as top contributors to their diet (Trulio and Higgins 2012)
- In rural areas, burrowing owls also prey on aquatic organisms that may have been exposed to selenium leached from agricultural run-off. This is of concern because it has had detrimental effects on bird populations (Ohlendorf et al. 1986, 1987, 1988).

Predators:

- There are two types of burrowing owl predators:
    1. Predators that enter the burrow to consume the eggs, chicks and/or adult females.
    2. Predators that prey on young and mature owls aboveground.
- Burrowing owls are mostly vulnerable to animals that are able to enter their burrows such as coyotes, foxes, raccoons, skunks, feral cats and snakes. Larger raptors such hawks, falcons and eagles prey on burrowing owls (Miller et al. 2003)
- In certain parts of Canada, fragmentation and cultivation of grasslands, has resulted in an increase of predators that prey on burrowing owls (Wellicome and Haug 1995).
- Some studies have shown a relationship between the abundance of prairie dogs and burrowing owl nest success. Prairie dog alarm calls help owls avoid predators and also decrease their chance of being a target. Prairie dog activity within a 75 meter radius will help the nest to be more successful (Desmond et al. 1995)

Fires

- Controlled natural fires or prescribed burns can help reduce the amount of non-native species that may interfere with the livelihood of the owls. Such controlled burns have shown success when performed in the late spring, due to the fact that it reduces seed production and seed bank size. Furthermore, it decreases competition and allows native perennial grasses to establish in the landscape (Menke 1992)
- It is still unclear whether prescribed burns in the Central valley of California have a positive or a negative effect on perennial grasses since loss can exceed establishment (Germano et al. 2001)

- The New Mexico Department of Game and Fish stated that fires do alter the vegetation and prey base. Recurrent fires can keep the vegetation short by preventing the establishment of woody plants. Diversity and density of the prey are also improved with fires (New Mexico Department of Fish and Game 2000)
- Prescribed burns can be used as management tool to keep a suitable habitat for the owls, however time and frequency are closely monitored (Rosenberg and Gervais 2009)

Grazing

- Grazing is another tool that can be employed to keep low ground cover and shorter vegetation. Some studies indicated that owls prefer cattle-grazed areas as opposed to rodent-grazed (Anderson et al. 2001)
- Grazed sites seem to be ideal for ground squirrel populations, which could translate to a higher number of burrows available to the owls (Green and Anthony 1989)
- In the San Joaquin Valley, grazing has been a traditional way to manage both native and non-native vegetation by controlling height, density and diversity. It also decreasing fuel for fires and may help out with native seed germination (Germano et al. 2001, CNMLM 1994)
- On the downside, it has been observed that important species for the owl's diet such as the California Vole, western harvest mouse and deer mouse do not perform well in grazed areas as they need some vegetative buildup in order to maintain their populations (Holmgren and Collins 1999)
- If heavy grazing is performed in foraging habitats, it may have a negative impact on prey availability and diversity (Dechant et al. 19999)

Herbicides/Pesticides

- Because many of the population owls reside in agricultural areas, many toxic chemicals are used to kill pests and weeds. Most of these chemical are harmful to the owls and other wildlife such chemicals also have direct impact on food supply and the number of burrowing mammals that inhabit the area (Rosenberg et al., 2009, Miller 2003).
- If pesticides are extremely pertinent for landscaping or another agricultural practice, it is recommended for them to not be sprayed within 400-600 meters of the nest burrows during breeding season (Haug1985, Haug and Oliphant 1990)

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A. Goals:

Even through their impressive tolerance to humans in some sites in the state of California (Klute et al. 2003), the burrowing owl is considered to be a species of concern in some states and even endangered in others. In order to mitigate the impact of the threats that impede its livelihood, the objectives of the management plan for populations living in the San Joaquin Valley should focus on the following main restoration goals:

1. **Preserve and protect the Burrowing Owl's habitat from loss and degradation in San Joaquin Valley while considering future human development**

- According to the Center of Biological Diversity, burrowing owls used to be a relatively unthreatened bird in California due to their large populations. However, with the rapid increase of urbanization, development of grasslands into agricultural fields and a decrease in colonial rodents in the past 150 years, the bird has become more vulnerable than ever in the Western U.S and Canada (Evans 1982, Haug and Didiuk 1993, Zarn 1974).

- **Habitat Loss**: In order to accommodate future human development, without causing too much disturbance or further range loss to the existing populations, a very detailed survey protocol and mitigation guidelines has been assembled by The California Burrowing Owl Consortium. This detailed document provides a framework to produce a standardized site survey that will produce better, solid and more accurate data that could facilitate environmental assessments required for urban developments (California Burrowing Owl Consortium, 1993). The creation of buffer zones to alleviate negative human impacts can also be used as a strategy to allow for further urbanization without hampering the owl's viability. A successful example occurs in the Naval Air Station in

Lemoore, where a large and active population of burrowing owls is known to inhabit a portion of the San Joaquin Valley where the station is located. The owls are active in wildlife areas nearby, adjacent to runways and in various buffer zones that surround the station (Rosenberg et al., 2009).

- **Habitat Degradation:** The main cause for habitat degradation is the decline in population of burrowing mammal populations (Klute et al., 2003). Burrowing owls depend heavily on burrowing mammals such as prairie dogs, ground squirrels and even badgers because their abandoned colonies will serve as nests for the breeding season and as shelter. The notorious decline of such mammals is due to urbanization and intentional eradication (McDonald, D., N.M. Korfanta, and S.J. Lantz, 2004). Secondly, grazing can also be seen as main component for habitat degradation, especially in agriculturally active areas. Heavy and unmanaged grazing can lead to soil degradation through compaction, removal of native vegetation and damaging of mammal excavated burrows (Rosenberg et al., 2009). If grazing is controlled and managed, it can serve as a restoration tool that could enhance the landscape (Rosenberg et al., 2009)

- Degradation of the habitat imperils the composition, structure and function of the habitat that the owls need in order to survive, therefore both habitat loss and degradation should be mitigated in accordance to the site's characteristics (biotic and abiotic). The plan should give room for adaptive management as well.

"HABITAT LOSS AND DEGRADATION FROM RAPID URBANIZATION OF FARMLAND IN THE CORE AREAS OF THE CENTRAL AND IMPERIAL VALLEYS IS THE GREATEST THREAT TO BURROWING OWLS IN CALIFORNIA" (Shuford, W. D., and Gardali, T., editors. 2008)

2. **The improvement of understanding concerning nesting and foraging behaviors.**

- Foraging and nesting are very important activities for the burrowing owl, therefore restoration efforts should be put into enhancing parts of the landscapes that provide these services.
- **Foraging:** Burrowing owls conduct their foraging activities in grasslands, croplands and fallowed fields (agricultural matrix), prairie dog colonies and other semi-vegetated areas (Butts and Lewis 1982, Thompson and Anderson1988, Desmond 1991, Haug et al. 1993, Wellicome1994). The minimum habitat that burrowing owls should be given to forage should be of 6.5 acres and more specifically 300 ft radius from their burrows (The California Burrowing Owl Consortium, 1993).

Other sub-objectives to consider for enhancement of foraging areas (2012 Shoreline Burrowing Owl Preservation Plan :

- o Preserve quality of the vegetation → Native/ perennial species, short and long term approaches.

- Removal of chemical pesticides or herbicides→ understand the nature of DDE and its effects on burrowing owls.
- Consider the local predators

- **Nesting:** When it comes to considering suitable nesting habitat, burrowing owls do better in areas with short grasses, spread out shrubs and preferably not many trees, but they can also nest near natural arroyos (Coulombe 1971, Zarn 1974, Rich 1985, Haug et al. 1993, Botelho 1996, Trulio, 2009. Ground squirrels are a very important benefactor to the livelihood of the burrowing owl, as they excavate the burrows that would later be used for nests. The number of ground squirrels and the density of vegetation have very heavy impacts of the success of the burrowing owl population. If there are not enough ground squirrels and very dense vegetation, less nesting sites would be available for owls to use (Rosenberg et al., 2009).

  Sub-objectives for improvement of nesting/ burrows (2012 Shoreline Burrowing Owl Preservation Plan:
    - Introduce/ Remove ground squirrels depending on the number of burrows available for the season
    - Mow and keep areas maintained
    - Provide artificial burrows if not enough burrows are available for the given population
- This restoration objective should be considered to be a long-term, large-scale effort because is prudent way to maintain healthy and stable populations in the Sn Joaquin Valley.

B. Restoration plan:

Methodologies:

In order to have the most success out of a restoration plan, one must consider the biological aspects of the area of interest and what are the various impacts that are affecting its natural integrity or state of equilibrium (Risk-assessment of the area). With what we know so far in terms of threats to this species, the following are some methods that can be utilized as restoration efforts.

Human impact/ disturbances→Habitat Loss/ Degradation Mitigation:

As a way to obtaining the initial status of a given site, the *Burrowing Owl Survey Protocol and Mitigation guidelines* provides a 4-step, standardized surveying guidelines that could potentially reduce or prevent direct and indirect impacts from urban development projects (The Burrowing Owl Consortium, 1993). Even though the protocol allows flexibility and adaptability in accordance to the features of the site, the typical structure for a burrowing owl survey is as follows:

Phase I→ Habitat Assessment:

- Habitat Qualities: Within the project site and an additional 150 meters of buffer zones, locate any burrowing owl activity and designate buffer zones in the periphery of selected area (Thomsen 1971, Martin 1973). An appropriate habitat for the owls would be composed shrub and three cover of less than 30% of the ground surface , and sufficient burrows that are either natural or artificial (Henny and Blus 1981).
    - Location, topography, vegetation and wildlife
- Activity/ Occupation of the habitat: Burrows are the most important component in a burrowing owl's habitat because they can use for shelter, breeding, wintering, foraging and migration (The Burrowing Owl Consortium, 1993). Most commonly, in order to determine owl activity, is by spotting at least one burrowing owl, any of their molted feathers, cast pellets, prey remains, eggshell fragments or excrement in the surrounding areas, and especially in proximity to their burrows. Furthermore, it can be assumed that owls are active in a given site, if any of the burrows has been used within the last 3 years (Rich 1984, Feeney 1992).

Phase II: Burrow Survey:

- Following the preliminary assessment, the next step is to physically survey the entirety of the area is the most suitable for the local owl population. Such survey should conducted in 30 meter spaced transects for major accuracy. In the process of gathering this data, is very important to not disturb any of the burrows or the owls themselves, which translates to keeping a distance of at least 50 meters (The Burrowing Owl Consortium, 1993).
    - Map concentration of plant and wildlife communities
    - Freshwater sources

Phase III: Burrowing owl Mapping and Census ONLY IF OWL ACTIVITY HAS BEEN FOUND

- Important data to collect include: number of owls sighted, number of borrows occupied and any other signs of owl activity (The Burrowing Owl Consortium, 1993).
- Burrowing owl surveys are divided into 4 visits that should be spread out in different days. Surveys must be held in favorable weather conditions and at least 2 hours before sunset or 2 hours after sunrise (The Burrowing Owl Consortium, 1993).
- Nesting season Survey (Required): Begins as early as February 1st and continues until the end of August although latitude and climate can change the date range. (Thomsen 1971, Zarn 1974). Ideally, the survey should be performed during the peak of breeding season between April 15 and July 15.Record: foraging areas, pairs, juveniles, behavior and copulation.
- IF NO OWLS ARE FOUND, PROCEED TO PERFORM A WINTER SURVEY
- Winter survey (December 1st- January 31st) : Same as the nesting survey, except there won't be any breeding behavior present. Record, all sightings and numbers of burrows being utilized (The Burrowing Owl Consortium, 1993).
    - Look for: pellets, scat, feathers and tracks

- Report: Behavior of both parental and juvenile, feeding, resting and mating patterns.
- Include: productivity of pairs, usage of borrows and any other relevant historical data.

Phase IV: Summary Report

- A conglomeration of all phases with their respective data and analysis. The more detailed the summary report, the more can be done in terms of restoration. This report will be submitted to the California Department of Fish and Game (The Burrowing Owl Consortium, 1993).

Although the protocol is very specific and may only be achieved under a longer time frame in the restoration plan, it shows great potential to better understand the burrowing owl's habitat in relation to human disturbances and impacts. Therefore, the more data collected and analyzed, the better we can mitigate for habitat loss and degradation.

Foraging habitat improvement

-As suggested by the 2012 Shoreline Burrowing Owl Preservation Plan, an area of about 100 acres should be reserved to grow high quality forage. Not only this will attract a more formidable number of insects but also promote the small rodent population. Ideally, the number of insects and rodents should be able to support 10 pairs of owls within those 100 acres. Maintaining the grasses at this height will help keep the site in good conditions for foraging, nesting and shelter (Rosenberg et al., 2009).

- Other features for good foraging include: Berms/ Mounds, Brush, Pipe, Rock Piles, Logs, mulch and native plants. → All combined to make a " foraging island"

- Preserving a healthy population of small rodents is also a good tactic to keep the owl's foraging habitat in good shape. The owl's top five most favorite prey include: California Vole, House Mouse, Pocket Gopher, Western Harvest Mouse and Deer Mouse (Trulio and Higgins, 2006)

-The quality of the vegetation is also pertinent to the foraging behavior of the owl. It is recommended to keep a population of diverse, native plants in order to preserve heterogeneity. A native-perennial community of plants would enhance the availability of prey for the owls (Moulton et al. 2009). These plants are very useful for such conditions because they produce enough seed to keep the year-round supply of fruits. The plants near by the burrows should be kept shorter than plants farther away. Some species of native perennials include Monardella ssp., Ribes ssp. and Salvia ssp.

Over 80% of foraging observations in agricultural areas of the southern San Joaquin and Imperial valleys occurred within 600 m of the nest burrow, however they are not able to detect when pesticides or herbicides in the fields (Gervais et al. 2003, Rosenberg and Haley 2004, Rosenberg et al. 2009). If site is near agricultural fields or the site itself depends on the use of pesticides and herbicides, the management plan should recommend a more thorough research in these chemicals that are being used and come up with alternatives such as IPM (Rosenberg et al., 2009)

Nesting habitat improvement

- Quality nesting sites are also very reliant on on the quality of foraging sites; hence the restoration plan should work on both improvements conjointly. For instance, conserving the presence of ground squirrels on the site is positively correlated to the success of nest creation (Wilkerson and Siegel, 2010). Having artificial burrows in years with a smaller squirrel population could be of great help to keep the burrowing owl population stable(Rosenberg et al., 2009)

- Mowing and landscaping of the vegetation, greatly helps with nesting quality. Burrowing owls are more prone to survive in areas where the vegetation is kept at less than six inches tall.

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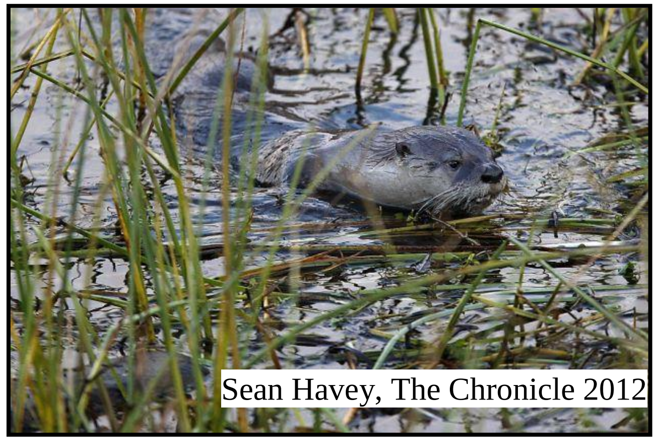
Mammals

River otter (*Lutra Canadensis)* Claire Bryant

North American River Otter
(Lontra canadensis)


Sean Havey, The Chronicle 2012

CLASSIFICATION

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Carniovora
Family: Mustelidae
Genus: *Lontra*
Species: *Lontra canadensis*

(Serfass et all, 2008)

Background and Justification

Lontra canadensis or the North American River Otter is a very charismatic species. Its range spreads from Alaska through Canada, down to Florida, and across to California. (Serfass et all, 2008) However it was extirpated from a good deal of that range after European settlement due to unregulated trapping, the filling in of wetlands, and the general decrease in water quality caused by industry. The populations are no longer in decline due to regulations on pollution and trapping, and L. canadensis are in the process of reclaiming or being reintroduced to their former habitat throughout the US. The IUCN Red list lists them as a Least Concern species because of this. However the support and conservation of river otters should still be taken into account. They will keep fish populations low, and can be an attraction for ecotourism, if the right boundaries are set in place. By considering river otters in the restoration program continued public support is courted and this beautiful species will continue to flourish.

Literature Review

LIFE CYCLE

Growth Characteristics

- When born the North American river otter is completely furred, but blind and toothless. (Boyle, 2006)
- Eyes open at 30-38 days after birth. (Larivière et all, 1998)
- Weaning occurs at 12 weeks after birth, but females continue to provide parental care in the form of food for up to 38 weeks after birth. (Larivière et all, 1998)
- In Idaho it was found that the young dispersed at 12 to 13 months old. (Boyle, 2006)
- The average dimensions of an adult river otter are 1.5 m and 15 kg, and it takes them 3 to 4 years to reach that size. (Larivière et all, 1998) (Boyle, 2006)

- L. canadensis can reach up to 13 years old in the wild, and 25 in captivity. (Larivière et all, 1998)

Reproduction

- Sexual maturity is reached at the age of two. (Larivière et all, 1998)
- Breeding takes place between December and April. (Boyle, 2006)
- Estrus occurs for 42 to 46 days, and gestation lasts 61-63 days. (Boyle, 2006)
- Otters can however delay implantation for up to eight months. (Larivière et all, 1998)
- Young are born between February and April. (Boyle, 2006)
- Normal litter size is one to three, but can reach five. (Larivière et all, 1998)
- Males do not provide parental care. (Boyle, 2006)
- Natal den sites can be burrows dug by other species including: woodchucks (Marmota monax), red foxes (Vulpes vulpes), nutrias (Myocastor coypus), muskrat (Ondatra zibethicus), and beaver lodges. L. canadensis also use undercut banks, favorable rock formations, backwater slough, hollow trees or logs, and flood debris. They have also been known to use human made structures such as brush piles. (Larivière et all, 1998) (Gorman et all, 2006)

Range and Distribution

- Canada: Alberta, British Columbia, Labrador, Manitoba, New Brunswick, Newfoundland I, Northwest Territories, Nova Scotia, Nunavut, Ontario, Québec, Saskatchewan, Yukon (Serfass et all, 2008)
- United States (Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico , New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming (Serfass et all, 2008)
- River otters occur in every form of aquatic habitat: marine coasts, lakes, marshes, reservoirs, and streams. (Boyle, 2006)

HABITAT AND ASSOCIATIONS

- The preferred habitat for L. canadensis has been said to be bog lakes with banked shores which contain semi-aquatic mammal burrows and lakes with beavers. Though studies found that conifers were essential in Pennsylvania and that coastal marshes were preferred in Texas. (Larivière et all, 1998) (Jeffress et all, 2011)
- In Idaho otters and beavers were seen to lodge together on three occasions. (Larivière et all, 1998)
- Otters avoid gradually sloping shorelines with sand or gravel. (Larivière et all, 1998)

- River otters will retreat in the dry times or during periods of resource shortages to where permanent ponds are available and food is more concentrated. (Boyle, 2006)
- They maintain the insulation of the fur by rubbing on grass, bare ground, and logs. (Larivière et all, 1998)
- They are social animals, and may cooperate while fishing. Adult males have been known to form groups up to 17 individuals. Family groups can include unrelated adults, yearlings, or juveniles as helpers. These groups hunt, travel, rest, and groom together. In Freshwater systems these groups often originate in early winter, and last through the breeding season, though they will move and den alone. (Larivière et all, 1998)
- Lontra canadensis isn't territorial, but there is an avoidance of individuals not in the same group. (Larivière et all, 1998)

TOLERANCES

- Mother otters build nests protected from flooding which ensures safety the babies who are unable to function without assistance for the first 3 to 6 weeks. (Gorman et all, 2006)
- When agriculture becomes the dominant land use fish habitat quality worsens, so then does otter habitat. (Jeffress et all, 2011)
- Grazed land had fewer otter latrine sites, signifying that fewer otters took occupancy there. (Jeffress et all, 2011)

INTERACTIONS

Wildlife

- The River otter will eat a variety of aquatic life from fish to amphibians and crustaceans, whatever is most available at the time. Small mammals, birds, reptiles and fruits are also eaten opportunistically. (Boyle, 2006) (Grenfell, 1974)
- River otters may compete with the American mink (*Mustela vison*) for resources. (Larivière et all, 1998)
- Few aquatic predators exist, alligators (Alligator mississippiensis), American Crocodiles (Crocodulus acutus), and killer whales (Orcinus orca) are the only species identified which have this capacity. (Larivière et all, 1998)
- On land the river otter is much more vulnerable. Bobcats (Lynx rufus), cougars (Felis concolor), coyotes (Canis latrans), dogs (Canis familiaris), and wolves (Canis lupus) are the major land predators for adults. (Boyle, 2006)
- For basic communication smell and sound signals are the primary methods, and otters will mark with various waste products for intergroup communication. (Larivière et all, 1998)

Pathogens

- L. canadensis host various nemaodes, cestoedes, trematodes, the sporozoan Isopora, and acanthocephalans. (Larivière et all, 1998)

- They also harbor ectoparasites including ticks, sucking lice (latagophthirus rauschi), and fleas (Orosulla arctomys). (Serfass et all, 2008)
- River otters are subject to canine distemper, rabies, respiratory tract disease, and urinary infection. In North America it was found they can contract jaundice, hepatitis, feline panleucopenia, and pneumonia. (Serfass et all, 2008)

Humans

- River otters are shy, and will avoid humans when possible, but when food is abundant and they are not harassed they have lived in close proximity. (Boyle, 2006)
- In Kansas it was found that on the landscape-scale human disturbance did not strongly affect river otter occupancy. (Jeffress et all, 2011)

THREATS

- Most mortalities are human related due to trapping, illegal shooting, roadkills, and accidental captures in fishnets or set lines. (Larivière et all, 1998)
- Oil spills present a localized threat to otter populations, especially in coastal areas. (Serfass et all, 2008)
- Water pollution and other degradation of aquatic and wetland habitats may limit distribution of otters and pose long-term threats if enforcement of water quality standards are not maintained and enforced. (Serfass et all, 2008)
- Acid drainage from coal mines is a persistent water quality problem in some areas that eliminates otter prey prevents thereby inhibits recolonization or expansion of otter populations. (Serfass et all, 2008)

REQUIREMENTS

- River otters must have permanent water with abundant fish or crustacean prey, and relatively high water quality. (Boyle, 2006)
- Riparian vegetation is necessary for cover so they can safely feed, den, and move across land. This also provides stability to banks and therefor decreases erosion increasing water quality. (Boyle, 2006)
- Areas for denning, such as fallen trees, logjams, undercut banks, and rocks are required. (Boyle, 2006)

KEY KNOWLEDGE GAPS

The maximum or minimum quality and depth of water needed for otter occupancy is unknown. As there are a wide variety of habitats which L. canadensis habituates there is no consistency of guaranteed techniques which work in all situations.

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Goals:

North American River Otters already have a stable sized population in California's Central Valley (Serfass et all, 2008). As there is no need to reintroduce them to the area, the main concern is habitat availability so that the population can grow and spread. Therefor the large, long-term goal of restoration for Lontra canadensis is the improvement of distribution of otter habitat, and the short-term being the increased quality of sites which already meet most of the water requirements for otter habitat.

The main requirements for otter habitat are:

- cover vegetation (such as grasses, trees, cattails, shrubs) (Tesky, 1993)
- permanent water with high water quality, (lakes, ponds, marshes or streams that have water year around. With low alkalinity, medium to low turbidity, and low nitrogen and phosphorous content) (Kiesow et. all, 2005)
- areas for denning (such as fallen trees, logjams, undercut banks, rocks, or other species abandoned dens) (Gorman et all, 2006)
- abundant prey (such as fish or crustaceans, though small mammals, birds, and amphibians can be additional food sources) (Boyle, 2006; Grenfell, 1974)

The short- term sites must already have a permanent water body and meet minimum water quality, because altering these takes an impractical amount of resources and time. However with those factors given we can adjust the other requirements as necessary. Ideally the sites would be within traveling distance of an already established romp of otters. The short-term project sites are medium to small scale restoration, with the goal that once established the habitat qualities will spread to nearby areas through the natural method, and so the long-term goal of dispersal will be enacted.

Explicit Description of sufficient habitat goals:

-Abundant prey: the presence of greater than 11 prey species. (Kiesow et. all, 2005)

-Areas for denning: the existence of areas for denning, such as those stated above, there is no official research on a favorable density of dens in an area, but I suggest that several (>5) be provided due to the tendency of otters to "wander". (Boyle, 2006; Gorman et all, 2006; Larivière et all, 1998)

-Permanent water: a water body that runs throughout the year. (Boyle, 2006, Larivière et all, 1998 Kiesow et. all, 2005)

-Medium to high quality water: low Alkalinity, so when using methyl orange to test <350 mg/l. Low phosphorus, meaning using orthophosphate to test <4 mg/l. Low Nitrogen levels, meaning when using nitrate-nitrogen to test <.15 mg/l. Of variable depth, and low turbidity, with a secchi depth of >20 cm. (Kiesow et. all, 2005)

-Cover vegetation: >44% graminoid and canopy cover. (Kiesow et. all, 2005)

<u>Management Plan</u>

The first action must be inventorying the site. Discover what sections of the habitat are already there, and what isn't. Do transects and collect water samples. Do this weekly for a calendar year, to see the variety of prey, commonality of predators, and to see how the area changes with the seasons.

If the percent of ground cover is not satisfactory, plant various riparian species. Suggested canopy cover plants are "willows (Salix spp.), cottonwoods (Populus spp.), birches (Betula spp.), and spruce (Picea spp.). Other vegetation common in northern river otter habitats includes cattails (Typha spp.), red-osier dogwood (Cornus sericea), black hawthorn (Crataegus douglassi), common snowberry (Symphoricarpos albus), grasses, horsetails (Equisetum spp.), bulrushes (Scirpus spp.), and sedges (Carex spp.)" (Tesky, 1993) Early to mid-Spring is the best time to plant most of these. Seeds, cuttings, transplants or saplings should be provided from a local variety. When grown these provide shelter, protection from predation and help the otter maintain its waterproof coat.

If there are too few prey species, do not introduce new prey species without carefully studying the ecosystem. Monitor the populations, if there is a sizable population of large to medium fish species (between 5-10) which is the main diet of the otter; continue with restoration on the site, other prey may come with different seasons. If there are only small fish, or few large fish (<5) and the water meets standards, then the options are consider introducing new local species, continue monitoring sparsely (once every two months) for a few more years to see if the population changes, or abandon the site and funnel the resources elsewhere.

If there are too few denning sites, make artificial ones. Gorman found that otters will use brush piles for dens. Leave snags, or cut down and dig under a few trees. Create "cave like" rock formations, or just leave stable rocks that jut out from the bank.

Monitoring: Otter's occupy randomly, so the best method of monitoring them is a community watch, once spotted, try to find a latrine. Collect scat from this area, this is the best non-invasive technique for monitoring the North American River otter. The presence of river otters is an excellent response, and does mean that the habitat is attractive, however due to their randomness; they are not a reliable measure for success. So the best way to evaluate the success of the project is to monitor the habitat relative to the goals set out in the *Explicit Description of sufficient habitat goals* section. Continue taking transects and water quality checks weekly for three months after the restoration is finished. Then slowly decrease the monitoring two twice a month for five months, then to once every month for a year, after four years once every two months should be sufficient. If you see a consistent decline in an area of the habitat goals increase monitoring, if it persists use the techniques in the management plan to remedy. After ten years of monitoring, review the information and decide if the habitat has become established enough for monitoring to end.

The threshold set out for water quality, prey abundance, and cover vegetation are in reference to Availability of Suitable Habitat for Northern River Otters in South Dakota, by Kiesow et. all, because in the study they reliably indicated medium to high suitability for the Lontra canadensis. The denning threshold was suggested after extensive reading about the species and their habits. Due to the bar being set at the edge between medium suitability to medium low suitability the results of monitoring can vary slightly below the thresholds set out above without seriously damaging the system. However if during restoration the water quality decreases without rebounding after two months I would stop inputting resources in that area and funnel them to another site. If they do rebound but not entirely I would continue working in that area, as after finishing the project disturbance will decrease and the quality may rebound. If no otters have taken residence in the habitat created, it may be due to difficulty traveling there, consider having otters relocated from populous sections of California's central valley.

Potential Problems: High amounts of predation or conflict from Bobcats (Lynx rufus), cougars (Felis concolor), coyotes (Canis latrans), and wolves (Canis lupus), and especially dogs (Canis familiaris). (Boyle, 2006) The dog is the especially worrying predator because more of the central valley is heavily populated, and there is a large amount of both pet and wild dogs in the area. Fencing around banks where otters are known to den could be erected.

Drought or flood in the initial stage of planting cover is an issue. Drought would be dealt with by adding drip line. However a flood before the roots had set would wash away the plants, or might not but would might cover the new plants in water and deprive them of oxygen, so a new planting would have to be done.

Related Research: As the research on preferred habitat of Lontra canadensis was done in a variety of areas other than California's central valley the results may not be perfectly matched to this region. So the habitat that is shown preference to by otters in the California central valley should be a topic of research. Areas with similar features and all the necessary accoutrements for otter occupation, but with varying depths, quality of water sources, percent ground cover, etc. could be observed to see which condition of each trait lead to increased population in that area. This could be monitored by video, local reports, or scat collection. The comparison and compilation of works and data done on this subject in other states and ecosystems would be a valuable resource for creation of tailored management plans and would allow a more intricate knowledge of Lontra canadensis.

Uncertainties and Risks: There is no guarantee that once provided the habitat that river otters will occupy it immediately or that once they do that they will remain there every year. Weather and other natural or human based disturbances such as an increase of human traffic or agriculture nearby, flood, drought, and disease will affect occupancy in unpredictable ways. Also if there is no romp in traveling distance, than relocation of some individual otters may be an option, however it is unknown the proper amount of females and males necessary for a successful relocation, meaning they become established and last for more than two years

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California vole (*Microtus californicus)* Garrett Allen

Garrett Allen

California Vole
(*Microtus californicus*)

Classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Family: Cricetidae
(ICUN 2013)

Background and Justification

Microtus californicus (California vole) is the most widespread Vole in the state, it is found mostly in the Owens and Central Vallies and is responsible for most damage done to agricultural fields, in California (UC IPM). Despite their destructive foraging behavior they can be very important in project restoration goals. California voles are very abundant and their conservation status is of least concern. Voles are really important for restoration because they are a keystone prey species (ADW). There are several birds of prey and mammals that eat voles including: Swainson's Hawks (which are endangered in the Central Valley), Red-tail Hawks, Red-shoulder Hawks, Barn Owls, American Kestrels, bobcats, coyotes and the list goes on(ADW). In order to attract a wide array of these species at restoration sites it is crucial that voles are established in great abundance. Voles feed on a variety of herbaceous plants and grasses. Voles feed on above and below ground plant parts such as foliage, seeds, stems, roots and bulbs (WSU.edu). Understanding this will become important and deciding how many voles to establish and how we can reduce their negative effects on newly planted woody and herbaceous species at restoration sites is crucial for project restoration success.

Distribution

- *M. californicus* is found in the interior valleys of Oregon and most of California (Cudworth and Koprowski 2010).
- Voles are commonly found in marshes, riparian areas, open grasslands, and in agricultural areas (ADW).
- California voles thrive in ungrazed and lightly grazed grasslands in coastal California (Fehmi and Bartalome 2002) (this will become important when deciding how we want to mow grass fields at restoration sites and how low do we mow them or whether or not it is a good idea to introduce grazers into a restoration site).
- The California vole inhabits the chaparral woodland shrubland of California. It is found in both wet and well-drained areas (O'Brien).

Habitat Requirements

- Microtus californicus is commonly associated with graminoids, but may be found in a wide range of habitats, including grasslands with considerable forbs and short, woody shrubs, marshy areas with standing water, coastal-area salt marshes, well-drained, arid uplands, and oak savannah (Cudworth & Koprowski 2010).
- *Microtus califronicus* demonstrates a preference for perennial grasslands (dominated by *Elymus cinereus:* Basin wild rye) over those dominated by common annual (Cudworth & Koprowski).

- Grass cover is essential for their underground burrow system. They need to be able to travel safely from burrow entry-to burrow entry in order to avoid common predator species (UC IPM).
- It feeds on grass seeds during the dry summer season (Fehmi and Bartolome, 2002).
- Water is often obtained from feeding on succulent vegetation (sibr.com)

Life Cycle

- Females can reproduce as early as three weeks of age, males require six weeks to reach sexual maturity (Cudworth and Koplowski, 2010).
- The breeding season in *M. californicus* is not clearly defined. It can range from 270-320 days in length (pretty close to year round). (Cudworth and Koplowski, 2010).
- California voles undergo both two and four year cycles of abundance. With this there is also a noticeable change in diet depending on time of year. The end of the breeding season in late spring is associated with lower growth rates, lower survival rates, and less fat reserves. Whne vegetation begins drying voles change their diets from one dominated by grass stems and leaves to grass seeds. (Batzli and Pitleka).
- Mean litter size is about four and there are two to five litters each year (sibr.com)

Interactions with Animals

- The California vole is a popular prey species for nocturnal and diurnal birds of prey, small predatory mammals, and snakes (sibr.com).
- Primary predators include: hawks, American kestrels, white-tailed kites, Barn Owls, and great horned owl, mammalian predators such as weasels, feral cats, gray fox, skunks and coyotes (Cudworth & Koprowski).

- Predators may negatively impact populations of *Micortus*, with mammalian predators removing up to 88% of vole population in a given cycle (Cudworth & Koprowski).
- California voles are a social species. Their runways are interconnecting but are very territorial during the breeding season (ADW)-example of intraspecies interations.

Interactions with Plants

- *Microtus californicus* forages on grasses, sedges and forbes, and subsists on seeds and roots during the dry summer season (Cudworth and Koprowski, 2010).
- One study showed that vole in the San Francisco Bay area preferred three types of annual grasses: *Lolium multiflorum, Avena fatua, and Bromus rigidus*, these foods formed the bulk of voles winter diets at both high and low densities (Batzli and Pitelka).
- Because voles seem to create a clumped pattern with their burrow entrances, the associated increase in plant species richness may have strong effect on the overall structure of the plant community (Fehmi and Bartalome).
- Voles use grasses to construct nesting sites within their burrows (UC IPM).

Disease and Parasites

- *Microtus californicus* is a known carrier or Sin Nombre *Hantavirus*, and Isla Vista virus, a genetically distinct *Hantavirus* species (Cudworth and Koprowski, 2010).

Management Strategies

- Removing or reducing vegetative cover (2 inches or less tall) can help reduce vole densities, making the area unsuitable to voles (UC IPM). If the grass covers is too low they will be seen more readily by common predators (Raptors, various mammals which were mentioned earlier).

- Using mowing techniques like “drunken mowing” (By mowing in a somewhat zig-zag manner in certain places of the grass land but not the entire area) can create open areas for voles to cross, thus giving predators a better chance of catching voles. This will be important for restoration if we are trying to restore voles in dense grasslands. We want raptors and other mammals to be able to see the voles running through the grass.
- Planting warm season perennial grass mixtures and perennial bunchgrasses will provide food and habitat cover for voles and other small mammals (NRCS). Perennial grasses are ideal because they grow greener, meaning they are more nutrient rich and they stay green longer (USDA: ARS). These grasses will provide food for voles year round.
- Constructing nest boxes for Barn Owls with the following dimensions: The floor space should be 10”X 18”, 20”-24” in depth, entrance should be 5” tall with the entrance at least 4” from the floor of the box and should stand a foot to a foot and a half off the ground (National Audubon Society).
- Creating a four foot buffer region surrounding trees can help deter voles from tree herbivory, because voles do not like being in the open (UC IPM).
- Wire meshes at least 12 inches off the ground will help keep voles from entering a garden. This same strategy can be implemented to small scale restoration or agricultural plots (UC IPM).

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I. Introduction

In order to establish and control California Voles (*Microtus californicus)* at our restoration site there are three conditions that need to be met in order for successful restoration of voles. First, before vole introductions can be accomplished there must be adequate perennial grass ground cover, they grow faster and greener and stay green longer than annuals (USDA 2004). These grasses provide habitat, food and nesting materials for voles and thus are of highest importance in the restoration goals for this target species . Second, by constructing Barn Owl nest boxes we can attract a major predator of voles to the area, in the effort to keep voles population in check and to reduce the amount of foraging destruction voles have on the surrounding vegetation. Voles are a keystone prey species in many food webs which is why they are important to predator species like the Barn Owl, Red-tail Hawk, Swainson's Hawk, many snakes, American Kestrels, Coyotes, foxes, bobcats. Thirdly, to prevent damage to site plants and trees it is important that we establish buffer regions (four feet in diameter) around new growth woody plant species. Voles are a very destructive foraging species that often will chew through tree roots, stems, and seeds especially in the summer (Cudworth and Koprowski 2010).

A. Goal:

Establishing, controlling and maintaining stable populations of California voles (*Microtus califronicus*) of 200 voles/acre (Batzli & Pitelka 1971) at the target site by the following ways:

1. Establishing native perennial grasses at a target site 2 acres (Batzli & Pitelka 1971) in size

This is the most important goal and will be the first goal to accomplish. A particular study showed that on a plot of land with high densities of perennial grasses (*Elymus triticoides*) the particular vole population recorded higher peak densities, more strongly female-biased sex ratios, longer average persistence, and higher rates of juvenile recruitment than were lower quality patches of annual grasses (Ostfeld et al 1985). These grasses last longer than annuals and grow greener, meaning they contain more nutrients (ARS) and therefore provide not only food for voles, but nest materials and habitat cover that functions as a refuge for voles (Cudworth & Koprowski 2010). A study conducted by Batzli and Pitelka in the San Francisco Bay area showed that voles use both annual and perennial grasslands, meaning that an aim for 65% cover of perennial grasses and 35% annual grass cover would be ideal at our target site. When the annuals die back annually this will create open corridors for predatory birds. Mowing can also be used to reduce grass cover at the site. Grass should not be mowed lower than 3" tall or voles will not inhabit the area (UC IPM). "Drunken mowing" can be used to create low cover corridors where raptors and other predatory mammals can predate on voles easier.

2. By establishing nest boxes for local Barn Owl (*Tyto alba)* populations.

This is a very important goal in order to help keep vole densities stable. If vole densities become too abundant (>400 voles/acre) and Barn owls alone are not enough to keep vole densities in check then constructing perch sites and planting Oaks on the perimeter of the grassland will attract other raptors like Swainson's Hawks and Red-Tail hawks that predate on voles as well. Another strategy would be to mow grass low (<2"). By reducing grass cover voles become easier to spot by predatory birds. Barn Owls are unique because they are non-territorial (Hungry Owl Project) and therefore we can start with 4 Barn owl nest boxes (2 per acre) and can always increase the number if need be. This is a long term goal that will require thorough monitoring of nets boxes to make sure that the Barn Owls are using them. Once we obtain a 75% occupancy of Barn Owl nest boxes (3 out of 4) then we can deem the goal as a success (Hungry Owl Project). Studies done at Sacramento River agricultural properties and restoration sites show that Barn Owls are the most common predator species that predate on California Voles (Golet et al 2008). This is why Barn Owls would be an ideal species to attract to a grassland restoration in progress. The study also included that vole densities were highest in young restoration site (did not specify time frame). If successful, vole densities will be kept stable (200/acre) and be able to not only sustain Barn Owls but other raptors and small mammals as well: coyotes, foxes, Red-tailed Hawk, Swainson's Hawk.

3. Establish buffer regions around new growth woody species, especially trees in the juvenile stages.

In order to achieve this goal we can establish four foot buffer regions (UC IPM) with no ground cover around newly planted woody species until they reach maturity. California voles persist on seeds and roots during the dry summer season (Cudworth & Koprowski 2010). This is when buffer zones will be of most importance. Voles often will not travel across surfaces where there is lack of adequate vegetation cover for they are easily spotted by predators this way. Another mechanism of control would be to place wire meshes about 12 inches off the ground surrounding plant vegetation (UC IPM).

Establishing perennial grasslands is the underlying success of restoration for California voles at our target site. Once grasses grow in and the first initial vole population inhabits the area we can begin building nest boxes for Barn Owls. if successful, Barn Owls should be able to keep vole populations at a stable level. Thirdly, by creating buffer zones around new growth vegetation (plants, trees, etc) we can reduce the chance of plant herbivory by voles. This can also be done using wire meshing surrounding trees. These goals should be able to be attained easily, and if all goes well we may even be able to attract more predator species into the area such as red-winged hawks, American Kestrels, coyotes, and foxes.

B. Restoration Plan:

I. Establishing native perennial grasses

II. Establishing Barn Owl nest boxes to attract common vole predators to the restoration site

III. Establishing buffer regions around juvenile plants and trees

I. Establish native perennial grasses.

There are two different restoration options for establishing perennial grasslands at a site: by seeding or by planting plugs. If planting native perennial grass seeds is the chosen method then it will be most efficient to purchase the seed (30$/lb) (ARS). Obtaining perennial grass seeds from local areas in nature is difficult considering the rarity of native perennial grasslands in the Central valley, local to our restoration site. It will be best to start in the fall after the first rains, in which case tilling the soil will be ideal before seeding (Hastings Natural History Reservation). Climate patterns are especially important to consider because tilling before an El Nino year can lead to catastrophic erosion events (Hastings Natural History Reservation). Planting of seeds should be done in October and November after the first few rains. Planting earlier than this time can increase the risk that rodents such as voles eat the seeds (Hastings Natural History Preserve). For a target site of about 2 acres it is ideal to walk out our use a tractor and drop 20 seeds per every few square feet (Hastings Natural History Preserve). The alternative method of planting would be to plant plugs. There are two sizes available for planting of perennial grass plugs. There is the LP50 and are 5" deep by 2" square as well as 3.5" by 2.5" square (North Creek Nurseries). The advantages of planting plugs are that they have robust root systems that make for quicker establishment at the restoration site and less initial watering (North Creek Nurseries). Plugs also are known to have higher transplant success rate and flowering success within the first year (North Creek Nurseries). Perennial bunchgrasses such as purple needle grass (*Nassela pulchra*), *Nasella lepida,* and *Danthonia californica* (Batzli & Pitelka). Creeping wild rye (*Elymus triticoides)* Is also commonly used by voles (Cudworth & Koprowski 2010).

In the event that we are not able to restore perennial grasslands entirely (100%) or only patches of grasslands (65% perennial vs 35% annual) a mix of native perennial and annual could work well considering the studies mentioned in the goals section that observed vole use of both annual and perennial grasses (Batzli & Pitelka). Once grasses become established mowing will become important. Using a technique known as "drunken mowing" will create low cover pathways that allow Barn Owls and other raptors to be able to spot voles crossing from one grass patch to another. Use of pesticides/herbicides for invasive weed treatment should be carefully considered. Pesticides and herbicides that don't stay in the environment long are usually less harmful than those that stay in the soil, water or air for a long time (Penn State: *Less Harmful* Pesticides). When perennial grasslands have become established it is important that monitoring be conducted on a monthly basis to determine vole abundance. Voles have a very short gestation period, females may reproduce as early as three weeks of age, males require up to 6 weeks (Cudworth & Koprowski 2010). Mean litter sizes in voles range from 5-9 offspring (Cudworth & Koprowski 2010). Because they populate so quickly it's difficult to be able to count the number of voles. Live trapping (Sherman or box-traps) can be used when population densities are low (O'Brien 1991), during the summer months (Cudworth & Koprowski 2010). Perhaps another way to determine population abundance would be to count the number of vole burrows and searching for vole scat near entrances of burrows. This way we can estimate the number of voles the site has and monitor to see if burrow presence increases over time.

II. Establishing Barn Owl nest boxes to attract common vole predators to the restoration site

Grasslands and croplands/pasture fields are ideal habitats for Barn Owls, through research it has been found that a single pair of feeding young (Barn Owls) can capture up to 70lbs of rodents especially during the breeding season (National Audubon Society 2013). Barn Owls breeding season begins in late winter (The Barn Owl Trust). There are two possible restoration plans that can be implemented at the site: Nest boxes can be built onto trees or poles can be built at the target site. These boxes will have the following dimensions: The floor space should be 10"X 18", 20"-24" in depth, entrance should be 5" tall with the entrance at least 4" from the floor of the box and should stand a foot to a foot and a half off the ground, these are ideal measurements suggested by the National Audubon Society for constructing Owl nest boxes. Ideally, Barn Owls will return to the same nesting box year after year, their typical clutch size consists of five to seven eggs and incubate in the nest for about 32 days (National Audubon Society 2013) most Barn Owl breeding pairs lay eggs during the spring (The Barn Owl Trust), at this time restoration crew should avoid using loud disruptive machinery that may disrupt nesting Owls. Nest boxes should be monitored on a yearly basis during the late winter breeding season (The Barn Owl Trust) which is from December-January, to ensure that Owls are using them for nesting. Motion cameras can also be set up near nest boxes in order to identify nesting Owls without physically checking their nest boxes. Clutch size and brood size are directly related to food supply, in this case rodents, like voles (The Barn Owl Trust). This means if there is high vole density then female Barn Owls will have larger clutch sizes, conversely, when vole densities are low, they have much smaller clutch sizes. Potential areas of conflict with this goal are the following: If target restoration site is near busy residential areas and often visited by people, loud noises can disrupt females during the breeding season (late winter). Nest safety is also important to consider. Some nestlings fall from the nest and cannot get back to the nest (The Barn Owl Trust), this is why the dimensions provided above should be ideal for the nest boxes, in order to reduce chances of nestling mortality.

Barn Owls cover a large range of about 35km and they need grassland within 2 km of their nesting site (The Barn Owl Trust). Since Barn Owls need a lot of space and our target restoration site is 2 acres large it might be best to start with one Barn Owl box. We know that they can consume a lot of pounds worth in voles alone. The number of Barn Owl nest boxes may vary with time. Interestingly enough Barn Owls are considered non-territorial (Hungry Owl Project). This is important when considering how many boxes to make at the target site. More research on ideal amount of nest boxes for specific plot sizes would be helpful in determining an appropriate number of nest boxes for our 2 acre target site. It will also be important to monitor the site on a monthly basis to determine how many voles are being taken by Barn Owls and other predators. Voles often rapidly colonize an area when densities are low and slow down the growth rate when densities are high (Peronne 2002). Voles naturally go through 3-4 year population cycles of abundance (Batzli and Pitelka 1971). These are two important things to consider when trying to balance vole abundance versus predator abundance.

III. Establishing buffer regions around juvenile plants and trees.

Voles will typically forage on stems of juvenile trees, especially fruit trees (UC IPM) since restoration will include planting of new trees and plants it is likely that these buffer regions will be essential for tree survival. By creating four foot diameter buffer regions around new growth woody species, we can help protect juvenile woody species from herbivory. To establish these areas we can either mow grass down to less than 2” this option would not be as efficient for mowing would have to occur on a weekly basis to keep grass height down. A second and more efficient option would be to spray herbicides to kill the grass surrounding the woody plants. Voles do not feel safe in the open and will likely not cross buffer regions with no grass cover (UC IPM). An alternative restoration plan would be to construct 12” wire meshes around juvenile plants and woody species to keep voles from foraging on them. Monitoring should be conducted on a weekly basis to check for signs of predation on woody plants, signs of destructive foraging would be chewed roots, and damaged plant stems. This plan will require monitoring for a year to ensure that buffer regions are effective. Once woody species reach maturity buffer zones will no longer be necessary to protect from vole herbivory.

This restoration plan highlights the most important factors regarding introductions of *Microtus californicus* (California Vole) at the restoration site. Establishing a stable population of California voles will help benefit other wildlife that interact with it, especially common predator species like the Barn Owl. Caution should be taken in areas with new tree growth or plant growth. It is common for Voles to go through 3-4 year annual cycles of abundance (Batzli and Pitelka 1971). Batzli and Pitelka recorded studies where vole peak densities exceeded 450 individuals per acre during peak in abundance. These plans are preliminary and subject to modification.

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Coyote *(Canis latrans)* Sylvie Josel

A. Background and Justification

The coyote (*Canis latrans*) originated in the Great Plains of North America almost 2 million years ago. An extremely adaptable species, the coyote can now be found from Canada to the southernmost points of Central America, and in every region in the United States (National Geographic). Unlike most wild animals, coyotes have largely extended their range since humans began to encroach upon their territory in the early 19th century. As coyotes continue to flourish in highly populated areas, their interactions with humans and attacks on pets have become increasingly common. The public largely considers coyotes to be a terror and a nuisance, using lethal traps and elongated hunting seasons to control their populations (Gompper, 2007). However, there are many humans that are captivated by coyotes and realize the crucial role that they play in the environment. The effects of coyotes differ with location but, as a prevalent mesopredator, their existence largely affects the populations of the species on which they prey, as well as the ones they compete with (Crooks and Soule, 1999). The reduction of coyote populations would result in an acute cascade effect, causing detrimental rises in white-tailed deer, rabbits, squirrels, and other prey species. Population booms in species like these can cause habitat degradation and wipe out plant species. Altered plant communities can change entire ecosystems and create opportunities for invasions of exotic species (Bekoff and Gese, 2003). The role played by coyotes in ecosystems throughout North America proves them to be a critical conservation issue, despite their thriving current state and some public disdain (Gompper, 2007).

B. Literature Review

Physical Characteristics

- The size of a medium dog (18-35 lbs., 30-40 in.), with relatively large ears and small feet (National Geographic)
- Thick grayish-brown to reddish-yellow fur with white markings on chest and belly (National Geographic).
- Black nose, yellow eyes, and a bushy tail (National Geographic)

Behavior

- Coyotes live in packs of 4-6 adults and the alpha pairs' pups, but often hunt and travel alone or in pairs (Fox, 1975).
- Fiercely territorial of home range (10-12 km), especially during pupping season (March- July) (Tokar, 2012).
- Travel an average of 4km in a night of hunting (Tokar, 2012).
- Nocturnal lifestyle, although they have become increasingly diurnal (Gese, Ruff, et al. 1996).
- Diet consists of insects, fruits, and fresh meat or carrion. Coyotes will eat almost anything but their preferred meat is that of small mammals (squirrels, mice,etc.) and weak or young ungulates (Bekoff and Gese, 2003).
- Run at speeds up to 40 mph and can jump over 8 ft. high (Ghert, 2007.)
- They are also very strong swimmers and swim to escape predators and to colonize islands (Tokar, 2012).

- Temporarily monogamous mating occurs between January- March, followed by a gestation period of approximately 60 days. The average litter size is 6 pups and both parents raise the young (Tokar 2012).
- The litter leaves the den after about one month, and by 9 months the males have dispersed while the females remain to form the basis of the pack (Tokar, 2012).
- Sexual maturity is reached at about one year of age and the average lifespan of a wild coyote is around 10-15 years (Tokar, 2012).

Habitat

- Found in an incredibly wide range of habitats from urban areas and swamps to forests and mountains, with the preferred landscape being open grassland/farmland. (Wells and Bekoff, 1982).
- Short grass (>10 cm) is favored because small prey is easier to see and catch (Gese, Ruff, et al., 1996).
- In the presence of wolves, coyotes prefer mountainous terrain where their light bodies can outmaneuver their attackers (Gese, Ruff, et al., 1996).
- Coyotes prefer temperatures between from 45 to 80 degrees Fahrenheit, although they can be well adapted to snowy and desert habitats. The shallower the snow and sand the better, as they have small feet and run on their toes (Wells and Bekoff, 1982).

Dens

- Dens are most often old fox or badger dens (3-6 ft. underground) that coyotes then enlarge. However, they can also dig their own (Tokar, 2012).
- Dens are only used during pupping season (March-July) and then deserted until the next year (Tokar, 2012).
- Two to three dens are often utilized within the same couple of miles and pups are moved between them about every two months to increase sanitation and discretion (Tokar, 2012).
- Ideal dens are within that distance of a water source and are secluded, due to the timid and wary nature of coyotes (Wells and Bekoff, 1982).
- A home range of ~10 km in diameter is established for each coyote/ breeding pair around dens, which is then defended against other coyotes (Ghert, 2007).

Diseases

- Most diseases that affect coyotes are the same as those that affect domestic dogs. These can be transferred to pets and in some cases, people as well (Timm, 2007).
    - <u>Distemper:</u> very common viral infection transmitted through air, affecting the respiratory, immune, and nervous systems for 2-5 weeks until death. (Conover, 2002).
    - <u>Mange:</u> a skin irritation caused by mites is estimated to infect 70% of the world's coyote population. It is extremely contagious and transferrable to humans and pets, causing rashes and hair loss (Conover, 2002).
    - <u>Rabies:</u> coyotes are one of the many carriers of this usually fatal disease that can also be spread to humans through infected saliva via a bite. For canines, foaming at the mouth and lethargic or extremely aggressive behavior are good signals for an rabid animal. (Conover, 2002).

Interactions

- Predators include mountain lions, wolves, and most predominantly, humans
- Symbiotic relationship with badgers, who attempt to dig prey out of the ground. As the prey try to escape onto open ground, the coyotes outrun the badgers and steal their prey (Ritchie, Euan, et al., 2009).
- Coyotes have been found to breed with domestic dogs (Coydogs), which are often confused with pure coyotes.
- Coydogs are often much more comfortable around humans than pure coyotes which makes them more prone to harass pets and livestock (Gompper, 2007).
- Less commonly, coyotes breed with wolves (Coywolves), which are larger than pure coyotes but hard to differentiate without DNA testing (Gompper, 2007).
- Wolves are coyotes' main competitor and threat, known to kill coyotes especially as they try to scavenge from a wolf pack's meal (Gese, Ruff, et al., 1996).
- Coyotes keep prey numbers in check and stopping small mammals from degrading habitat (ex. eating roots, saplings, and tunneling detrimentally) (Ritchie, Euan, et al., 2009).

Human Interactions

- Coyotes have adapted to living in highly urbanized areas due to their extensive range in diet and relatively small home-range size (Ghert, 2007).
- Many have lost fear of people due to consistent exposure, lack of threat, and sometimes even encouragement (i.e. feeding). This has resulted in a rising number of stalking and attacks on pets and, very rarely, on humans (Timm, 2007).
- Coyotes eat accessible trash, pet food, pets, and livestock (Timm 2007).
- Hunting seasons vary with location with most states having no seasonal restrictions or limit to the amount of coyotes that can be killed (Gompper, 2007).
- Most coyote deaths in urban areas are attributed to cars (Gompper, 2007)
- Coyotes have been a nuisance to ranchers since raising livestock began in North America, often killing sheep, poultry, goats, pigs, and calves (Knowlton, Gese, et al. 1999).

Management Options

Out of heavily populated areas

Trapping, poisoning, and hunting keeps the populations in check, but it is impossible to eliminate coyotes in specific areas. Coyotes are too numerous and resourceful to be kept out and there will always be more to replace those that are hunted or relocated (Timm, 2007). Dispersal will affect the intensity at which the control program is enacted, bur the commonality of coyotes necessitates a relatively large geographical plan that must be continually sustained (Roemer, Gompper, et al. 2009). Education is the best way to keep both coyotes and humans safe. Simple steps, such as putting up signs and handing out pamphlets can raise awareness of what to do in the case of coyote interaction (Timm, 2007). Coyotes are shy by nature and will remain fearful of humans if proper hazing techniques are consistently utilized (loud noises, appearing larger by waving arms, etc.). People should also feed their pets indoors, be mindful of small children when outdoors, and utilize large watchdogs to protect their livestock (Knowlton, Gese, et al. 1999).

At a restoration site

Although their attacks on pets and livestock irritate many humans, coyotes benefit ecosystems and are appropriate at a restoration site (Crooks and Soule, 1999). Ideally, this site would be away from humans so coyotes are afraid if they ever do come into contact with people. Due to the flexibility of coyotes' needs, they require very little special attention when designing a habitat site. Ideally, a coyote pack would have at 5-13sq. km for a home range (Ghert, 2007). Without that amount of nature to roam in, they will surely enter populated areas for easier food availability (human trash, pets, etc.). Coyotes are an easy way to ecologically control other animal populations that would otherwise overcrowd or damage an area (Ritchie, Euan, et al. 2009). Other necessities that would need to be present at a restoration site for coyotes would be small mammals to feed on (preferentially 3 lbs a day/coyote), dry land that can be traveled across and burrowed into easily, a source of water within their home range, and lack of extreme weather (<20°F, >90° F) (National Geographic). Their natural desire to live in pairs or small groups ensures that there will not be an overpopulation problem at the site (Tokar, 2012). There is a very good chance that a coyote will end up at a site even if it was not planned.

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A) Goals:

Educating the public

This is the most critical of all of the goals to restore coyotes in California's Central Valley. Humans are one of coyotes' few threats and, through widespread, long-term education programs, we can increase our understanding of the key role that they play in the environment. By enhancing public knowledge and respect for these creatures, we can hope to minimize human-coyote interactions that often lead to negative stereotypes, such as attacks on domestic animals and the transfer of pathogens. Even if coyotes cannot be removed entirely from populated areas, tips on how to coexist with coyotes can reduce their presence to rare sightings in the night.

Maintaining a sufficient habitat

The ideal habitat for a coyote is open grassland, with enough room for a territory of around 10 sq. miles and temperatures around 70 degrees Fahrenheit (Gese, Ruff, et al. 1996). Much of the Central Valley fills this requirement, which makes it an idyllic area for coyote conservation. What is needed, however, is wilderness that is adequately sized so that coyotes are not tempted into towns and cities. By conserving large areas of grasslands, coyotes will be able to naturally colonize and exist sustainably living off of the many resources that are present in a healthy ecosystem. Because the natural of habitat of coyotes continues to decrease at alarming rates, it may not be possible to create an optimal habitat. The prey species of coyotes have significantly smaller space requirements, so they can be provided for easily and the coyote will be able to manage around a plentiful food source. Maintaining healthy prey populations will supply coyotes with their natural diet and will keep them from trash bins and back yards.

In a perfect world, the coyotes would be able to exist in an area where they would not have any human interaction at all. However, as this is not possible, it is essential that humans learn to coexist with these petite canines. Money that is put into educational programs or commercials will detract from the effort of conserving coyotes in the field. Although, due to the coyotes' extreme ability to habituate to nearly any environment, humans do not need to expend too many resources to make sure that they are surviving in nature. What should be focused on is how to allow them to survive amongst humans. Old hostilities that many humans harbor for coyotes will be difficult to overcome and will need to be executed over long amounts of time and on a large scale. Providing necessary food sources may also prove to be difficult because much of coyote prey are pests to humans and their numbers cannot be allowed to increase to detrimental levels. Also, although coyotes are a necessary part of the environment, their numbers are only controlled by humans so is important that they do not become too populous either.

B) Management Plans: Conservation and Monitoring

The education of the public on the importance of coyotes and how to respectfully coincide with them can happen in many different ways. One of the most successful avenues for relaying information would be to make presentations in schools throughout the area. Wildlife conservation groups, ecologists, and even well read volunteers could give brief lectures on the role that coyotes play in ecosystems and how to live alongside them. Teaching the next generation is a good tactic as children are the adults of the future and much of the older generations are already set in their ways.

Each lecture will begin with some basic facts about coyotes, as well as questioning the students about how much they already know. Although coyotes do cause problems for humans, such as killing pets and livestock, the children can understand that the reason coyotes are present in suburban areas is because their natural habitat has been destroyed (Timm and Baker, 2007). Cute pictures and videos will be incorporated into the presentation to retain the attention and participation of the young audiences. Instilling curiosity and sympathy for coyotes in the children will make them more eager to support the conservation of these vital creatures.

Speakers will emphasize the role that coyotes play in an ecosystem and, more specifically, how they limit the populations of many pest species. Without coyotes, the numbers of rodents and rabbits will skyrocket, and not only cause habitat degradation, but will also create competition for forage with livestock (Knowlton, Gese, et al. 1999). Another concern is that more rodents means a higher chance of human interaction and the infestation of homes, barns, and sidewalks. They also regulate other mesopredators such as opossum, skunks, and raccoons (Ritchie, Euan, et al., 2009). These creatures often feed on songbirds and waterfowl, so the presence of coyotes actually benefits avian diversity even though birds are often on the coyote menu (Bekoff and Gese, 2003).

Brief infomercials are another good way to address the public, as people are more likely to watch TV than read an environmental article. It is a good way to confront the older parts of the population and impressive visuals can create a subliminal compassion within the viewer. Infomercials can also call attention to more mature topics that would not be appropriate in schools. They can exemplify the harshness of traps and poisons, and take a more detailed approach to the ecological significance of the *Canis Latrans.* For example, coyotes also limit deer populations by preying on fawns, which keeps deer, and the ticks they carry, out of people's yards and gardens (Bekoff and Gese, 2003). Although this point may be too severe for a classroom, adult audiences can appreciate the dangers of Lyme disease and the benefits of keeping infected ticks at a distance.

Another type of infomercial could be how to limit coyote interactions and what to do if one occurs. Even if after learning about the benefits of coyotes to the environment, the public still called for their elimination, complete eradication of all coyotes would be next to impossible (Roemer, Gompper, et al. 2009). Therefore, it is critical to create boundaries between humans and wild animals to minimize contact. Coyotes are shy by nature so a large part of why they have grown comfortable enough to appear around humans, let alone harass them, is due to people being uneducated (Timm, 2007). Humans should be taught not to feed the wild animals and to shout menacingly when coming into contact with them (National Geographic). The natural fear of humans can be easily reinstated in coyotes if the public knows how to respond. Other tips such as securing trash cans, keeping pets inside, and removing food from coyote-accessible places will also reduce the appeal of urbanized areas (Timm, 2007). This increase of awareness and respect by the public will not only benefit coyotes, but the environment and wild animals in general.

Limiting food options in populated areas is one way to decrease coyote presence but the same effect can also be reached by supporting natural prey species in the wild. Coyotes are opportunistic omnivores but prefer meat like voles, rats, and squirrels, especially during the winter (Bekoff, Gese, 2003). Due to the prolificacy of small rodents, it may not be wise to help them increase their populations, especially if there are not enough coyotes around to manage them. Because coyotes eat such a wide variety of foods, it is not necessary to aid their prey species most of the year. However, in the winter, lack of food may be incentive for the coyotes to overcome their fear of humans and enter towns in search of a meal (Timm and Baker, 2007).

In sparsely populated places, plants that reach maturity or drop seeds during the winter months may be planted to increase food availability to coyotes and their prey. Hellebores and Hazelnut trees both pollinate and bloom in the winter. Other plants like cabbage, broccoli, and turnips reach maturity during the winter months and could help support the coyote population outside of neighborhoods. Hazelnut trees are native to North America so they do not pose the same uncertainties as an exotic species (Henry and Kaiser, 2000). Planting them could counteract the lack of food in the winter months, and depending on the amount of space available, 6 plants per estimated coyote should be sufficiently helpful in feeding coyotes' prey species as well as the coyotes themselves.

Hazelnut trees need to be planted near one another, as they are self-infertile and require a slightly acidic soil (Clatterbuck and Fare, 2014). A soil test will need to be applied before planting, and then sulfur should be added if the pH is too high (Everhart, 1994). Depending on the original pH level of the soil, sulfur can be spread during the spring (approximately .2 lbs/ 10 sq. feet.) (Everhart, 1994). After three months, another soil test can be taken and sulfur can be added again, if necessary. The soil should also be well- drained so the planted area should preferably be uphill from water sources and be without tillage (Clatterbuck and Fare, 2014). If this presents a problem, a small hole (about one foot in depth and diameter) can be dug as a drain (Clatterbuck and Fare, 2014), as constant rain is not an issue in the Central Valley. Trees should be planted with 20 ft. between them and then should not need long-term tending as they are hardy and come in many pathogen-resistant strains (Henry and Kaiser, 2000).

Another management option to increase the amount of natural prey available is prescribed burnings to make the environment more suitable for coyotes and would therefore decrease the chance of them existing among humans (Gehrt, 2007). Coyotes would not be harmed by the fires, as they are quick and extremely mobile. The fires would reduce vegetation height and create a habitat that is more like the preferred open grassland, where hunting is easier (Tesky, 1995). Small mammal populations would also benefit from the periodic fire due to increase food availability (Tesky, 1995). Burnings should occur once every seven years and in patches of ~10 acres, depending on the size of the site. This allows the chaparral environment to revive itself enough to sustain a community while still remaining a young system.

Monitoring coyote populations will allow us to know the success of the conservation efforts, especially the effects of the Hazelnuts. The fewer coyote sightings the better so tracking collars can be used to evaluate the movement towards, and away from, populated regions. Coyotes that are spotted amongst humans should be trapped and collared. This may prove difficult but blockades, animal control pole-leashes, and sedatives should aid in restraining the animal. It is important to track the animals that are found amid humans because they could be “problem animals.” (Gehrt, 2007). These coyotes have lost their fear of humans or have gotten very good at surviving in urban sections. Suspected problem animals can be tracked as often as needed and then removed far enough to where they can no longer pose a problem. Other collared coyotes can be tracked on a monthly basis to see their patterns of movement, which can lead to our understanding of when and why they encroach on populated places.

As with all restoration projects, there are many degrees of uncertainty. It is possible that it is not lack of food that drives coyotes into cities and towns, in which case the planting of hazelnut trees would be a waste of time. Also, although educating the public is a priority goal, its success is highly variable, due to its reliance on the willingness of the community. Even with education, there is a very high chance that people will not participate, and trash and pets will still tempt the coyotes, and the conflict will persist. However, even with minimal aid from people, coyotes will probably continue to adjust to their shrinking natural habitat and somehow remain flourishing amongst the ever-growing and intrusive human population (Timm and Baker 2007).

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Mountain lion (*Puma concolor)* Anais Castillo

Mountain Lion
Puma Conolor

Classification

Kingdom: Animalia
Phylum: Chordata
Subphylum: Vertebrata
Class: Mammalia
Order: Carnivora
Family: Felidae
Genus: Puma
Species: Puma concolor
Common name: Cougar
(Shivaraju 2003)

Photo 2011 Barry Breckling

Background & Justification

The mountain lion is the most widely distributed terrestrial vertebrate species in the western hemisphere (Riley 1998). Historically heavily persecuted, the mountain lion is currently listed as threatened on the US federal list (Shivaraju 2003). As top predators in the environment in which they live, they play an important role in stabilizing ecosystem cycles by controlling populations of large ungulates (Shivaraju 2003). In areas where mountain lions are present, multiple biodiversity elements are also well represented, such as multiple rare and endangered plants, fish, and over 7 different habitat types (Thorne 2006). Mountain lions also have economic importance to humans; they have considerable trophy value, are hunted for sport, and greatly contribute to the profits made in zoos (Shivaraju 2003).

Mountain lions were eradicated in most of North America by 1930, and were hunted more in California than any other state. From 1907 to 1963 a record 12,462 mountain lions were killed and turned in for the bounty. Since the early 1970s mountain lion distribution and abundance have increased, and have been "reported in areas where they were historically rare or absent" (Riley 1998). The current population in the United States is believed to be around 30,000 ("MLF 2014"). Mountain lions in western North America are 1 of only 2 large felid species, globally, to increase their distribution and abundance coincidental with increased human development (Riley 1998).

Though mountain lions may be one of the most difficult terrestrial mammal species to census, population estimates in the last few decades have confirmed that populations are smaller than they were at their peak 10 years ago, and seem to be declining with an estimated 3,000 mountain lions dying each year. Though the desire for mountain lion populations to be restored in western ecosystem subsists, there are conflicting agriculture concerns regarding mountain lion depredation on livestock. There has also been an increase in the frequency of mountain lion-human incidents, a persisting problem for people living in the west (Riley 1998). These conflicting viewpoints have raised questions as to how expanding populations of mountain lions and humans will coexist. Because wildlife agencies lack needed information to manage mountain lions in their changing environment, many states have no formal management plan for mountain lions.

Life History

Mating System: Mountain lions are **polygynous**; one male mates with multiple females. Once a mountain lion has established a home territory, it will attempt to mate with the females in which their home range overlaps with (Thorne 2006).

Breeding Season: Mating can occur throughout the year but is most common from **December to March** in northern latitudes (Shivaraju 2003).

Reproduction: Estrus usually lasts about 8 days, in which during this time the female initiates the mating signal by vocalization and rubbing against objects nearby. The male then responds with similar vocalizations and by sniffing her genital area (Shivaraju 2003). Sexual intercourse lasts only about a minute, but they can do this up to nine times in an hour, with a 67% chance of conception per act.

Breeding Interval: Pregnancy can last up to 3 months but females will only give birth **every other year**.

Gestation Period: Pregnancy can last from **82- 96 days**.

Average Number of offspring: Mountain lions produce litters anywhere from 1-6 cubs with an average of **3 cubs**.

Sexual Maturity: Females are reproductively active until an age of at least 12 and males until an age of at least 20. Males are sexually mature at **3 years** and females at around **2 and a half years** (Shivaraju 2003).

Time to independence: At ten days old cubs open their eyes, start to hear, their teeth begin to grow, and they begin to play. As soon as 40 days old the cubs can start to eat the hunted food provided by their mother. Mothers care for their young until they are about **a year old**. This is necessary for the helpless young who need to be sheltered until they can learn to hunt themselves.

Average Dispersal at independence: The young then disperse to establish their own home range, with males typically traveling a bit further, dispersing from **23-274** km while females disperse from **9-140 km** (Shivaraju 2003).

Siblings sometimes disperse as a group and may remain together for 3 months or longer (Tesky 1995). This juvenile dispersal is necessary in order to maintain stability in mountain lion populations (Thorne 2006).

Average Lifespan: Mountain lions live slightly longer in captivity then in the wild, they may live up to 18 to 20 years in the wild with an average of about **9 years**.

Range and Distribution

Mountain lion is a wide-ranging species, having the widest distribution of any mammal in the western hemisphere. Though they used to range from coast to coast in North America, various human threats have restricted much of their range to mountainous, unpopulated areas (Shivaraju 2003). Mountain lion sightings in eastern North America, outside of southern Florida, are now very rare. In recent years populations have begun to expand into areas of human habitation in the western United States. Mountain lions are now fairly common in suburban areas of California and have been hit by cars (Shivaraju 2003). In these suburban areas they are most abundant where there are high numbers of deer and enough cover for them to hunt (Thorne 2006).

An adult male's home range is larger than that of a female and is often around 280 km2. Male home ranges do not overlap and their range typically encompasses the home ranges of two females. Female home ranges are usually only about 140 km2 (Shivaraju 2003). Mountain lion densities vary with deer abundance, with high densities around 10 adults per 260 km^2 in areas with high deer concentrations, to one adult per 2600 km^2 in desert regions (Thorne 2006).

Habitat Structure Needed

Mountain lions use a wide variety of habitats; they occur in temperate, terrestrial, and tropical areas. Their preferred habitat is essentially that of their preferred prey. Their habitat needs to be thick enough to provide enough cover for hunting (Shivaraju 2003). Mountain lions occupy a wide variety of plant communities. "In western North America mountain lion habitat contains open woodland such as oak scrub, pinyon, juniper, curlleaf mountain-mahogany, snowbrush ceanothus, and manzanita communities (Tesky 1995). " "In California mountain lions occur primarily between 1,980 and 5,940 feet in mixed conifer and brush habitats**"** such as curlleaf mountain-mahogany communities (Tesky 1995)." Mountain lions prefer steep and rocky habitat that is inaccessible by humans. Riperian vegetation such as cottonwood is ideal habitat as it provides cover and shelter for traveling mountain lions (Tesky 1995). which provide shelter. Females may use the same den for years and typically contain protective cover or piles of boulders to help protect kittens from harsh weather and predators (Tesky 1995)**.** Dispersing mountain lions need this type of habitat present at road crossings, and if cover is not high enough in these areas, stream courses and ridgetops are typically used.

Food Habits

Mountain lions are carnivores. In North America mountain lions feed primarily on large ungulate species including "white-tailed deer, elk, moose, and caribou" (Shivaraju 2003). For these large species, they stalk prey and attack the animal breaking its neck, making it easier to carry it back near a sheltered area. Mountain lions will travel vast distances with their prey, up to 350 meters, in order to feed themselves and their families. Once prey is captured, it is often buried in order to avoid other predators from stealing the meal; the mountain lion will return to feed on the corpus at night. At times when their large prey species are unavailable, mountain lions often kill and feed on domestic livestock such as calves, sheep, goats and pigs in the agricultural areas nearby (Shivaraju 2003). Mountain lions need to feed on larger prey to satisfy their metabolic needs per unit effort; if they only consumed smaller prey they would have to catch a substantial amount and the prize wouldn't be worth the effort. Small mammals are easier to catch and are therefore taken opportunistically, representing a minor part of the diet (Tesky 1995). This includes species such as porcupine, squirrels, muskrat, beaver, raccoon, skunk, coyote, bobcats, rabbits, birds, and even snails and fish.

Interactions

Communication: Mountain lions rely mainly on vision, smell, and hearing (Shivaraju 2003). They growl or hiss when they feel threatened, purr to show signs of content, and scream when frightened. For young where their growl may not be yet fully developed, loud, chirping whistles are used to call the mother. Bonding between the mother and her young is developed primarily through touch. Touch also plays an important role for establishing territory as mountain lions use scent marking to publicize to other mountain lions their boundaries, especially during reproduction (Shivaraju 2003).

Predation: Although mountain lions are top predators, they are especially vulnerable at young ages and during times of sickness. Potential predators include other mountain lions, wolves, and bears (Shivaraju 2003). Adult male mountain lions are known to kill mountain lion kittens and sometimes eat them. In addition, adult female mountain lions are occasionally killed by other mountain lions (Tesky 1995)

Humans: Mountain lions generally avoid humans, but sometimes may attack them. These attacks are usually on small adults and children traveling alone at night. It is possible that they are mistaken for their large ungulate prey. Though mountain lions have these negative impacts for humans they also benefit humans; Their body parts are a source of valuable material to the locals as their fur and body parts are sign of power, they are beneficial for education and research, and they also control pest populations. Mountain lions are important in controlling herbivore populations; they influence competition between herbivores and suppress population sizes. Since they are top predators in the ecosystem, this is important as controlling these populations have important effects on subsequent tropic levels. If followed down the food chain, mountain lions are shown to indirectly affect plant communities.

Threats

Habitat Loss: The loss of mountain lion habitat increases as urban development continues and especially affects mountain lions near areas with rapidly growing human populations. Roads that are built for human needs, and land that is turned into agriculture to also supply human needs, is limiting mountain lion movement throughout their range (Thorne 2006). Fragmented habitats directly cause mountain lion mortalities through vehicle-related deaths, human induced killings due to potential threat, increased transmission of diseases, and other risks. (Thorne 2006)

Hunting pressure: Mountain lions are hunted for sport and also killed when humans feel threatened. Depredation permits are issued to property owners who have experienced damage from a mountain lion. In the past hunting pressures have become so high that humans almost wiped out the entire population of mountain lions in the 1900s. Current hunting pressures are also becoming a main concern as mountain lion populations begin to come in contact with and threat human populations.

Genetic Isolation: This is a problem specifically occurring in the mountain lions in California. Obstacles to genetic interchange in California include the Central Valley, San Francisco Bay and Delta, and the Los Angeles Basin (Ernest 2003) . The low, flat, and highly agricultural Central Valley separates two long, linear mountain chains, and the San Francisco Bay and Delta divide the Coast Ranges. The diverse ecological communities that occupied the Central Valley prior to the mid-1800's have been replaced by agriculture and cities. (Ernest 2003)

Tolerances

Fire: Mountain lions generally avoid areas with fires in progress. Fires generally reduce prey cover needed for mountain lions to hunt and thus makes the habitat unsuitable. Prescribed burning programs designed to improve habitat for large ungulates such as deer and elk, however, also benefit mountain lions. For one of their main prey species such as deer, their abundance is generally more productive and easily accessible following fire. For deer, frequent fires over large areas maintain many stands in an early successional stage and as a result they commonly increase dramatically following forest fire (Tesky 1995).

Limits to Restoration

- The relationship between humans, anthropogenic disturbance, and mountain lions is unclear (Riley 1998). Differing population numbers with respect to humans in the past have varied dramatically over time. (However it is thought that alteration of environmental factors do not affect mountain lion populations over the short term)
- The effects of a fire to mountain lion home ranges are unknown. Differences in temperature, drought, and distribution of prey animals that are observed could account for the new patterns, or could be due to prescribed fires (Tesky 1995).
- It is unsure how to effectively keep mountain lions away from agricultural areas. However it has been suggested that an increase the amount of wild prey in combination with sustainable hunting practices, could reduce levels of livestock predation and simultaneously boost the local game hunting economy.

Management Options

Effective: Prescribed fires have improved winter range for mule and white-tailed deer and are currently being used in Florida panther habitat for fuel reductions to prevent catastrophic wildfires. To provide maximum benefits for deer and other important Florida panther prey species, prescribed fires are conducted on a 2- to 5-year rotation, depending upon fuel type and site conditions. Burn areas are less than 6,177 acres (2,500 ha); annual partial fires or fires every 2 to 5 years are be used when possible to increase habitat heterogeneity (Tesky 1995).

Effective: In the short term, managers most affect population growth of mountain lions by regulating adult survival. Many management practices such as hunting or animal damage control target survival of adults if the goal is to maintain or increase populations (Riley 1998).

Ineffective: Because genetic isolation is a problem, management and conservation efforts constrained by political boundaries have been ineffective (Ernest 2003) A suggested solution is that management incorporate ecosystem considerations for predator and prey habitat, protect connectivity of regions, and prevent further degradation of regions that already have been severely fragmented.

Ineffective: Attempts to address livestock damage have been ineffective. With no solutions, state agencies have made it legal to kill mountaion lions should they be a threat to human populations. A suggested solution is to manage for habitat fragmentation; if there are clear connections between mountain lion and deer habitats, mountain lion populations will have no need to attack livestock, as they prefer large ungulates. In addition, to discourage mountain lions from living close to homes in the area, any pet food and garbage, including fallen fruit tree's or rodents, should be maintained indoors. Water bowls for pets; ponds and pools should also be covered. Any habitat that can be considered shelter should also be removed, this includes boulders, open spaces under porches or under the house.

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Restoration Plan for the Mountain Lion

Goals

In order to maintain mountain lion populations in the Central Valley, short-term goals primarily involve restoring the habitat that they heavily rely on. Mountain lion populations are especially vulnerable to habitat isolation due to the lack of habitat connectivity in the short-term (USFWS 2008). Although the landscape of the Central Valley is unsuitable for the mountain lion, they frequently travel through the area as it separates two of the main mountain ranges that are primary habitat. Approximately 7,812 – 11,719 square miles of habitat would be needed to support an effective population size of 25 individuals, which would hold an actual adult population of 50 - 100 panthers (USFWS 2008). Restoration goals for the mountain lion in the Central Valley are therefore to maintain, restore, and expand the quantity and quality of suitable habitat linkages. Maintaining connections among suitable habitats primarily involves identifying and protecting core areas of high suitability and ensuring that sufficient passages among these habitat patches are protected (Ernest et. al 2003). Restoring habitat linkages between previously fragmented areas is necessary to ensure that passages contain suitable habitat for the mountain lion to travel among. In areas that haven't been destroyed by human influences, the goal is to create additional habitat linkages for the mountain lion to travel upon and protect core areas between them (Ernest et. al 2003). Success of the long-terms goal for maintaining connections for mountain lion populations throughout the Central Valley will be based on the achievement of short- term goals; long- term goals include restoring genetic diversity of the mountain lion and maintaining at least 90% of the current genetic diversity for 100 years or longer (USFWS 2008).

Consideration of goals

A restoration plan focused on a localized area like the Central Valley is important in areas where human influences are limiting mountain lion movement (Ernest et. al 2003). Since a majority of the land in the Central Valley has been turned into agriculture and cities, restoring fragmented areas within the mountain lions' range is critical for their success (Ernest et. al 2003). Mountain lions require large continuous habitat free from human populations in order to maintain their populations (Ernest et. al 2003). Moving through the Central Valley to habitats that are more suitable, however, may require that mountain lions pass through busy roads and urbanization. Furthermore, fragmented patches sometimes leave mountain lion populations in isolated patches surrounded by areas containing unsuitable habitat. In order to reduce these habitat related threats, restoring habitat linkages is imperative. Identifying the most suitable core areas away from humans and with ideal cover for the mountain lion, will work to reduce the frequency of cougar-human interactions and thus reducing the number of human related deaths. The habitat chosen for habitat connections and core areas should provide at least 2 feet of cover for food and shelter and area to support each "metapopulation at a minimum density of 2 to 5 animals per 100 square miles (USFWS 2008)." This includes riparian vegetation such as Fremont Cottonwood, and areas that provide steep and rocky habitat (Tesky 1995).

In addition to reducing the number of cougar-human interactions, habitat linkages will facilitate natural gene flow between populations, reducing the threat for inbreeding depression between individuals. The Fish and Wildlife service stated that in a species of puma in Florida, the long-term persistence of the panther depended on populations that are spatially separated and "able to fluctuate independently from one another in response to environmental disturbances (USFWS 2008)." Choosing a habitat linkage restoration design will also, therefore, likely help long term-persistence of the mountain lion.

Restoration Plan

Method: This restoration plan entails selecting specific locations that contain elements important for mountain lion survival and maintaining connections between them. Three primary core areas in the Central Valley that are of highest value to the mountain lion include the Santa Cruz Mountains, the northern Inner Coast Range, and the southern Inner Coast Range (Ernest et al. 2003). These core areas were evaluated for containing high quality and high suitability for the mountain lion. Habitats of high quality and suitability contain characteristics of favorable habitat for the species as they include areas with low road density, high deer density, and high riparian vegetation cover, integrate least distance from other core areas, and examine how efficiently the area can be connected to others (Ernest et al. 2003). These habitats were determined for its interconnectedness, to ensure that these are the best areas to maintain connections among and were identified to contain low resistance to animal movement and away from large areas containing human populations or agricultural areas (Ernest et. al 2003). The resistance of a corridor is evaluated by a balance of multiple factors including the least distance to core areas, fewest roads, least human development, roads, and agriculture (Ernest et. al 2003). Habitat suitability for any location may be determined using habitat suitability rankings from the California Wildlife Habitat Relationship (CWHR), which can identify suitable habitat for the mountain lion. The total area in the Central Valley containing high quality mountain lion habitat for habitat linkages is 2,596 km2 (Ernest et. al 2003). The primary goal in the Central Valley is to maintain linkages to surrounding areas. The amount of habitat selected for linakge is similar to the amount implemented in a management plan for pumas in Florida (USFWS 2008).

Since areas near the Santa Cruz Mountains are being rapidly developed and interfering with the connections to and from this core, areas within cores also need to be connected by establishment of wildlife underpasses or roads. Special underpasses were created for wildlife in Florida and where successful in improving conditions for mountain lions, and helped lead to the recovery of the species (USFWS 2008). Underpasses need to be created in areas that have high mountain lion movement, which are characterized by areas with adequate cover, least human activity, and high prey abundance. In the long term, more wildlife underpasses can be developed as funding becomes available. Until these can be established, durable fencing may be put up along roads in order to avoid vehicular related deaths. Fencing would need to be at least 45 feet high and made of strong wood or thick wires. In Florida, panther-vehicle collisions were minimized my installing fencing along major highways (USFWS 2008). For long-term maintenance to be possible, it is important to develop wildlife underpasses within a reasonably short time scale since the area runs a high risk of isolation due to lack of connections; as suggested by Carroll et al (2004), the persistence of mountain lions can be largely dependent on preserving connectivity in landscapes before they get heavily degraded.

Much of the northern Coast Ranges is primarily on private lands. In order to protect these areas, gaining the proper rights (conservation easements) for private lands can be obtained in order to prevent any urbanization in the area to further effect mountain lion populations (Ernest et. al 2003). The linkages between core zones are of highest conservation priority because these are likely to be lost quicker than the areas within the cores themselves (Ernest et. al 2003). Protecting large areas within the identified core areas that are in public lands is likely economically infeasible. Conservation easements in core areas would be the most ideal situation for protecting these lands and maintaining the high quality panther habitat that is currently in these areas (Ernest et al. 2003).

In addition to gaining conservation easements for the core areas located on public lands, long- term protection of core areas and linkages is needed. Protection of these core areas can be implemented by reducing nighttime speed limits, and ensuring new roads are not built in these areas (USFWS 2008). Reduction of nighttime speed limits have been implemented in Florida at 45 mph but have not been lowered enough to reduce puma deaths, and therefore adjustments in speed limits can be tested in the Central Valley until an ideal speed limit is achieved. When new roads are built, government intervention needs to require that they be built away from mountain lion habitats. After 5 years of monitoring, areas that have had high mountain lion activity can be used to determine favorable locations for building wildlife underpasses and crossings (USFWS 2008).

Monitoring: Radio-collared panthers should be monitored by airplane surveillance about three times per week in order to "determine location, habitat use, movements, interactions, births, and deaths (USFWS 2008)." In the case that mountain lion populations cannot be radio- collared, populations need to be monitored at least 5 times a week. Monitoring will be testing the effectiveness of this plan by testing genetic diversity of the mountain lion. Monitoring mountain lion populations in the area includes enforcing federal and state laws on any mountain lion killings in the area that may occur. This also includes monitoring the physical characteristics of mountain lion populations in attempt to prevent inbreeding depression. Increased connectivity between habitats over time should slowly restore the genetic diversity. The goal that needs to be achieved in this restoration is the same of that in the Florida puma populations, which is to "retain 90% of the current genetic diversity for 100 years or longer (USFWS 2008)." Monitoring should include the detection for any diseases in the wildlife populations in and surrounding the area and the implementation of eradication methods for the event that this may occur. In addition, the status of deer populations in panther habitat needs to be assessed and monitored to ensure that populations remain stable and sufficient for mountain lion populations in the area. The amount of deer needed in the area will be determined by the size of the mountain lion population; each family of mountain lions can survive on up to two deer per week.

Potential problems: When implementing reduced speed limits in Florida, there was an initial regulation problem of proper enforcement of these limits and obedience by the public. If this problem arises, additional officers will be hired to enforce speed limits in the area until the risks associated with vehicle related deaths of pumas are understood in the community. A big factor in this issue is education and outreach to the populations surrounding core areas, thus educational brochures will be made and distributed throughout these surrounding areas. Another major problem includes the cost of buidling wildlife crossings and to establish connections between core areas. If this becomes a main issue, agencies that are building in areas that affect the mountain lion will need to double the amount of offset that their impacts have to mountain lion populations. This will allow the government to build crossings in new areas that historically had no mountain lion protection (USFWS 2008).

Risks and Uncertainties: When creating restoration plants that are focused on an entire large area like the Central Valley, the biggest implication is the lack of detail at particular sites that may be missed but important to the mountain lion survival (Ernest et. al 2003). Habitat linkage plans are difficult to manage due to the high risks involved with linkage vulnerability. It is very difficult to protect over long periods of time, and very costly to establish new habitat linkages, and they can be destroyed with any development along the entire linkage (Ernest et. al 2003). A possible implication of this plan may include the effectiveness of the minimum core area size recommended. The are chosen for habitat linkages, is 2,596 km2, was determined through mountain lion model testing, but has not been implemented in any location and therefore cannot ensure the long-term viability of the mountain lion with certainty (Ernest et. al 2003). In addition, it is uncertain how mountain lion populations will respond to environmental and demographic stochastic, or to catastrophic events (USFWS 2008). Because it is unlikely that one of these events would wipe out separated populations, it is important to implement this restoration plan in a reasonable short time scale (USFWS 2008).

Research Questions: In order to improve this restoration plan, camera stations should be established in some of the core areas that were mentioned as having high quality mountain lion habitat in order to establish a population trend. This will also aid monitoring efforts to test the effectiveness of this plan by capturing and sampling mountain lion populations for their genetic diversity. In addition, specific sizes for buffers around core areas need to be tested and implemented in the five core areas (USFWS 2008).

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Julia Furstenau

The Bobcat (*Lynx rufus*)

Background and justification

The bobcat (*Lynx rufus*) is a carnivore that occurs all over the United States. Bobcat populations are quite stable or increasing in most of the states in the United States and are also stable in California (Robert & Crimmins 2010). The California Department of Fish and Game protects the bobcat as a furbearer. The harvest of bobcats is regulated and the decreased demand for furs led to a strong reduction of harvest (Harris et al. 1997). However, bobcats are reclusive, occur in low densities as top predators and have large home ranges. Therefore, bobcat populations are very vulnerable to fragmentation and land conversion (Donovan et al. 2011) and are limited in agricultural lands in the Midwest of the United States (Lovallo 2001). Especially the Central Valley has lost huge areas of native habitat. Agricultural area increased dramatically over the last 100 years, while grassland, riparian areas and wetlands decreased (Geographic Information Center 2003). Since bobcats occupy the top of the food chain, they play an important role in controlling the abundance of their prey, maintaining the prey population in carrying capacity of the environment. Consequently, the pressure on vegetation is limited and biodiversity is enhanced (Roberts & Crimmins 2010). As a charismatic predator, bobcats also have an emotional conservation value for the public (Donovan et al. 2011).

Literature review

Characteristics of bobcats

<u>Reproduction</u>

- Theoretically, female bobcats are able to reproduce at 9 to 12 months of age. However, due to the lack of hormonal secretions at their first year to maintain pregnancy (Lovallo 2001), breeding generally occurs at their second summer (July – August) (Winegarner & Winegarner 1982). Mating happens mostly during February and March. The time also depends on prey abundance (Lovallo 2001)
- Gestation takes from 63 to 70 days (Lovallo 2001)
- Bobcats give birth to one litter per year, except if a litter is lost shortly after birth. Then the female can give birth to a second, probably in late summer before the breeding season ends (Lovallo 2001). Generally, the litter consists of 2-3 kittens (Tesky 1995).
- Kittens are born in caves or similar sites. While they are rearing, the females move their denning sites many times and normally don`t reuse them, only if the sites are rare in the area (Lovallo 2001)
- When kittens are born they are blind until 9 to 18 days. They remain in the cave until 33-42 days, and afterwards they start to feed on solid food. At the age of 3 months, young bobcats start to accompany their mothers. They remain in the area where they

were born for several months, until they disperse. Juvenile bobcats disperse mostly when their mother will give birth to the litters of the next year (Lovallo 2001).

Food habits

- Bobcats hunt solitarily (Riley 1999)
- Bobcats are generalist carnivores and consequently have a diverse prey. Their preferred prey consists of lagomorphs (rabbits, hares, pikas), rodents such as rats and voles, deer and birds. Females feed on smaller prey than males. There is a small chance that bobcats feed on livestock such as sheep, goats and chicken (Lovallo 2001)
- Bobcats usually eat 0.9-1.4 kg of meat per day (National Trappers Association, accessed 2014)

Space use

- Home ranges for males are approximately 70.9 km^2 and for females 22,9 km^2 Males use a larger home range to increase the chance of mating (Donovan et al. 2011). Home ranges are larger when prey abundance is low (Lovallo 2001).
- Home ranges of bobcats generally do not overlap as they are territorial, females more than males (Riley 1999). However, if there is less suitable habitat with limited cover and low prey occurrence, intrasexual home ranges might overlap (Lovallo 2001). Males are more tolerant of overlap than females, and male home ranges may overlap those of several females (Riley 2006).
- Bobcat males move approximately 1.8 km to 4.5 km per day and females 1.2 km. The distances depend on many biotic and abiotic conditions such as regions, individuals and weather (Lovallo 2001).

Habitat preference and requirements

- Many different habitat types are used by bobcats as areas to breed, hunt and refuge, including grassland, forests and woodlands (Tucker et al. 2008), chaparral, scrub and rock areas (Donovan et al. 2011)
- When prey abundance is high, bobcats prefer more closed habitats like forests and areas with dense understory and much shrub cover (Tucker et al. 2008). When prey abundance is low, bobcats forage in habitats that also have some open areas where prey is more visible or in some regions more abundant, such as edge habitats and forest openings and grassland (Rolley & Warde 1985).
- Bobcats are most active during dawn and dusk. During the day they use to rest and during the night they generally forage and sometimes rest. At sunset bobcats travel to foraging areas and at sunrise they travel to resting areas (Tigas et al. 2002). Bobcats often prefer to forage in edge habitats and open or semiopen areas such as grasslands and to rest they prefer forests and rocky areas and areas with bushes, brushes and hollow trees (Tesky 1995).
- Due to the large home ranges of bobcats, a connectivity of suitable habitat with enough cover should be provided (Tigas et al. 2002)

- Cover sites have to be present, preferably ≥52% of obscurity in a habitat area, for protection from abiotic conditions such as severe weather, resting and denning and for escape from human activity/disturbances. Moreover, habitats with some cover areas use to have larger prey densities and enhance ambushing hunting strategies (Lovallo 2001). Especially females need them to care for their kitten (Riley et al. 2003).

Threats

- Roads not only cause habitat fragmentation, they also cause a high mortality rate due to vehicle collisions (Tigas et al. 2002)
- Habitat loss and fragmentation mainly caused by urbanization are a major threat to bobcat requirements of large areas (Donovan et al. 2011)
- Domestic dogs can cause mortalities (Lovallo 2001)
- There is a possibility that bobcats are illegally harvested (Blankenship et al. 2006)

Potential management actions

Improve habitat

- Corridors and patches of trees of different heights and shrubs may provide the connectivity between fragments (Tigas et al. 2002)
- Restore riparian areas, woodlands and scrublands to create different states of succession, which provide cover (Litvaitis et al. 2006), and implement sustainable forest management to create forest patches (Interagency Lynx Biology Team 2013)
- A nature reserve should be as large as possible; the ideal would be to have different kinds of habitat in the reserve, or at least a mosaic landscape. Edge effects of the reserve should be minimized by having vegetation area (shrubs, trees) at the surroundings of the reserve and not an abrupt edge with urban areas (Riley 1999).
- Focus on habitat suitability for reproduction by enhancing brush and tree cover and dead trees that might provide dens, and monitor location of females to increase the chance of reproduction (Donovan et al. 2011)

Further management

- Culverts, green bridges and fences along roads to provide safer crossings over/under roads. The use of culverts depends among other things on adequate vegetation near them, therefore shrubs should be planted at their sides to attract bobcats and provide cover (Cain et al. 2003). Also, the degree of openness of the culvert has to be planned (Tigas et al. 2002). Fences are expensive and may be restricted to areas along the road that have higher chances to be crossed by bobcats (Cain et al. 2003)
- Maintenance of a sustainable harvest rate (20%) (Roberts & Crimmins 2010)

- Management of livestock grazing to assure that small prey such as voles, which avoid grazing areas, are sufficiently abundant (Riley 1999) and also deer, mice and cottonrats may avoid grazed areas (Rolley & Warde 1985).
- Monitoring bobcat populations in the Central Valley to understand movement patterns, distribution and relative abundance (Roberts & Crimmins 2010)

Gaps in knowledge

- Bobcat populations and their demographic rates in the Central Valley
- Reintroducing bobcats and its success

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A. Goals

Restore and improve habitat for bobcat population stability

Bobcats need a diverse mosaic habitat with different successional states of hardwood forest, for example oak and pine regeneration areas, and forest openings (Rolley & Warne 1985). ≥52% in a habitat area should be vegetation that provides cover, and as bobcats use a high variety of habitat, it can be shrubs, trees, brush and rocks. Cover provides protection from severe weather and human disturbances, are used for resting and reproduction sites and enhance ambushing hunting strategies (Lovallo 2001). Although bobcats prefer areas with much vegetation cover, open areas such as forest openings and edges, wetlands and grasslands often have a high prey abundance and also facilitate hunting (Rolley & Warne 1985, Tesky 1995). In the Central Valley, the most important habitat types for bobcats, which provide both cover and also open areas, are valley foothill hardwood, riparian forests, grasslands, chaparral and scrub areas (Geographic Information Center 2003). As it is impossible to restore everything and as bobcats are not very selective regarding habitat types, this goal will focus on riparian forests and chaparral areas, because these habitat types hold high wildlife diversity and have been reduced and fragmented to a high extent in the Central Valley (Alpert et al. 1999, Geographic Information Center 2003). To not neglect the other important habitat types, a connectivity network throughout the Central Valley should be aimed, but this will be discussed in the second goal. The restoration plan for riparian forest may serve as a reference for restoring other types of forests, of course with different species composition and site conditions.

Fire management at chaparral areas can be implemented, to promote areas with half burned and half unburned patches to restore the natural disturbance regime and promote prey abundances such as mice and Cotton rats (Longhurst 1978, Tesky 1995).

Forest clear cutting practices to enhance mosaic landscapes would also favor bobcat habitat (Rhodes & Mitchener 2009). Restoration of native habitat and creating mosaic landscapes increase small mammals like cotton rats, mice and rabbits. Rolley & Warde (1985) evaluated prey density in 5 different forest cover types. Only 12% of their census route passed ungrazed clear cuts and 42% of all observed rodents were in ungrazed clear cuts.

Restoring and managing riparian forests and woodland should be long-term, about 6-10 years including monitoring and planting time, as the recover of forests is a long process. Restoration sites have to be selected carefully. For this, space use of bobcats in the Central Valley has to be monitored. Because of the large home ranges of bobcats, the long-term restoration of forests should not be too small-scale.

Create connectivity of habitat patches and minimize bobcat mortalities caused by traffic

Landscape fragmentation leaves patches that may not provide enough habitat for bobcats, especially because of their large home ranges, and therefore may influence population viability. It is important to create safe corridors that help bobcats move between fragments. They encourage bobcats to move, enhancing gene flow, and also decrease the chance of bobcats being killed by traffic on their way (Tigas et al. 2002). The corridors should consist of shrubs and trees of different heights to offer enough cover and also prey occurrence and to create a soft transition between the corridor and the surrounding areas. The vegetation in corridors depend on the regions they are built, they can for example consist of pine and oak trees or chaparral shrubs. There is no guideline that says how wide is wide enough, but the corridor should at least be 100 m wide. The distance between the natural areas that are to be connected determine the length of the corridor. Corridors should not be too long and narrow, otherwise, there is a great chance that bobcats do not use them to move between patches because of their sensitivity to human disturbances. (Tigas et al. 2002, Fleury & Brown 1997). When roads are barriers to the movement, culverts and crossings provide safe passages (Tigas et al. 2002). Again, appropriate vegetation near them attracts bobcats and increases their use for crossing roads. However, bobcats may use the culverts for other purposes like resting and thermoregulation. Thus, it also may increase the probability of bobcats being near traffic, increasing the chance of road mortalities (Cain et al. 2003).

The goal should be aimed to be a long-term restoration, as the establishment of vegetation to create corridors takes some time and always can be improved. Moreover, connectivity is also beneficial for many other species (Fleury & Brown 1997).

The spatial scale of establishing corridors is hard to determine and requires monitoring of bobcat populations in the Central Valley to determine space use, preferred habitat patches and high-impact-highways and crossing points of bobcats (Tigas et al. 2002).

B. Restoration plan

Restore and improve habitat for bobcat population stability

- **Restore riparian forest**

To restore riparian forests, many factors have to be analyzed at the restoration site. A site consists of patches with different soil conditions and thus different plant species are suited (see below) (Alpert et al. 1999). The soil texture, that is proportion of gravel, sand, silt, and clay, should be analyzed (Griggs 2009) to determine suitable vegetation. Willows (*Salix* spp.) and cottonwoods (*Populus fremontii*) require water table and should be planted at sandy soils with lower depth to ground water. Willows require a maximum of 3 meters depth and cottonwoods 6 meters. Oaks and elderberries (*Sambucus mexicana*) may be planted at silty-loam soils with a higher depth to ground water (ca 10 meters) and do not require to reach the water table (Griggs 2009). The frequency of flooding, different weed communities, previous land use and topography are also very important. (Griggs & Golet 2002). The restoration site should be adjacent to an existing riparian forest in order to facilitate restoration by dispersal. In the Sacramento Valley, the following native species should be planted along large rivers: box elder *(Acer negundo* var. *californicum*), Oregon ash (*Fraxinus latifolia),* western sycamore *(Platanus racemosa),* Fremont cottonwood *(Populus fremontii),* valley oak *(Quercus lobata*), California rose (*Rosa californica)*, sandbar willow *(Salix exigua)*, Goodding's willow *(Salix gooddingii*), arroyo willow *(Salix lasiolepis)*, and blue elderberry *(Sambucus mexicana*). The area planted at the restoration site can be, for example, 20 ha (Alpert et al. 1999). To enhance different vegetation structures that benefit foraging and resting of bobcats, one could design openings, tree groves and shrub thickets. Seeds and stem-cuttings should be collected from local sources to make sure that the species are adapted to the local site conditions. There are different methods of site preparation before planting such as discing, burning, removing of stumps and also different weed control methods like herbicides (monthly spraying) and mulching, which are expensive. Removing weeds by discing and mowing is cheaper. Weeds can overwhelm native species, then it becomes very expensive and hard to remove them. It is also critical to remove invasive species. For Fremont cottonwood and willow species it is advantageous to do stem cutting and for oaks to plant seeds. They should be collected in fall and planted in winter. There is a risk of seeds being washed away or not being able to compete with weeds (Griggs 2009). The plants may be planted in rows that are 4 meters apart. Fertilizers may not be necessary, as riparian soils are generally very nutrient rich. Irrigation methods depend on drainage velocity and thus on soil texture. The plants can be irrigated for the first three growing seasons. On sandy soils sprinklers are suited and on silt and clay soils flood-furrow (Griggs 2009). If the irrigation system fails or it is too expensive, than coarse and very sandy soils should be avoided for planting. After planting, a protection from grazing is critical. The site should be monitored for 4 years, recording height of each species (Alpert et al. 1999). Different growing success of the plants can be favorable for bobcat populations and their prey, creating a mosaic of different successional states (Griggs 2009).

- **Fire management in chaparral areas**

Bobcats prefer to forage in young 1-3 year old burned chaparral than in older chaparral (Longhurst 1978). This is due to higher prey abundance, when more food becomes available, and a higher facility to hunt in more open areas. Cotton rats and Cottontail rabbits are both important bobcat prey and they are abundant and gain weight when vegetation grows after a fire (Tesky 1995). Fire sites should be burned at 3-year intervals in winter when soil moisture is than in the rest of the year. Consequently, fires will burn at a relatively low intensity and are easier to control. However, too low intensity could impede heat-requiring seeds to germinate. Such fires also have the benefit that chaparral areas become less flammable in hot summers and thus the chance of very high intensity fires that could be dangerous to human settlement can be decreased (Beyers & Wakeman 1997).

- **Forest management**

Prey abundance can be increased by clearcutting and planting small patches of forests. Clearcuts provides area for natural regeneration and increase understory vegetation and small mammals prefer these areas to feed. However, relatively small areas, around 30 ha (also depending on the size of forested area) should be cut to provide better habitat interspersion (Rolley & Warde 1985). If the clearcut is too large, it could modify the site conditions like microclimate and decrease species diversity (Tesky 1995). Moreover, there still have to be enough cover for bobcats. It is important to leave den trees for cavities, preferably 4 den trees per acre, food trees such as oaks and standing dead trees (Rhodes & Mitchener 2009). To delay canopy closure the space between planting rows should be 3 meters and the forest may also be thinned (Tesky 1995).

Create connectivity of habitat patches and minimize bobcat mortalities caused by traffic

- **Corridors**

First, one should create a map of the Central Valley with the patches and also protected areas used by bobcats and find ways to connect them. Corridors should be oriented perpendicular to patches and they should have a constant width. An example of an effective corridor that runs through human developed area is 150 m wide and it may be 400 m long (Fleury & Brown 1997). Shrubs of different heights and deciduous and coniferous trees can be planted, depending on the location of the corridor and the site conditions. Rocks and dead trees can enhance the structural diversity for protection from human disturbances and weather. The width and length of corridors depend on matrix factors such as surrounding human land use. The width should be wider than 2 meters (Fleury & Brown 1997).

- **Culverts and crossings**

Vegetation preferred by bobcats that provide cover for them, like thornscrub, should be planted on crossings and near culverts to attract them and avoid the dangerous crossing of roads elsewhere. However, this attraction of bobcats may increase the chance of interaction between bobcats and traffic and consequently may lead to a higher mortality. To enhance the use of culverts, a fenceof 1.5 m height should be established at both ends of the culvert and along 100 meters of the road at both sides of the culvert opening. Longer fencing might be too expensive. Bobcats may use existing culverts constructed for other purposes. More research is required to plan culvert dimensions, but the width may be ca. 2 x 2 meters. Culverts must provide water drainage and enough air circulation. During hot summer days, bobcats like to use cool and dark culverts for resting, therefore culverts should not be too open. A long-term maintenance program is necessary (Cain et al. 2003).

Monitoring

Before the implementation of the restoration goals, bobcats should be monitored monthly for 1-2 years throughout the Central Valley, to detect behavior, spatial use, density and relative/total abundance. After the implementation, bobcats should still be monitored at a long-term scale, e.g. twice per year for 10 years, to see the impacts of the restoration process on bobcat populations and see how the plan can be improved (Lovallo 2001). Monitoring should occur first in June, when bobcat kittens are usually born (Tesky 1995) to evaluate reproduction success and dispersal, and second in December/January, when winter conditions make foraging harder for bobcats, to evaluate bobcat fitness.

A good method for studying the behavior of carnivores is radio telemetry. Bobcats are captured in live traps with live chicken to attract them. They have to be checked each day. Trapped bobcats are sedated, fixed with a radio collar and released when the sedation effect is gone. Traps should be placed in shaded areas and widely distributed at the restoration site (Cain et al. 2003). However, the method is time intensive and expensive. Also, the radio collar may have an impact on bobcats. An alternative is using automatic cameras. Camera stations are installed, e.g. 1 station/130 ha. Cameras can be active for a couple of days, depending on the batteries. Bobcats can be identified by their fur patterns, thus individual abundance estimates are possible and it is non-invasive. However, areas with low bobcat occurrence can be a problem, leading to very low numbers of photos (Heilbrun et al. 2006).

If the photos reveal a bobcat density of e.g. 5 per 100 km^2, it would be a low density and 48 per 100 km^2 a high density (Heilbrun et al. 2006, Jones & Smith 1997). The results may be related to vegetation types – low densities in open areas, high densities in dense vegetation cover areas –and the occurrence of travel paths used by bobcats. Also other influences such as overlap with coyote territories or human disturbances can be the reason for different densities (Larrucea et al. 2007).

Further research and improvement

The impacts of harvest management strategies and harvest rate in the Central Valley may be evaluated to gain more information of bobcat population stability. Also, interactions with other predators, like coyotes and Mountain Lions, can be interesting (Lovallo 2001).

Oak woodlands provide high biodiversity and are also a very valuable habitat to be restored (Bernhardt & Swiecki 2001).

A financial plan should be developed and the knowledge of the situation of land ownership where restoration takes place is important to being able to implement the goals.

Moreover, public awareness has to be improved, for example by public presentations about bobcat populations and their value and workshops (Lovallo 2001).

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Introduced/invasive animals

Feral cats/ house cats (*Felis catus)*Arielle Crews
Arielle Crews:

Feral Cat

CLASSIFICATION
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Carnivora
Family: Felidae
Genus: *Felis*.
Species: *F. catus*
(USDA 2012)

Background and Justification

A pest is defined as an organism that is observed to be harmful to a person's health, the natural ecosystems or the economy (Southeast Missouri State University, 2014). With this definition in mind, the general public automatically has images of cockroaches, mice, rats, and other unsightly creatures pop into their heads. In general, control mechanisms of such pests is widely accepted and un-debated. However, the issue is not as black and white when the animal that is causing the harm is the species *Felis silvestris catus*, the common cat. Today, our view of the common cat revolves around images of fluffy kittens wearing funny outfits on YouTube and singing in Meow Mix commercials. After all, people are raised to see animals of domestication as their friends, not their enemies. This is why it may be so difficult to convince people of the latter in terms of feral populations.

By definition, feral cat colonies are not only considered a pest species but an invasive one as well. The domestic cat was brought to the United States in the 19th century by European settlers. Since then, the population of this generalist species has sky rocketed in the United States into the estimated range of 70 to 100 million (Jessup 2004, Mott 2004). As with many invasive species, the escalating number of feral cat populations have taken a toll on the ecosystems through predation, competition, and disease.

<u>Feral Cat Reproduction</u>

Female cats reach sexual maturity at the age of 10-12 months and reproduce twice per year (Jones, 1977). Litters of 4.4 kittens are produced in spring and in summer or early autumn (Jones, 1982). One study concluded that in 7 years, a single female cat and her young can produce 420,000 cats (Webb). Reproduction rates decrease with food availability especially in winter months (Jones 1977).

<u>Feral Cat Predation</u>

One of the main direct impacts feral cats have on the natural ecosystem is the effects of predation. Feral cats prey upon birds, herpetofauna, and small malls (Crooks and Soule 1999, Kays and DeWan 2004, Lepczyk et al. 2004, Nogales et al. 2004, Dauphine and Cooper 2009). With the base knowledge of their diet and rate of population growth, it can be reasoned that feral cats are directly tied to a large percentage of global extinction (Nogales et al. 2004). In feral cats, it has been estimated that 90% of their diet consists of wild animals. Of which, 70% are small mammals and 20% pertains to birds (Fitzgerald, 1988). To apply the ramifications of these numbers to a real world situation, an ornithologist of the University of Wisconsin estimated that around 39 million songbirds are killed each year by rural cats in Wisconsin alone (Gray, 1999).

These numbers can be disastrous for ecosystems, especially in terms of endemic species and biodiversity. It has been found that feral cats have depleted several endemic species of mice and woodrats to near extinction (Humphrey, 1981). Other animals that are at risk due to cat predation include Least Terns (*Sternula antillarum*), Piping Plovers (*Charadrius melodus*), Loggerhead Shrikes (*Lanius ludovicianus*), and Marsh Rabbits (*Sylvilagus palustris*) (Fitzgerald, 1988).

Feral Cat Competition

Feral cat population densities exceed those of like-size predators by a factor of 10 – 100 (Liberg et al 2000). This not only amplifies predation but also adds a significant level of competition for other predators. In many cases, the high abundance of feral cats greatly impacts the health of the environment by simply outcompeting native species(Crooks and Soule 1999). Competition between species can be especially influential when resources are limiting (Glen and Dickman 2005, 2008). Resources include both prey and habitat availability. It is hypothesized that feral cats add a high level of competition for other species in terms of prey availability. However, accurately assessing this quantitative impact is extremely difficult (Medina, 2014). A study in 2007 attempted to analyze the predator/prey interaction between feral cats and an endemic island fox (*Urocyon littoralis clementae*) (Phillips, 2007). It was found that although the two predators have a considerable amount of prey overlap they are both able to coexist (Phillips, 2007).

Apex predators' aside, it is also thought that feral cat trophic competition can occur among reptiles and birds (Medina, 2014). This correlation has been shown in multiple studies. In northwest Mexico, feral cats compete for food resources with an endemic kingsnake *(Lampropeltis zonata herrerae)* by predating lizards and skinks (Donlan, 2000). In Australia, trophic competition occurred between an endemic kite (*Elanus scriptus*) (Pavey, 2008) and on the Niau Island between an endangered kingfisher (Todiramphus gambieri) (Zarzoso-Lacoste, 2013).

While each of these studies provided evidence of negative effects feral cats impose, they did not address specific impacts on native species due to food competition (Medina, 2014). It is possible that stress on native populations is due to other factors such as habitat limitation and human interference (Glen and Dickman, 2005). More studies are required in order to solidify a factual basis of trophic competition between native and invasive species.

There is often a high overlap of spatial use between feral cats and native species. Due to human settlements, cats can strongly compete for habitat and spread rapidly from their introduction site (Medina and Nogales, 2007). In Japan an Iriomote cat (*Prionailurus bengalensis iriomotensis*) and a marsupial in Australia are at the verge of extinction due to range restrictions caused by feral cat presence (Watanabe, 2003 and Dickman, 1996).

Feral Cat Disease

Feral cats carry and suffer from bacterial, viral and parasitic diseases (Kitchener 1991). Some of these disease can affect humans (Robertson 2008), livestock and wild carnivores (Macdonald et al. 2000). These diseases include: feline leukemia (FeLV), feline panleukopenia Virus, feline infectious peritonitis (FIP), feline immunodeficiency virus (FIV) and taxoplasmosis (Medina, 2014).

FeLV is the leading cause of death for feral cats and can be found worldwide (Lopez, 2009). FeLV comprises a cat's immune system and can lead to a variety of complications such as blood disorders and infections (Fremont, 1998*)*. The disease has infected and spread to populations of mountain lions (*Puma concolor*) , wild cats (*Felis silvestris*), and the endangered Florida panthers (*Puma concolor coryi*) (Roelke, 1993).
Another disease of concern is toxoplasmosis. Toxoplasmosis is caused by the protozoan parasite, *Toxoplasma gondii*. Cats are the main host for the parasite but it can affect a large array of animals, including humans (VanWormer, 2013). Cats themselves,usually become immune to the disease through exposure but they will continue to carry the parasite in their systems. Parasites will reproduce inside the cat and produce oocysts which are then excreted in the feces. The first time cats are infected with the parasite they may shed more than 100 million oocysts in their feces (VanWormer, 2013). Unfortunately, cats have the tendency to bury their feces in shady areas. This action promotes the survival of the parasite and in the right conditions, the soil may remain infected for up to 2 years (Yilmaz, 1972).
Due to agricultural runoff, sewage systems, stormwater drainage, and feral cats along coastlines, the parasite has been found in marine and freshwater systems (VanWormer, 2013). Filter feeders, such as mussels accumulate the parasite in concentrated amounts within their tissues (Miller, 2008). The ramifications of this may be monumental for populations of native wildlife such as the California sea otter (*Enhydra lutris nereis*). Mussels are a large staple in diet of sea otters (Miller, 2008). Research has discovered that seventeen percent of sea otters die from brain disease caused by *Toxoplasma gondii* (VanWormer, 2013). Sea otter populations are considered to be a keystone species due to their large impact on the ecosystems they live in. With the degradation of the otter populations, environmental communities such as kelp forests may collapse. .

<u>Feral Cat Quality of Life</u>

Containment of feral cat populations is not only beneficial for the environment but for feral cats themselves. For feral cats, the quality of life among populations is important to consider. The death rate among colonies is considerably high and the life expectancy of a feral cat which survives as a kitten is less than two years (LaCroix, 2006). The short lifespan is due to the challenges the animals must face such as diseases and physical injury.
Unfortunately, feral cat health is seen more as a animal welfare issue than environmental. In the United States it is common practice to establish supplemental feeding stations, water sources, and shelter for feral cat populations. Doing so is thought to limit predation due to lack of hunger. Evidence suggests that hunting for cats is strictly instinct and providing food subsidies does not curb predation (Liberg 1984, Warner 1985). Instead, the common practice encourages populations to grow to high levels which may even lead to hyperpredation (Tennant, 2008). Providing feral cats with the basic needs of life has allowed them to reach densities 100 times higher than those of their native counterparts (Coleman, 1992). Supplemental feeding promotes continued suffering of feral cat and increases deleterious effects they impose on wildlife. In order to successfully implicate management strategies the general public needs to be educated on the feral cat's negative impact on the environment. Those concerned with animal welfare of feral cats and native populations should focus efforts on controlling feral cat populations.

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Marseille University, Marseille, France

Large Scale management of feral cats (*Felis catus*) in Central Valley, California

Goals:

Short term Goals

- Determine the extent of invasion in terms of feral cat population size
- Stabilize feral cat populations

Direct Long term Goals

- Educate the public on the dangers feral cats impose on the environment
- Follow eradication with trap-vasectomy-hysterectomy-release

Indirect Long term Goals

- Increase biodiversity, improve water quality, provide habitat, and preserve species.

All of these goals are of local spatial scale.

Determining Population size

Due to feral cats behavioral plasticity their home ranges can be very broad. Thus, their populations have the potential to affect riparian, upland, and wetland species directly through predation and indirectly through competition and disease. Do to their mass distribution there are multiple goals to address when planning the restoration of areas invaded by feral cats. Before mechanism of population control can be discussed, it is critical to measure the magnitude of invasion. Doing so will determine the method of control and predict the success of management techniques (Bengsen, 2011). Many organizations have committed to the goal of managing feral cat populations, however, there remains a high degree of uncertainty about the ability to estimate feral cat abundance (Gormley, 2010).

In order to o determine the best available control technique to implement, this ambiguity must be solved. To minimize the use of resources, camera-trapping methods can be used to identify individual feral cats and population size can be estimated through a robust capture-mark-recapture model (Bengsen, 2011).

Abundance estimates should be conducted during pre-restoration as well as post-restoration. It is imperative to monitoring feral cat populations in order to prevent re-infestation. A combination of the use of heat-in-motion activated digital cameras and statistical modeling can best assess changes in feral cat population over time and to assess the success of feral cat control operations (Gormley, 2010).

Mechanisms of Control

Feral cats are an introduced, invasive species that are imposing a serious stress on native populations. They have been identified as one of the world's most invasive species and are widely considered to be the leading cause of species endangerment in the United States (Loyd, 2010). The diet of feral cats is extremely plastic which allows them to consume a large variety of birds and small mammals. Feral cats kill millions of birds a year (Coleman, 1996) making predation the strongest effect cats impose upon wildlife. However other deleterious impacts include competition, hybridization, disease transmission, ecological process alteration, and behavioral change (Felix, 2014). These factors impose a major threat to terrestrial biodiversity (Jessop, 2013) from upland to riparian habitat. To minimize deleterious impacts, the major goal of my project is to stabilize feral cat colonies and maximize native biodiversity. To achieve this, three different mechanisms of feral cat population control can be utilized. The control mechanism are the following: trap-euthanize, trap-neuter-release, and trap-vasectomy-hysterectomy-release. Each mechanism has a separate set of interactions and trade-offs.

1. ***Trap-Euthanize***

If the population exceeds 50 cats, trap-euthanize would be an optimal management decision (Lloyd, 2010). Removal by eradication can be done manually (Robinson, 2014) or chemically (Twyford, 2000). For rapid, widespread eradication of feral cat populations, chemical poisoning is the best method of control (Twyford, 2000). To maximize cat attraction, a toxic polymer fish meal bait with 2mg of sodium monofluoroacetate should be used (Eason, 1992). It is important to understand that eradication techniques are not a permanent fix to the feral cat populations. While it may be possible to eradicate feral cats within a study site, it is impossible to remove all cats from adjacent areas. Home ranges of feral cats depend on resource availability (Recio, 2013). Simply eliminating the species from one area leaves an available niche for nearby colonies. In order to maintain low population densities, the area should be periodically monitored to reduce the risk of re-infestation. A combination of other control mechanisms should be used for best results.

Tradeoffs/Interactions

Eradication is a proven control mechanism of feral cat colonies. However, the use of toxic baits provides a risk of poisoning native, non-target animals. Some trials suggest that suspending bait may increase feral cat ingestion and prevent the non-target species from consuming the poison (Algar, 2008). Aside from wildlife interaction, human contact needs to be taken into consideration. Cats have a complex relationship with humans in the United States. This relationship and the lack of education may be seen as a form of animal abuse in the public's eye. Unfortunately, the over-bearing feral cat population is often viewed as an animal welfare issue rather than an environmental tragedy. Uproar may be initiated if feral cat eradications were implemented. In order to avoid public backlash and minimize non-target (such as house cats) poisoning, eradication techniques should be reserved for isolated areas like National Parks.

2. ***Trap-Neuter***

In contrast to the original situation, if the population of feral cats is below 50 individuals, trap-neuter release strategies should be administered (Lloyd, 2010). Many jurisdictions in the United States have adopted this method in controlling the feral cat populations. The trap-neuter-release procedure is to capture individuals, and remove the testicles in males (neuter) and the ovaries and uterus in females (spay) (McCarthy, 2013). After testicles are removed in males, testosterone is eliminated and cats are no longer territorial. While this method is vastly used, it is seen as an inappropriate control mechanism in areas with high feral cat densities (Lloyd, 2010).

Tradeoffs/interactions

Sterilizing individuals and releasing them back into the environment allows cats to participate in less risky, territorial behavior. With the cat uninterested in copulation, more time is available for hunting and prowling. Thus, sterilization may expand an individual's lifespan and increase predation. No scientific papers have been able to show that trap-neuter-release programs have been able to stabilize feral cat populations on their own (Zaunbrecher and Smith 1993, Castillo and Clarke 2003).

3. ***Trap-vasectomy-hysterectomy***

One alternative to these methods remains but the effectiveness is completely theoretical, such method is trap-vasectomy and hysterectomy release. Scientists and veterinarians from Tufts University developed a computer model in August, 2013, with engineers to predict how various population control measures would best fare large feral cat population colonies (McCarthy, 2013). Through statistical analysis, they found that unless more that fifty-seven-percent of cats are captured and neutered annually by either trap-neuter-release or removal by lethal control, there will be a minimal effect of feral cat population size (McCarthy, 2013). To establish zero population growth the percentage escalates even further to a necessary eighty-two-percent capture rate.

Trap-vasectomy and hysterectomy release allows males to maintain sex drive and territorial behavior, while females that undergo hysterectomy still attract males. Treated males who copulate with untreated females initiate a pseudo-pregnancy for 45-days where the female is unable to reproduce during that time period (McCarthy, 2013). The Tufts computer model concluded that in order to stabilize feral cat colonies thirty-five-percent of the population should be captured annually and trap-vasectomy-hysterectomy-release performed. If fifty-seven-percent of the population underwent the procedure the colony would be eliminated in a matter of 4,000 days (McCarthy, 2013).

Tradeoff/Interactions

Data on real time application of trap-vasectomy-hysterectomy is absent, however the computer shows high evidence of success. If successful, it may become the new norm for feral cat control and will successfully achieve the long-term goal of preserving biodiversity.

Potential Problems

While the negative impacts feral cats impose on native populations are clear, the feral cat remains the most controversial invasive species in the Pacific region because of its close relationship with humans (Duffy, 2012). Any negative treatment of feral cat populations may cause animal rights activist to protest. In order to successfully implicate management strategies the general public needs to be educated on the feral cat's negative impact on the environment. Those concerned with animal welfare of feral cats and native populations should focus efforts on controlling feral cat populations.

To reduce the effects cats have on the ecosystem the following should be publicized:

- Do not feed non-native animals

- Keep house cats indoors
- Do not put bird feeders in a yard where a cat might ambush feeding birds
- Eliminate sources of food such as open garbage cans, or outdoor pet dishes that attract and increase the number of stray cats.

(CalPIF, 2008).

<u>Risks and Uncertainties</u>

Under the California Environmental Quality Act (CEQA), it is necessary to conduct an Initial Study to evaluate the environmental impact the removal of feral cats may impose on the physical and biological world. If there is significant evidence that a control mechanism may degrade the quality of the environment, an Environmental Impact Report (EIR) is required. An EIR would need to be conducted if the Initial Study concluded any of the following:

- The project has the potential to achieve short-term goals to the disadvantage of long-term environmental goals;
- The project has possible environmental effects which are individually limited but cumulatively considerable;
- The environmental effects of a project will cause substantial adverse effects on human beings, either directly or indirectly.

(CAFWS, 2014).

It is possible that each control mechanism would require an individual EIR. All of the control methods listed have their own set of risks that may impose a negative effect on the environment. Trap-euthanize runs the risk of hurting non-target animals. Trap-neuter-release may increase the lifespan and hunting time available to a feral cat. Lastly, trap-vasectomy-hysterectomy-release is untested which leaves room for a great deal of uncertainty/risk. If an

EIR is not conducted, the control mechanism may be in violation of CEQA and even the Endangered Species Act (ESA).

<u>Research questions</u>

Sample research questions that need to be answered to improve the plan:

- Where should the digital camera traps be set up in order to obtain an accurate measure of feral cat population size?
- How large of an area should be monitored for control?
- Can education fix the issue? Will people allow eradication methods?
- What is the most adequate method of control?

<u>Answered Questions</u>

These research questions can all be answered with trial and error analysis. It may be beneficial to test all three control mechanisms in different plots of land. To avoid contamination, land plots should not contain overlap of feral cat home-range territory. Assuming all plots contain relatively the same number of individuals, three plots should be utilized: 1. Trap-neuter-release 2. Trap-euthanize and 3. Trap-vasectomy-hysterectomy. Depending on time constraints, areas should be monitored with heat-in-motion activated digital cameras. The top two methods that best control feral cat populations should then be applied in combination with each to achieve best results. Conducting this experiment would answer all of the unknowns at the start of the project.

<u>The Big Picture: incorporation of individual goals with the class goals</u>

These methods of control are extremely costly but crucial for the long-term success of native species. Removal of feral cats would achieve the class goal of providing habitat for apex predators, endangered wildlife, and maintaining biodiversity as a whole.

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Feral pigs (*Sus scrofta*) Lori Anderson

Feral Swine

Sus Scrofa

Justification

The goal for most areas that see wild pigs as an invasive species is the complete eradication of the animals. The problem with shooting for the complete removal of the pigs is that they alter most behaviors if any sort of "pressure" is applied to them (I.e hunting, competition for land, conflicts with farmers). It is much more attainable to start with a thorough survey of the population, bait the local sounder, then begin removal of the pigs. Feral swine are currently in 56 of 58 counties throughout the state. They are considered pests to farmers, a burden on local vegetation and economically undesirable to communities. The impact feral pigs have on their local ecosystem is immense, facilitating the establishment of weeds and invasive species, rooting with their snouts, and, being omnivorous, can even pose threat to small mammals and invertebrates. The state of California is on its way to being overrun with pigs, and most counties have their own management programs.

General Facts

- can be 60 – 95 inches in length, average body weight is 145 - 599 lbs, but body size can vary with geographic location (Dewey 2013)
- There are currently populations recorded on every continent except Antarctica due to omnivorous diet and high reproductive capacity. Feral swine are habitat generalists, making them a high risk species due to high chances of establishment if the environment provides enough resources. Swine are detrimental to an area, not only environmentally but also economically. It's estimated that feral pigs inflict ~800 million each year in the United States (Rouche 2007)
- The increasing range of wild pigs in California was facilitated by hunting-related introductions, deliberate release of domestic pigs, and increasing number of food resources associated with agricultural development (Waithman 1999)
- Social groups are called sounders, mainly consisting of 6 – 20 closely related females. Males are typically solitary after 1-2 years, except during months of peak testosterone production (triggered by decreasing day length). Males compete for access to females, becoming extremely aggressive towards other males. (Iacolina 2009)
- Sows are mainly limited by food availability, not by season in the wild. Females are sexually mature after ~10 months, and can produce up to two litters a year. Each litter can consist of 5 – 6 piglets, although there is a high mortality rate. Females work as a group to protect all the offspring within their sounder. Young are often left with one female while the rest forage. (Andersen 2011)

Requirements

- Access to food, shade and a water source is all feral pigs really ask of their environment. The level of activity in a sounder could depend on the local climate, but only if shade is not readily available to them- in which case instead of being active day and night, pigs may be more active during one and not the other. (Chapman and Trani 2007)

Environmental Interactions

• Feral pigs diet consists of plant matter (including roots and tubers), crops, mast (nuts), fruit, and green plants. Pigs have been reported to seek out bird eggs, small rodents, insects, reptiles, and worms. Wild boars have been reported to prey on small calves lambs and other livestock when they come into contact with them. Being omnivorous means that feral swine can adjust their diets according to location, weather conditions and seasons. (http://feralhogs.tamu.edu/frequently-asked-questions-wild-pigs/)

• When disturbances were measured, it is clear that non-native plants are able to recolonize more steadily and rapidly when disturbed by a population of feral pigs. Native plants were able to make a comeback, but it was at a much slower rate than the exotic plants. (Tierney 2006)

• Areas which are moderately to densely populated with feral pigs have been documented as suffering from the following: facilitation of noxious weed invasions, shifts in dominant plant species, reduction of forest regeneration, and soil erosion (Rouhe 2007)

• Wild boars host a variety of parasites including *Trichinella* species, l*ungworms*, *kidney worms*, *stomach worms*, ascarids, *whipworms*, *American dog ticks*, and *hog lice*. Many of these are transmissible to humans and other animals. While the parasites may directly lead to death, in most instances they cause the animal's health to deteriorate and they succumb to various environmental elements. (Graff 2000)

Current Management in California

• The Department of Fish and Wildlife is in charge of preparing plans for the management of wild pigs, after a status and trend of the local feral pig populations are determined and management services are designated within the state. May but not limited to: regional needs, distribution of pigs, extent of damage/range damage, among other ecosystem factors. There is virtually no hunting season, anyone 12 or older just needs to possess a valid California or nonresident license can take the legal limit of feral swine. (Law Verbatim)

• Feral swine are currently found in 56 of 58 counties across the state. (Waithman 1999)

• Implementation of fee-hunting is beneficial to both wildlife and landowners. Money earned by proprietors allows them to take better care of their own land, in turn providing a better habitat for desired animals. Recreational hunting of wild pigs helps keep the population down some, and hunting on reservations enforces the practice of safe hunting techniques. (Hamrick 2011)

• Different management techniques are used across the country and across the world. Some management techniques include: hunting, trapping, poisoning, and spatial techniques/fences. No one practice is 100% effective, but if used in the right combination, feral pigs may be able to be kept in check

Proposed Management

Due to the large populations of feral swine in California, management tactics must be constant if you wish to control the feral pigs in your area. Solano county does have a pig population, but from 2009-2011, Solano county only contributed ~0.62% each year to the total population of pig tags that were returned to the state. No daily or seasonal limits exist when it comes to hunting wild hogs. A 4 year plan for Solano county is proposed for the eradication of feral swine.

1. Community education and support

- stop release of domestic pigs (tag all domestic pigs)
- get permission from local farmers/land owners to remove feral pigs from private property
- educate public as to why feral pigs are detrimental to restoration projects, local farmers, etc

2. Population assessment

- survey to estimate population locations and size of sounders
- ask community to report swine related disturbances in area
- determine when they are most active (day or night)
- determine if local community supports or participates in hunting wild pigs
- ask local farmers when/where pigs are usually

3. Removal

- plan eradication of existing populations
- develop quick alert system for fast removal of new pigs
- combination of baiting, setting traps, and relocating pigs to a more rural area
- removed swine could also be taken and released in hunting grounds further from suburbs

4. Maintenance

- monitor each eradication location for 2-3 years
- success measured by lack of feral pig disturbances

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Goals

1. Involve and Educate Local Community – A stable population of feral pigs can be harmful not only to the ecosystem, but impacts can have large-scale effects on human land use and environment quality. (1, 2,4, 10) It will be crucial to the success of all goals to have some public support. Surveying local communities will give a history of the land use, which could be useful if there are gaps or discrepancies in any written histories of the area. Having public support could help with funding for management, as educating the public could also benefit the funding of management by bringing awareness to an issue local people may not recognize. If the neighboring communities or agriculture areas have a history of feral pig issues, this could also be useful information in that managers will be able to assess the effect of current management practices in the area and adjust efforts accordingly. The public outreach could be a small-scaled effort at first, then after gathering public opinion and human-pig interaction history over the landscape, if necessary, outreach efforts could be increased as needed.

2. <u>Operate within all Legal Guidelines</u> – In California, feral pigs are classified as a big game species versus being labeled a pest or invasive species. (6) This requires other considerations when formulating management actions. Information regarding the local hunting rates and popularity should be the first consideration, as deterring sounders to areas where hunting pressure is higher may be beneficial to management staff because physical removal will be minimal or not required whatsoever. The popularity and acceptance of questionable methods of population management, such as poisoning, trapping and hunting, could be assessed at the same time as the public education goal is being assessed.

3. <u>Assessment of Feral Pig Population Size</u> - Due to contrasting results in studies done on feral pig's impact on various biomes and communities throughout California, the first priority should be to conduct a thorough assessment of the effects of feral pigs on the soil health, plant communities, established seed banks of native and exotic species, and the effects of pigs presence on populations of native animals in the area. (1, 2, 3)

4. <u>Identify Various Habitats and Communities in Area</u> – Surveying and identifying the plant communities in the area will be essential in anticipating feral pig movement, activity and impact on the ecosystem. Knowledge of the communities will help predict impact because there have been many studies done on the effect of feral pigs, in which the natives and exotic taxa in the area demonstrated varying responses. (1) Identification of habitats in the area will give management an accurate scope of what other species of wildlife may share the area. Pig's rooting also damages the habitat of many native amphibians, reptiles, mammals and ground nesting birds. (4) Pigs cause economic damage in wetlands and riparian zones, especially in areas that have been or are being actively restored (where large amounts of time and money have been spent), from their rooting, trampling, and wallowing. Rooting loosens the soil as well, which may contribute to a higher erosion rate and compromise the water quality of

streams and creeks. (5) Exotics commonly found in grasslands (5) are generally able to colonize rapidly and are fairly unaffected by disturbances, whereas natives slowly but steadily rebound. (1) The deeper feral hogs root into the ground, the more plant roots or rhizomes are exposed to the atmosphere, leading to reduced plant growth and increased plant mortality variability. The amount of pig rooting can cause variability in responses, seen in studies where the consistency of rooting was associated with reduced above ground plant biomass, primarily native species, in one area and increase in population of exotic plant species in another location. (1, 8) The long term, overall larger-scaled goal will be the eradication of sounders in areas containing a population of exotic taxa that could potentially benefit by the foraging of feral pigs. Seed banks are an important factor in the geographic areas of study because, for example in oak woodlands, pigs reduce abundance of acorns on the ground – increasing density of pigs was associated with reduced abundance of oak seedlings. (1)

5. Implement Beneficial Plans of Action to Control Current Population - Effectively and sustainability manage natural landscapes which are plagued by feral pigs, with an approach that evaluates community-level effects of the pigs and the responses to management action. Reducing or eliminating the population of pigs and the effect they have on the ecosystem is key for effective management in inland systems. (1) Once established, pig populations are difficult to remove because of their adaptability in a novel environment. (7) Coordinating eradication efforts concurrent with monitoring efforts should be carefully planned due to the continuous efforts that will be needed in order to efficiently and effectively maintain control on the feral swine's impact on the terrestrial area.

6. Reduction of Population Range, Eradication and Maintenance of Efforts – Through population assessment, monitoring and reducing geographic area available to the feral pigs, the long term goal is to rid the area of the feral pigs, restore original ecological conditions and

prevent the reintroduction of feral pigs to the site. Feral pigs are omnivorous opportunists, which will require limiting the opportunities the sounders will have to areas they once occurred.

Restoration Plan

1. <u>Community Education and Public Notification of Efforts</u> – Efforts would need to be presented in local government gatherings to ensure the public is aware of ecological changes in close proximity of their homes. If trapping were to be put into practice, neighborhoods near traps should be notified there will be live animals in the area. Due to the adaptability of feral pigs, a combination of strategies may need to be employed to be efficient in labor and time invested. The community could contribute to the monitoring efforts if an outlet for people reporting wild swine activity in the area. It may not be extremely effective, but it would be an inexpensive and casual way of establishing a history of activity (I.e no reports of sitings in early afternoon). All domesticated swine in the area should be tagged and registered to ensure positive identification if pig gets off the property or is released.

2. <u>Survey and Zone Local Habitats</u> – A map of dense vegetation patches, bodies of water, and topography would help to determine the fundamental niche of the pigs in the area, and would also provide mangers with a general idea of accessible areas of study. This is both a short and long term effort in that monitoring biomass and distribution would be the ideal measurements of health in a widespread area. These measurements would indicate reproductive success of species by distribution patterns, and fluctuation of biomass could be an indication of the processes of the local environment being intact and functioning properly. (7) The surveying

and zoning would be factors that need to be monitored periodically in order for measurements of native versus exotic or invasive species densities to be compared to the level of activity of feral pig populations in that area. The short term challenges would be collecting the data, but for the monitoring, all that would need to be measured of would be the surface area covered by the two species.

3. Assess Area, Measure Population Density - In order to implement management activities that will be the most beneficial to the area, an estimate of the feral pig population density is necessary. Without an idea of how many individuals are present in an ecosystem, monitoring activities may or may not be implemented more frequently. The critical factor to determining the population size will be to find areas in with monitory and management techniques will be the most effective. An assessment of the landscape and identification of vegetation zones and types should minimize labor and allow for an accurate assumption of the local population size. One method of assessing feral pig population was developed at Tejon Ranch in California. The areas were assessed for accessibility to management staff, then zoned and checked for two days continuously for signs of pigs and referenced against the nearest plot with showed activity to calculate an approximate population range. (3) Another means of estimating an area's population size would be to set up motion sensitive cameras. The cameras would be less man power, and could possibly be set up in areas deemed inaccessible to staff. There are costly efforts made with this method of population estimate, but due to the adaptive ability of the wild pigs, it requires effort to survey the wide range of land they could easily inhabit.

4. Implement a Combination of Monitoring and Eradication Efforts – The management of feral pigs is a delicate balance of reducing the size of foraging ground and allocation of the population. Through a combination of actions, time, labor and money should be used efficiently.

• Fencing – One effective method used in management of feral pigs is fencing. Fencing, especially in an agricultural setting, can be labor intensive, but the benefits are quick to come after the fence is up. The areas in which fences would be put in would be the areas actively under or just altered by restoration efforts. If saplings had just been planted, the fence would be the easiest solution to keeping most of the pigs out. Fences would only need period check ups, and if one were to fall down or end up being ineffective, repairs would need to be made.

• Trapping and Relocation – Ultimately, it would be ideal to just remove the invasive species negatively impacting an ecosystem, but, especially in the case of feral pigs, trapping is not only risky for the animal, but also for the management staff. Feral pigs are known to be aggressive towards humans, and seem to respond to environmental pressures relatively quickly if there is a consistent disturbance in their ecosystem. Trapping and relocation requires a huge time and energetic investment. This includes checking traps daily, relocating whenever necessary, and safely handling animals when needed.

• Predator Population Densities – If the given area in which feral pigs are rampant, there are usually some species which feed on the pigs. Some natural predators of the feral pig include black bears, mountain lions, and coyotes. (5,8) Manioulating the density of the predators in one area could work in management's favor when attempting to alter the feral pig's range, but taking a “Top-Down” Trophic approach may have faster effects versus the benefits solely focusing on the feral pigs.

- Hunting/Hunting Guides – Seeing as feral pigs are recognized as a big game species in California, it would be cost and labor savvy to encourage some hunting in an ecosystem overrun with pigs. All hunters need is a current, valid form of identification issued by the state. Encouraging hunting or purposefully increasing hunting pressure in a given area can alter distributions of feral pigs. Pigs are reported to have altered diurnal activities due to hunting pressure. (9, 10)

5. <u>Alter Intensity of Efforts in Accordance with Ecosystem Response</u> – Monitoring biomass and distribution will communicate whether or not fencing, trapping and hunting are having any effect on the population of feral pigs. With these on-going measurements, intensity of monitoring can adjust quickly, hopefully allowing for effective management. Most studies conducted involving the management of an invasive, large mammal are encouraged go to on for a few years due to gestation periods, sexual maturity and resource availability alterations in the environment. (4,7,8)

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Red-eared slider (*Trachemys scripta elegans)* Justin Brieno

Management of the Invasive Red-Eared Slider Turtle (Trachemys scripta elegans)


(Somma et al, 2014)

Classification

- Kingdom: Animalia
- Subkingdom: Bilateria
- Infrakingdom: Deuterostomia
- Phylum: Chordata
- Subphylum: Verbrata
- Infraphylum: Gnathostomata
- Superclass: Tetrapoda
- Class: Reptilia
- Order: Testudines
- Family: Emydidae
- Genus: Trachemys
- Species: Trachemys scripta
- Subspecies: Trachemys scripta elegans

(itis.gov, 2014)

Background and Justification

Trachemys scripta elegans, also known as the red-eared slider, is a turtle that is indigenous to the American southeast, but has been introduced to many new habitats in both the United States and abroad (Somma et al., 2014). This is mainly due to people purchasing them as pets, but then releasing them after the juvenile turtles reach maturity and the owners no longer wish to care for them. *T. s. elegans* is a highly adaptable species, being able to thrive in a wide range of environments (Somma et al., 2014). This is one of the key reasons that makes it a competitive, invasive species to native turtles, such as *Emys marmorata* (western pond turtle) (Somma et al., 2014). Once *T. s. elegans* is introduced to a new site, it can outcompete with native turtles, such as *E. marmorata*, for resources such as basking sites, space and food. Additionally, it is also believed that *T. s. elegans* can serve as vectors for diseases to native turtles (Silbernagal, 2013). The implications of the introduction of *T. s. elegans* are that the native biodiversity is being lowered and native turtles are being driven to lower population levels and potentially to extinction.

Because this species competes so fiercely with native turtles, eradication of introduced *T. s. elegans* is very important (*issg.org*, 2010). Although, there are some obstacles to overcome with this type of management strategy. The capture of invasive *T. s. elegans* is quite difficult. These turtles can be elusive when they're being pursued, and strategies for tracking them down could include using sniffer dogs and draining waterways with nets to capture fleeting turtles (*issg.org*, 2010). Monitoring after capturing the invasive turtles is also very important to ensure the population was fully eradicated. Public awareness and education is also crucial for the management of this species. Social and cultural views on these turtles might strongly differ from scientific views, as there is a large lack of public knowledge for invasive species and their effects on ecosystems (*issg.org*, 2010). Additionally, because of this lack of knowledge, the problem of people getting the turtles as pets and releasing them to the wild could still continue, making management futile.

1. Basic Information

- Characterized by a carapace (upper shell) length can that can range from 125 to 289 mm, a dark green or brown shell, thin yellow stripes along is extremities, and it's unique red stripes behind each eye (Somma et al., 2014).
- Introduced *T. s. elegans* compete with indigenous turtles, such as the western pond turtle, *Emys marmorata*, in the California Central Valley (Lambert et al., 2013).
- *T. s. elegans* is now the most widely invasive reptile in the world and it can now be found on every continent except Antarctica (Thomson et al., 2010).
- *T. s. elegans* exhibit larger body sizes, a more varied diet, and an earlier sexual maturity than most native turtles (Lambert et al., 2013). These are key factors that make this turtle an aggressive invasive species.

2. Reproduction
- Females become sexually mature in 2-5 years (Nafis, 2013).
- Breeding occurs from March to June in it's native habitat. Although, this could change in introduced habitats based on environmental factors and competition (Nafis, 2013).
- Females prefer to dig a nest for it's eggs in soil that is not muddy (Nafis, 2013). They can generate from 1-3 clutches with 2-25 eggs per clutch. Egg production takes place from April to July.
- Hatchlings tend to emerge after about two and a half months and generally spend winter in the nest (Nafis, 2013).

3. Behavior
- Diurnal (Nafis, 2013).
- Frequent basking for warming up body temperature (Nafis, 2013). Basking often occurs in groups and they tend to stack on top of one another, producing more warmth.
- Often becomes dormant during the cold of winter, sometimes even hibernating or burrowing in the mud to retain body heat (Nafis, 2013).

4. Habitat Requirements
- *T. s. elegans* prefers calm waters, but it is also highly adaptable and can thrive in many different environments, from marshes to manmade canals (Somma et al., 2014). They are tolerant of different types of waters, from brackish to completely freshwater, and from clean to relatively dirty (Nafis, 2013). Additionally, they are capable of traveling on land for relatively long distances, making it easy for it to rapidly colonize new areas (Somma et al., 2014).
- *T. s. elegans* are omnivorous generalists, meaning that they will eat a variety of both plants and animals, but they tend to prefer a more herbivorous diet as they get older. (Somma et al., 2014). They will eat such organisms as aquatic invertebrates, fish, frog eggs, aquatic snakes, and many different aquatic plants and algae (Somma et al., 2014).
- *T. s. elegans* requires large basking sites, such as rocks and logs, where it can warm up from the sun to regulate its body temperature, sometimes in groups (Nafis, 2013).

5. *Conservation and Management*
- Stocks of *T. s. elegans* in it's indigenous homes are depleting due to the pet trade and a large demand for them as food in Asia (Nafis, 2013).

- Introduced *T. s. elegans* compete with indigenous turtles, such as *E. marmorata* in California (Somma et al., 2014). These two species compete for food, habitat space, and basking areas.
- *T. s. elegans* can vector many different infectious diseases, such as the bacterium *Mycoplasma agassizzi,* to native turtles (Silbernagal et al., 2013). Contraction of these diseases to native turtles can result in less growth and possibly death.
- The most significant way we can manage the dominance of invasive *T. s. elegans* is to constantly monitor for population changes in both the invasive and native turtles, monitor the levels of infectious diseases in both turtles, remove the invasive turtles whenever possible, and prevent the release of more invasive turtles at all times (e.g., making it illegal to dispose of pet turtles in the wild) (Thomson et al., 2010). Other policies could also be enforced, such as making it illegal to sell the turtles for food or as pets.
- It was observed by Lambert et al. in 2013 that *E. marmorata* preferred areas that were somewhat free from human disturbance, as opposed to *T. s. elegans,* who don't mind occupying urban areas. This implies that we should set aside habitat areas for *E. marmorata* that are relatively free from human intervention. Basking sites could be created either by natural materials or artificial materials in the center of pools, and more aquatic plants could be grown surrounding the habitat to provide better habitat for *E. marmorata* (Lambert et al, 2013).
- Capturing of *T. s. elegans* is vital to thier management. Sniffer dogs can be used to track their scent (issg.org, 2010). Turtles can be captured by hand or by trapping devices, such as using baited cages by their basking sites. Netting draining water bodies will ensure that all turtles have been captured, though the type of net and draining strategy must be taken into consideration because the turtles tend to burrow into the mud when the water is drained. The removal of eggs is also crucial to ensure that the population is fully eradicated.
- Once captured, common practice is to euthanize the turtles with an inhalant anesthetic agent (issg.org, 2010).
- Public education about these invasive turtles is just as important, if not more so, than all other management strategies (issg.org, 2010). When selling these turtles as pets, proper care sheets and brochures must be given to the new owners so they are aware of the responsibility of owning the pet and the effects of releasing them into the wild.

6. Data Gathering

- I compiled my data from several sources. First, I went to Web of Science and typed in "red-eared slider invasive California." From there I found three articles that covered topics about the interactions between *T. s. elegans* and *E. marmorata.* To download the articles, I searched for the full texts, which were available via Google Scholar. The rest of my sources came from typing in the same terms as before into Google. There I found websites with fact sheets from the United States Geological Survey and California Herps.

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Ecosystem services
Minimize Wildfires- Clark Richter

Minimize Wildfires

Project Background and Justification

Wildfire is an important disturbance component in many ecosystems. Fire is responsible for clearing away dead fuel and rejuvenating the system it occurs in by returning nutrients to the soil that aren't lost from the system via vaporization among other services (DeBano et al. 1998, Sugihara et al. 2006). In these ways, fire is a vital facet of the health of the fire-adapted system it is found in and can often be utilized in a controlled manner as a tool to restore and encourage native species in an area (Larios et al. 2013). But nearer to the wildland-urban interface, fire poses a threat to human health and safety and thus it is not always an option as a restoration tool, but more often systems need to be managed to ensure that wildfires don't occur (Stephens and Ruth 2005, Wills 2006). By accepting that wildfire is a useful but much more limited option in urban areas undergoing ecological restoration, managers are required to think in more creative ways on how to go about encouraging desired species and characteristics to occupy their system. Therefore, minimizing wildfires forces us to accept that human influence shapes new disturbance regimes and drives us to know our systems in greater detail to find options besides fire to achieve our goals. The history of human interaction with fire since the early 1900s has been largely about suppression. Various land management organizations and government bodies like the US Forest Service have done their best to put out any fires that start and thus prevent most ecosystems that would typically burn from burning (Stephens and Ruth 2005). In recent decades, we have become aware that this policy of fire suppression could be resulting in more frequent high severity fires with the attendant danger to human health and safety being higher (McKelvey et al. 1996, North 2012). Research continues to shape and clarify how we should go about altering our policy of suppression and encourage controlled burning and other managed disturbance components (Mallek et al. 2013, Tullis 2013, van Mantgem et al. 2013, Stephens et al. 2014). However, in areas where the wildland-urban interface is largely weighted towards the urban side, keeping fire out entirely is the safest option. To this end, the policy of 'defensible-space' encouraged by the US Forest Service and other land management organizations provides home-owners in fire-prone areas of the wildland-urban interface with direct instructions on how to minimize wildfires. These include removal of fuels on the ground near homes and sensitive areas and the removal of ladder fuels that would allow a wildfire to spread from the ground into the canopies (2006, North 2012). In order to minimize wildfires in restoration sites, these 'defensible-space' guidelines should be followed.

Fact Sheet

Key factors affecting wildfires

- Fire requires:
  - Ignition sources
    - Wildfire can be started by the ignition of fuel from cloud to ground lightning strike. However, continued burning depends on the moisture present in the fuel and conditions that would allow the fire to smolder and spread to other nearby fuels (Deeming et al. 1977). The rate at which this happens is highly variable, but in one example van

Wagtendonk (1994), found that only 5% of lightning strikes in Yosemite National Park produced fires between the years 1985 to 1990.

    - Ignition of wildfire is more often a result of human activity. Human activity leading to wildfire ignition could be unattended campfires, errant cigarettes, or cars sitting in tall grasses with hot underbellies. In any case, the risk of wildfire ignition is dramatically higher in areas with human populations (at the Wildland-Urban interface) (Syphard et al. 2007).
- Climate conditions
    - Fire weather is the climatic conditions 8 to 16 km above the surface that influence fire characteristics (Schroeder and Buck 1970); these conditions include:
        - Air temperature – the hotter the air around fuels, the less time it takes for moisture to evaporate from the fuels and thus lower the ignition point (Schroeder and Buck 1970)
        - Atmospheric moisture – the humidity of the air around fuels affects the ignition point of the fuels; the lower the humidity of the air, the drier the fuels and the lower the ignition point (and vice versa) (Schroeder and Buck 1970)
        - Atmospheric stability – surface winds can dry out fuels faster than stagnant air and can provide a fire with more oxygen which allows it to burn hotter and spread faster; the updraft created by a fire generates its own winds that bring oxygen into the fire and disperse smoke above the fire and throughout the nearby area (Schroeder and Buck 1970)
        - Clouds and precipitation – cloud shading can raise the relative humidity (and fuel moisture content); precipitation often defines the beginning and end of fire season, but thunderstorms during a fire can cause unstable atmospheric conditions and generate severe fire behavior (Schroeder and Buck 1970)
- Available fuel
    - "Fuel is the source of heat that sustains the combustion process." (van Wagtendonk 2006)
        - fire is characterized by physical and chemical properties:
            - surface area to volume ratio – the smaller the fuel particle the larger the ratio between its surface and volume (and thus easier to raise each point along the surface area to ignition point) (Burgan and Rothermel 1984)
            - fuel moisture – the more moisture, the lower the ignition point (van Wagtendonk 2006)
            - packing ratio – the amount of air present in a bundle of kindling vs. a "log cabin" or "tepee" configuration is comparatively small, since fire needs oxygen, the right packing ratio will be that which provides the fire with the necessary oxygen (van Wagtendonk 2006)
            - fuel load – more fuel available, the more energy is released by a fire (van Wagtendonk 2006)

- Severity and intensity depend on (van Wagtendonk 2006):
    - Optimum fire weather (unstable atmospheric conditions, low atmospheric moisture, no precipitation) in combination with an ignition source and fuel with optimum characteristics (low moisture, large surface are to volume ratio, ideal packing ratio, high load) will mostly likely burn at high intensity (large amount of energy released) and post-fire show signs of high severity (large magnitude of effect on the environment) (van Wagtendonk 2006).
    - Non-optimum fire weather (stable atmospheric conditions, high atmospheric moisture, precipitation and clouds) in combination with an ignition source and fuel with non-optimum characteristics (high moisture, small surface area to volume ratio, non-ideal packing ratio, low load) will most likely smolder and burn at a low intensity (very little energy released) and post-fire show signs of low severity (small effect on the environment) (van Wagtendonk 2006).
    - Fires will also burn along a spectrum of varying intensities and severities with a mixture of the characteristics described above (van Wagtendonk 2006).

Key processes/components of the ecosystem that naturally burn

- Grasslands
    - Fire regime components
        - Ignition sources
            - Lightning strikes occur at extremely low densities (Wills 2006).
            - Human activity largely responsible for ignitions, both historically for agricultural uses (Anderson 2005) and unintentionally (forgotten campfires, cigarettes, etc.) (Syphard et al. 2007).
        - Seasonality – summer-fall (Wills 2006)
        - Fire return interval (frequency that an area burns on the landscape) – short intervals between 1 and 3 years (Wills 2006)
        - Regime changes due to exotic annual grasses
            - Fire in grasslands is generally considered to be less frequent now than it was when Native Americans dominated the landscape, but in areas with high amounts of exotic grasses, fire activity has increased (Anderson 2005, Balch et al. 2013).
            - Fire regimes have greatly changed from historic patterns with the introduction of exotic annual grasses (D'Antonio and Vitousek 1992).
    - Fire characteristics
        - Spatial size – medium-large (10 to 100 hectares) (Wills 2006)
        - Spatial complexity – low (areas that burn typically burn at the same intensity and show the same severity) (Wills 2006)
    - Fragmented landscape (urban influence) burning pattern
        - Spatial size – more patches of medium or small size as control efforts keep fires from burning houses and buildings
        - Spatial complexity – high heterogeneity (high complexity) in the effects of fire in landscapes influenced by grazing and human activity (Harrison et al. 2003)

        - Fire return interval – medium to long since humans will put out fires to protect homes and other building, thereby keeping points on the landscapes from burning regularly (Syphard et al. 2007)

Key disruptions by humans to the natural burning process

- Fire suppression
    - USFS policy
        - Since the early 1900s, suppression of fires in all landscapes has been the policy of the US Forest Service and other major landowners and land managers. In the 1960s and subsequent decades, a more informed approach has allowed experimentation with and a greater public appreciation for the benefits of controlled burns and fuel reduction to minimize the need for full fire suppression (Stephens and Ruth 2005, Mallek et al. 2013).
    - Human health and safety
        - "Defensible space"
            - Landowners in places very near the Wildland-Urban interface (like towns in the Sierra Nevada) are encouraged to maintain an area of 'defensible space' around their property. Actions to achieve such status include removing all fuel (dead and dying wood) to act as a firebreak within 30 feet of any building, grinding down stumps and downed logs from the property, separating fuels by thinning trees nearer to buildings, and removing all ladder fuels that could allow the fire to climb from the ground into the canopy on the property (Stephens and Ruth 2005, 2006).
        - Air quality
            - The biggest resistance to controlled burning programs, or the decision by land managers to allow a lightning strike burn to continue burning, is the decrease in air quality and subsequent effect on human health (respiratory illnesses) and well-being (line of sight) in the area affected by the burn (Stephens and Ruth 2005, Sugihara et al. 2006).
    - Removing fire from tallgrass prairies has been shown to dry out soils further down the soil horizons, and this has reverberating effects on microorganisms and nutrient capacity as well as hydrological dynamics (Craine and Nippert 2014). We could expect to see similar results in California due to the Mediterranean climatic conditions.

Key enhancements by humans to the natural processes of burning

- Controlled burns
    - Difficult because of air quality standards and threats to human health and well-being (Stephens and Ruth 2005, Sugihara et al. 2006).
    - Proximity to houses/urban areas makes burning difficult, but can be an effective way to reduce fuel loading in the Wildland-Urban interface and encourage ecosystem responses that more closely resemble those of historic fire regimes (Syphard et al. 2007).

- Reducing burning in California grasslands already subjected to encroachment by exotic species can be an effective way to prevent further invasion by exotic plants. The high propagule pressure of exotic species often finds great success in areas that were recently burned, so preventing these areas from burning could be an effective management strategy (Larios et al. 2013).

- Or how can human activities be substituted for the natural process?
    - In several projects, the effects of grazing were very similar to the effects of burning in a grassland. They found a similar effect on native species establishment as environments post-fire and nutrient characteristics similar to areas post-fire (Meyer and Schiffman 1999, Potts and Stephens 2009).

Key gaps in knowledge

- Despite charcoal records and collected oral histories, there is still not a lot known about historic burning regimes of grasslands (Wills 2006).
- How will the climate influence grassland response to burning in particular?
    - Some knowledge exists to suggest that grasslands are at greater risk of wildfire as the climate changes (Fried et al. 2004), but there remains few studies that have undertaken the task of projecting wildfire risk in response to climate change.

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Part II: Goals and Management Plans

<u>Goal: Reduce the frequency and severity of wildfires</u>

Wildfire poses many dangers in areas like the Central Valley where the wildland-urban interface (WUI) is closely intertwined, but it can also provide options and benefits to restoration projects aimed at encouraging sustainable ecosystems and native species establishment (van Wagtendonk 2006, Syphard et al. 2013). Considering these dynamics, the first goal of this particular project will be to reduce the rate of ignitions and frequency of wildfire. The second goal will be to reduce the severity and intensity of wildfires. Inherent in each of these goals is the option to use fire for the services it provides to ecosystems, as well as recognizing that often within the WUI the risks outweigh the benefits, and we must seek other options to replicate the benefits of wildfire.

Detailed descriptions of goals

Reduce the rate of ignitions and frequency of wildfire: In order to reduce the rate of ignitions in sites throughout the Central Valley, our goal will be to take steps to prevent human-caused ignitions. This will be accomplished by restricting automobiles and motorcycles from driving off of designated parking spots and onto trails or other areas where the possibility of ignition increases due to the contact of tall grasses or forbs with hot motor vehicle underbellies. Another form of human-caused ignition commonly found in grasslands like the Central Valley is errant cigarette or cigar disposal. To this end, our goal will be to provide designated locations to dispose cigarettes and cigars to provide safe options for the disposal of such items. The ultimate goal will be to eliminate human-caused wildfire from the system entirely with the understanding that lightning-caused ignitions will occur but steps to reduce their intensity and severity will also be undertaken.

Reduce the intensity and severity of wildfires: Wildfire ignition cannot be completely stopped because regardless of our actions we cannot stop lightning strikes, and so the second goal is to acknowledge this possibility and take steps to prevent wildfires from burning out of control and negating the benefits they can provide to a system. Fire intensity is defined by the energy (in the form of heat) produced and flame characteristics while burning (van Wagtendonk 2006). The aim of this project will be to take steps to ensure that when fire does occur, it does not burn so hot as to change soil properties, or so tall as to initiate crown fires that could spread rapidly and cause great danger to the surrounding WUI (Sugihara et al. 2006, Mallek et al. 2013). Fire severity is defined by the amount of living material remaining after a wildfire and the overall size of the area burned (van Wagtendonk 2006). The aim of this project will be to ensure that if unintentional wildfire occurs desired plant species will not be adversely affected by burning, and also that the overall fire perimeter will be defined by land managers and fire control personnel and housing and sensitive areas will be protected. Achieving this goal would mean that houses and sensitive areas never burn because unintentional wildfires are kept completely under control and burn at low intensity and severity.

Caveat to minimizing wildfire characteristics in fire-prone areas

Wildfire is known to provide services and benefits to the ecological systems it occurs in, and species present in these systems often rely on wildfire for reproduction and other life processes (Wohlgemuth et al. 1998, Sugihara et al. 2006, Wills 2006, Potts and Stephens 2009). Successful restoration projects aimed at minimizing wildfire in these systems need to consider other options for disturbance regimes in the absence of wildfire. Without disturbance regimes of similar temporal and spatial scales to wildfire the restoration of native species and sustainable ecosystem function could suffer and exotic plant species and undesirable physical characteristics could outcompete native species and establish themselves, thereby complicating the restoration process (D'Antonio and Vitousek 1992, Potts and Stephens 2009).

Management and Monitoring

To reduce rate of ignitions and frequency of wildfire:

The lack of public awareness of the potential for wildfire ignition in grassland ecosystems is a major culprit in the occurrence of human-caused wildfire ignitions in the WUI (Syphard et al. 2007, Bar Massada et al. 2009). In order to reduce the rate of ignitions, permanent signage should be erected near trail entrances and parking lots that clearly warn of the dangers of wildfire ignitions by errant cigarette or cigar disposal onto the ground or into trashcans. These signs should clearly state where safe cigarette disposal posts are located and these cigarette disposal posts will be located near parking lots or trail entrances.

In order to reduce the rate of ignitions by motor vehicle underbelly-fuel contact, fencing or permanent posts should be placed on the site near parking lots and trail entrances. This will help prevent cars and motorcycles from driving out of designated parking areas or onto trails where tall grasses and forbs may come in contact with the hot underbelly of their motor vehicle.

Erecting signage and fencing to warn people and prevent accidents can often be misinterpreted by the public as an encroachment of their enjoyment of the area. However, taking the steps to avoid such accidents and providing people locations to safely dispose of burning materials should dramatically decrease the rate of ignitions. In doing so, it will reduce the costs to fire control teams and the dangers to nearby houses and sensitive areas. In coordination with other facets of this project, a public education campaign held in the form of a public meeting or general mailing could reach the surrounding community and make them more receptive to the restoration program and aspects of the wildfire reduction that they may come in direct contact with. It would also provide a forum for the public to ask questions and clarify portions of the project they might find confusing, and in doing so the restoration team would receive the feedback it needs to adaptively manage the project, and the public would feel some personal responsibility for the continued progress of the project.

To reduce the intensity and severity of wildfires:

Lightning caused wildfire ignitions are not preventable, but are known to occur in the Central Valley (albeit at a very low rate) (Arnold 1964). Being that this is the case, taking steps to reduce the intensity of a wildfire should it occur are necessary and a major goal of this project. The intensity of wildfire depends on the weather at the time of ignition and the fuel present when the fire starts (van Wagtendonk 2006). In short, the more fuel present the hotter a fire will burn and the taller the flames will be. In order to minimize the intensity of a wildfire, some type of fuel reduction needs to take place. Being that we are working in a grassland ecosystem, the most effective ways to reduce fuel load in a site is the manual removal of fuels either by mowing, applying herbicide, allowing grazing or using prescribed burning. Choosing among these options requires a full understanding of the benefits and risks of each one.

- Mowing: Using machinery to mow fuel down to a low level (less than 1" tall) will require time and machinery. This method is easy to control (since presumably someone is driving or handling the mower), but in a grassland like the Central Valley it also carries the risk of errant ignition since it involves a hot engine over grass fuels if done during the summer or other periods of the year that are especially hot and dry. This method would allow restoration managers control in choosing particular locations throughout the site to remove fuels, but it would likely have to be an annual process occurring just before the summer fire season when fuel moisture is low.
- Herbicide: Herbicide can be used in spot treatments or across a wide spatial scale if desired to reduce fuels. Applying herbicides in spot treatments could allow land

managers to reduce fuels and control exotic species at the same time. Herbicides however, require some training and foresight since they carry some risks of potential contamination to the surrounding ecosystem. This would have to be an annual process initiated before the summer fire season, but could occur throughout the year. Depending on the life history characteristics for instance, it may be more effective to treat some species in the spring before germination and others just before seeding.

- Grazing: Some research has found grazing to have similar effects upon systems as burning (Meyer and Schiffman 1999, Harrison et al. 2003, Potts and Stephens 2009). Grazed ecosystems are often nutrient rich after grazing in similar ways to post-fire environments, but show differences in their effect on the topography of a site. Grazing animals are also typically easily corralled and controlled and can be employed across the landscape in relative ‘spot’ treatments, and are considered ‘safer’ to the surrounding area than fire. However, grazing animals have been observed feeding on native species over exotic species and vice versa depending on the characteristics of the species (whether they have spines or other defensive mechanisms), making their use as specific fuel-reduction tools somewhat complicated. Grazing animals have also been known to both introduce exotic species into ecosystems they weren’t at before as well as encourage exotic spread by reducing competition with native species (Meyer and Schiffman 1999, Potts and Stephens 2009). Therefore, with this method steps must be taken to ensure that grazing animals are cleaned of exotic propagules before entering a new area, and other control methods may be necessary to eliminate exotic species from a system that the animals may not be willing to eat. In terms of specific species of grazers that have been employed in this capacity, goats are considered generalist herbivores willing to eat nearly anything, and have been used as fuel reduction tools in many locations (Tsiouvaras et al. 1989, Pilliod et al. 2006). If grazing animals like goats are chosen as the desired fuel reduction tool, they should be allowed to consume as much as they can over a typical period of several days or more, depending on the size of the area, until the fuel load is decreased by at least 80%. This would have to be an annual process that occurs before the summer fire season.

- Prescribed burning: Using prescribed burning to reduce fuel load could be considered the most "natural" method in that grasslands are fire-prone ecosystems and the species that inhabit them often rely on the nutrient and resource fluxes that occur after burning to reproduce. The fact that native species often favor burning has been established in the literature (Wohlgemuth et al. 1998, Larios et al. 2013). However, prescribed burning requires many permits due to the fact that burning near the WUI carries with it the dangers of a burn getting out of control and harming houses or other sensitive areas in the vicinity. Deciding to burn therefore would require the approval of the surrounding community and the local fire department. This would have to be an annual process that occurs well before the summer fire season when temperatures and precipitation are at their coolest and wettest (ideally) and fuel moisture is highest. This would ensure land managers the most control over their burn since fuels would be wet and therefore fire much easier to put out if it gets out of control.

My proposed plan would be a combination of herbicide application and mowing to reduce fuel loads across the landscape. Applying herbicides like glyphosate in spot treatments would also land managers to protect native and sensitive species and provide greater control and impact on particular exotic plant species. Mowing annually on a cool, possibly wet day would reduce the danger of errant ignition, be cheaper than grazing and less dangerous than prescribed burning.

Reducing the severity of wildfires in this system would require a reduction of fuel loads as described above, as well as steps undertaken to ensure that in the case of a lightning-strike or other errant ignition, fuel breaks and defensible space are present near houses and sensitive areas to reduce the chance that they burn as well. Fuel breaks and defensible space are often utilized to protect homes and other sensitive areas from burning. Fuel breaks are strips in the landscape where little to no fuel is present and therefore would not allow a fire to burn and spread if it were to get to them. Ideally, these are set up at least 30 feet from a house or building. Surrounding sensitive areas with fuel breaks would require more fuel reduction that that described above, but over a much smaller scale on an annual basis. Defensible space is a term utilized by the US Forest Service and other land management organizations to describe the fuel reduction strategies undertaken in the area around a home or building resulting in sparse or absent fuel loads or ladder fuels by which fire could climb into the canopy and spread (2006). This ensures that the desired area is easily protected in the case of wildfire because fire over defensible space can be easily put out (Deeming et al. 1977, Stephens and Ruth 2005). My recommendation would be to install fuel breaks around desired spaces and sensitive areas, and ensure through public awareness campaigns that homeowners in the area have taken steps to ensure that they have 'defensible space' around their property. These steps specifically include removing all fuel (dead and dying wood) to act as a firebreak within 30 feet of any building, grinding down stumps and downed logs from the property, separating fuels by thinning trees nearer to buildings, and removing all ladder fuels that could allow the fire to climb from the ground into the canopy on the property (2006).

Monitoring plan

Fuel load surveys

The most efficient way to determine if fuel loads have been reduced is to use Lutes and Keane's Fuel Load method (2006) before and after fuel reduction treatments. The Fuel Load method is widely used and simple to undertake with transect tapes and a ruler. By quantifying the amount of fuel of various sizes present at a site, one can determine the amount of fuel over a larger spatial scale and draw well-reasoned predictions about how hot and wide an area a wildfire would burn. This should be conducted just before the summer dry months on a yearly basis at each site, and surveys should be replicated according to topographic complexity (more surveys for more complex sites) and variation in full load across a landscape.

Cooperation and coordination with fire personnel

In grassland ecosystems like the Central Valley where the WUI is widespread, cooperation and coordination with fire departments and land managers will be important to determine whether fire frequency and fire severity have been reduced to a desired level (or eliminated completely). Certainly, the first step will be securing 'defensible space' around houses and other sensitive areas according to US Forest Service guidelines (2006), but beyond that human-caused wildfire should be eliminated from the system entirely, and wildfires started by other ignitions should remain low intensity and severity throughout the fire perimeter.

<u>Research questions could/need to be answered to improve the plan</u>

Reducing fuel loads and fire frequency in grassland ecosystems like the Central Valley allows researchers to investigate the benefits and costs to altering fire regimes or encouraging fire regimes (if prescribed burning is utilized). This may include specific analysis of species response to burning (or the lack of) as well as other various reduction methods discussed above (mowing, grazing, applying herbicides).

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Increase Carbon storage on-site Haley Stott

Literature Review: Increase Carbon Storage On-site

A. Background & Justification: 1 paragraph

Carbon Cycle

In the last century, atmospheric carbon dioxide has increased exponentially to current levels just under 400 parts per million, the primary source being anthropogenic fossil fuel combustion. In efforts to mitigate the associated climate change, scientists, policymakers, and land managers are examining methods to sequester atmospheric carbon (EPA). Carbon sequestration occurs naturally in plants and soils. Through photosynthesis, plants uptake atmospheric CO2 and store it in their living tissue (UCCE).

Define Carbon Sources and Sinks
Soil
Plants

- Why do we care about this goal?
  Sequestering carbon is a relatively low-cost way to reduce atmospheric CO2 and mitigate climate change
- Why is this restoration goal important and interesting? For example, what is your target goal's conservation value, its impact on agriculture and/or the environment?
- What is the current state of your target goal? (Not necessarily at our project site, but overall).
  Global CO2 levels
  Places where things can be stored
  Estimate of how much CO2 is currently being stored

- What is the history of degradation of your goal? (e.g. This was a widespread native plant in riparian systems, but since the 1930's, it has been eliminated from most of its range. It is only still present in perennial streams of the Central Valley, where average population sizes have been reduced by 90%).

B. Literature review- this should be presented as a 2-4 page fact sheet, not including references (e.g. see examples on Smartsite). This fact sheet must be clearly organized into key topics (which may vary project by project). Formatting can range from bulleted phrases to short paragraphs summarizing each key point, but must clearly convey the main message to unfamiliar readers. Unlike examples on Smartsite, each key fact requires citations immediately following it, and a full reference list must be included at the end of the document. Key topics that should be covered:

- What are the main factors affecting your goal? (Biotic, abiotic, human land use, etc.).
  Consider all topics covered in class- at the levels of physical site conditions, organism, population, community, ecosystem, landscape, socio-economic, global change, etc.)

Organism: woody species sequester more carbon in above-ground growth, topsoil

For ecosystem services:

What are the key processes/ components of the ecosystem that naturally provide this service?

- The Carbon Cycle
  - -Photosynthesis: plants uptake CO2 (UCCE)
  - -Mycorrhizal fungi take soluble carbon directly from plant roots and add it to soil as humus
  - -Plant decomposition adds carbon to soil (some is returned to the air) (UCCE)
-
- (e.g. key species, disturbance regimes, topography, etc.) One way to think of this is how does provision of this service naturally vary over the landscape? What are the key controllers over that?
- What are the key disruptions by humans to the natural processes that sustain that service?
- What are the key enhancements by humans to the natural processes that sustain the service? Or how can human activities substituted for the natural processes?

How does your goal respond to: climate change, grazing, fire, nearby plowing, herbicides/pesticides? other potential management actions?
Erosion releases CO2 back into the atmosphere

- Grazing: positive response, when grasses are grazed, natural root dieback occurs, returning carbon to the soil. When grazing is held off intermittently, grass and associated root systems return, beginning the cycle again. (UCCE)
  - -represents 20-30% of the global capacity to store carbon
- Management is key as too much grazing can deplete CO2 sinks
- Browsing: also helpful, especially for trees because it encourages new growth (UCCE)
- Consumption: plant material consumed by grazers is returned to soil with relatively low amounts lost to the atmosphere
-

- For all of the above information, focus on potential: constraints, non-linearities/ thresholds, interactions, feedbacks
- What scale (spatial and temporal) do these controls operate over?
- What restoration/management options have been effective or ineffective? Do these change site-to-site or project-to-project?
- What are key gaps in our knowledge that limit effective restoration planning?
- Other relevant information

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Water purification Sara Hutton

Project Part 1: Literature Review

Water Pollution: Causes, Effects on Human and Ecological Health, and Possible Solutions

A. Background and Justification

The growing spread of urban development has led to direct changes in biotic environments. Of these changes, urban environments experience the worse water pollution, followed respectively by suburban and rural communities (Wang, et al. 2008). Urban development creates pollution problems such as increased impervious areas, which most directly increases over-flow into watersheds (Schoonover, et al., 2005). This overland flow also increases sediment, heavy metals, nutrients, and bacterial loading (Schoonover, et al., 2005). The Environmental Protection Agency claims that drinking or coming into contact with contaminated water can induce problems such as respiratory, reproductive, developmental, or neurological effects, and even cancer. Additionally, Contaminated water poses a variety of health effects for humans, ranging from developmental problems to waterborne illnesses(Routledge and Stewart, 1988)Land use has increased the stress on water systems, especially urban streams, which has led to increased effort to develop sustainable and ecological based solutions to current water quality problems. Improving potable water sources are specifically important because of the direct ingestion by humans. The Environmental Protection Agency estimates that 120 million people in the United States are affected by contaminated water. However, water quality also affects agriculture and food production, especially cattle, and other species that rely on clean water, such as fish, birds, and other marine species (Grismer, et al. 2006; U.S Fish and Wildlife Service). In order to combat the health and ecological effects of water pollution there have been multiple research studies done to address the issue of water pollution. This report will focus on ways to improve nonpoint source water pollution in urban settings from an ecological and natural perspective through the use of Riparian Buffer Strips.

B. Literature Review

Goal: Improvement of water quality from a natural, ecological perspective.

Water Pollution Effects on Human Health

1.1 Effects of Microbial

- These organisms can survive in water for extended periods of time and are caused by human and animal agricultural feces, as well as storm runoff, sewage overflow, and wastewater treatment plants (Paul and Meyer, 2001;Arnone and Welling, 2007) .
- Pathogens, bacteria, viruses, and protozoa are waterborne microbes that can cause a range of health effects including; fever, diarrhea, pneumonia, and gastroenteritis (Arnone and Welling, 2007).

1.2 Chemicals

- There are 40,000 chemicals found in drinking water (Arnone and Welling, 2007). However, of these 40,000, five are the most common. These include Arsenic, Fluoride, Chlorine, Iodine, and Nitrates (Ahmed, 2010).
- Arsenic is a Category 1 Carcinogen that can lead to vascular and liver disease, skin lesions, and brain damage while fluoride and chlorine can be toxic at high levels and cause cell damage. However, iodine is s vital dietary source. A deficit of iodine is related to severe health problems such as thyroid enlargement (Ahmed, 2010).

- Urban gardens use 10 times the amount of chemicals as farmers, causing chemicals from fertilizers to be concentrated highest in urban settings (Paul and Meyer, 2001). Of these chemicals, phosphates and nitrates are the most common found in drinking water; nitrates cause the most harm to human health, such as blood poisoning and, in extreme cases of contamination, death (Ahmed, 2010).

2. Riparian Vegetated Buffer Strips

2.1 Sediment Loading

- There are two ways in which Riparian VBS control sediment loading in bodies of water.
- First, they control the flow rate of surface runoff, sheet flows, and increase infiltration rate through the use of grasses and shrubs with above ground roots and stems. Buffers with multi species riparian strips are fives times more effective at reducing infiltration rate (Anderson et al, 2005).
- Riparian buffer strips also prevent sediment loading by stabilizing the soil along the stream bank and preventing erosion. It is important to consider that VBS require "maintenance of shallow sheet flow" throughout the buffer which is not as feasible in the field as in practice (Thawait and Chauhan, 2014).

2.2 Nutrient and Pesticide Control

- VBS improve water quality by removing contaminants from pesticides and nitrogen and phosphorus from fertilizers. Retention of sediment bound nutrients through surface runoff, filtration of suspended soils due to vegetation removes soluble nutrients, and absorption of soluble pollutants by plants and soils surfaces are control mechanisms provided by buffer stirps.   (Lammers-Helps and Robinson, 1991;Thawait and Chauhan, 2014).

- Grassy VBS were found to be more effective at eliminating nutrients and pesticides, followed by tree dominated VBS and then shrubs (Osborne and Kovacic, 1993).

2.3 Physical Properties

- The width of buffer strips is correlated to the amount of pollution control and shading effects needed. Fixed width parameters are easily enforced and administered but do not provide a full range of ecological services. Variable widths tend to be catered to specific sites and fulfill multiple ecological functions (Osborne and Kovacic, 1993).
- Buffer strips with widths between 1-10 m are most common in agricultural dominated areas. It is recommended to have a VBS between 12-20 m long with a .7-1.5 m increase for every 1% slope increase and a general slope of 5% (Grismer, et al. 2006).
- If a slopes steepness exceeds 12% it is not suitable for buffer strip establishment (E. Canada Soil and Water Conservation Centre).

2.4 Maintenance

- Regular checks to ensure that erosion, compaction, and channels are not occurring (Grismer, et al. 2006).
- The first year of establishment will require maintenance checks at least once a week, due to the high likelihood of competition between natives and non-natives (Barrett et al, 2004).
- After heavy storms or rainfall buffer strips will need to be checked to ensure recovery maintenance does not need to occur (Sabbagh et al, 2013).

3. Constructed Wetlands to Control Nonpoint Source Pollution

3.1 Sedimentation

- Wetlands decrease the velocity of water flow, this decrease causes solid sediments in water to fall onto the surface soils reducing the turbidity of the water. Vegetation also helps filter out sediment by further slowing infiltration rates. The deposition of sediments not only improves the turbidity but also decreases the amount of phosphorous and other harmful nutrients and pesticides that are a part of the waterborne solids (RBE Shuttes, 2001). The sediment that is trapped in the vegetation buffers of the wetland prevent sediment particles from entering the watercourse by retaining them in the vegetation or through absorption of the soil or plant matter (Barling and Moore, 1994).
- Grasses are most efficient at sediment retention, the recommended grass cover is 75% (Budd et al, 2009; Barrett et al, 2004)
- Constructed wetlands reduce sedimentation within a range of 52 to 94% (Budd et al, 2009).

3.2 Nutrient Control

- Similar to Riparian VBS, wetlands control excess nutrients by uptake from the vegetation and microorganisms and absorption onto wetland soils. Additionally, pesticides are broken down and transformed by bacteria and other microbes (Moshiri, 1993).
- Constructed wetlands control nutrient loading and disease causing organisms by approximately 60% and 90% respectively (RBE Shuttes, 2001).

3.3 Physical Properties

- There are seven important physical properties to consider when constructing a wetland treatment system: area requirements, water depth, number of cells, cell shape, flow velocity, wastewater retention time, and substrate. The requirements for these properties vary conditionally upon the current ecological conditions of the site. (Moshiri, 1993).
- To find the ideal area of a wetland the flow rate and depth must be analyzed prior. Equations have been derived to establish efficient area - Area = [Flow HRT]/Depth (WRP, 1994)

- Water Depth should not exceed 18 inches in wetland areas. Treatment areas are recommended to have depths of 6 to 18 inches, while wildlife habitats and sediment retention areas have depths of 2 to 10 inches.
- Wetlands should have 3 to 4 cells, the effectiveness of multi celled wetlands increases with connectivity cells (Morris, Ferwerda, and Papas, 2012). Wetland cells should have a flat topography and a large length to width ration to enhance treatment and ensure short-circuiting does not occur (Moshiri, 1993).
- The flow velocity within wetlands should range from 0.1 to 1.0 ft/s with a wastewater retention time ranging from .25 to 75 days with a 5 day average (Moshiri, 1993).
- Permeable substrates composed of native soils and clay are most common in constructed wetlands and help prevent seepage (Wetland International, 2003)

3.4 Flora to Improve Water Purification

- Bulrushes, cattails, and rushes are all easy to propagate, have large biomasses, and survive in a range of environmental and water quality conditions. These are beneficial to use in constructed wetlands because they have a higher likelihood of surviving and their large biomass aides in sedimentation and nutrient control (Moshiri, 1993).

3.5 Management and Important Environmental Factors

- Storm run off is the main cause of erosion in wetlands, in order to mitigate the effects of runoff, dams and spillways are a vital aspect of constructed wetlands. However, storms still raise the concern of flooding which can cause problems in wetlands; flooding increases flow velocity and decreases retention times (Moshiri, 1993).

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Part 2: Goals and Management Plans

A. Goals

I. Establish physical characteristics of Buffer Strips for Urban Streams

The physical guidelines of any buffer strip needs to be the first part of any management plan. Depending on the environmental and ecological conditions of the site, as well as the slope bank of the stream, the width of the buffer strip will vary. The steeper the stream bank the wider the buffer strip requirement will be (Belt et al. 1992).

II. Along already established Buffer Strips take out detrimental non-native plants

Depending on the type and extent of invasive plant species found along the stream bank various measures should be take to eradicate non-native plants. If the plant is not causing harm to the ecosystem or has become an important habitat to animal species at the site it’s removal should be reconsidered. Any plant removal should use herbicides and pesticides as a last resort. In the event of using chemical means to remove invasive plants it should be done with minimal damage to any other plant species.

III. Use native plants that help maintain buffer strips, nutrient uptake, and erosion control

In order to maintain the common goal of re-establishing native plants we are proposing that measures be taken to ensure that native plants grow and are used to provide erosion control and nutrient uptake for the buffer strips. This may require a significant amount of management within the first year of establishment. However, we are confident that once native plants are established they will prevent non-natives from re-invading.

B. Restoration Plan

Width and Slope Recommendations

There are two possibilities for determining the width of a buffer strip. The first is a fixed width, these do not take into account the varying conditions of a stream and provides minimal ecological support. The second is a variable width buffer strip, these provided specified widths throughout the site as land use and other ecological conditions change (Fischer et al, 2000). We are recommending a variable width buffer strip be used for any site in question. The recommended width of a buffer strip varies throughout the literature, however, we are recommending a strip of at least 10-30m. The minimum width of any strip is 10m and taking into account the possibility of limited land space, too wide of a buffer may not be feasible at the site (Barrett et al, 2004). Again, this is dependent on the specific strip of land and can vary drastically throughout. In order to determine the precise width of the area in question the steepness of the slope throughout the site needs to be measured. With every 1% increase in steepness there needs to be an approximately 1m increase in width (Grismer, et al. 2006). To ensure maximum efficiency in sediment, nutrient, and excess metal removal, as well as a healthy vegetation system the slope should range between 5% and 15% (Grismer, 2006).

Planting and Vegetation

If the bank of the stream is already eroded and cannot support the growth of the desired plants we recommend the use of geotextiles. In order to limit the environmental impact and the maintenance required at the site we suggest using a biodegradable geotextile reinforcement mat that decreases the initial risk of erosion and requires less maintenance (SEPA, 2009).

Once these have been established, or if the soil is not eroded and planting can occur immediately, the best time to start growth of vegetation is early spring, therefore, providing enough time for growth to occur (SEPA, 2009). Since grasses where found to be the most efficient at removing metals and pollutants we are recommending the vegetation be 75% grasses (Barrett et al, 2004). However, to ensure that the buffer strip controls erosion and sediment loading it is best to not rely on grasses alone. We recommend a mixture of shrubs, trees, and grasses be planted along the buffer. Grasses provide sufficient nutrient and excess metal removal, at an efficiency of 96-99%, whereas shrubs and trees help stabilize banks and provide sufficient root mass to limit erosion and sediment removal during floods and storms, as well as aiding in nutrient and pesticide removal (Castelle, 1994; SEPA, 2009).

It is important to remember the spacial location of vegetation. Too much shade could decrease plant growth due to a lack of sunlight. Therefore, when planting trees it is important to anticipate how far apart the are planted to reduce overgrowth in the future. As trees grow and create more shade, trimming my be important in maintaining adequate sunlight throughout the strip. Also, a mixture of plant species prevents fast growing species from over-dominating others (SEPA, 2009). An ongoing management plan will need to be established to ensure that native plants are not overtake by non-native species. The first year of the project will require the most attention and time; non-native annuals have been shown to outgrow native perennials especially in the first year of seeding (Barrett et al, 2004). Maintenance is discussed in farther detail below.

We are recommending an overall vegetation cover of 80%. Studies of buffer systems in California found this to be the threshold for efficiency, anything below 80% resulted in a rapid decrease in water purification (Barrett et al, 2004).

Removal of non-native species

In the event that non-natives are not needed but are present, or where used and can now be eliminated, the removal of them should not be harmful to other plants in the vegetated strip. Therefore, we recommend pulling or weeding by hand any invasive weeds and plants without the use of herbicides, before turning to the use of chemicals. Mowing can also be used to control invasive species. Within the first year of establishment we recommend not mowing any lower than six inches in order to protect seeding and growing plants. After the first year, spot clipping is recommended if non-natives still persist (Michigan United Conservation Clubs, 1997). This would eliminate the risk of cutting established plants or disrupting wildlife habitats that have developed in the buffer strip. If invasive species cannot be removed without the use of herbicides then a limited and direct application to the plant is highly recommended.

It is important to do routine checks of the site even after full establishment of the vegetation strip to ensure that invasive plants do not return. This way, in the event of re-invasion, they can be controlled before the problem grows.

Potential Problems

Buffer strips that are in the first stages of development (i.e there is not complete coverage or establishment of larger trees and shrubs) are not guaranteed to be able to withstand a severe storm. This concern is mostly for the health of the vegetation within the buffer strip in the event of a storm. However, water quality is also at risk in the event of flooding and storm runoff. Most buffer strips, even those that are well established, cannot handle large inflows of water and therefore cannot purify storm runoff before it reaches the stream (Sabbagh et al, 2013). We are proposing that in the event of a large flood or severe storm the site be checked and assessed afterwards. Based on the damage done to the site it should be determined if the plants can recover naturally or if measures should be taken to re-establish growth.

Maintenance

Within the first year, maintenance of the vegetation will be high, especially if a need for weed control. As growth is established the need for inspection and maintenance will decrease. This will be conditional to environmental and ecological factors at each site. Overall, it is estimated that a healthy buffer strip should only require two inspections annually, before and after the rainy season to ensure storm runoff won't damage the vegetation and to assess damage, respectively. However, this is conditional and my be different for each site. Years with high rainfall or severe storms may require more maintenance than others. After any severe environmental events the site should be inspected for damage and assessed for any repairs. If a site is found to be in need of more weed control or if an invasive species starts to re-establish than this site would require more maintenance. Also, if the buffer strip is along a roadway or a populated area there may also be a need to litter and garbage removal.

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Pollination Anna Nichols

Pollination

Background and Justification

Pollinators are keystone species, which affect food sources for many animals. They pollinate plants that provide nutrients, fruits, and nuts, which many other animal species depend on for survival. The restoration of pollinator habitat is important because in addition to natural services that pollinators provide for terrestrial animals, pollinators additionally provide services to crops for agricultural uses and the pollination of restorative vegetation that could be used as a conservation approach for other species. Pollination has a great impact on surrounding environments. There is also the potential of mass devastation on a broad scale if conservation efforts are not made to preserve habitat for pollinators. Today, human intervention such as pesticide usage and introduction of disease are threatening pollinator species and habitat in many areas.

Fact sheet

Pollination

Key Processes

- The primary components of pollinator habitat space include places **to** nest or egg-laying sites, flowers to gather nectar and pollen, secure places to use for shelter during extreme weather, and a refuge from pesticides.
- Native plants are suggested for use with pollinators because pollinators and plants are thought to have coevolved.

Key Disruptions

- The broad usage of pesticides can destroy beneficial pollinators, particularly during early development stages
  o Lack of knowledge of organic pesticides that are also toxic to pollinators can pose as a threat as well
- The broad usage of non target herbicide can destroy foraging habitat for pollinators
- Over grazing has the potential to destroy shelter and foraging habitat
- Lack of efficient planning in controlled burning can directly affect the survival of pollinators and the development of habitat space
- Lack of efficient planning for mowing or plowing
  o Timing of mowing or plowing should be considered during times when flowers are not in bloom
- In efficient crop management strategies which do not consider pollinators

Key Enhancements

- Patches of vegetation with flowers can be created around property to provide foraging space for pollinators in areas where there is not much greenery
- The use of native plants in gardens or restoration sites can increase the presence of pollinators
- Reducing the use of pesticides will provide a healthier environment and

increase pollinator survival.
- Plan activity that may be disruptive around the times when flowers are not in bloom

Response to Grazing, Fire, Nearby Plowing, Herbicides/Pesticides

- Broad usage of non-selective herbicides can result in the reduction of habitat space for beneficial pollinators.
- Herbicide should be selectively used if necessary
- Avoid broadcast spraying or pellet dispersal in order to maximize damage reduction
- Insecticides can severely damage pollinators and pollinator habitat and should only be used when flowers are not in bloom.

Plowing:

- Mowing or plowing should be done in the Fall or Winter when flowers have already died in order to reduce direct impacts to larvae.
- Plowing can directly impact pollinators by causing damage or death to larvae.

Fire/Burning:

- Burning can be fundamental to the maintenance of a healthy habitat space for pollinators, however, it should be done in increments and it should not be done so that all of a pollinator's habitat space is burned all at once.

Grazing:

- Knowing the life cycle of certain pollinators can be useful in making sure that young pollinators are provided with necessary habitat space to survive.
- Over grazing can create situations where pollinators have no place to collect nectar or pollen
    - Grazing should be increments in order to protect habitat space

Erosion control Leigh Hiure

Soil Erosion

Soil erosion is an increasing issue within the Central Valley because leads to higher levels of nutrients, increased turbidity, and lessens the potential growth of plants and animals. It often leads to the flooding of an area. As erosion increases, the amount of plants and animals able to live in the area decreases (Pimentel, et al. 2003), so our main goal is to decrease erosion. An example of this tragedy is Easter Island, where erosion was so great that it destroyed all forms of growth (Radford, 2004). In order to not end up like Easter Island, soil must be restored to acceptable levels. The topsoil that is swept away often contains three times the amount of nutrients and 1 to 1.5 times the amount of organic matter than the soil that is left behind (Caltrans, 2010). It is estimated that each year more than 75 billion metric tons of soil is lost to degradation (Pimentel, et al. 2003). Soil quality standards were put in place in 1991 and since then, soil and erosion defenses have been slowly improving (Eto et al. 2003). Although there are standards in place, soil remediation still needs much attention. A few ways of decreasing erosion are through soil improvement, planting vegetation, mulching, and farmscaping. These methods are discussed in the fact sheet.

Fact Sheet

<u>Causes</u>

- **Overgrazing:** Cattle repeatedly graze the same area, which causes the grass to be diminished to a point where it can no longer grow back. The loss of vegetation leads to erosion because the roots of the plants are no longer there to hold the soil in place. Also, as the cattle graze, they compact the soil, which reduces infiltration rates, allowing soil to be more easily washed away with water runoff (World Wildlife, 2014).
- **Agricultural practices:** When crops replace natural vegetation, soil is exposed and is dried out. This allows the arid soil to be easily blown or washed away with air or water. Water methods also influence how much erosion there is. Overwatering crops causes runoff, which takes soil away (Pimentel et al., 2003).
- **Steep slopes:** The steeper a slope is, the more likely soil is eroded. Gravity causes the loose soil to go into waterways. This is especially important when the slopes are not covered in any vegetation to keep the soil anchored down (Pimentel et al., 2003).
- **Soil Type:** The three main types of soils are sand, silt, and clay. Silt has smaller particles than both sand and clay so it is more susceptible to wind and water erosion. Sand is the least susceptible to erosion because it has the largest particles. Clay is also not susceptible when the soil is aggregated. When there is poor soil structure though, clay is susceptible to water erosion because it is not very cohesive and therefore more easily swept away (Caltrans, 2010).
- **Water:** Water erosion comes in many forms; a few include raindrop, sheet, and mass wasting. Raindrop erosion is when rain hits uncovered earth and displaces the soil, sheet erosion is when there is little infiltration so the top layer of soil is removed, and mass wasting is when the slope is so steep that the soil slides or slumps down (Caltrans, 2010). Increased runoff is often a symptom of soil erosion. The runoff goes into the

nearby waterways and can cause eutrophication, which often leads to algal blooms because of the increased amount of nutrients in the water. The turbidity, or clearness, of the water is also worsened due to runoff. Often, buffer strips are planted along rivers or streams to lessen the impacts of the runoff (World Wildlife, 2014).

- **Wind:** Wind erosion is an issue because the wind blows sediment and soil into waterways. This is similar to erosion due to water because it leads to eutrophication and increased turbidity. Another problem with wind erosion is that it carries particles throughout the air, which may cause health issues to humans. In order to counter the problems caused by wind erosion, rows of trees could be planted to create windbreaks. (Caltrans, 2010)
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Natural Soil Remediation

- **Vegetation:** Grasses, shrubs, and trees hold down soil and prevent it from eroding because their roots act as anchors. Vegetation also increases infiltration, protects the soil from erosion due to raindrops, and slows the rate at which water runs over the surface. This means that there is less water runoff that washes away topsoil. Typically in restoration, a mix of grasses, shrubs, and trees are used. Grasses are good to use at first just to get some vegetation down because they are typically fast growing and will decrease the amount of wind and rain erosion. Shrubs and trees are beneficial because their deep roots hold the soil in place and also defend against wind and water erosion. The only problem with shrubs and trees is that they take longer to grow. Some native grass types that could be used as remediation include:
    - *Elymus glaucus* or Blue Wildrye, which is a short-lived bunchgrass that is largely self-pollinated and drought tolerant.
    - *Festuca occidentalis* or Western Fescue, is a medium sized bunchgrass that is short-lived and adapted to sloped areas.
    - *Bromus carinatus* or California brome, is a large, leafy, short-lived bunchgrass that is adapted to hot dry climates and beneficial in restoring areas that need a fast growing grass. It is also very competitive with herbaceous weeds.

  There are many others and also some introduced species of grasses that Craig Edminster lists as well (Edminster, 2014).
- **Soil:** Healthy, nutrient rich soil allows more plants to grow and water to seep down into the soil. Some of the necessary nutrients are Sodium, Boron, Nitrogen, Phosphorus, and Potassium. These can be added into the soil through fertilizers. However, there are environmental risks that go along with using fertilizers. For example, the runoff from the fertilizers can lead to dead zones in any nearby waterways. There are three main soil textures that should be looked at when thinking about erosion and plantings. Sandy soil has larger particles compared to silt and clay, poor nutrient quality, and less susceptible to soil erosion. Silt soil has particle sizes between sand and clay, are moderately reactive, have a medium to high nutrient quality, and are susceptible to water erosion. Finally, clay has the smallest particles, easily transported, high in nutrients, and if they have a good soil structure, not very susceptible to water erosion (Caltrans, 2010).

- **Mulch:** In order to lessen erosion and weed growth, two to three inches of mulch can be added to cut or fill slopes. Mulch is a combination of organic matter such as composted material, wood chips, tree bark, and other materials. This will lessen the effects from raindrop splash erosion, competition from weeds, and slow the rate of water runoff so more water is able to infiltrate. There are a few problems with using mulch though. For example, it only has a lifetime use of approximately three years and the use of organic matter may not be beneficial in arid areas because in those conditions, it will breakdown faster and release Carbon into the atmosphere (Caltrans, 2010).
- **Farmscaping:** Farmscaping means using farmland for positive environmental results. The farmers use non-production land to enhance the environmental outputs by planting shrubs and grasses along waterways and creating buffers between the crop fields and streams. By farmscaping, the farmers not only lessen erosion along the waterways and in the previously bare land, but they also create more habitat for species, and lessen the runoff and contamination of the water (Smulker et al., 2010).

<u>Human Impacts</u>

- **Tilling:** Conservation tillage helps to reduce erosion because it leaves 30% of crop residue on the surface after planting. There are three types of conservation tilling: no till, ridge till, and strip till. No till means that the soil is not disturbed at all during planting. Ridge till uses ridges made during the previous season and shallow cultivation equipment. Strip till cuts residue from small areas ahead of the planter, which again causes only small soil disturbances. The main goal of tilling is to keep the soil in place as much as possible, meaning it will reduce erosion and runoff (Mitchell et al., 2007).
- **Rotational crops:** Currently, the same types of crops are being planted over and over again in the same area. This depletes the soil of nutrients causing the soil to become arid and uninhabitable for crops. In order to counter this problem, fertilizers are added to the soil, but again, that may lead to problems in the waterways. Another way of solving the nutrients problem is to do crop rotations where one season the farmers plant corn or their normal crop and then the next year they plant legumes, which will replenish the nutrient supply in the soil. One of the problems with this method is that the output of each crop from the farmers will not be as great because they are changing crops each season (Pimentel et al. 1995).
- **Rotational grazing:** Overgrazing is a huge cause of soil erosion because the cattle are depleting the vegetation and are compacting soil. Rotational grazing allows the grass and vegetation to grow back and recover, eliminating the problem overgrazing causes. While this form of grazing is beneficial for the environment and soil, it requires a large amount of land, which is sometimes unavailable (Pimentel et al. 1995).
- **Streambank Stabilization:**
    - **Live Planting:** Live plantings are when vegetation, live stakes, and live fascines are used to lessen erosion through natural methods. This is beneficial because they cost less than other methods of streambank stabilization and still reduce wind, rain, and water erosion. They use live vegetation to cover the ground and hold the soil in place. The only constraint is that live plantings should be used in areas that are not heavily eroded (TVA, 2011).

- **Bioengineering:** Bioengineering is when structural support and plant materials create vegetation buffers. This is more expensive than live plantings but more effective because it combines many techniques. Also, they should be used in areas that are not heavily eroded because it only provides intermediate cover. This method needs at least three years to establish roots before becoming effective (TVA, 2011).
- **Hard Armoring:** Hard armoring is when rocks and grading are used to lessen erosion. These methods are used in highly eroded areas to reduce wave erosion because the rocks are placed along the shoreline. This method is extremely effective but costly because the materials are pricey and installation is intensive (TVA, 2011).

<u>Knowledge Gaps</u>

- **Climatic change:** As the climate changes, erosion may increase due to higher temperatures or increased rainfall. Although we do not know exactly how the climate will change, by taking preemptive measures such as planting more grasses, we will be able to decrease the chances of erosion.

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Soil Erosion Remediation

<u>Goals:</u>

My main goals for remediating soil erosion are to:

1. Stabilize streambanks: to ensure that the area around a streambank is secure and erosion is not getting into the waterways.
2. Increase soil health: to help cultivate vegetation and lessen erosion by increasing infiltration, slowing runoff, and protecting soil. In order to effectively grow vegetation, the soil must match the wanted plant species.
3. Plant vegetation: to increase plant cover and lessen erosion due to wind and water.

Each of these goals is talked about more in-depth below and have the temporal and spatial scales addressed. For each, I have given the optimal uses as well as some things to be cautious of. For each of these goals, there are multiple management approaches depending on the site's current state. For example, when restoring a streambank, bioengineering should be used when there is moderate erosion and hard armoring when there is severe erosion.

Restoration Plan:

For my restoration plan, I suggest using many different restoration methods. For streambanks, depending on the status of erosion, using a mixture of live plantings, bioengineering, and hard armoring would be best. I have outlined the different types of stabilization techniques that would be most beneficial for streambanks below. Then, for other areas in the Central Valley, I suggest planting vegetation and improving soil health in the eroded areas.

Streambank Stabilization

When restoring a streambank from erosion, there are multiple approaches. The most common are: live planting, bioengineering, and hard armoring. Before implementing any of these solutions, it is important to determine the erosion levels to see what method or methods would be the most beneficial. For example, bioengineering is best used in moderately eroded areas and hard armoring is used in severely eroded areas. Also, live planting is often used in conjunction with these methods because it is an inexpensive and simple way of preventing erosion (TVA, 2011). One of the first aspects that must be determined is the erosivity to see which method would be best for the site. In order to find the potential erosion of a site, the Revised Universal Soil Loss Equation Version 2, or RUSLE2, should be used. This equation is

A = R x K x LS x C x P. A is the average annual soil loss (tons/acre/year), R is rainfall erosivity, K is soil erodibility, L is slope length, S is slope steepness, C is soil cover management, and P is the effect of conservation practice (Caltrans, 2010).

Live planting consists of planting vegetation, using live stakes, and using live fascines to naturally lessen erosion (TVA, 2011). Live planting prevents erosion by wind, rain, and water by covering and holding the soil in place. Using vegetation is a good way of lessening erosion because it has a low cost. However, they do require more attention in the beginning when roots are being established. There is more information about general vegetation planting below in the "Planting Vegetation" section. Live stakes is when branches of rootable plants are inserted into the bank and is beneficial because it does not cost very much and is fairly flexible (TVA, 2011). Woody plants are the optimal plants for this method. They should be put into the ground approximately 2 to three feet from each other and have a live cutting of ½ to 1 ½ inches in diameter (GAEPD, 2011). Overtime these stakes will root and grow into shrubs that will stabilize the streambank. Live Fascines are bound bundles of live branch cuttings that are buried into the bank and staked into place along the slope contour (GAEPD, 2011). Woody branches are most often used for fascines as well and are beneficial because they induce colonization and increase infiltration (TVA, 2011). This method is effective but works best when used with a mixture of bioengineering techniques and vegetative plantings (TVA, 2011).

Bioengineering is beneficial in areas that are not severely eroded according to RUSLE2. In order to accomplish bioengineering, there must be "structural components and plant material to produce a dense strand of vegetation" (TVA, 2011). This will reduce erosion by creating anchors to protect and hold the soil in place. Vegetated geogrids, brush mattresses, and tree revetments are three bioengineering techniques that are used in streambank stabilization and while these methods are effective in the long run, they need approximately three years for basic root establishment. Vegetated geogrids are layers of live branch cuttings and compacted soils that are wrapped in geotextile materials, which slow the flow of water down the slopes. Each cutting should be approximately 3 to 4 feet in length with one foot of compacted soil between each layer of branches (GAEPD, 2011). The ideal branches used for this method also come from woody trees and are often used in areas outside of river bends (TVA, 2011). While this method is effective for steep slopes, it costly and has a maximum height of eight feet from the top of the slope to the base of the stream (GAEPD, 2011). Brush mattresses are a combination of live branch cuttings, live stakes, and live fascines put into the ground to cover and secure the entire streambank. Each stake is placed about two feet from each other and are at least 2 ½ feet long (GAEPD, 2011). This method is best for immediate cover and long-term results but since it is a mixture of many techniques, it can become expensive. Each stake costs approximately $1 to $2 and must be planted 1 to 3 feet apart; this becomes very costly when spread over an acre of land (TVA, 2011). Finally, tree revetments are rows of cut trees, typically cedar in eight-inch diameters, anchored to the toe of the bank for toe protection (GAEPD, 2011). This method is the least expensive of all of the bioengineering options but is usually used in conjunction with other bioengineering methods for the best results (GAEPD, 2011).

In highly eroded areas, based on RUSLE2, the best option would be using hard armoring to protect streambanks. The two suggested methods for hard armoring is rock riprap and gabions which both require the use of rocks and grading the bank into less steep slopes. Both of these methods are often very expensive but are extremely effective (TVA, 2011). The average cost of 8-tons of rock riprap without instillation is approximately $17 and for a square meter of gabion basket wire, it costs around $4. Rock riprap is when you place large stones along the slope of a streambank or shoreline to protect the bank from waves, creating a minimum of a 1:2 (vertical to horizontal) slope (GAEPD, 2011). This method does not allow much vegetation to grow, however, the bank may only need to be reinforced at the toe of the slope so vegetation could be planted elsewhere. Rock gabions consist of rectangular baskets filled with stones to form a vertical wall. This helps eliminate erosion because it replaces the slope with rocks. It is also possible to implement vegetation into the wall by adding branches on top of the gabion baskets (TVA, 2011).

<u>Planting Vegetation</u>

Vegetation such as grasses, shrubs, and trees helps lessen soil erosion because their roots act as an anchor to hold the soil in place and they protect the soil from raindrop erosion. Also, vegetation increases infiltration of rainwater. This lowers the amount of soil that is washed away from runoff. In particular, trees and shrubs act as a windbreak to prevent soil erosion (Forman, 2001). Windbreaks protect the soil from wind by slowing the speed and turbulence. For optimal results, a highly or medium-porous windbreak should be used (Forman, 2001). This is because the turbulence of downward wind is greatly reduced with porous windbreaks. One example of a porous windbreak is a row of poplar trees (Forman, 2001).

In the first year of soil restoration, the main goal is to have a diverse species composition in order to establish surface cover and to have roots of a beneficial depth to increase soil strength. Some of the recommended types during early succession are forbs, grasses, mixed herbaceous plants, and sub-shrubs. These plants are optimal for initial erosion control because they grow quickly, spread easily, has good soil coverage, sun loving, and short-lived (Caltrans, 2010). Then, by the third year, there should be healthy plant communities that include a good amount of native grasses and forbs and diverse shrubs and trees. These plants should be planted soon after the early succession vegetation has taken root because they take longer to grow than the early succession plants. The roots of the plants in year three should also be strong by this point with some taproots. Finally, after ten years, there should be a large, natural amount of native grasses and forbs, increased canopy cover from native shrubs and trees, and strong roots with well developed taproots (Caltrans, 2010). The best plants for later succession are grasses, woody shrubs, and trees because they provide long-term stability, are long living, have a larger canopy, and have extensive root systems (Caltrans, 2010). These later succession plants are the same ones that were planted in the beginning. The shrubs and trees should be planted in the early stages because they take longer to grow than most grasses. By year ten and on, the shrubs and trees should be well established.

After planting the vegetation, the sites will need to be monitored at various points, typically at one, three, and ten years. For the first few, the areas should be looked at every three months but after the plants have been established and are thriving, monitoring can be dropped to every year. During these checkups, the vegetation should be inspected to ensure that the vegetation doesn't have any diseases, have enough room to grow and are growing at the expected rate, and the area should be checked for invasive plants. Also, the litter or duff location and depth should be measured (Caltrans, 2010).

In terms of planting densities, trees should be planted 10 feet on center or 436 trees per acre. When planted alone, shrubs should be planted at an average density of 6 feet on center or 1210 shrubs per acre and ground covers at 1.5 feet on center or 19,360 containers per acre. However, when combined with trees, shrubs and groundcover should be planted at 774 shrubs per acre and 18,250 containers per acre (GAEPD, 2011).

<u>Increase Soil Health</u>

It is important to have healthy soil because good soil, with optimal levels of nutrients and organic matter increase the infiltration of water, slows runoff, and helps with plant growth. In order to know what your soil is in need of, it should be tested for texture, bulk density, organic matter content, pH, salinity, sodium, boron, nitrogen, phosphorus, potassium, and recommended amendments (Caltrans, 2010). Typically, organic matter greater than 2% is good, the pH should be between 5.8 and 6.5, the texture should be more clay like because it contains more nutrients, and phosphorus levels should be between 36 and 50 ppm (Espinoza et al, 2014). There are many ways to increase soil fertility in nutrient deficient soil. Some include adding: local topsoil, duff, mulch, and organic or commercial fertilizer (Caltrans, 2010).

Local topsoil is one of the most effective methods in aiding native plant growth because it contains many characteristics that the vegetation requires. It should be used on 1.5:1 of horizontal to vertical slopes or flatter; Slopes 1.5:1 (H:V) - 2" maximum thickness, slopes 2:1 (H:V) - 3" maximum thickness, slopes 3:1 (H:V) - 4" maximum thickness, and slopes ≤ 4:1 (H:V) - 6" maximum thickness (Caltrans, 2010). While this method is one of the most effective, it is also costly and requires the removal of all weed species before implementation. One very effective method is to spray the entire area with herbicides to kill off all of the plants. This requires in depth knowledge on how much of the particular herbicide to use for the specific types of plants, but is extremely effective. A less effective method is to mow or cut down all of the invasive species manually. In the end however, it is important that the area is monitored every other week for approximately three months to ensure that the invasive plants do not grow back (Caltrans, 2010).

Duff is chipped vegetation that is removed from the project site and it is later reapplied to the disturbed soil areas (Caltrans, 2010). Duff has the same use specifications and limitations as local topsoil although duff does not consist of local topsoil. Duff works well with the implementation of local topsoil (Caltrans, 2010).

Mulching an area, similar to grass, will increase infiltration and protect soil from raindrop erosion. Mulch also lessens weed growth. This is a very effective method of preventing soil erosion, however it has a short life of only three years and eventually contribute to greenhouse gas emissions because it is composed of organic matter and as it breaks down, it releases carbon (Caltrans, 2010). Mulch is also beneficial because it is inexpensive and can be used over a large area of land. For optimal results, approximately three inches of mulch is laid out over cut or fill slopes or flat areas.

Fertilizers are often a cheap and quick way of adding nutrients to soil. However, there are environmental risks that go along with using fertilizers. For example, the runoff from the fertilizers can lead to dead zones in any nearby waterways (Caltrans, 2010).

Overall Applicability

Erosion control is an important issue over all forms of restoration because it deals with many issues that must be addressed in order for other species to survive. The soil provides a habitat for many species and vegetation would not survive without a healthy, non-eroded soil. Also, along rivers, streams, and other waterways, erosion will deter the survival of aquatic species. Specific interactions will need to be looked at when performing a restoration project because with a general plan, we do not know what the specific species of vegetation that will be planted with the particular type of restoration techniques. Also, the budget of the project will impact the types of control methods that are used.

Research Questions

While going through this restoration project, I was unsure of the most effective methods of dealing with streambank restoration. There are many possible solutions but since each method is dependent on the type of site, there would have to be more research and analysis of the site. Also, the specific species of vegetation should be considered carefully before planting.

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Other case studies

Northern and Southern California species to use in drought gardens- landscape architecture to design demonstration garden Katie OMalley

As issues surrounding climate change emerge, one major concern facing individuals is a future of possible droughts. Much research has shown that with global climate change increasing due to greenhouse gas emissions, extreme weather events are likely to become more common and severe, particularly droughts (Easterling, 2000). As drought conditions continue in California, watering of lawn and yard landscapes will become less of an option, making a shift toward more drought-tolerant gardening techniques vastly beneficial. Cities all over California have already begun reflecting upon the notion of reduced home-garden watering in response to the drought, often in the form of lawn-watering schedules. For example, the City of Sacramento watering schedule dictates when residents are permitted to water yards (based on their street address), and watering is only allowed on two designated days of the week (CityofSac, 2014). Currently, outdoor water usage is considered highly expendable, as many people do not consider the watering of their lawns when trying to reduce personal water use. However, one study conducted in Washington showed that in the warmer months (April-September), outdoor watering accounted for up to 56% of the water use for the average household (Syme, 2004). In California this amount is estimated to be about 50%, while in the Sacramento area the outdoor water use accounts for 65% of household water usage (Arrington, 2014; CDP, 2014) . Therefore, if we are able to greatly reduce the amount of water being put onto lawns and landscapes through the use of drought tolerant gardens, the total amount of water used statewide could be greatly reduced.

<u>Environmental conditions/limitations:</u> There are many conditions that need to be taken into account before planning the implementation of a drought-tolerant garden. Some of these conditions include soil quality, hydrology and climate. Other limitations need to also be considered, such as potential weeds that may pose a threat to garden establishment, and how to keep water in the soil for longer (ex: mulching).

- Soils and hydrology: The soil located at the garden site is Rincon clay loam that is considered well drained. The parent material of the soil is alluvium (Hillhouse, 2014). The soil samples provided showed that approximately 35% of the soil is clay, having a very fine texture (WebSoil, 2013). The soil is ranked as a group C soil by the USDA, which “have slow infiltration rates when thoroughly wet….with a slow rate of water transmission” (WebSoil, 2013). This means that the water that does get into the soil moved slowly through, which is good for the plants, as it gives more time for the water to be taken up by the roots. (Soil analysis for the site was also conducted by Carol Hillhouse, of the UC Davis Student Farm).
- Climate: The climate in Vacaville can range from just above freezing temperatures in the winter to near 100 degrees in the summer. Average annual temperatures for Vacaville area high of 76.2 degrees, and a low of 48.8 degrees (U.S.Climate, 2014). The average annual precipitation in the site area is 25cm, falling primarily from December through February (U.S.Climate, 2014). This relatively short period of rainfall means that plant species in this area will need to be able to survive roughly nine

months of warmer weather without precipitation. The temperature extremes mean that plants in this site will also need to be able to tolerate the cold, which not all drought-tolerant species are able to do.

- Weeds: Invasion of new shrubland plantings by nonnative grasses is extremely common, but can present a massive problem when trying to establish an entirely new site design. When the site is tilled under and the soils are being prepped for planting, nonnative grasses in the area will spring up without any competition, and these must be dealt with before any plantings can proceed (Cione, 2002). One solution is to allow the grasses to come up, mow them down, and then as the new seedlings come up again, spray them with herbicides. By going through this process, the weeds are killed in their most vulnerable stage, giving the highest chance of success to the newly planted native seedlings (Holmes, 2014). Further maintenance will be needed in several years following the plantings to ensure that nonnative species that pop up are able to be removed by hand before crowding out well-established natives.
- Keeping soil moisture: One major concern in drought tolerant gardens is that all plants, even drought-tolerant ones, need some form of water to live. In these types of gardens, the volume of water can be miniscule, but an important factor in this type of garden management is being able to keep any water that is put into the system within the soil for as long as possible. One way in which this is accomplished is through mulching. Mulching with materials such as woodchips helps to reduce evaporation of water off the soil surface, keeping the soil moist (McDonald, 1990). Mulching can also provide other benefits, such as shelter from the direct sun for microorganisms living in the soil, which can be vital for the breakdown of nutrients in the system (McDonald, 1990). Mulching also discourages the establishment of nonnative grasses by covering exposed soils. In respect to garden layouts, mulch can also give a more appealing visual affect to a garden, and can help designate areas that are to be kept off of by people (LVMWD, 2009).

Xeric/Mesic (for drought garden): For choosing plants for the drought garden, the environmental conditions mentioned above had to be taken into account. The semi-clay soils in the area do not have great drainage, which had to be considered when compiling this list of plants. The drought garden area has partial shade from a large tree, while there are also large areas with direct sun throughout all parts of the day. The plants chosen for this area were compiled using a native plant horticultural guide (ThomasPayne, 2014), which allows sorting by water needs and plant communities. I was able to search the native plant database for drought-tolerant plants of both Northern and Southern California, and then eliminate species which did not fit into the constraints mentioned above (such as soil type, hydrology, and temperature extremes). The list was also compiled with the help of Katherine Holmes, director of the site management project, who provided some species which the Resource Conservation District of Solano county wanted to be included in the garden (designated as Holmes, 2014). The list below represents the plants already chosen for their drought-tolerant qualities, and the descriptions that accompany them touch on some of their other qualities besides their low water needs (qualities to appeal to those considering placing these plants in their own gardens).

These descriptions are all summaries of the descriptions provided by the citation source, unless otherwise stated.

- Box elder *(Acer negundo)*
  - Habitat needs: full/part sun, moderate water when getting established, all soils
  - Characteristics: 30-80'H x 15' W, winter deciduous, , flowers winter/spring, pink flowers (CNPD, Acer negundo)
  - Benefits: This tree has beautiful pink flowers in the spring which attracts many pollinators to the site, while providing necessary shade for some of the smaller species
- Interior live oak *(Quercus wislizeni)*
  - Habitat needs: full sun, well-draining soil
  - Characteristics: 33-60'H x 40-65' W, evergreen, drought tolerant, spring flowering, acorns (CNPD, Quercus wislizeni)
  - Benefits: This tree can be placed on the sloping edge of the site where the soil is well-draining. This drought-tolerant tree provides habitat for many bird species (Fryer, 2012).
- Valley Oak *(Quercus lobata)*
  - Habitat needs: full sun to light shade, all soils
  - Characteristics: 30-90'H x 30'W, winter deciduous, drought tolerant, yellow flowers in spring (CNPD, Quercus lobata)
  - Benefits: This tree is very tolerant to hot and cold temperature extremes, and provides shade for more sensitive plants in the summer. Also attracts birds and butterflies (Howard, 1992).
- Blue blossom *(Ceanothus thyrsiflorus)*
  - Habitat needs: partial shade, all soils
  - Characteristics: 6-20'H x 15'W, evergreen, drought tolerant, blue flowers in spring (CNPD, Ceanothus thyrsiflorus)
  - Benefits: This shrub with vibrant blue flowers gives off a sweet smell which attracts birds, bees, and butterflies to your drought garden
- California buckeye *(Aesculus californica)*
  - Habitat needs: full sun, all soils
  - Characteristics: 30'H x 18' W, summer/winter deciduous, drought tolerant, white flowers in spring (CNPD, Aesculus californica)
  - Benefits: This drought tolerant large tree has a good smell and attracts hummingbirds
  - Detriments: be careful because the leaves and sticks are toxic to all mammals (including humans)!
    - May mean not a good place for this tree to be planted (site is near a little league baseball field with kids and dogs)
- California coffeeberry (*Rhamnus californica)*
  - Habitat needs: full sun, all soils

    - Characteristics: 8-12'H x 4-8'W, evergreen, drought tolerant, yellow flowers in spring (CNPD, Rhamnus californica)
    - Benefits: This large thicket provides excellent habitat for the pale swallowtail birds, and stays green throughout the entire year
- California rose (*Rosa californica)*
    - Habitat needs: partial shade, all soil
    - Characteristics: 5'H x spreading, spreads by rhizomes forming thickets, winter deciduous, drought tolerant, pink flowers in spring/summer (CNPD, Rosa californica)
    - Benefits: This rose bush is beautiful when it flowers, and forms a strong barrier on the edges of a garden. It also smells wonderful.
- Coyote bush (*Baccharis pilularis)*
    - Habitat needs: full sun, all soils
    - Characteristics: 2'H x 6-8'W, groundcover, evergreen, drought tolerant, cream flowers in fall
    - Benefits: This groundcover helps to fill in blank spaces between planting beds, remaining green throughout the year, and attracting many butterflies. (CNPD, Baccharis pilularis)
- Hollyleaf cherry (*Prunus ilicifolia)*
    - Habitat needs: full sun, all soils
    - Characteristics: 15'H x 15'W, evergreen, slow to establish, drought tolerant, white flowers in winter (CNPD, Prunus ilicifolia)
    - Benefits: This shrub has white flowers in winter, but does take a long time to become fully established. It attracts birds and butterflies.
- Silver bush lupine (*Lupinus albifrons)*
    - Habitat needs: full sun, well-draining soils
    - Characteristics: 3'H x 5'W, dense and spreading, semi-deciduous, drought tolerant, purple flowers in spring, silvery leaves shimmer, reliable (CNPD, Lupinus albifrons)
    - Benefits: Goes well on the sloping edge of the garden where soils are better drained. Silvery leaves shimmer, making this shrub beautiful even when it's not flowering. This plant is also considered one of the more reliable in drought conditions.
- Toyon (*Heteromeles arbutifolia)*
    - Habitat needs: full sun, all soils
    - Characteristics: 8-15'H x 8-10'W, evergreen, drought tolerant, white flowers in summer, showy leaves (CNPD, Heteromeles arbutifolia)
    - Benefits: This dense shrub is a great garden border plant, as it forms a thicket that provides habitat for many birds year round (McMurry, 1990).
- Western redbud (*Cercis occidentalis)*

    - Habitat needs: full sun, all soils, moderate watering. It does require moderate watering when getting established.
    - Characteristics: 15’H x 10’W, winter deciduous, hot pink flowers in spring, heart shaped leaves (CNPD, Cercis occidentalis)
    - Benefits: Heart shaped leaves and hot pink spring flowers make this shrub quite showy in a garden setting.
- California fuschia (*Epilobium canum)*
    - Habitat needs: full sun, all soils
    - Characteristics: 2’H x 4’W, low and spreading, semi-evergreen, drought tolerant, red flowers in summer/fall (CNPD, Epilobium canum)
    - Benefits: This low growing plant spreads along open space in the garden, with stunning red flowers in summer and fall when many other species are dormant. It is also a favorite for hummingbirds.
- Monkey flower (*Mimulus aurantiacus)*
    - Habitat needs: full sun, all soils
    - Characteristics: 2-3’H x 3’W, semi-deciduous, drought tolerant, orange showy flowers in spring (CNPD, Mimulus aurantiacus)
    - Benefits: Major attractor of the common checkerspot and buckeye butterflies in the local area. This plant also has showy orange flowers during spring.
- Snowberry (*Symphoricarpos albus)*
    - Habitat needs: Full sun, all soils
    - Characteristics: 6’H and spreading, mounding and climbing, winter deciduous, drought tolerant, pink flowers in spring, very easy to grow, large white berries (CNPD, Symphoricarpos albus)
    - Benefits: This thicket-forming shrub is extremely easy to grow with very little water, and the white berries it produces are a wonderful food source for local animal species. It also attracts hummingbirds and butterflies.
- Pipestem clematis (*Clematis lasiantha)*
    - Habitat needs: partial sun, occasional watering
    - Characteristics: 10-15’ long, climbing/twining, winter deciduous, cream flowers in jaunary-june, showy leaves (CNPD, clematis lasiantha)
    - Benefits: This plant climbs and twines through a garden, growing into empty spaces. It flowers for almost half of the year and has showy leaves.
- Narrow leaf milkweed (*Asclepias fascicularis)*
    - Habitat needs: fullsun, all soils, moderate water requirement
    - Characteristics: Flower spikes to 4’H, winter dormant, white flowers in spring (CNPD, Asclepias fascicularis)
    - Benefits: This unique looking plant has flower spikes that may reach 4 ft tall, and is the main food source for the monarch butterfly.
- Showy milkweed (*Asclepias speciosa)*
    - Habitat needs: full sun, adapts to all soils(prefers clay)

    - Characteristics: 2-4’ H and spreading, winter dormant, drought tolerant, pink flowers in summer (CNPD, Asclepias speciosa)
    - Benefits: This plant thrives in the clay soils found at our site, and provides food for the monarch and striated queen butterflies
- Summer lupine (*Lupinus formosus*)
    - Habitat needs: full sun, all soils
    - Characteristics: 1-3’H x 2-4’W, evergreen, drought tolerant, purple flowers in spring/summer (CNPD, Lupinus formosus)
    - Benefits: Lupines are a beautiful flowering plant that gives off a sweet smell when in bloom. The smell attracts many butterflies and hummingbirds.
- Yarrow (*Achillea millefolium)*
    - Habitat needs: full sun to high shade, all soils, moderate watering
    - Characteristics: 6” H x 2-3’W, upright with creeping rootstocks, evergreen, white/light pink flowers in spring/summer, aromatic, feathery fern-like leaves, spreads by rhizomes (CNPD, Achillea millefolium)
    - Benefits: This evergreen plant has unique leaves resembling a fern, is extremely aromatic, and serves as an excellent substitute for turf lawns (Aleksoff, 1999).

<u>Mesic/Hydric (for edges and adjoining detention basin):</u>The following plant list refers to plants that need slightly more water to survive, and these will be used on the edges of the site that border the detention pool, as well as in the pool itself. Some constraints that had to be considered here is that the detention pool dries up during summer, so the species in this area must be able to tolerate inundation by water, as well as drought. This led to use of more mesic species, which could tolerate wetter conditions, as this proved easier than finding aquatic species that could adapt to drought. Many of the species below were also identified by Katherine Holmes as a priority for use in the garden, and methods similar to those mentioned above were used to locate other species that would thrive under these environmental constraints.

- Big leaf maple (*Acer macrophyllum)*
    - Habitat needs: full sun, all soils (prefers drainage), moderate to regular water
    - Characteristics: 30-100’H x 10-20’W, winter deciduous, yellow flowers in spring (CNPD, Acer macrophyllum)
    - Benefits: Provides dense shade for the smaller plants within the pool that must avoid the extreme summer heat. Beautiful fall colored leaves.
- Black willow (*Salix gooddingii)*
    - Habitat needs: full sun, all soils, regular watering
    - Characteristics: 20-30’H x20-30’W, winter deciduous, yellow flowers in spring (CNPD, Salix gooddingii)
    - Benefits: This tree is very fast growing, and is good at erosion control on slopes near water. This would help stabilize the edges of the water detention pool.
- Oregon ash (*Fraxinus latifolia)*
    - Habitat needs: full sun, grows in standing water

    - Characteristics: 75’H, deciduous, flowers in spring (CNPD, Fraxinus latifolia)
    - Benefits: Can grow in standing water, but once established this tree can withstand long periods of time without surface water due to its deep root system. It also serves as important habitat for many bird species.
- Red willow (*Salix laevigata)*
    - Habitat needs: full sun, regular watering, all soils
    - Characteristics: 10-40’H x 25’W, winter deciduous, yellow flowers in spring (CNPD, Salix laevigata)
    - Benefits: This tree needs regular watering to establish, but is also very good at erosion control along the edge of waterways. This helps keep the edges of the detention poor from caving in (off the slope).
- Buttonbush (*Cephalanthus occidentalis)*
    - Habitat needs: full sun, all soils (prefers clay), regular watering
    - Characteristics: 8-30’H x 12’W, deciduous, white flowers in spring/summer; yellow and orange fall colors (CNPD, Cephalanthus occidentalis)
    - Benefits: This shrub prefers clay soils (as at our site), and can tolerate extreme heat during the summer. It has wonderful orange and yellow fall colors, with white flowers in spring/summer (colorful year round)
- Spice bush (*Calycanthus occidentalis)*
    - Habitat needs: full sun, regular watering
    - Characteristics: 9’H x 9’W, winter deciduous, red flowers in summer, bright green leaves, smells “like an old wine barrel” (CNPD, Calycanthus occidentalis)
    - Benefits: Bright green leaves and red flowers in summer make this shrub beautiful most of the year. It also has a unique smell of wine.
- Pipevine (*Aristolochia californica)*
    - Habitat needs: part sun to shade, all soils, regular watering
    - Characteristics: 10-15’ long, climbing, winter deciduous, cream flowers with purple veins in winter/spring; grows up into shrubs, (CNPD, Aristolochia californica)
    - Benefits: This climbing vine grows up into the shrubs with cream colored flowers. It helps fill in possible blank spaces in a planting bed.
- Western clematis (*Clematis ligusticifolia)*
    - Habitat needs: , partial shade, all soil, regular watering (summer)
    - Characteristics: 15-20’ long, climbing, winter deciduous, white flowers from june-september (CNPD, Clematis ligusticifolia)
    - Benefits: Beautiful climbing plant that has white flowers during summer. Requires watering during the summer months due to the extreme heat.
- California grape (*Vitis californica)*
    - Habitat needs: full to partial sun, all soils, regular watering
    - Characteristics: Up to 40’ long, climbing vine, winter deciduous, yellow flowers in spring; edible purple fruit ripens in late summer (CNPD, Vitis californica)

- Benefits: Climbing grape vine is beautiful and the edible fruit ripens in late summer.
    - Detriments: Requires watering so may not be able to survive in long droughts, fruit toxic to dogs
- CA aster (*Aster chilensis)*
    - Habitat needs: full to part sun, all soils, regular watering
    - Characteristics: 1'H x 5'W, low and spreading, evergreen, violet flowers year round,garden tolerant with lush growth (CNPD, Aster chilensis)
    - Benefits: Evergreen spreading plant that maintains purple flowers year round. This helps maintain the color in the garden when many other things go dormant. Grows very well in a garden setting.
- Goldenrod (*Solidago californica)*
    - Habitat needs: full sun, all soils
    - Characteristics: 2'H and spreading, spreading, deciduous, drought tolerant, yellow flowers in summer/fall (CNPD, Solidago californica)
    - Benefits: Low spreading plant with showy leaves and yellow flowers in summer and fall which attract butterflies and bees.
- Mugwort (*Artemisia douglasiana)*
    - Habitat needs: full sun, well-draining soils, moderate water needed
    - Characteristics: 4'H and spreading, evergreen, grey/green flowers in summer(CNPD, Artemisia douglasiana)
    - Benefits: Evergreen plant that does better in well drained soils (on our slopes) and controls erosion near the water's edge

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Implementation plan:

- Summer 2014
    - Remove gravel from the site-pile along sides
    - move shed to opposite corner of the parking lot
    - remove any obvious invasives in the site (very few as it has been completely covered in gravel)
- Fall 2014 (before rains)
    - Till the soil on the site to a shallow depth (2-3 feet) in order to bury current weeds and allow for new weed seeds to germinate
    - Wait for any invasives to germinate
    - Spray site with Imazapyr to kill off any invasives that germinate in the tilled soil

- Obtain and install presentation area in center of the garden
    - Gazebo, benches
- Install benches in the triangular sitting area of the site (near the baseball field)
- Create the planting bed areas
    - Define the edges using borders
- Lay down drip irrigation lines throughout the beds
- Cover in paths with gravel that was removed from original site
    - Gravel is to be placed between all the planting beds as a natural path
- Define border of the site using a short fence (1-2 feet) or a border of large stones

- Winter 2014-2015
    - Prep planting beds
        - Remove any debris from the top of the soil (that may have landed there since beds were formed in fall)
        - Add organic plant/animal mixed compost to soil to enrich with nutrients
            - Form a layer of 3-5 inches on the top of the soil
        - Rake and flatten out soil in the beds so they are all an even height
    - Begin planting (see next list for when to plant each species)
    - Place plastic tubes around bases of trees to prevent herbivory
    - After planting, water in species, and then initiate the drip irrigation lines
        - Aim for water twice a week initially, with less frequent watering as plants become established
        - Adjust water schedule depending on rainfall events during the season
        - Reduce watering to once a week by spring (except around any new individuals that are put in during this time)
    - Cover planting beds with a 2-3 inch layer of mulch to retain soil moisture and reduce invasion
        - Ideally use pine, oak, redwood, or cedar mulch (or a combination of any) as these mulch varieties tend to be most compatible with California natives
    - Place information signs among the garden to provide information about key species
        - Install front sign for the garden- information on the purpose, types of species, and links of where to find more information
- Spring 2015
    - Monitor success of the site

    - Check for invasive species which can be removed by hand
    - Replace any bare spots which may not have survived the planting process
    - Remove any dead plants
- Summer 2015- summer 2018
  - Continue monitoring of the site for three years
  - Maintain drip irrigation weekly during summer months
    - Monitor to adjust watering to be more frequent during first summer
  - Remove any invasives and look for potential disease or other issues

Planting considerations:

- Many of the plants should be put into the ground during January as seedlings, rather than seeds, however some having specific planting requirements, discussed below. Seedlings of at least 6 inches are ideal for most of the larger species. All of the information below was gathered through the USDA plant database (USDA, 2014).
- Box elder
  - Saplings need to be in full sun for the first 2-3 years in order to establish successfully
- Valley oak
  - When planting from containers, the holes need to be made twice as wide and deep as the container before placing the plant in the ground
  - Mulching around the tree until it is about 10 inches tall will decrease likelihood of competition with nonnatives and help the sapling retain necessary extra water
- California buckeye
  - Harvest seeds to start in pots in November
  - When planting the seed, you will notice a light spot on one end. Make sure this end is planted downward into the soil, as this is where the root head will emerge from
  - Water seeds immediately after planting, and water the tree 2-3 times per week for the first month.
  - Water weekly through the first summer, and then the tree should be fully established and be able to do without much water
- Hollyleaf cherry
  - Plant 2-3 seeds in gallon containers to start with. After 20-40 days, once seedlings have sprouted, choose the healthiest one and remove the others from the container.
  - Use seeds as soon after collection as possible, as they do not have a long period of viability

- Toyon
  - This plant does better if it is a slightly larger size, approximately 12-15inches, in the container before being transplanted.
  - Toyon can also be planted earlier than most of the other plants, ideally in November.
- Western redbud
  - This can be planted earlier than most of the garden- late fall
  - Requires weekly summer watering the first summer in the ground (after transplanting)
- Snowberry
  - Grow in a greenhouse in pots for their first winter, and then place into the ground in late spring or early summer.
- Narrow leaved milkweed
  - Place into the ground as a seedling (>5inches) in late fall in order to allow for enough root growth to survive through the winter
- Showy milkweed
  - Place 3-4 seeds in groups on the surface, do not cover with soil. Plant the groupings of seeds 36 inches apart. Plant in late fall to allow enough time to establish a good root system before the winter
  - This plant has an extremely high mortality rate when propagated in pots, so sowing directly into the ground is the most successful
- Common yarrow
  - Plant transplants(>5 inches) 18-24 inches apart on the site during spring(February-April)
  - Be careful to not pack down soil around the plant when placing it in the ground, as it needs lots of aeration and space when first establishing its root system
- Big leaf maple
  - Plant seeds into containers and do not transplant into the site until they reach a minimum height of 25cm in order to ensure successful establishment
- Common buttonbush
  - Unrooted cuttings can be pushed into soil if moistened immediately before planting (during winter, assuming there will be more rain in the season)
  - Can establish on their own if irrigation is provided during initial month (if planting during spring)
- Western clematis
  - Mulch around the base of the plant once transplanted in order to help retain moisture and reduce competition as it gets established

Additional plants added:

- California poppy (*Eschscholzia californica)*
  - 1' H x 1'W, annual, clumping growth, full sun, orange flowers in spring, attracts butterflies (CNDP, Eschscholzia californica)
  - Turn over soil to 5-6 inches prior to planting, and sow seeds directly into the ground after the last frost
  - Place groups of 2-3 seeds 4-5 inches apart in rows 12 inches apart from each other
  - Cover seeds with up to 1/16 inch of soil (only to protect from birds)
  - Water in immediately after planting
- Deer grass (Muhlenbergia rigens)
  - 2-4'H x 4'W, bunchgrass, evergreen, full sun to partial shade, attracts birds and butterflies, helps create natural borders (CNDP, Muhlenbergia rigens)
  - Plant transplants (>6 inches) after the last frost, minimum 30 inches apart
  - Water in initially after planting, but water sparingly after that (no more than biweekly)

Site map:

- Front border: This border is made up of deer grass, lupines, and California poppies. This elongated edge bed serves as a great example of a natural border, as well as effective ground cover. It also serves as an aesthetic benefit as it draws in the eye of visitors with colors of purple and orange.
- Back hedgerow: This hedge border along three edges of the site function as a wonderful example of natural fencing. Instead of using fences to show people where the edge of the site is, tall bushes and shrubs (often reaching 6-8 feet high), serve to define the borders. These also offer a more aesthetically pleasing option, as every color of flower is represented throughout the shrub mix. This border will also be vital species habitat, as many of the plants are thicket-forming and will be used by many bird and mammal species
- Interior beds: These beds were designed in order to give examples of how drought tolerant plants can be mixed together to replace lawn turf. The general goal was to place larger shrubs in the middle of the beds, and then intermix medium and small plants towards the outside of the beds in order to increase aesthetic viewing. Colors were arranged in each bed in order to represent as many different shades as possible, while ensuring that at least 1/3 of the plants would be in bloom at any given time.
- Educational area: This area was designed to provide an area where educational talks could take place, or groups could sit in the center of the garden

to enjoy snacks or take a rest. The benches are arranged inwards, and the area is surrounded by planting borders, with plants no taller than three feet to allow site across the entire garden when sitting down. Trees were planted on two corners of this area to provide shade over the benches.

Sources (those not mentioned in part I):

"Plants Profiles." *Plants Database*. United States Department of Agriculture, 2014. Web. 10 May 2014. <http://plants.usda.gov>.

"Eschscholzia californica." *California Native Plant Database.* Theodore Payne Foundation, 14 Aug. 2011. Web. 10 May. 2014.
< http://www.theodorepayne.org/mediawiki/index.php?title=Eschscholzia_californica>

"Muhlenbergia rigens." *California Native Plant Database.* Theodore Payne Foundation, 12 Oct. 2009. Web. 10 May. 2014.
< http://www.theodorepayne.org/mediawiki/index.php?title=Muhlenbergia_rigens>

Demonstration "native lawn" garden- Alexandre Dopkin

A. The usage of water in California has quickly become a hot topic of debate. With the current drought California water reservoirs have dropped far below their average levels. Agriculture, urban areas, and conservationists alike advocate the necessity of their usage of the water. This said, residential garden and lawn irrigation in the US are responsible for the consumption of nearly 9 billion gallons of water per day (~50 gallons of water used per household on gardens and lawns per day) (**http://www.epa.gov/WaterSense/pubs/outdoor.html**). Non-native turf lawns are largely responsible for this excessive water use. On average turf lawns require 1 to 1.5 inches of water per week to keep the soil moist. Commonly used turf species in California include: hybrid bermudagrass, common bermudagrass, zoysiagrass, St. Augustinegrass, kikuyugrass, tall fescue (and dwarf varieties), Kentucky bluegrass, various ryegrass species, and bentgrass (http://www.ipm.ucdavis.edu/PMG/r785900111.html#COMMON and http://anrcatalog.ucdavis.edu/pdf/8044.pdf). Unfortunately, these grass species are not adapted to the hot dry summers of the central valley and much of California.

With regards to climate change, the Northern Hemisphere may be experience an increase in extreme drought events (http://www.pnas.org/content/108/4/1474.short and http://www.agci.org/docs/2068.pdf). Continuing to divert crucial water supplies to maladapted turf grasses is an unsustainable prospect. Fortunately, there are a wide variety of native grasses that can reduce the amount of water needed as much as 66% (http://www.epa.gov/greenhomes/ConserveWater.htm). Veering away from turf grass lawns can result in even greater water savings.

B. To demonstrate the viability of low water use gardens and parks, I am tasked with developing an aesthetically pleasing, functional, and natural low water meadow in the Vacaville/Central Valley area. Specifically, my site is located next to the Three Oaks Community Center, Vacaville, CA. This requires incorporating trees, shrubs, forbs and wildflowers as well as the grasses.

Environmental Conditions in Vacaville –

Soil – On the site the soil is Yolo silty clay loam. Other soils in Vacaville include Yolo loam, Brentwood clay loam, Dibble Los-Osos clay, Millsholm loam, Altamont clay, Rincon clay loam, and Capay silty clay loam.

Climate – On average Vacaville receives 24.55 inches of rain annually.

Period of Record : 1/ 1/1893 to 12/31/2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	55.4	61.3	66.6	72.9	80.9	88.6	95.2	93.9	89.6	79.8	66.4	56.1	75.6
Average Min. Temperature (F)	36.7	39.6	41.7	44.1	48.8	53.5	56.1	55.0	52.6	47.3	41.0	37.3	46.1
Average Total Precipitation (in.)	5.48	4.45	3.28	1.51	0.65	0.14	0.02	0.04	0.30	1.20	2.77	4.73	24.55
Average Total SnowFall (in.)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table from http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca9200

Species list –

See table on excel sheet.

Salt grass – Can do well in xeric environments. Seems alright to walk on.

Box elder and cottonwoods are not good choices for the site – prone to getting bores when not watered frequently enough.

Blue Oak should be able to establish and grow well under the conditions of the site. Concerns with this species would be dropping acorns on paths. The infrequent 1-2 times a month irrigation system set up for the grasses will support this species.

Black Oak – (http://www.fs.fed.us/database/feis/plants/tree/quekel/all.html) - Can be very tall 30-80 ft, great for shading except lower branches often near ground. Taproots on clay often decay (issues?). Can be grown from seed. Very high acorn production. Short term seed banking.

Interior Live Oak – (http://www.fs.fed.us/database/feis/plants/tree/quewis/all.html) - Can grow on really harsh terrain. Does not need much water at all, great for low water habitat.

California Bay Laurel – (http://www.fs.fed.us/database/feis/plants/tree/umbcal/all.html) - Not a very common tree anymore – would be good to plant for this reason. Seeds supply food source for birds and rodents. Transplant when under 1 year old. 40-80 ft tall. Does well in xeric environments. Individuals of this species are doing well in Vacaville.

California Buckeye, Toyon, Coyote Bush are great dry habitat shrubs native to the Central Valley.

Valley Oak – Will be placing this on the site. Want to support Valley Oaks as much as possible. Flood and drought tolerant. 30-75 ft.

- California Buckeye – (http://www.fs.fed.us/database/feis/plants/tree/aescal/all.html) - great for rehabilitating soil and preventing erosion. Easily planted.
- Toyon – (http://www.fs.fed.us/database/feis/plants/shrub/hetarb/all.html) - Coexists with Coastal Live Oak. Erosion control. Great for dry soils. Transplants can grow 11 to 18 feet. Collect seed in fall. Great species to support avian biodiversity.
- Coyote Bush – (http://www.fs.fed.us/database/feis/plants/shrub/bacpil/all.html) - Seedlings grow well in the spring, keep soil moist enough for root development during this stage. Will need to keep soil moist during establishment. Great for pollinators.

Blue blossom, California coffee berry, Hollyleaf cherry, Silver bush lupine, & Western redbud should all be relatively successful under the conditions for our site – source John Lichter.

Milkweed species will take very easily to the site. Great to support butterfly life.

Most forbs will need to be planted 1-2 years after the establishment of the grasses, trees, and shrubs, and after the hardscaping on the site. This is due to weed issues on the site and the need to spray pesticides that will harm the forbs and wildflowers.

I am in contact with Hedgerow Farms about viable forbs and will be using them extensively as a resource, especially once the other meadow species and irrigation systems are confirmed. A list of native forb species from Hedgerow Farms will be submitted as well.

Restrictions – ADA guidelines for sloping and disability access underline the layout of the site hardscaping. Also, key to this project is the use of the area as a public site. This is not meant to be a restoration project so much as it is a demonstration of low water use species that are native and aesthetically pleasing. It is meant to educate visitors on what each species is, and of the potential water savings from replacing traditional turf lawns with these species.

Please note that the list of potential natives is constantly expanding. Current project priorities are to complete the general site layout with meadow types and tree locations. From there picking optimal species will become priority.

Riparian woody species in general- zonation (where can grow in terms of depth of water table compared to rooting depth, frequency of flooding, etc.) Rhia Bordon

Riparian vegetation in the Central Valley of California is dependent on perennial moisture sources, so is restricted to the drainage areas of major rivers and tributaries which receive snowmelt runoff from neighboring mountains and uplands. Before man's interference, the natural levees of the Sacramento rose from 5 to 20 feet above the flood basin, and avergaed 3 miles in width, although they ranged from about 1 to 10 miles (Thompson 1961). Today, riparian areas usually exist as narrow corridors adjacent to streams, lakes and springs, and thus occupy a small proportion of the landscape in the United States. However with optimal sunlight exposure, high nutrients and the support of nearby water, riparian sights are capable of supporting high levels of productivity (Vaghti & Greco). Riparian areas are also capable of supporting high forest complexity due to the occurrence of vegetation zonation. Riparian plants exist in different community groupings which occupy strips at varying distances from the river channel based on species' tolerance of various conditions. The complexity created by vegetation zonation and productivity of riparian systems allow them to support a variety of wildlife (Stringham & Repp 2010). For example in southeast Oregon, 80 percent of terrestrial wildlife species are dependent on riparian systems for some portion of their life cycle. Despite this, riparian ecosystems are among the most disturbed in the state due to land conversion for agriculture and riverbank stabilization. Today, an estimated 2 to 6 percent of historical riparian areas remain in California while half of the remnant sites have been logged or otherwise degraded (Warner & Hendrix 1984). Restoring and preserving riparian areas is critical to achieving biodiversity goals for many species of plants and animals. The complexity of interactions between various factors in different riparian zones makes developing general rules for managing restoration sites challenging (Merritt et al. 2009). Therefore understanding the zonation of riparian species is essential to planning restoration efforts which can successfully promote high biodiversity and productivity.

Key Constraining Factors Which Influence Riparian Vegetation Zonation

HYDROLOGY:

Flooding Recurrence

- floods may be catastrophic occurrences which bury plants in sediments, physically damage and uproot plants, and deprive roots of oxygen during a period of inundation
  - floods influence plant species composition by elinating non-riparian species that are intolerant of the physical disturbance regime and root anoxia, while providing riparian obligates with moisture conditions they require for establishment, survival and reproduction (Merritt et al. 2009)
- Frequency
  - site must flood periodically for all riparian species
  - a regularly inundated site which floods every year should facilitate establishment of all riparian tree species
  - more frequent floods (more than a few days recurrence interval) prevent the establishment of later successional species close to the river channel
  - less frequent flood events (less than 5 year recurrence interval) maintain habitat heterogeneity, and hinder the growth of non-native species which are not well adapted to scour and burial associated with flooding (Merritt et al. 2009)

- ◦ flood events carrying in seeds of other species onto the site which can work to increase species biodiversity by allowing an opportunity for new species colonization (Sacramento 1998)
- ◦ small rodents on a site, such as voles and pocket gophers, which are major herbivores of seeds and seedlings of riparian trees are drowned by floods (Sacramento 1998)
- ◦ when sites are flooded, it results in inputs of nutrients, soil, and creation of areas of fine-grained alluvial soils

- Duration
  - ◦ riparian trees and shrubs are differentially adapted to the duration of flood events
    - most are able to tolerate several days, while a few are able to tolerate a few months of flooding (Griggs 2009)
- tolerance of plants to inundation, scour and burial, anoxia, and drought vary as a function of developmental stage for many riparian species
  - many pioneering species are intolerant of inundation at a young stage of development because seeds fall and germinate on freshly deposited alluvium near the channel, and can be removed easily by a flood
  - adult pioneers can persist as water levels drop and soils dry over time because they can use their root system to reach groundwater (Merritt et al. 2009)

Shape of hydrograph

- majority of riparian species in the Central Valley are phreatophytes – plants which require that their roots be in contact with a stable water supply during long periods of time in each year (Lange 1934).

- adequate moisture is necessary for seedling survival and plant establishment, while excess water can result in anoxia due to root inundation, and mechanical disturbance by scouring and flooding

- Natural vs. unnatural flow regime
  - humans dam many rivers and control the flow of water that is released downstream
    - if the hydrograph gradually rises and falls in the year, it is a natural flow regime
    - abrupt changes in flow or steady flows throughout the year produce an unnatural flow regime
  - timing of seed release, dispersal and establishment are adapted to the hydroperiod of the river
    - springtime decline in hydrograph is ecologically critical for seed dispersal and establishment for several important riparian species since they are adapted to a slowing or reduction in magnitude of flows during late spring and early summer, as rainfall tapers to nothing (Griggs 2009)
    - when flows are at their spring and summetime lows, seeds can fall into place and establish without being washed away by excessive water
  - if the hydrograph has a natural, smooth rising and falling relative to rainfall and run-off, this allows natives to successfully establish.

        - natives will not establish under a flat-line hydrograph, such as occurs on rivers with dams
        - it would be necessary to restore a site with a flat-line or erratic hydrograph to a natural flow regime before it may be planted (Griggs 2009)
    - root development varies as a function of water availability conditions
        - trees which develop roots in relation to a highly variable flow and groundwater level may develop more vertically extensive roots
        - those developed under a more stable surface and groundwater condition will develop more shallow roots, which may predispose them to moisture stress when the water level decreases or there is prolonged drought (Merritt et al. 2009)

SOILS:

Texture

- all riparian trees prefer loamy soils and few will grow well in very fine or coarse soils (sand or gravel) without maintenance
    - smaller particles such as silt do not allow water to drain as quickly, so water is available to roots for a longer period of time
    - larger particles such as sand allow water to drain more quickly and do not hold water for long periods
- stratification of soil textures
    - stratification (presence of sand or clay layers) from top to bottom creates

differences in soil water holding capacity, root aeration, and nutrient levels

    - usually varies greatly across the entire site (Griggs 2009)
    - can also vary greatly with depth, causing discontinuities which affect root growth patterns
        - root growth may be restricted to layers with finer textures
    - essential to assess soil texture features at the start of a restoration project, before a planting design is made
        - in some situations, soil stratification can be ameliorated by using a tractor-mounted auger to mix the soil profile before planting

STREAM MORPHOLOGY

Shape and position of landforms relative to the stream (e.g. low swales and adjacent higher ground)

- different species will be able to establish at different topographic gradients
    - variation in landforms aid restoration because different species will establish along different topographic gradients
    - plant species are adapted to different soil textures, which often correlates with topography.

Sediment erosion & deposition

- the force of river flows against substrates on the adjacent banks causes a breakdown of substrates into sediments

- during floods, sediments suspended in the river are deposited onto the banks with larger particles falling out closer to the river channel and finer particles extending into the higher banks (Warner & Hendrix 1984)
- sediments in flowing water can scour and/or bury plants
    - some plants adapt by adventitiosly rooting from stems (Merritt et al. 2009)
- mechanical flood disturbance regulates the rate of landform formation and destruction, and can lead to destabilization of banks, channel incision, and river meandering (Merritt et al. 2009)

Depth to water table

- must be known for several points across restoration site because it may vary greatly throughout
- Winter and Spring water table levels normally higher than Summer and Fall levels
- Depth to water table is critical for certain riparian species (e.g. cottonwoods and willows) which must grow their roots into the capillary fringe above the water table in order to grow without additional moisture from precipitation or flooding

EXISTING VEGETATION:

- regeneration potential of the site is based upon the surrounding vegetation since it provides the source of seeds that could possibly colonize and establish in the area

Native species

- success of existing natives should be promoted

- additional natives should be incorporated into the planting design

Invasive and exotic species

- invasives and exotic weeds should be managed in the short term so that they cannot establish, grow and dominate the system
    - Giant Cane (*Arundo donax*) and Tamarisk spp. are invasives which can develop large stands of dense stems in riparian areas which provide little to no habitat value to wildlife, and may cause flood conveyance problems (Griggs 2009)
- most non-native invasive weeds cannot tolerate flooding, so flooding frequency and duration will determine which species may colonize, and period flood recurrence will help to manage weeds in the long term

Key California Riparian Tree Species

Acer (Maple)

- 200 species of mostly winter deciduous trees
- of four species, only Box elder (*Acer negundo)* is primarily riparian, and is common in drier parts of the Coast Ranges and lower parts of the Sacramento and San Joaquin Valleys, altough it is dominant nowhere in California
    - normally a shade-tolerant subordinate tree in dense Cottonwood and Mixed Riparian forest stands dominated by cottonwoods or willows
    - less common in Valley Oak Riparian Forests but will tolerate drier conditions there

    - seedlings are common in Willow Scrub
- conditions for establishment and growth:
    - fast-growing tree which prefer moist, well-drained soils with high humus
    - can tolerate annual flooding and will benefit from the availability of water throughout the entire water column
    - found in coarser texture soils with high moisture, will germinate and establish in moist riparian conditions adjacent to parent trees (Sacramento 1998)
- good indicator of drought stress because it will be the first tree in riparian areas to wilt when soil isdry (Sacramento 1998)
- declining in California since it is a relatively poor competitor which has been restricted to highly competitive riparian zones (Warner & Hendrix 1984)

Alnus (Alder)

- genus of 35 species of deciduous trees and shrubs of the Northern Hemisphere and Andes
- large, obligately riparian trees in warm temperate climates
- symbiotically fix nitrogen
- four California species
    - Red alder - largest of American alders, is very common on moist slopes
    - White alder – obigately restricted to streamsides
        - usual dominant in California montane riparian forests up to 1,600 m

        - most common along fast-flowing mountain streams west of the Sierra Nevada crest, suggesting intolerance for summer heat
        - ditribution most controlled by need for constant saturation of root zone by cool, well-aerated water (Warner & Hendrix 1984)

Cephalanthus (Button Bush or Button Willow)

- only one species in California, which is an obligate riparian small deciduous tree or shrub
    - occurs in Mixed Riparian Forests, and is less common and generally occur as younger individuals in Cottonwood Riparian and Willow Riparian Forests
    - common along many permanent natural streams, often lining high water flood channels (Sacramento 1998)
- conditions for establishment and growth:
    - limited to areas with mean July temperatres above 20 degrees C and where most of the root zone is reliably saturated throughout the year
    - highly tolerant of flooding, should be planted where on sites which receive annual flooding and where water table is 5 to 10 feet deep to ensure adequate moisture (Sacramento 1998)
    - seeds are able to germinate in moist, well-drained, fresh silt and organic debris along the edge of the high water table

- relict species which has survived the transition to a drier and cooler climate because the low-lying Central Valley and high surrounding mountains keep it continuously supplied with abundant water (Warner & Hendrix 1984)

Fraxinus (Ash)

- Oregon ash (*Fraxinus latifolia*) is common sub-canopy tree in Mixed Riparian Forests and less common in Valley Oak Rparian Forests
- conditions for establishment and growth:
    - prefer sandy loam soils, but can tolerate coarser texture soils found closer to the active channel
    - rely almost entirely on riparian water during the growing season
    - can tolerate inundation during the summer growing season
- biology and distribution suggest they are declining relicts which are somewhat more tolerant of heat and low humidity, but less tolerant of low soil moisture (Warner & Hendrix 1984)

Platanus (Sycamore)

- *P. racemosa* is an obligate riparian species and important secondary component of the Mixed Riparian Forests of the Sacramento Valley, where it is often associated with higher and drier sites (Warner & Hendrix 1984)
    - distribution into northern Coast Ranges is possibly significantly limited by cool, wet spring (Warner & Hendrix 1984)
- conditions for establishment and growth:

    - preference for deep, rich, moist, well-aerated soils where roots can grow into water table, but tolerates many soil types including dry, porous, coarse grained substrates within riparian zones
        - tend to become dominant in sandy soils where root aeration is high and the water table is deep (Sacramento 1998), suggests a requirement for aeration in at least part of the root zone (Warner & Hendrix 1984)
    - tolerates considerable inundation

Populus (Cottonwood)

- Fremont cottonwood (*Populus fremontii*) is the most important riparian genus in California
    - grows at a range of sites with a medium of July temperatures, limited to coastal areas around San Francisco and San Luis Obispo where winters are mild and the growing season is long (Warner & Hendrix 1984)
    - dominant tree in Cottonwood Riparian Forests, many Mixed Riparian Forests, and occurs as seedlings in Willow Riparian Forest
    - can form dense thickets on lower terraces of the floodplain, and then closed-canopy forest stands as they mature (Sacramento 1998)
- conditions for establishment and growth:
    - deep-rooted and should be planted where water table is 5 to 15 feet below
    - do best on medium to fine texture soils about 10 feet above the water table

    - can tolerate one to three month periods of inundation and benefit from the moisture provided by annual flooding (Sacramento 1998)

Quercus (Oak)

- huge genus of 450 species dominates the upland deciduous forests of the Northern temperate zone
- Valley Oak (*Quercus lobata*) is California's only major riparian oak, and is better suited to germination in mature forests than regularly disturbed riparian zones where they are outcompeted by more easily dispersed species
- conditions for establishment and growth:
    - oaks must have access to water throughout the growing season, which may determine their density – closed forests dominated by *Q. lobata* can occur where water is available at relatively shallow depths, and open woodland and savanna with scattered oaks are found where water is more limiting (Warner & Hendrix 1984)
    - common in sites which have heavy, poorly aerated soils with high water-holding capacity
    - can dominate riparian forests adjacent to streams when *P. fremontii* is not dominant due to to poor soil aeration, and forest, woodland, and savanna on alluvial plains and terraces, usually above the riparian forest normally dominated by *P. fremontii*
    - adaptable to a wide variety of soil and moisture conditions
    - established trees will not tolerate soil compaction or change to soil grade within root zone (Sacramento 1998)

Salix (Willow)

- genus consists of 500 species of trees and shrubs
    - Goodding's willow (*Salix gooddingii*) is dominant in less disturbed Willow Riparian Forest, and is also common in Mixed Riparian Forests and shares dominance with Fremont cottonwoods in intermediate floodplain levels of Cottonwood Riparian Forests
        - most important willow of riparian forests in California's Central Valley since they are pioneering species which stablize banks to allow succession of later species
        - more tolerant of weeds and stress than *P. fremontii*, as long as water table is abundant, often dominates new riparian forests
    - Narrowleaf willow (*Salix exigua*) is dominant on sandbars of Willow Riparian Forests, and also common in Cottonwood Riparian Forest subcanopy
    - Arroyo willow (*Salix lasiolepis*) is most abundant and forms dense thickets in openings of the canopy on older gravel bars and intermediate floodplain levels of the Willow and Mixed Riparian Forests
- conditions for establishment and growth:
    - limited to riparian areas, suggesting a need for hot growing seasons and abundant groundwater (Warner & Hendrix 1984)
    - willows are the riparian species most tolerant of inundation in the growing season (Sacramento 1998)

    - colonization and long-term survival are closely linked with the river's flow regime
        - if the flow level recedes to summer lows too rapidly, the roots of young willow plants will not be able to maintain adequate moisture and mortality will occur
        - disperse seeds during spring and summer, in time with the decrease of incoming precipitation, river flows and recurrence of flood disturbance (Boland 2014)
    - young willows are adapted to coarse substrates such as gravel and sand which are abundant at close distance to the active channel, and their roots must stay in contact with the water table
        - these adaptations enable them to survive in a the narrow band along the river edge that meets the substrate and moisture conditions required by germinating seeds (Lange 1934)
        - can tolerate many types of soils as long as there is adequate moisture (Sacramento 1998)
- among the fastest-growing tree species so develop rapidly once seedlings are established (Vaghti & Greco)

Sambucus (Elderberry)

- Mexican elderberry (*Sambucus mexicana*) grow in the sub-canopy of Mixed and Valley Oak Riparian Forests, and can be form small savannas
- conditions for establishment and growth:
    - tolerates many soil types but requires good drainage and prefers light, moist soils

- intolerant of prolonged inundation in late spring to early summer (until late May) growing season (Sacramento 1998)
    - can tolerate infrequent inundation (less than 3 or 4 years flood recurrence) when fully established (Sacramento 1998)

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Species Gradation by Community –

Plant communities were designated and named following Tu (2000) and Holland (1986), found in Vaghti & Greco. Riparian areas can be classified into several distinct communities which differ in their community composition and site conditions. The vegetation associated with each community are adapted to colonize and establish themselves in successional stages. As community areas are physically changed over time, secondary successional species are able to outcompete pioneering species for resources and colonize higher community levels. This is the theory of riparian areas, but it is far more complex in the field, where any one plant species can occur in more than one community in riparian areas. Moreover the communities are rarely distinctly separated, but instead intergrade into one another (Lange 1934).

Great Valley Valley Oak Woodlands & Forests are dominated by mature valley oaks (*Quercus lobata*) in stands that are typically less dense than Great Valley Cottonwood and Mixed Riparian Forests. These communities are the most endangered riparian community type in the Central Valley (Sacramento 1998). They typically occur in the highest elevation floodplains and terraces around major rivers and tributaries of the Great Valley most distant from the active river channel. This makes the vegetation the least subject of riparian vegetaion to disturbance from flooding, and allows the forests to be composed of late successional species which are intolerant of frequent or extended disturbance. As part of the riparian corridor, Valley Oak Woodlands and Forests are still close enough to access subsurface irrigation when the river bed is filled in spring, and receive inputs of silty alluvium when flooding occurs ("Sensitive" 2004). Soils are saturated seasonally, and are comprised of fine textured silt to clay loam (Sacramento 1998). Flooding is infrequent (greater than 5 year flood recurrence) and is usually of short duration (floods last 0.1% of the year) (Vaghti & Greco, Sacramento 1998). They commonly exist at elevations of three to four meters above the water table depth, and greater than 100 meters from the river or tributary (Harris 1987).

Dominant Species in Great Valley Valley Oak Forests & Woodlands (Sacramento 1998, Harris 1987):

- Valley Oak
- Mexican Elderberry

Less Frequent Species:

- California sycamore

- Box elder
- Fremont cottonwood
- Oregon ash
- Arroyo willow

Great Valley Mixed Riparian Forests are composed of a diverse, often dense, mixture of winter deciduous cottonwoods, willows, and a variety of other key Central Valley riparian species. Occurring on high levels of floodplains, these communities experience intermediate recurrence levels of flooding (3 to 5 year flood recurrence) with moderate durations of inundation (floods last 0.1 to 5% of the year) (Vaghti & Greco). Intermediate disturbance levels allow intermediate sucessional species to establish and grow here. These community types are usually found at elevations of two to three meters above water table depth, and 100 to 200 meters away from the channel (Harris 1987). At this substantial distance from the river channel, sediment deposition occurs but does not necessarily cause physical damage to plants and subsequent erosion. The soils in this community type are medium to fine textured, and are comprised of sandy loam to silt (Sacramento 1998). Mixed Riparian Forests intergrade with the Great Valley Valley Oak Forest at the drier parts of this community, located furthest from the active channel and water table below.

Dominant Species in Great Valley Mixed Riparian Forests (Sacramento 1998, Harris 1987):

- Fremont cottonwood
- California sycamore

- Box elder
- Oregon ash
- Goodding's willow
- Arroyo willow
- Buttonbush

Less Frequent Species:

- Valley Oak
- Sandbar willow
- White alder
- Mexican elderberry

Great Valley Cottonwood Forests are dominated by broadleaved, winter-deciduous Fremont cottonwoods (*Populus fremontii*) which can create dense stands alongside river channels and lakes where they are the only upper canopy species (Lange 1934). These community types are usually located between one and two meters from the water table depth, and 50 to 100 meters away from the stream or river channel (Harris 1987). At a distance from the river, sediment deposition raises the level of the land and diminshes the frequency of flooding. Riparian cottonwood forests are prone to yearly flooding during spring ("Sensitive" 2004), and have flood recurrence intervals of one to three years (Sacramento 1998) and have access to subsurface irrigation even when the river bed is dry. Further away from the river, this community intergrades with the Great Valley Mixed Riparian Forest.

Dominant Species in Great Valley Cottonwood Riparian Forests (Sacramento 1998, Harris 1987):

- Fremont cottonwood
- Goodding's willow
- Box elder
- Sandbar willow

Less Frequent Species:

- California sycamore
- Oregon ash
- Arroyo willow
- Buttonbush
- Gravelbar willow

Great Valley Willow Riparian Forests are broadleaf winter-deciduous thickets tolerant of frequent flooding and sustained inundation (Vaghti & Greco). They are dominated by willows, typically narrowleaf willow (*Salix exigua*), and are the most common pioneering community found on the river's edge. They commonly occur within one meter of water table depth and 50 meters from the channel (Harris 1987). Willows are among the fastest-growing tree species so develop rapidly once seedlings are established (Vaghti & Greco). As vegetation amasses, it slows the velocity of flows and increases deposition, which in turn reduces the frequency and duration of inundation . As this occurs, later successional species are able to establish, and the willow scrub community intergrades with the Great Valley Cottonwood Riparian Forests (Lange 1934).

Dominant Species in Great Valley Willow Riparian Forest (Sacramento 1998, Harris 1987):

- Sandbar willow
- Gravelbar willow
- Goodding's willow

Less Frequent Species:

- White alder
- Buttonbush
- Oregon ash
- Fremont cottonwood
- Valley oak

Planting and Maintenance Guide –

Flooding frequency, or recurrence interval, on a site is the main factor to determine what plant species will be able to establish on a restoration site (Griggs 2002). The geomorphology of the site interacts with flooding recurrence intervals to determine the hydrologic conditions of the site. Therefore, it is important that flood regimes be maintained for each of the riparian community types. It will provide for determination of the weed community composition and pest population levels. Flooding occurs most seldomly and lasts for the shortest amount of time in Valley Oak Forests and Woodlands since they are located farthest from the channel and highest from the water table depth. Flooding occurs most commonly and lasts for the longest times in the Willow Forests. By the end of the first year, the positions and patterns of the zones among adults will be established through erosion and sedimentation mainly caused by stream flow during flooding. The banks may be altered, but remain essentially the same until the recruits have fully developed into an even-aged stand in each zone after 20 to 30 years (Boland 1994).

For sites which are not normally inundated by winter floods and which are distant from a natural seed source, horticultural restoration practices should be used. Horticultural restoration is a technique where genetic sources of plants are taken from offsite and transplanted or seeded in. Using this style of restoration is likely to increase success at these sites because planting can be designed to mimic natural riparian communities. Horticultural projects are more likely to be successful if abundances, spatial arrangements, and densities more closely resemble those observed in natural riparian communities (Boland 2014). Horticultural restoration should be planned to create a down-slope zonation toward the water source of the dominant species, where plants are placed into appropriate zones as opposed to mixed arrangements across the site. If plants are not placed into appropriate zones, this may result in poor survivorship of individuals planted at less than optimal conditions, especially after irrigation is discontinued.

For sites which are normally inundated by floods during winter and which have nearby natural seed sources, natural restoration should be used. In this method, the site is prepared, usually by being cleared and graded, and re-vegetation is allowed to proceed naturally with little or no human intervention. Riparian woodlands that have developed naturally are of high quality and may be more successful than horticulturally restored sites. Naturally restored sites are adapted to frequent disturbances and have the ability to regenerate quickly afterward, and produce a community with a high density and cover of seedlings and adults. Over time, naturally restored stands remain denser and have greater cover than horticulturally restored sites. Moreover, natural restoration promotes the production of a community with appropriate sex ratios and genetic diversity. With certain practices in horticultural restoration such as multiple cuttings from only a few source individuals or use of non-local stock, it can result in unnatural sex ratios or genetic diversity among plants (Boland 2014)

Boland's 2014 study found that established natural riparian forests of 19 to 32 years old are relatively dense, and so horticultural sites should be planted at high densities which take into account survivorship. For example, if 95% survivorship is assumed at 19 years after installation, planting densities need to be 2.6 to 4.4 times greater than originally planted to produce densities of natural 19 year old stands. Restoration sites are usually planted at ~200 per acre or ~500 per hectare. If this density is not successful, then the restoration team can decide whether to increase or decrease the planting density.

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Development of a forb seeding mix for the basin James Mizoguchi

Development of a Forb Seeding Mix for the Basin site

Background and Justification

Forbs are herbaceous flowering plants which are not grasses, sedges, or rushes. They play important roles in nitrogen and water cycling, successional processes, and nutrient transfer within ecosystems (Chapin et al, 2011). Forbs and other plants promote the desired functions of flood control basins by increasing soil infiltration, evapotranspiration, resistance against flows, sediment deposition, and bank stability and have the added benefits of mitigating contamination of detention water and the associated watershed (Janecki & Associates, Inc). Forbs also supply habitat and forage for wildlife, especially pollinators (USDA NRCS). Many plants native to California have restricted ranges and low regional abundances (Brandt and Seabloom, 2012). Revegetation for the purpose of increasing desired ecosystem function can also be tailored to increase the abundance and diversity of native forbs. Formulating the appropriate forb seeding mixture is important for maximizing function of the basin and return from investments into the basin (Janecki & associates).

Environmental Issues at Basin Site

Recruitment, population size, and persistence of a population within a biotic community are influenced by both abiotic and biotic factors (Brandt and Seabloom, 2012). Hydrology is the most important abiotic factor influencing plant community composition in floodplain meadows (Jung et al, 2008) and is likely the most important factor at the drainage basin site. The basin site will be periodically inundated resulting in temporarily hypoxic or anoxic conditions. Oxygen depletion at and around roots can result in death or reduced growth (Friedman and Auble, 2000). Flooding also inhibits gas exchange (Jung et al, 2008). Flooding frequency and duration increases with greater depths (Jung et al, 2008). Plants can be damaged or uprooted by strong flows or debris carried by the water (Friedman and Auble, 2000). Incoming water is also a vector for nutrients, diseases, and exotic or invasive species (Friedman and Auble, 2000). Lack of flooding at the upland perimeter of the basin site will also influence plant community composition (Jung et al, 2008).

Previous Efforts' Species Mixes

- A list of forb candidates for inclusion in drainage features of Salinas, CA included: yarrow, western columbine, California coffeeberry, and yerba buena (Janecki &

Associates, Inc).

- The Yolo basin management plan notes a variety of native bulb in its grasslands: *Brodiaea* spp., *Tritelia hyacynthia, T. laxa,* and *Calochortus* (California Department of Fish and Game).

Candidate Species

In a plan developed for the Salinas, CA, Janecki & Associates, Inc recommended that only native species be planted since they are best adapted to local conditions and should therefore require less management. Seeding mixtures for drainage basins should account for changes in the nature, duration, and extent of flooding that will occur at different depths and locations within the basin (Janecki & Associates, Inc). Tolerance for periodic inundation and associated hypoxia vary with timing, species, size of individuals, and the water itself (Friedman and Auble, 2000). The basin's bottom will be the wettest site, inundated the most frequently and for the longest periods of time (Janecki & Associates, Inc). Plants selected for this area should be tolerant of stress from flooding, submersion, saturated soils, hypoxia and anoxia (Janecki & Associates, Inc). Additionally, Janecki & Associates, Inc recommends native grass and forb species with dense root structures and vegetative cover to minimize erosion, slow floodwater velocities, and increase pollutant filtration. At intermediate depths plants need to cope with the physical force of incoming flow, short periods of inundation, and longer more regular periods without water. (Janecki & Associates, Inc) recommends that plants used here have characteristics which will help to prevent erosion of the detention basin's sides. Finally, the upland portion of a detention basin, the area is never inundated but its soils may be saturated. Janecki & Associates, Inc recommend that vegetation here be tolerant of these water conditions and have deep roots which to stabilize and provide structure for the perimeter of the basin.

Preliminary surveys of the basin site documented the presence of 1) California poppy, *Eschscholzia californica* ssp *californica,* 2) Wavyleaf soap plant, *Chlorogalum pomeridianum,* and 3) *Broidaea spp.* (http://plants.usda.gov/plantguide/pdf/pg_esca2.pdf, http://plants.usda.gov/core/profile?symbol=CHPO3). Previous or stable occupancy of a site was found to be a statistically sound predictor of recruitment success for six different forbs native to California (Brandt and Seabloom 2012). Mean frequencies observed in surveys was not a successful predictor of recruitment success (Brandt and Seabloom 2012). This lead Brandt and Seabloom (2012) to suggest that revegetation may be most effective using desirable species already present at the revegetation site. Since California poppy, soap plant, and *Broidaea spp.* are all perennial it may be reasonable to assume that they have an established occupancy of the site, a tolerance for the site's stresses, and would be valuable components of the seeding mixture. California poppy, a native perennial dicot and the state flower, is deep rooted and therefore often used for erosion control. It requires good sun exposure and water from precipitation, ground water, or fog drip and can tolerate high temperatures and a variety of soil types and precipitation regimes (USDA NRCS). (USDA NRCS). When these conditions are met and competition for light and water resources are low, California poppy can persist in disturbed sites (USDA NRCS). Water availability greatly affects California poppy growth which may fluctuate between summer dormancy in arid environments and non-stop growth in stable hydric environments (USDA NRCS). Pooled water or frequent and lengthy periods of soil saturation inhibit optimal growth (USDA NRCS). In light of this information California poppy should be kept at the mid and upland portions of the basin site. Transplanting usually fails while seeding is successful and can be done with dormant seeds at a quarter to a half inch depth or with non-dormant seeds at an eighth of an inch at a rate of about 20 seeds per square foot (USDA NRCS). Seeding is best done in fall so that natural environmental conditions initiate emergence and promote establishment (USDA NRCS). Local native propagules should be used to maintain local adaptations, especially seed dormancy characteristics, which are correlated with local environmental conditions are maintained USDA NRCS .

Wavyleaf soap plant a native perennial monocot and a member of Liliaceae, the lily family. Wavyleaf soap plant reproduces asexually via a true bulb and through sexual reproduction can set seed (USDA NRCS). Bulbs can be planted in fall, before October, in any soil type as long as the area gets full sun (USDA NRCS). The top of the bulb should be visible once planted and do not require irrigation (USDA NRCS). Seeding Wavyleaf soap plant should occur during the same time frame as bulb planting. Transplanting greenhouse-raised seedlings is recommended. Seeds should be planted in well drained, coarse textured soils and given sun during the early and late portions of the day. Supplemental irrigation should be given during drought years. Seedlings can be planted out after two years (USDA NRCS).

The cluster lillies, *Brodiaea* spp. are a genera of native perennial monocots (http://plants.usda.gov/core/profile?symbol=brodi). According to Calflora.org the following species of *Brodiaea* have been recorded in Solano county and their presence confirmed by the Consortium of California Herbaria: *B. elegans, B. elegans* ssp. *elegans, B. coronaria, B.*

coronaria ssp. *coronaria, B. californica, B. terrestris,* and *B. terrestris* ssp. terrestris. Harvest Brodiaea, *B. elegans,* prefers partial shade, its seeds should be planted a quarter inch into the ground, and its corms may also be used as propagules (http://www.wildflower.org/plants/result.php?id_plant=BREL). *B. coronaria,* crown brodiaea, used to be far more common to the central valley than it is today (USDA NRCS). Planting can be from seed before October in soils which will be kept moist and in partial shade (USDA NRCS). Corms may also be planted in the fall in full sun at a depth of four inches and about 4 inches of distance between corms (USDA NRCS). The USDA plant guide for this species recommends transplanting nursery grown seedlings in Autumn once plants have already had their first bloom (USDA NRCS). If soils are too wet the corms of *Brodiaea* spp. will rot (USDA NRC). To avoid corm rot *Brodiaea* spp. should be planted at mid-depth or the upland portion of the basin.

Other native forb candidates include: *Asclepias fascicularis, Centromadia spp., Glycyrrhiza lepidota, Lupinus spp.* and *Trifolium wormskioldii.* These species were chosen because they are native to California, documented in Solano County, and have varying ecological, cultural, and aesthetic appeals.

Asclepias fascicularis, narrow leaf or Mexican whorled milkweed, is a native perennial dicot known for attracting insects and Monarch butterflies obligate use of the plant for egg-laying and completion of the larval stage (USDA NRCS). Seeds of *A. fascicularis* are wind dispersed, can be collected from ripened, but preferably not cracked seed pods, and propagation is often more successful when done through seeding as opposed to transplanting (USDA NRCS). Seeding of vegetative spread through rhizome cuttings when the plant is dormant should occur in the fall at the beginning of the rainy season (USDA NRCS). According to hedgerowfarms.com *A. fascicularis* are tolerant of both flood and drought conditions making this forb a prime candidate for the bottom of the basin.

Centromadia spp. are native, annual dicots often referred to as tarweed, though this common name also is used to describe other unrelated species. *C. pungens* can grow in many different soil types and has been found in dry grasslands, seasonal wetlands, and lowlands which may be flooded intermittently (Randall, John). *C. pungens* is therefore a good candidate for the upland, mid-depth, and low land portion of the basin. Its seeds germinate readily and should be planted during October. Information about the propagation of *C. parryi,* a related and notably rare tarweed, and *C. fitchii* could not be found but these two plants may also be suitable for the basin if they are functionally similar to *C. pungens.* This seems likely since a management report by DiTomaso et al. (2013) treats the three as one species.

Wild licorice, *Glycyrrhiza lepidota,* is tolerant of moister settings and short term flooding making it a viable option for all portions of the basin (USDA NRCS). Wild licorice reproduces asexually and sexually (USDA NRCS). Asexual reproduction is vigorous, seed germination rates have a large range, and its seeds have higher germination rates after physical scarification (USDA NRCS).

Lupines, *Lupinus* spp., are native perennial dicots and a flagship species of sorts. *L. latifolius, L. formosus,* and *L. succulentus* are all local to Solano county and possible candidates for the forb mix. Physical scarification apparently increases germination rates of *L. latifolius* (USDA NRCS). The USDA recommends seeding *L. latifolius* at 50 pounds/acre (USDA NRCS). Information on propagation of the other *Lupinus* spp. is not available.

Trifolium wormskioldii, commonly known as cow's or marsh clover is a native perennial dicot which does well in moist and periodically inundated environments (USDA NRCS). This tolerance for inundation makes it a potential candidate for the seeding mixture of forbs for the basin site. Information about seeding is not available but it can be spread by dividing and replanting established individuals or their rhizomes (USDA NRCS).

Species	Flowering	Location	Notes
California Poppy	February-September	Mid-depth and upland	State Flower, attracts insects and pollinators, deep rooted, drought tolerant
Wavyleaf Soap Plant	May-August	Mid-depth and upland	May become weedy
Brodiaea elegans	March-August	Mid-depth and upland	Propagation through corm or seed
B. coronaria	May-June	Mid-depth and upland	Propagation through corm or seed
B. terrestris	April-July	Mid-depth and	Propagation

		upland	through corm or seed
Asclepias fascicularis	June-September	Lowland, mid-depth, and upland	Attracts insects and pollinators, esp. Monarch Butterflies. Drought and Flood Tolerant
Centromedia pungens, C. fitchii, and C. paryyi	June-Early Fall	lowland, mid-depth, and upland	Invasive native, spiny
Glycyrrhiza lepidota	June-August	lowland and mid-depth	Invasive native, N-fixer, deep rooted,
Lupinus spp.	June-October	mid-depth and upland	N-fixer, fabaceae
Trifolium wormskioldii	May-June	lowland	Asexual and sexual spread, erosion control

Forb Management and Maintenance

Restoration plantings should be done promptly to maximize cover by desirable plants, minimize bare ground, erosion, and time without cover (Janecki & Associates, Inc). The timing of restoration plantings must be done in time for natural rainfall to aid in the establishment of plantings before the onset of the dry season (Stromberg et al, 2007). Restoring plant communities can occur via seeding or direct transplanting of plugs. Although expensive, plugs have very high survival rates and will have a head start establishing themselves when compared to seeding projects (Stromberg et al, 2007). Seeding is more cost efficient and may be preferable for vegetating larger areas but determining appropriate species ratios and seeding rate is difficult and must account for individual differences in phenology and ecology of each species (Stromberg et al, 2007). Preparation of the restoration site may include removal of undesirable species through manual or chemical efforts. However, ecological interactions are complex and management of undesirable species may have unintended consequences (Cox and Allen, 2011). Removal of exotic grasses resulted in significantly greater cover of both native and exotic forbs but also increased cover of exotic forbs. Exotic forb removal resulted in decreased native forb cover in a year with average rainfall but had no effect during a subsequent dry year when native forb cover was less than five percent irrespective of exotic forb removal (Cox and Allen, 2011). Removal of both exotic forbs and exotic grasses resulted in the greatest amount of native forb seedlings per square meter (Cox and Allen, 2011).

The basin site will be expected to function after planting is done and the selected species are established. Ensuring persistence of the desired species and associated ecosystem functions depends on successful recruitment of future generations. The candidate species list includes forbs which produce both asexually and sexually. Brandt and Seabloom (2012) found recruitment of native forb seeds to be significantly negatively correlated with litter mass, likely due to litter reducing light penetration. Maintenance of the basin site may need to include removal of plant litter and other waste which could block light and inhibit emergence and establishment of propagules. Brandt and Seabloom (2012) also found predictors of native forb seed recruitment in California's Hastings Natural History Reservation to be species-specific. It follows that maintenance of the site should include monitoring of abundance, frequency, survival, and reproductive success of the selected forbs in order to identify abiotic and biotic influences on recruitment and function.

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Part 2: Development of a Forb Seeding Mix for the Basin Site

<u>Management for Native Forbs and Site Preparation and Maintenance</u>

Background

Restoring plant communities can occur via seeding or direct transplanting of plugs. Plugs have very high survival rates and a head start establishing themselves compared to seed-recruits, but are more expensive than seeding operations (Stromberg et al, 2007). Seeding is more cost efficient and may be preferable for vegetating larger areas, but determining appropriate species ratios and seeding rate is difficult and must account for individual differences in phenology and ecology of each species (Stromberg et al, 2007). Due to cost efficiency, potential need for reseeding, and a greater amount of available information, a seeding mix will be advocated over out-planting green house plants or plugs.

The zones within the basin site will have significantly different abiotic conditions for portions of the year as a result of occurrence, frequency, depth, and duration of flooding events. Despite the enormous importance of these hydrological conditions, changes in community composition at floodplain sites are not due entirely to environmental conditions. Competition with other plant species, especially those adapted to the dynamic hydrological conditions of wetland systems, plays an important role in determining which plant communities will establish (Toogood et al, 2008). An understanding of abiotic and biotic interactions, especially competition, at the basin site will promote success in restoration efforts and can be accumulated through management and monitoring.

Site Preparation

Before planting, weedy species at the site and general locality should be inventoried to inform site preparation plans. Control of weedy species infestations may require multiple seasons before planting (Gallitano, et al 1993). A generalist, non-residual herbicide can be used, in accordance with product-specific instructions, to eliminate undesirable vegetation. The site should be shallowly tilled then treated with herbicide again to remove whatever undesirable vegetation emerged in response to tillage (Gallitano et al, 1993). In experimental plots focused on restoring native forbs in the Sacramento Valley, Brown and Bugg (2001) tilled to a depth of 10-15cm for their aforementioned forb mix and to 2-3cm for a forb and grass mix. Tillage should always take into concern potential soil erosion, especially if tillage will consistently occur over many years or seasons or if tillage is occurring during an El Nino year (Stromberg and Kephart). The basin site could also be prepared through fumigation which may beget more growth of planted species and better wildflower establishment (Gallitano et al, 1993). However, fumigation is a much more expensive and complicated process. Canopy and ground cover by undesirable and weedy plants should be minimized, all the forbs seeded by Brown and Bugg (2001) emerged at lower rates in established vegetation relative to the treatment seeded into tilled soil. It must be kept in mind that ecological interactions are complex and management of undesirable species may have unintended consequences (Cox and Allen, 2011). In a Californian reserve, Cox and Allen (2011) found that removal of exotic grasses resulted in significantly greater cover of both exotic and native forbs. Exotic forb removal resulted in decreased native forb cover in a year with average rainfall but had no effect during a subsequent dry year when native forb cover was less than five percent, irrespective of exotic forb removal (Cox and Allen, 2011). Removal of both exotic forbs and exotic grasses resulted in the greatest amount of native forb seedlings per square meter (Cox and Allen, 2011). Regardless of growth type (i.e. forb, grassy, woody, etc.) exotic, invasive, and otherwise undesirable species should be removed with equal effort and intensity to help ensure establishment of the forb seeding mix.

Goal	Timing	Importance
Clear site of undesirable species and manage the seed bank to reduce future competition	Before planting	Minimize competition from undesirable species
Establish and maintain a minimum of 15% coverage by desirable species.	Immediately after planting	Suggested as the minimum threshold from which a native California grassland can be maintained through management without planting (Stromberg and Kemphart)
Monitor site for understanding of biotic interactions, abiotic interactions (esp. with hydrology) and recruitment dynamics	After establishment	An in-depth understanding can facilitate future management decisions here and elsewhere
Adapt and renew the restoration process, including planting if cover by desirable species falls below 10%	After establishment	It is important to know not just when goals have not been achieved but when goals and the efforts employed to reach them need to be changed. Threshold suggested by Stomberg and Kemphart

Planting

Restoration plantings should be done promptly to maximize cover by desirable plants, minimize bare ground, erosion, and time without cover (Janecki & Associates, Inc). Virginia's Department of Transportation Best Management Practices for Dry Extended Detention Basins suggests that vegetation should be installed within a week of establishing the site's final grading. The timing of restoration plantings must be done in time for natural rainfall to aid in the establishment of plantings before the onset of the dry season (Stromberg et al, 2007). After weed control and any other site preparations are completed, soils should be very slightly loosened to promote contact with the seeding mixture without dragging up weed seed. Most of the annual weed seed bank exists in the top quarter inch of soil (Gallitano et al, 1993). Species should be seeded based on their needs for space and soil resources (Gallitano et al, 1993). Forb restoration in the Central Valley by Brown and Bugg (2001) varied seeding rate, by species, between 1 and 6.7 kg/hectare. Seeding rates used by Brown and Bugg (2001) for individual species suggested for the basin site are included in the Candidate Species section above. Many popular online wildflower seed mixes have recommended seeding rates of about 10-20lbs/acre. Previous forb restoration efforts in the Sacramento Valley have simply hand broadcasted seed. Bugg and Brown (2001), hand broadcasted their two seed mixes: forbs and forbs with grasses. Water application or light soil packing should follow seeding to ensure good soil-seed contact (Gallitano et al, 1993). Mulches can then be applied to protect seeds from predation and to help prevent germination of undesirable species (Gallitano et al, 1993). The timing of seeding is incredibly important and should be done after the first significant rainfall event, planting earlier increases the risk of desiccation upon emergence and seed depredation (Stromberg and Kephart). Establishing a relatively closed canopy of desirable species will help to exclude undesirable and weedy species from the site but may also result in competition between desired species, which should be minimized (Gallitano et al, 1993). Forb and grass cover is significantly, negatively correlated with weed cover (Bugg and Brown, 2001).

Seed germination and competitive plant interactions, are influenced by fluctuations between dry and wet conditions which alter concentrations of oxygen, nutrients, pollutants and toxins, change light availability, and may cause desiccation (Cassanova and Brock, 2000). Seeding efforts at the basin site must consider the timing of planting in reference to potential flooding events and their impacts on seeds and emerging, establishing plants. It may be wisest to seed the different zones, or micro-sites, of the basin at different times to reduce chances of failure due to flooding and associated stressors. Additionally, the zones vary in hydrology, other abiotic factors, biotic factors, and therefore also vary in which species are choice for each zone. Success may also be increased by having seeding mixes, composed of different species or species ratios, unique to each zone. Another consideration in formulating seeding mixes, zone-specific or not, is the phenology of the species, Brown and Bugg (2001) proposed that certain species in their restorative forb mixtures failed to establish, despite emerging, due to temporal mismatches between those species' normal growing seasons and their time of emergence after seeding in the restoration effort.

Based on a threshold set by Stromberg and Kephart, the minimum goal for percent cover of established, desirable forb species may be set at 15%. At 15% cover the two argue that management options, discussed below, can be used to promote the desirable species already extant in the present plant community. If each zone is planted with a different mix each zone should achieve this goal. This threshold should be achieved as soon as possible, hopefully after the first planting, and should be maintained in perpetuity. Should this be achieved and management be unable to increase percent cover then the goal should be changed and the minimum percent cover increased.

Monitoring and Site Maintenance and Management

Ensuring persistence of the desired species and associated ecosystem functions at the basin site depends on successful recruitment of future generations. The candidate species list includes forbs which produce both asexually and sexually. Brandt and Seabloom (2012) found recruitment of native forb seeds to be significantly negatively correlated with litter mass, likely due to litter reducing light penetration. Maintenance of the basin site may need to include removal of plant litter and other waste which could block light and inhibit emergence and establishment of propagules. This is especially relevant to the basin site as flooding may decrease seed availability for future recruitment (Friedman and Auble, 2000). Additionally, litter should be removed to prevent flow backup and clogging (CASQA).

Weed control will continue to be a part of site management and maintenance even after the establishment of desired vegetation. Maintaining a high percent cover and dense canopy of desirable species will help to competitively exclude undesirable species (Gallitano et al, 1993). Undesirable species which do germinate in the basin site should be removed through physical, chemical, or cultural control techniques. Hand-weeding is valuable for its simplicity, accuracy, and precision (Gallitano et al, 1993). Hand-weeding is a time intensive but simple task that could be delegated to community volunteers helping tie local residents to their natural surroundings. Grazing may be considered as a means of control but should be done when soils are least vulnerable to compaction and erosion, in California this will usually be at Winter's end (Stromberg and Kephart). Mowing when annual weeds are grown and bearing seeds, not yet viable, can control weeds and help prevent accumulation of weed seed in the soil (Stromberg and Kephart). Controlled burns can reduce annual weed populations, promote the growth of wildflowers and reduce wildfire fuels (Stromberg and Kephart). Forbs are generally thought to be a dominant component of California grasslands in early successional stages before grasses take over in later stages of succession (Chadden et al 2004). Mowing, grazing, and burning could be incorporated, with care, so as to not adversely effect residents and native biota, by managers to mimic the natural disturbance regime of the area and promote forbs by resetting succession. Chemical control is often very effective but use of chemical agents may be undesirable due to the basin's involvement in the local water cycle and region's watershed. Another complication is that desirable and weedy species may be vulnerable to the same types of herbicides, especially if they are closely related (Gallitano et al, 1993). Chemical management of weeds at this site, should employ post-emergent herbicides used as either spot-sprays, a small application targeted at one individual or small groupings of undesirable species, or wick-applications, where highly concentrated herbicide is applied via a rope wick to emergent individuals of undesirable species (Gallitano et al, 1993). Any of these control methods should be done after the planted forbs have set seed and should not be done so frequently that desired perennial species exhaust their root reserves and fail to produce seed (Stromberg and Kephart).

The composition of an invaded system's plant community will be strongly influenced by seed dynamics (Chadden et al 2004). Brandt and Seabloom (2012) found predictors of native forb seed recruitment in California's Hastings Natural History Reservation to be species-specific. Maintenance of the site should also include monitoring of environmental conditions and the abundance, frequency, survival, and reproductive and recruitment success of the selected forbs in order to identify abiotic and biotic influences on recruitment and function and future management (CASQA). This is especially relevant due to the dynamic and unpredictable nature of the basin's hydrology. The plant community will fluctuate annually based on survival, reseeding potential, and realized reseeding potential of annual and perennial species (Gallitano et al, 1993). If flooding disturbances denudes soil of its vegetation, colonization by new vegetation begins, altering biotic and disturbance regimes (Friedman and

Auble, 2000). A wide array of the selected candidate-forbs may establish initially but over time years of varying hydrological conditions may narrow down the mix to those species which are actually suitable for the site and its micro-sites. However, a community may only be selected for if sufficient seeds or propagules already exist at the site (Casanova and Brock, 2000). Accordingly, seeding and maintenance for functional diversity may need to be extended for multiple seasons to ensure that conditions during initial years do not exclude species with functional roles important over the long term. Stromberg and Kephart suggest that for California grasslands, having less than 10% surface cover by the desired plant community necessitates active restoration via seeding, transplants, or other revegetation techniques. This level of surface cover should be considered failure, adaptive management should take its course, and what has been learned during management and monitoring should be used to inform the next restoration effort. Without management, colonization by undesirable species may occur and jeopardize the function of and biodiversity at the basin site. Responses by plant communities to even small alterations of water regimes can be rapid (Toogood et al, 2008). Monitoring will ensure those changes are noticed and can inform future management decisions and be used to hone down the candidate-forb list for future use by the Solano RCD or other interested parties. The Industrial and Commercial Handbook from California Stormwater Quality Association, readily recognizes that preserving, promoting, and then maintaining existing native necessitates extensive planning and resource use and subsumes risk, much of which arises from environmental stochasticity.

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Interactions Between Invasive and Native Plants and the Mycorrhizal/Fungal Community Kayla Spawton

The soil microbiota is made up of both bacteria and fungi that can be pathogenic or saprophytic. These organisms are important for the cycling of nutrients like carbon and nitrogen in the system. One type of fungus in the soil is arbuscular mycorrhizae (AM). These are common symbioses between plant roots and fungal species. Most simply, the fungus gives nutrients to the plant by expanding the plant's root system in exchange for the plant's photosynthetic sugars. Just as certain microbes in the soil can harm or help an individual plant, so can the AM. This symbiosis can be parasitic to the plant if the fungus takes too much sugar from the plant or it can be mutualistic if the plant can grow larger because of the fungus's trade of nutrients (Hoeksema et al. 2010). It can also be parasitic if an invasive plant is capable of accessing a native plant's AM and can then take nutrients, like carbon, from the native plants (Carey et al. 2004). Additionally, the AM can affect where allelochemicals are concentrated in the soil, potentially reducing the growth of surrounding plants (Barto et al. 2011). Therefore, it is important in a restoration project to establish a microbial environment in which fungi, like AM, benefit the native plant populations over the invasive plant populations. In this review, I will discuss the various ways that AM and the general microbial community can affect native and invasive plant populations in California grasslands.

<u>Variation between invasive and native microbial communities</u>

The extent of similarities between native and invasive plant microbial communities can vary. One study found that the microbiota, especially fungi, of a grassland invaded by annual grasses was more similar to a recently restored perennial grassland than long term fallow soil (Pothoff et al. 2006). The restored plot had been intensely tilled, weeded, and had herbicide applied in preparation for the restoration of the native grasses. These results suggest that invaded and restored grasslands can still share very similar AM community densities in the soil, even if the restored community was put through intense disturbances. The presence or absence of plant matter in the soil appears to affect the soil fungal community more than species of plants present (Pothoff et al. 2006). In contrast, a later study specifically looked at the AM communities of invaded and native grasslands and found that AM was denser in soils of native Southern Californian grasses that soils of invasive grasses in the area (Vogelsang & Bever 2009). Similarly, a different study found that the presence of an exotic grass reduced the diversity of AM that colonized native plants (Hawkes et al. 2006). Additionally, the diversity varied between grassland sites in Utah and California (Hawkes et al. 2006). Thus, the similarities between the microbiota of soils with invasive and native plants may vary by site or region.

<u>Plant growth can vary with the mycorrhizal community</u>

Native Californian plants respond differently to different mycorrhizal communities in the soil. Some studies have found native plants to grow better in soils with native mycorrhizal communities (Berman & Bledoe 1998; Owen et al. 2013). For instance, valley oak seedlings had greater ectomycorrhizal diversity and shoot growth when grown in soils from native oak stands (Berman & Bledsoe 1998). Similarly, native squirreltail (*Elymus elymoides*) was more successful at nutrient uptake and reproduction when inoculated with soil microbes from masticated or undisturbed native soils than from burned or sterilized soils (Owen et al.. 2013). Those that had the greatest biomass were those that had the most colonized AM (Owen et al. 2013). This suggests the importance of the native soil microbiota for the growth of native plants. Yet, native soils do not always provide the most growth for a native plant. A rare Californian forb (*Erodium macrophylum*) had more growth in soil with AM inocula from an invaded grassland (Gillepsie & Allen 2005). Therefore, not all native species may benefit the most from their own native mycorrhizal communities.

<u>What determines plant responsiveness in a given microbial community?</u>
Some studies argue that invasive grasses may be less responsive to a microbial soil community than native plants. In one case, invasive grass species in California responded less to the soil community, possibly because they do not depend on AM as much or are not affected by the same pathogenic microbes in the soil (Bennet & Strauss 2013). Similary, cheat grass (*Bromus tectorum*) inoculated with soil microbes from masticated, pile burned, undisturbed, or sterilized soils had similar growth among all treatments (Owen et. al 2013). On the other hand, native squirreltail (*Elymus elymoides)* had varied growth among the same treatments (Owen et al. 2013). This suggests that invasive species may not depend on AM, thereby, allowing them to quickly colonize an area before native perennials can establish themselves. Yet, this was not the case for a different nonnative grass (*Carduus pycnocephalus)* that grew best in a soil with AM and in a soil with AM from various nonnative species (Vogelsand & Bever 2009). Therfore, the response of invasive grasses to different AM communities may vary depending on the species of the invasive plant, but many species have been shown to be unresponsive. Phylogeny can also contribute to the differences between plant responsiveness (Brandt et. al 2009). Despite invasiveness or ecological role, more closely related grasses in California performed similarly with a given soil microbial community (Brandt et al. 2009).
The inconsistency in what factor was most important in determining the responses of plants to the soil microbiota (i.e. phylogeny, invasiveness, or neither) suggests that there is no single trend true for all cases and that it likely varies by site, AM community, and plant species.

<u>Influence of plant neighbors</u>
The dynamics between grass species can change depending on the composition of the plant community at a given time (Callaway et al. 2003; Hawkes et al. 2006; Hausmann & Hawkes 2009; Hausmann & Hawkes 2010). For instance, one study found that the effects of a fungicide that reduces the abundance of AM vary depending on whether there is a neighboring plant and the species of that neighbor (Callaway et al. 2003). Without the fungicide, the invasive grass (*Centaurea melitensis*) had greater biomass when it was grown with a native perennial grass (*Nasella pulchria*) than in a monoculture. When the fungicide was applied, the effect was the opposite although not to the same intensity. One hypothesis for this is that the native fungal pathogens in the soil may be targeting the native plants over invasive plants because they have long co-evolved. Another hypothesis is that the invasive plant could be parasitizing the native plant's carbon source through AM linkages. Either way, the soil microbial community and neighbor may be affecting the growth of native plants (Callaway et al. 2003).
This neighbor effect was also seen specifically in changes with the AM community and their effects on the AM available to plants within a plot (Hawkes et al. 2006). The AM community diversity of native perennial hosts decreased after invasion by exotic annual grass species, and the AM community shifted to one similar to the invasive grass community (Hawkes et al. 2006). This could be due to the different phenologies or life histories of annual and perennial plants. Another hypothesis is that exotic species may provide more sugars to their AM, which would makes them more competitively dominant AM (Hawkes et al. 2006).
The neighbor effect can be asymmetrical between two plants (Hausmann & Hawkes 2009). One individual's AM community can become a hybrid of the two plant's AM communities,

become almost identical to the neighbor's AM community, or remain unaffected. As a result, one host plant can potentially have many different types of AM communities depending on the neighbor, and it may be novel AM community from other plants' AM communities in the area. For instance, one native annual grass (*Vulpia microstachys*) influenced a native perennial grass (*Nasella pulchria*) by giving the perennial plant a hybrid AM community while exotic annuals (*Avena barbata* and *Bromus hordeaceous*) either had no effect on the AM community of the native perennial (Haussman & Hawkes 2009). This suggests that an invasive neighbor and a neighbor can have different effects on the mycorrhizal community of an individual plant. Therefore, the composition of a plant community can influence the microbial and AM community associated with native plants.

Native AM may harm natives

Native AM can help invasive plants grow by allowing for the exotic plant to tap into the native plant's AM symbiosis and take the nutrients away from the native plant (Callaway et al. 2003; Haussman & Hawkes 2009; Owen et al. 2013). One study found that invasive grasses (*Avena barbata* and *Bromus hordeaceaous*) had greater biomass when grown with the native perennial grasses (*Nassella pulchra)* than when grown alone, and that the exotic species often associated with the same AM species as the neighbor. As a result, the researchers speculated that the invasive species may be parasitizing native plants through the native plant's AM (Haussman & Hawkes 2009). This trend was also found with native squireltail (*Elymus elymoides*) and invasive cheatgrass (*Bromus tectorum*) (Owen et al. 2013). The researchers speculated that this was due to the invasive grasses parasitizing the AM symbiosis of the native grasses (Owen et al. 2013). Similarly, a different study had the same speculation after finding that reducing the mycorrhizal community through fungicide resulted in greater growth of native *Nasella pulchra* and decreased the growth of the invasive *Centaurea melitensis* in the same plot (Callaway et al. 2003). When the fungicide was not used in the plot, the effect was the opposite with *N. pulchra* having less growth than *C. melitensis* (Callaway et al. 2003). Therefore, the mycorrhizae associated with a native plant can actually hurt the plant if an invasive neighbor parasitizes the symbiosis.

Soil legacies from earlier species

Exotics plant species can affect native species' biomass even after the invasive plant is removed by altering the soil before their removal (Grman & Suding 2010; Hausman & Hawkes 2010). Yet, native plants were not found to leave these same profound effects in the soil to affect later exotic colonizers' biomass (Grman & Suding 2010). This may be due to abiotic changes or alterations in the microbial community such as the fungal pathogens or AM. Simply removing the invasive species may not be enough to restore the native AM because of the changes these invasive species leave in the soil (Grman & Suding 2010). A later study confirmed that the AM community of a plant can change depending on the order of plants present before it (Hausmann & Hawkes 2010). This was especially true for invasive *Vulpia* and *Avena* species. The first grasses likely set up the initial AM community and the following plants formed AM symbioses from that pool. Therefore, the success of those plants that follow the first community may be determined by how beneficial the AM in the initial pool are to the following plants and how host-specific the AM are (Hasussman & Hawkes 2010). This suggests the importance in understanding the previous community's plant composition in order to gauge the success of later planted species.

Conclusion

The effects of AM and the general soil microbiota vary by study, most likely due to the composition of the plant community and characteristics of the soil. This makes it difficult to apply the knowledge from one researched case to a restoration project. Yet, these effects are important and can result in the collapse of plant growth by certain species, thereby, resulting in a plant community different from the one expected. For instance, AM inoculations in restoration can be important in conditioning highly disturbed soils to ones more suitable for vegetative growth (Quoreshi 2008). As a result, it is important to consider the importance of the interactions between fungal organisms in the soil and plants when organizing a restoration project. The inoculation of AM into the soil is necessary in order to prepare a conducive soil environment that will be able to sustain and favor the growth of native plants over invasive plants.

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Part II: Using Arbuscular Mycorrhizae to Restore Native Perennials over Invasive Annuals

A. **Goal:** Establish an arbuscular mycorrhizal (AM) community that will benefit Central Valley native perennial grasses over invasive annual grasses by:

- Understanding the condition of the current AM community in order to coordinate an effective plan that will build off of the present conditions
- Creating a new AM community through inoculations of the soil in the field and native plant seeds in a greenhouse with the AM fungal spores from a remnant site's topsoil.
- Short-term (3-5 years) monitoring of the site after transplanting the native plants in order to evaluate and choose the best option to remove establishing invasive plants (fire, mowing, grazing, herbicide, etc.)
- Informing the manager of how to best monitor the native grasses and remove invasive plants for long-term (after 5 years) monitoring

B. **Management Plan**

<u>I. Introduction: Potential of using AM to exclude invasive plants</u>

AM are important fungal symbioses of plant roots that generally allow for better absorption of nutrients, aggregate the soil, improve water absorption, and increase plant biomass. The interactions between invasive and native plants through AM are little understood and complex processes. Research suggests that invasive species can permanently change soil conditions after removal, including changes in the AM community (Grman & Suding 2010, Hausmann & Hawkes 2010). Additionally, invasive plants may influence the AM of neighboring native plants and are thought to parasitize native plants through these AM interactions (Callaway et al. 2003; Carey et al. 2004; Hawkes et al. 2006; Haussman & Hawkes 2009; Owen et al.2013). Often, invasive species are unresponsive to the AM fungal species they interact with while native plants tend to have varied growth, reproduction, and nutrient absorption depending on the AM fungal species, especially in the case of later successional species (Berman & Bledsoe 1998; Chaudhary & Griswold 2001; Vogelsang & Bever 2009; Middleton & Bever 2010; Bennett & Strauss 2013; Owen et al. 2013). The intact native soils are thought to have a more diverse and dense AM community than invaded soils (Vogelsang & Bever 2009; Pothoff et al. 2006).

The combination of these effects means that a plant's AM community, and often its biomass or other components of fitness, depends largely on the species of plant, pool of AM in the soil, and neighboring plants. With the current research emphasizing the complexity and lack of knowledge on how the mechanisms work, it is impractical to meticulously manipulate the AM species in order to benefit native over invasive plants. This would involve extensive micromanagement in an open system with the threat of unforeseen or little understood biotic and abiotic interactions. Instead, I think that the focus should be to establish an AM community that will help the native plants establish sooner and in better quality so that invasive plants will have a more difficult time entering the community and colonizing. Because most of the research suggests that native plants tend to be more successful in soil with diverse and dense native AM, this will be the reference AM community. Monitoring the site after establishing the native plants should involve weed control to prevent invasive plants from parasitizing native plant's AM. The manager will have to maintain such monitoring in the long-term. Once the native plants have established and grown with their AM, they will ideally be able to exclude invasive plants more effectively than if they did not have these native-associated AM.

<u>II: Survey</u>

It is important to understand the state of the AM community we are working with, and this will be done by surveying the plant species present and accessing knowledge on past land use. One would expect an area in the Central Valley that was once used for agriculture to have a very different basic soil microbial community than land that has been invaded by exotic grasses. Land previously used for agriculture has a history of frequent and extensive abiotic disturbance through weeding, tillage, and use of herbicides, so its AM community would be low in diversity and density (Potthoff et al, 2005; Potthoff et al.2006). We may expect the community to be even more degraded in a site that was used for mining or other human uses because of the severe compaction and pollutants like heavy metals.

On the other hand, an invaded grassland can have a denser AM community than an agricultural field. Invasive plants can utilize AM, although the AM community may not be quite as dense as that in a native plant community (Potoff et al. 2006; Vogelsang & Bever 2009). In an invaded community, we would expect the neighbor effect and soil legacies to come into play where the exoctic grasses' AM could influence the AM of native plants that are being planted (Nelson & Allen 1993; Grman & Suding 2010; Hausmann & Hawkes 2010).

Therefore, if this restoration site is an invaded grassland, we have to factor in the AM already present and how they may form symbioses with the native plants that will be planted. Because various studies show that native CA grasses do best with AM from a native system, the AM already present in the invaded grassland may reduce the biomass of the native plants. To prevent this, the soil should be conditioned to reduce the influence of invasive grasses' AM by adding more AM fungi associated with native plants to these types of systems to increase the ratio between AM associated with native than invasive plants. If the site is instead one that is damaged with little plant biomass, the AM is more or less absent so having to reduce the relative abundance of AM associated with invasive plants is not as large of a concern. Therefore, these sites with little biomass do not need as large of additions of the AM associated with native plants.

<u>III. Inoculation</u>

In order to ensure an AM community that enhances native grass growth and reproduction, both the field soil and the plants should be inoculated. Inoculating the soil will be less important in an abandoned field because of the very low abundance of AM initially present, but an invaded field will have AM associated with the invaded plants. To minimize the impact of AM that invasive plants may leave behind after removal, soil with the native inoculum should be applied to field soil more generously to increase the diversity and density of native plant-associated AM.

Additionally, growing the plants in a greenhouse will allow for the plants to establish themselves in a controlled environment where they will not have to compete with invasive plants to germinate and grow. This will also give the plant the opportunity to grow with the desirable (pre-planned AM associated with natives) as a germinating seed until it has an established root system and sufficient shoot growth.

a. *Inoculated Greenhouse Transplants*

Because native perennial plants inherently take longer to grow than invaded annual grasses, it is important to provide a controlled environment where they can grow without the threat of a nearby invasive annual outgrowing it or taking nutrients through the native plant's AM. This has been proven to work on inoculated big sacaton that were transplanted to an abandoned agricultural field (Richter & Stutz et al. 2002). Those that were inoculated in a greenhouse did not have significantly more growth, but did overall benefit by having increased survival rates, basal diameter, and flower production. By inoculating the perennial grasses as seeds, it will ensure that these plants will enter their natural environment with the AM they have evolved with without invasive plants influencing the AM of the native plant.

The methods for inoculation and greenhouse duration are adopted from the Richter & Stutz study (2002) because of their success. We will begin by inoculating seeds of the native plants that are desired, either obtained from a local seed collector or our own collection depending on the wishes of the manager. Inoculated soil will be a mixture of topsoil collected from a local remnant native perennial site, similar to the type of community we want to establish. This topsoil will naturally have AM spores and colonized root pieces. Another option is using commercial inoculum, but because these products have a lower diversity in AM fungal species, I think it should be avoided (Chaudhary & Griswold 2001; Stromberg et al. 2007). Additionally, there is no inventory of the AM fungal species associated with California native grassland species, so we would not know which AM fungal spores we should buy to represent the native community. Therefore, taking topsoil from a reference site is the best way to recreate the AM community associated with a native California grassland. The remnant soil will come from the top 10 cm of the topsoil to minimize any damage to the remnant site but ensure that AM fungal spores are being collected from a portion of the rooting zone (Strohmayer 1999; Nelson & Allen 2006). In order to collect the AM inoculum (fungal spores), the soil will be wet sieved. We will then use conic pots because the study found that big sacaton had greater root density in these pots. Each pot will first have a marble placed on the bottom to prevent the inoculum from leaching, then 10 cm^3 of sand, 60 cm^3 of autoclaved 2:1 soil/sand mixture, 10 cm^3 of inoculum, and 30 cm^3 of soil/sand mix. To each pot, 3 seeds of one species of perennial grass will be sterilized in 10% bleach solution and placed in the pot, and then 0.5cm soil/sand mix will be placed on top. The number of pots we will prepare will depend on the size of the site. Roughly, we will want to prepare one pot for each one meter area, as done by Middleton and Bever (2010).

These pots will be in a greenhouse with a sprinkler system and swamp cooler that replicates the conditions the native plants would experience in nature. They will remain in the green house for 8 week like the researchers did with the perennial big sacaton (Richter & Stutz et al. 2002). At this point, the grasses should have germinated, been infected with AM, and developed both root and shoot growth.

b. Field Inoculation

In addition to inoculating the plants to help with their establishment, it is also important to inoculate the field. This is most important if the site is an invaded grassland because one study provided evidence of an inoculated native plant (*Nasella pulchra)* reverting to the AM that was already present in the soil where an invader (*Avena barbata*) was present (Nelson & Allen 2006). Especially because of possible soil legacies that invasive plants can leave behind, such as the invader's AM community remaining in the soil, it is important to reduce the ratio of AM associated with an invaded grassland. Using AM from a remnant native site to inoculate the field soil has proven to be effective in growing middle and late successional grassland species in Indiana (Middleton & Bever 2010). Therefore, we will use the top 10 cm of native topsoil similar to that used in the transplants.

This field inoculation will begin within the week that the greenhouse plants will be transplanted (approximately week 8). The methods for inoculating the soil are adopted from the Middleton & Bever study (2010) because of their success. Inoculum will be produced by taking a 1:1 mixture of sterilized site soil with sand and mixing it with remnant soil. 150 mL of this mixture inoculum can then be randomly scattered throughout the site. I would recommend using more if it is an invaded site because the threat of AM associated with invaded plants is stronger, so a higher ratio of native to invaded associated AM would be better. As a result, the bulk amount of mixture inoculum will depend on the land use of the site as well as the size.

After this inoculation, the greenhouse plants can be transplanted into the field at a high density of 9-27 transplants per square yard (Anderson no year). We want a high density of grasses in order to minimize any opportunity for invasive species to colonize, and we want to emulate the densities that these grasses are adapted to.

IV. Monitoring and post-transplant treatment

Monitoring will occur for at least a year but ideally for 3-5 years, depending on funding, to make sure that the planted perennials survive through the potential establishment of invasive annuals. Monitoring will mainly rely on visiting the site biweekly to evaluate the native growth and the removal of establishing invasive plants as the native plants continue to grow. Establishing the native associated AM community should support the growth of native plants to make the establishment of invasive plants more difficult. Because the restoration project presumably covers a large amount of space, it is not reasonable to manually remove invasive plants. Thus, there are various monitoring options to selectively remove invasive plants as the native perennial grasses grow. Whatever the monitoring option, we will be involved for the short terms (3-5 years), but the manager should be responsible for maintaining the management of the native plants and removal of invasive plants over the long term. Therefore, we will advise the manager on how to best care for the grassland after we are done monitoring.

One option to monitor and manage for the removal of invasive species is the use of prescribed fire because native grasses and their AM have co-evolved with fire while many of the invasive grasses have not (Seymour et al. 2008). This may be a possible option if there are few structures, like homes, in the area, if it is a larger property, and if air pollution is not a large concern (Stromberg et al. 2007). A prescribed fire could take place in April to remove invasive plants like medusahead, goatgrass, and yellow star thistle (Stromberg et al.; Seymour et al. 2008). This would have to take place under the supervision of the fire department in order to prevent the fire from getting too large or out of control, and the prescribed fires would have to occur periodically over the long term (Stromberg et al.; Seymour et al. 2008). This can be done every 2-5 years over the long term with some variation in the interval in order to mimic the variability that would be present in nature (Seymour et al. 2008). Therefore, the manager would have to continue this treatment after we are done monitoring.

Another option is mowing, which can only be used if the invasive plants are annuals and not perennials (Stromberg et al 2007). This is because the exotic perennial grasses have a similar life history to the native perennial grasses, and so they will have similar growth rates. Mowing should take place at heights above the native perennial grasses so they are not affected, and this will have to be determined during monitoring visits after observing how tall invasive plants are relative to native plants. It will take place early in the season every year because this is after invasive grasses have immature seed but native plants have not yet begun growing, and the exact month this occurs can vary by year. Over the course of a few years, the seed bank of invasive annual grasses will be significantly reduced. This may not be effective if the invasive grasses have deep roots and can regenerate from these roots (Stromberg et al. 2007). The AM would not be harmed by mowing.

Post-emergent herbicide can also be used against broadleaf forbs and annual grasses, but one must be very cautious that the chemical product is selective enough to cause little damage to the newly planted native transplants (Stromberg et al. 2007). The type of product used also depends on what native grasses the manager decides to be planted in order to choose a product that will not affect our newly planted natives. Spot spraying would probably be the best option in order to minimize how much the native plants are sprayed with herbicide. Therefore, with every biweekly check on the plants, any observed invasive growth will be spot sprayed with most likely a glyphosate herbicide or a more selective imazaphic herbicide (Stromberg et al. 2007; Seymour et al. 2008). No more than 6 ounces will be used per acre (Seymour et al. 2008). For taller weeds, a hand-held wick can be used to target the towering weeds to absorb the herbicide (Stromberg et al. 2007, Seymour et al. 2008). A tradeoff is that these spot applications must be manually done, and so they may be time-consuming. Additionally, different herbicides can have different harmful effects at various concentrations on the growth of the AM in the soil and the plant using the AM, depending on the chemical (Bilalis et al. 2012, Makarian et al. 2013; Pasaribu et al. 2013. For instance, once study found that AM fungi associated with peanuts decreased spore production and infection rates when glyphosate was applied, thereby decreasing the ability of AM to colonize plants (Pasaribu et al. 2013). Although a lot of these studies focus on agricultural systems, it is still important to understand that the herbicides can affect the AM community. If this practice is chosen, we must minimize the concentration, amount, and frequency of herbicide added to the soil to prevent harming the AM community.

Grazing is another option, but must be highly controlled in order to prevent the removal of native grasses (Stromberg et al. 2007). The right animal should be chosen; for instance, cattle usually will eat invasive grasses while goats or sheep prefer invasive forbs (Stromberg et al. 2007). This is a good option if the area is very hilly, making mowing very difficult. One possible plan is to graze for several days in early spring to remove the flowers of invasive grasses but still allow for growth of the native plants for the season (Menke 1992). The AM community should not be harmed by this practice.

As previously stated, all of these options will be considered, and the best option will be chosen after observing the intensity and concentrations of invasive growth during the biweekly monitoring periods. From then, grazing, mowing, prescribed fire, and herbicide application will be considered and discussed with the manager in order to choose the best option that is also possible with the manager's wishes and means under the circumstances. The option chosen will be maintained by us for the short-term (3-5 years), as long as there is funding. After that monitoring period is up, we will inform the manager of the best management he/she can do to maintain the work from the restoration so that he/she can do it independently over the long-term.

VI. Possible Problems and Uncertainties

A potential problem is that this plan is more appropriate for a smaller area since it does involve labor intensive activities such as hand-made inoculum and preparing plants to be grown in a greenhouse. If this site is a large area, we would have to reconsider the practicality of this plan or use it as a test to see if it is successful. If it was successful as a test, then we would have to consider whether it is worth investing in on a larger scale.

Another uncertainty and possible problem is that the guidelines were taken from studies not specific to the Central Valley, so they may not have replicate results in our system. The Richter and Stutz study (2002) adapted for our transplants used big sacaton, a native southern

CA perennial grass that is adapted to dryer conditions than the Central Valley, so using the same soil inoculum measurements and duration to grow may not be the best for our plants. Also, the Middleton & Bever study (2010) adapted for the field inoculation was based on a grassland in Indiana that likely does not have the same species that we are dealing with. Also, they did an experimental study focusing on the effects of nurse plants and were not specifically emphasizing an entire field inoculation, so that technique may not be the most effective or convenient.

Another issue is the general uncertainty in the monitoring after transplanting. I was given the task of researching the knowledge on AM and how it works in native systems, but the monitoring largely involves all the possible way to remove invasive plants, a facet of restoration I am not as familiar with. There are a lot of options to consider and it is difficult to be specific when we will not know how successful the native community is or the intensity of the risk of invasive growth. Therefore, this monitoring part of restoration is very much something we will have to learn how to deal with as the project progresses, and we will have to accept that there are uncertainties in this planning stage.

VII. Research Necessary for Future Applications

Because the relationships between plants, AM, and neighboring plants is not completely understood, it would be helpful to have a better understanding and more extensive study of how many different combinations of plant species, neighbor plant species, and AM species differ. Currently, similar studies look at only a few combinations (Callaway et al. 2003; Haussman & Hawkes 2009; Owen et al. 2013). The likely reason why such a study has never been done is because it would be very time consuming to set up and analyze, but the information would be valuable. If we were ever to have such an extensive summary of these interactions, they could potentially be used in restoration projects to develop the best AM community systematically for a combination of plant species.

Also, it would be helpful to have more long term studies that look at how the AM community changes over years and decades and how that can affect the plant community. This would give a clearer idea on whether my management plan would be beneficial in the long term.

VIII: How this fits into the research

This restoration project's outcome will add to the previous research regarding how AM can be used in a restoration and management setting. If it is successful, it will provide a new viable option to managers on how to remove invasive species, particularly for grasslands. If it is unsuccessful, the project will at least suggest that more research is needed to learn how to better understand these interactions in order to manipulate the AM for our benefit and ultimately the benefit of native plants.

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APPENDIX- ASSIGNMENT DETAILS
Project Details

Project Scope- The focal experience of this class will be to develop a restoration handbook for Solano County Resource and Conservation District, focused on their Vacaville sites. These projects balance a number of goals, including: (1) decreasing invasives and increasing natives in riparian, upland, and creek habitats, (2) preventing floods, erosion and fires, and (3) accommodating recreational activities. In order to manage for multiple goals, it is critical to bring together the latest information on each goal, and to use this information to develop management plans that can achieve multiple goals. This is where you come in. Each student will rate their preferred topics from the list (separate handout), and based on these rankings, will be assigned a given topic. You will research this topic, summarize your key findings, and make a management plan based on that information (see details below). Students working on similar goals will then work together to:

1. Develop management plans that can balance multiple goals (each goal represented in the group). This is not always possible through one approach, but is often possible by varying management goals and practices over space and time. When some goals conflict, it may be necessary to provide multiple management plans, each with different goals (and then the RCD will have to prioritize one set of goals over others).
2. The group will present a short summary of their topics and management plan to the class.

After the group presentations, as a class, we will discuss management options that encompass as many of these goals as possible. All individual projects, as well as a class synthesis, will be compiled and sent to Solano County RCD.

General approach- The project will be divided into different stages, which will allow you to develop the project step-by-step. In addition, we provide extensive feedback on the 1st versions you turn in, which provides you with the opportunity to resubmit an improved project (your project grade would then be the average of your 1st and 2nd submissions). The project has been designed this way to reflect actual restoration planning- where each step of the planning process is improved based on feedback from various stakeholders. Thus, the first version you turn in for each section should reflect a serious attempt to "get it right", and will be graded for overall quality. If you choose to resubmit an improved draft, its grade will be based on overall quality and how well you address suggestions you received on your first versions of each section. Details on each step are below.

Writing style- The project is intended to be a brief overview of the key issues involved in your selected restoration topic. As such, it is entirely appropriate to touch on key points through the use of bullets and numbered lists, *as long as you are conveying enough information for the reader to follow along with your logic and story*. Remember, this is a professional document that will be used to inform managers—be sure your writing is clear, concise, and professional. Be sure to cite all reference sources, including websites, newspaper articles, journal articles, books, etc. Provide complete information for each reference at the end of each section (for most sources that includes author, date of publication, article/chapter title, journal/book title, publisher, city of publication, page numbers). See below for more details about proper citations. See handout on avoiding plagiarism.

Specific requirements:
Below you will find *guidelines* for addressing your target restoration goal in each section of the project. Different goals will require some different information, or have different information available. If after a thorough search, you cannot find some of this information, make it clear that this is a current hole in our knowledge about the subject. The guidelines below will fit most projects, but feel free to expand on certain topics, add certain components that are critical for your goal, or briefly describe why a given topic is not relevant to your goal. You're encouraged to look at examples from previous years (available in the resources folder on smartsite) as examples of what is expected. <u>The sections of their papers were not identical to this year's assignment, but most of the key information/approaches are still valid to your assignment.</u>

<u>Part I: Literature review: Project background and justification</u>

Part I should focus on YOUR specific goal- providing the conceptual background that will be needed to make a management plan. Do not cover the background of riparian, wetland or upland systems that is provided in class—rather, the background on your specific goal. In this part, you should NOT yet focus on our project site.

A. Background & Justification: 1 paragraph

- Why do we care about this goal? (e.g. this invader decreases native diversity and lowers the depth of the water table).
- Why is this restoration goal important and interesting? For example, what is your target goal's conservation value, its impact on agriculture and/or the environment?
- What is the current state of your target goal? (Not necessarily at our project site, but overall). For example, to what extent are populations in decline?
- What is the history of degradation of your goal? (e.g. This was a widespread native plant in riparian systems, but since the 1930's, it has been eliminated from most of its range. It is only still present in perennial streams of the Central Valley, where average population sizes have been reduced by 90%).

B. Literature review- this should be presented as a 2-4 page fact sheet, not including references (e.g. see examples on Smartsite). This fact sheet must be clearly organized into key topics (which may vary project by project). Formatting can range from bulleted phrases to short paragraphs summarizing each key point, but must clearly convey the main message to unfamiliar readers. Unlike examples on Smartsite, each key fact requires citations immediately following it, and a full reference list must be included at the end of the document. Key topics that should be covered:

- What are the main factors affecting your goal? (Biotic, abiotic, human land use, etc.). Consider all topics covered in class- at the levels of physical site conditions, organism, population, community, ecosystem, landscape, socio-economic, global change, etc.) Some specific examples include:

  <u>For species/ community types:</u>

- Specific characteristics of your species- germination controls, seed bank dynamics, environmental tolerances and preferences, key mutualists and competitors, pathogens, etc.
- Specifics needed from ecosystem- what are your species requirements in terms of: inundation depth or duration or frequency, location (in relation to creek vs. upland, depth from water table, etc.), phenology (timing of activity, particularly in relation to timing of water flow)
- How does your goal respond to: climate change, grazing, fire, nearby plowing, herbicides/pesticides? other potential management actions?

<u>For ecosystem services:</u>

- What are the key processes/ components of the ecosystem that naturally provide this service? (e.g. key species, disturbance regimes, topography, etc.) One way to think of this is how does provision of this service naturally vary over the landscape? What are the key controllers over that?
- What are the key disruptions by humans to the natural processes that sustain that service?
- What are the key enhancements by humans to the natural processes that sustain the service? Or how can human activities substituted for the natural processes?
- How does your goal respond to: climate change, grazing, fire, nearby plowing, herbicides/pesticides? other potential management actions?

It is critical to be as specific as possible about the factors that can increase or decrease your goal, and your goal's dependence on site conditions and timing of management/key life stages. For example: ground nesting bird X requires brush-covered habitat that is not subjected to flooding, grazing, or feral cats from February through May.

- For all of the above information, focus on potential: constraints, non-linearities/ thresholds, interactions, feedbacks
- What scale (spatial and temporal) do these controls operate over?
- What restoration/management options have been effective or ineffective? Do these change site-to-site or project-to-project?
- What are key gaps in our knowledge that limit effective restoration planning?
- Other relevant information

While the presentation of this section will be brief**, it needs to highlight the most important aspects of your topic, derived from your comprehensive review of our existing knowledge on your topic—this requires considering multiple sources of information**. This is particularly critical because it is common to draw very different conclusions about restoration effectiveness at different sites. It is critical that you base this review on trusted sources (e.g. peer reviewed literature and government reports) and emphasize specific facts—avoid citing opinions or propaganda that you may find on the web, and avoid speculation or vague comments. For example, rather than making a vague comment about an invader decreasing ecosystem health, an example of a proper description: because the invader has higher evapotranspiration rates than natives, invasion dries up vernal pools faster, thus disrupting the period of inundation needed for a specific native species of interest.

Part II: Goals and management plans- focused on your target topic

Part 2 again should focus on YOUR assigned topic (not the overall class project), and will be focused on California's Central Valley, in general (not the actual project site). Your goal(s), restoration plan, and monitoring plan should be specific, clear, and actionable. For example, rather than saying seed will be collected and spread on the site—you need to be specific about where it will be collected (what type of site), and what seeding rate you will use. Similarly, if you suggest using grazing or fire as a management tool, you need to be specific about the timing of the fire, the frequency (every year?), and how much flexibility there might be in this plan (refer to specific examples given in lecture #3).

A. Goals: Outline the key goal(s) relevant for the restoration of your focal topic (a list or table is fine, as long as you have descriptive phrases about each goal). Be sure to be explicit about the spatial and temporal scale of these goals (and in many cases, it may be appropriate to have different goals focusing on short- vs. long-term, small- vs. large-scale). Discuss the potential for restoring these goals, giving careful consideration of tradeoffs, feedbacks, interactions, and thresholds.

B. Restoration plan: Describe your restoration plan(s) and be sure to justify your choices. If possible, discuss a few different restoration options (which will really help fit your project into the class' multiple goal plan), and the relative effectiveness of each. Points to include:

- specifics on methodologies (e.g. genetic sources of seeds, seeding in vs. transplanting, density and configuration of introductions, frequency and intensity of manipulated disturbance regimes)
- the temporal and spatial scale of your plan
- monitoring techniques (pre- and post-restoration) and "thresholds of action", justify the measurements and thresholds you have selected as indicators (For example, with complete failure of reestablishment of a population you plan to…….. versus with species establishment at only small, sporadic locations, you plan to ……). Be sure to be specific about when you will monitor, for how long monitoring must occur (and will it be of equal intensity the whole time, or change over the years?). Again, be sure there is enough detail to be actionable.
- potential problems you might encounter, and how you might adjust the plan along the way if you encounter those problems
- a description of the risks and uncertainties associated with your plan
- highlight research questions that need to be answered in order to improve the plan
- what research questions could be answered by this restoration project (or by comparing a suite of similar restoration projects?) How does your restoration design allow for those to be tested? (e.g. the presence of control plots, replicate treatments, etc.)

This section should be approximately 4-7 double-spaced pages (not including references), and must be written up in paragraph form (will not be in fact-sheet form). The plans must be based on the literature review you did in part I. Be sure to refer to specific information about the ecology of your goal to justify your plans. Cite references as appropriate.